Why Projections of China's Feedgrain Demand and Supply Differ: A Review [1]

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Abstract

In the past two decades, feedgrain consumption in China has increased rapidly. China's fast rising demand for feedgrains has attracted much attention from both academia and government departments within and outside China. Consequently, there have been a number of studies that attempt to examine and forecast China's feedgrain demand and supply. However, large discrepancies exist in projections on China's feedgrain demand and supply. In this paper, we review some of the major projections and explore the reasons for discrepancies between projections. We then establish areas where attention should be given in future studies in order to produce more realistic projections on China's feedgrain demand and supply.

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1. Introduction

In the past two decades, China experienced rapid livestock production expansion. Indeed, the rapid expansion of worldwide livestock production in the past few decades is to a large extent attributable to the remarkable growth of livestock industries in China. During 1989-99, world annual growth rate of total livestock production was 2%. Excluding China, this rate, however, was merely 0.8% (Bruinsma 2003, p. 161). As a result of the growth of livestock industries, China's demand for feedgrain has increased and China has now become a major feedgrain consumer. In 2005, around 165 million tonnes of grains were used for feed purposes in China. The rising demand for feedgrains by China's fast expanding livestock industries has attracted much attention around the globe. Many researchers have projected that China's demand for feedgrain will continue to increase and China may need to import a large quantity of feedgrains.

How much feedgrain China may need to import remains controversial. On the other hand, it has been widely accepted that China's feedgrain demand will continue to rise and feedgrain demand will become the major component of China's total grain demand in the future (Crook and Colby 1996, Tian and Chudleigh 1999, Zhou and Tian 2003). According to Wu (2003), by 2010, China's demand for feedgrain is expected to exceed that of foodgrain (feedgrain: 48.7%; foodgrain: 38.3%; and other uses: 13.0%). Hence, any future increase in total grain demand in China will be mainly caused by an increasing demand for feedgrains.

China's rising demand for feedgrains is likely to have an important impact on the international grain market, particularly if China needs to import a large amount of feedgrains. Then, what is China's likely feedgrain demand and supply in the years to come? Will China need to import a large amount of feedgrains? There have been studies that attempt to address these important questions. Unfortunately, they have produced very differing projections and some projections deviated greatly from the actual observations. In this paper, we review available projections from some major studies and discuss why these projections differ.

In the next section, we first present China's past and present feedgrain demand and supply situations. We then in Section 3 examine the projections of some major studies. Section 4 discusses why existing projections differ. Section 5 highlights the major findings from a GRDC project on China's feedgrain demand and supply in which the authors were involved. In Section 6 we identify and discuss various factors that may cause difficulties to future studies on China's feedgrain issues. The last section concludes the paper.

2. Feedgrain Demand and Supply: Past and Present

The rapid increase in Chinese consumers' income in the past two decades has led to a significant increase in the consumption of animal products by both rural and urban residents. In rural areas, per capita meat consumption has increased from 9.4 kg in 1981 to 20.8 kg in 2005. During the same period, per capita egg consumption increased from 1.3 kg to 4.7 kg, and per capita aquatic products from 1.3 kg to 4.9 kg. For urban residents, per capita meat consumption has increased from 20.5 kg in 1981 to 32.9 kg in 2005. Per capita egg

consumption increased from 5.2 kg to 10.4 kg, and per capita aquatic products from 7.3 kg to 12.6 kg (SSBa 2002, pp. 328, 350; SSBb 2006, pp. 112, 117).

The rapid increase in demand for animal products has so far been met by increased domestic supply. The increase in production of animal products in China in the past two decades is most impressive. Total meat production increased from 12 million tonnes in 1980 to 77 million tonnes in 2005. During the same period, milk production increased from 1.4 million tonnes to 28.6 million tonnes while aquatic products increased from 4.5 million tonnes to 51 million tonnes. Poultry eggs increased from 5.3 million tonnes in 1985 to 28.8 million tonnes in 2005 (SSBa 2002, pp. 406-408; SSBb 2006, p. 129). Among all animal products, the increases in beef, poultry meat, and aquatic products have been the fastest.

The demand for, and the production of, more animal products have generated a strong and growing demand for feedgrains. Surprisingly, in the past two decades China's feedgrain imports have been minimal. In fact, China was a net exporter of feedgrains (chiefly, corn) since 1990 (except 1995 and 1996). It was a major feedgrain exporter in the world market in the past few years, even after China joined the WTO in 2001 (Tian et al. 2005). Clearly, China's domestic supply of feedgrains must have also increased. But roughly how much feedgrain has been produced and supplied in recent years?

Unfortunately, there are no authoritative and reliable statistics about the actual amount of feedgrain supplied and demanded in China. Nevertheless, there have been attempts to gauge the amount of feedgrains consumed. Two basic approaches have been used: the demand approach and the supply approach. The former estimates the amount of feedgrain demanded and the latter the amount of feedgrain available or supplied.

When using the demand approach, feedgrain demand is calculated by multiplying the outputs of animal products by estimated feed-meat conversion ratios (Cheng and Wang 1997). The demand approach, however, encounters a number of difficulties. First, China's animal product output data is unreliable. Second, reliable feed-meat conversion ratios are not available. Further, little information exists on the prevalence of different kinds of animal-raising practices. Finally, for each kind of animal-raising practice, especially traditional backyard animal raising, there is a lack of data on the proportion of feedgrain out of total feed. Because of these limitations, the demand approach is used infrequently and the corresponding results are suspicious. China's Ministry of Agriculture used this approach and obtained the results as reported in Table 1. The results are rather different from those obtained employing the supply approach – see, for example, the estimation of feedgrain supplied for 1980 to 1994 by Cheng and Wang (1997) given in Table 1. Aubert (1999) used the demand approach and officially published meat output data to estimate the amount of feedgrain that would be required for 1985-96. The estimates are unrealistically high, especially for the years after 1991 (see Table 1). Aubert argues that it is likely that the meat output statistics have been inflated.

[Table 1 here]

The supply approach, on the other hand, involves deducting human consumption, seeds, industry usage, storage wastage and so on from total grain output. The residual is treated as total feedgrain supply. Some believe that this approach is more appropriate for China (Garnaut and Ma 1992, p. 77; Cheng and Wang 1997). Using this method, RGCFDS (1993, p. 180) estimated the amount of feedgrain available in 1987 at 86 million tonnes, accounting

for 21% of total grain output. Cheng and Wang (1997) provided estimates of feedgrain supplied for 1980 to 1994 (included in Table 1). Their estimate of feedgrain supply was 59 million tonnes in 1980 and 134 million tonnes in 1994, implying an annual growth rate of 6%. According to their results, feedgrain represented 18.5% of total grain output in 1980, and this increased to 30% in 1994. Garnaut and Ma (1992, p. 77) believe this same proportion was 22% (92 million tonnes) in 1987 and 25% (115 million tonnes) in 1990.

Proponents of the supply approach have obtained similar results (see Table 2). Taking 1987 as an example, the estimate of Cheng and Wang (1997) was slightly higher than those of Garnaut and Ma (1992) and RGCFDS (1993). This could be attributed to the fact that, in addition to the usual deductions from human consumption, Garnaut and Ma (1992) deduct the grains used for producing Chinese spirits. RGCFDS (1993) goes even one step further by deducting the amount of grains consumed by the unregistered population.

[Table 2 here]

Then, what was the level of feedgrain consumption in China in the recent years? Provided below are two sets of recent estimates: one is based on a study led by China's State Statistical Bureau (Table 3) and the other is from the National Feed Industry Statistical Data (Table 4). The estimate in Table 3 is about 10 million tonnes lower compared to the estimate of the corresponding year in Table 4. According to our judgement, the estimates from the National Feed Industry Statistical Data are likely to better represent the reality. Thus, China's current feedgrain consumption level is likely to be in the range of 165-170 million tonnes.

[Table 3 here]
[Table 4 here]

3. Feedgrain Demand and Supply: the Projections

Feedgrain did not become an "issue" in China until the late 1980s. Till the mid 1980s, China had great difficulty in producing sufficient foodgrain to feed its huge population and moderate imports of foodgrain had to be sought. Consequently, little grain could be spared to feed animals. Not surprisingly, few bothered to pay much attention to the issue of feedgrain. Feedgrain emerged as an issue only after several consecutive years of good harvests in the early 1980s, which resulted in difficulties in selling, transporting and storing grains. After the need to feed the human population had been basically met, some grains could be spared to feed animals. CAAS (1985) and Liu (1988) are among the pioneers who tried to draw people's attention to feedgrain issues and to the development of China's animal husbandry industry.

Liu (1988) was the first to attempt to forecast feedgrains to be demanded and supplied in 1990 and 2000. Since then, there has been increased interest in projecting China's feedgrain demand and supply. However, the research frameworks of some of the available studies seem to lack rigour. While making projections, some authors provide no details about the data and models (e.g., Liu 1988; Zhang 1997). Others seem to just guess based on other research findings (e.g., RGCFMR 1998). In this paper, representative projections are included for discussion and their projections are summarised in Table 5.

[Table 5 here]

CAAS (1989), RGCFDS (1993), Cheng et al. (1997), and Guo et al. (2001) are all studies based on large projects funded by Chinese government agencies. These authors all had good access to data and information. CAAS (1989) represents one of the few pioneer grain research projects. However, few details are given about how the projection is carried out. In addition, feed-meat conversion ratios are based on carcass weight rather than animal liveweight which is the case in most other studies. RGCFDS (1993, p. 22) provides projections on feedgrain supply but gives no details on how they are derived.

Cheng et al. (1997) is based on a project on feed demand and supply commissioned by China's Ministry of Agriculture. The study uses both time-series analysis and demand systems to estimate the demand for animal products. The feed-meat conversion ratios used seem reasonable, compared with most others (see Table 6 for details). Guo et al. (2001) is based on another project funded by the Ministry of Agriculture conducted in 1996. No details about research methodology were given. Further, they used the same feed-meat conversion ratio (4:1) for pork, beef, mutton and poultry (p. 23), although the conversion ratio for mutton and poultry is generally thought to be lower.

Acknowledging the difficulty in obtaining reliable feed-meat conversion ratios, Zhu (2000) used the 'supply approach' to gauge the likely feedgrains available in 2000, 2010 and 2020. Then he treated such estimates as the amount of feedgrains to be demanded. However, the 'supply approach' takes little account of the possible influence of important factors on the demand side such as consumer income, urbanisation and changes in population structure.

Huang and Rozelle (1998), using econometric techniques, also allow varying growth scenarios (high, medium, and low) for some key variables such as income and population. However, even with high growth scenarios in both population and income, the amount of feedgrains demanded for 2000 is only 117 million tonnes, which is rather low. This could be due to two factors: (1) The income elasticities of demand for animal products they use seem to be too high (Huang and Rozelle 1998, p. 245). For details, see Table 7; (2) Per capita consumption of animal products is based on official statistics from the State Statistical Bureau, which, according to Wang, Zhou and Cox (2005), are low estimates. While higher income elasticities will result in higher quantity of animal products demanded, lower per capita consumption of animal products will have a much greater impact on the quantity of animal products demanded due to the huge population base. On balance, this would have yielded a lower quantity of animal products demanded and thus a lower quantity of feedgrains demanded. Further, Huang and Rozelle gave few details about the feed-meat conversion ratios used.

Garnaut and Ma (1992) used the 'demand approach' to predict demand for feedgrains, employing minimum feed-meat conversion ratios available at the time of their study. They make use of the similarity of China's food consumption patterns to those of Taiwan in the early 1960s to draw on the experiences of the 1960s in Taiwan. Garnaut and Ma's study is heavily based on a set of assumptions and suffers from the lack of some data.

Findlay (1998) projected feedgrain demand for 2000, 2010, and 2020 as part of the projection of grain demand, conducted by a group of researchers from Australia and China. They take into account changes in feeding efficiency by having two efficiency scenarios: high and low. They also had two growth scenarios: 8% and 10% of GDP growth. According to their results, feedgrain demanded in 2000 would be nearly 240 million tonnes and imports would be nearly 30 million tonnes under the low feeding efficiency scenario. Clearly, this significantly

exaggerated China's demand for feedgrains in 2000. However, information on methodology used for the predictions is limited in Findlay (1998).

Xian (2003) and Chen (2004) are two recent studies that attempt to forecast China's grain demand and supply but also dealt with feedgrain demand and supply. In Xian (2003), a kind of balance sheet approach was used to estimate China's grain demand and supply and details on its methodology are not available. They provided forecast on China's feedgrain demand for 2001 to 2005. The estimates by Xian (2003), though slightly lower, seem to be pretty close to the actual consumption between 2001 and 2005. Chen (2004) represents a most recent and comprehensive study on China's grain demand and supply. Various econometric modelling techniques are used. However, while the study correctly pointed out that the demand for feedgrain will continue to rise, it chiefly focused on forecasting grain demand and supply but did not provide a forecast on the likely level of feedgrain demand.

Clearly, available studies show that there are discrepancies in projections. This is hardly surprising given the differences in assumptions, research methods and data used. Generally speaking, discrepancies in demand projections are greater than those in supply projections. Taking 2000 as an example, the projections for feedgrain demand range from 109 million tonnes to 239 million tonnes. On the supply side, projections range from 125 million tonnes to 210 million tonnes. Given the fact that China's imports of feedgrains were minimal in 2000, actual feedgrain usage should be roughly equal to available domestic supply, unless there was a major drawing from stocks. Based on the discussion in the previous section, the available supply of feedgrain in 2000 is likely to be some 156 million tonnes. If so, all authors underestimate feedgrain supply for the year 2000, except Findlay (1998) who overestimated supply by almost 60 million tonnes. On the other hand, the demand projections by Liu (1988), Garnaut and Ma (1992, normal growth scenario), Cheng et al. (1997), and Guo et al. (2001) are close to the likely supply.

In short, existing projections indicate that (1) China's demand for feedgrain is increasing and (2) demand for feedgrain is greater than supply and feedgrain imports would be needed. However, there exist substantial discrepancies in demand and supply projections and the quantity of imports required. As projections are meant to guide future policy initiatives and market activities, the reliability of such projections is of utmost importance. Clearly, some of the projections (as for 2000) are far from the actual picture. Then, why are there such discrepancies?

4. Why Do the Projections Differ?

Discrepancies among projections are hardly surprising. However, too large discrepancies or projections deviating too much from the actual observations will be a concern. Understanding the causes that may have led to discrepancies or deviations helps to improve future projections. Many factors affect projections and in the case of China factors affecting its demand for or supply of feedgrains could be even more complex.

On the demand side, demand for feedgrains is a derived demand. The more animal products to be produced, ceteris paribus, the more feedgrains will be demanded. Holding the demand for animal products constant, the amount of feedgrains demanded will be inversely related to the feed-meat conversion ratio. Any factors that affect the demand for animal products and the conversion ratio will affect the demand for feedgrains. In addition to the conventional determinants of demand, some other factors must also be taken into account when assessing

the demand for animal products in China: i.e., urbanisation, the government's food consumption policy choices, and China's access to the overseas meat market. As for the conversion ratio, it is primarily determined by a range of technological factors. These include breeds of animals, use of additives, feed compositions, methods of animal raising (backyard, specialised, feedlot), and animal accommodation. However, the conversion ratio also responds to prices of feedgrains and animal products.

On the supply side, factors such as the prices of outputs and inputs, price expectations, technology, weather, and the number of suppliers are important. Other factors that need to be taken into consideration when addressing China's ability to supply feedgrains include total grain production and government policy choices. As a residual of total grain output and foodgrain, everything else being constant, the higher the total grain output, the greater the supply of feedgrains. Similarly, if government policy favours the production of grains, the supply of feedgrains may also increase.

Further, unlike the situation in many developed countries, feedgrain is not necessarily the primary source of feed in animal feeding by all practices in China. For example, backyard pig-raising is still predominant in China (as high as about 80%, Qi 1999, p. 2). Feed used to raise animals in this kind of practice may include anything that animals eat (such as table scraps, grasses, tree leaves, crop straws), and feedgrains typically account for a much smaller portion (Tian and Chudleigh 1999). Recent surveys in rural China also reveal that some specialised animal-raising households do not feed grains directly to animals. Instead, they use cereals, beans or tubers first for producing other products (e.g., liquors, starch products, bean curd) and then use the residues to feed the animals (Zhou et al. 2003). An increase in non-grain feed will reduce the demand for feedgrain, and the use of such feed inevitably complicates any projection of China's feedgrain demand-supply balance

In the rest of this section, we will focus on several major variables and examine how they may affect China's feedgrain demand and supply projections.

4.1 Demand Side

On the demand side, major factors that may cause differences in feedgrain demand projections include feed-meat conversion ratios, income and income elasticities, and animal feeding methods.

Conversion ratio Which ratios should be used in feedgrain demand projections? There are few commonly accepted ratios. It is believed that insufficient attention has been given to studying feed-meat conversion ratios (Cheng and Wang 1997; Findlay 1998, p. 28). However, feed-meat conversion ratios are indispensable for any feedgrain demand calculations or projections. Consequently, many researchers have tried to calculate the likely conversion ratios for their research work and, not surprisingly, their results vary, sometimes vastly (see Table 6). For example, Liu et al. (1988) put forward a conversion ratio for pork at about 8:1, whereas many others use a ratio in the range 3.5-4.0:1 (e.g., Wang and Huo 1996; Cheng et al. 1997; NORHS 1998; Guo et al. 2001). Given the use of such vastly different conversion ratios, the difference in projected feedgrain demand is unavoidable.

[Table 6 here]

Animal feeding practices An important factor that contributes to uncertainty concerning feed conversion ratios is lack of knowledge on different animal feeding practices. These practices are associated with different feed compositions, which, in turn, lead to different feed conversion ratios (Tuan et al. 1998; NORHS 1998; Fang et al. 2000). NORHS (1998) believe that specialised households have a lower feed-meat conversion ratio while backyard animal-raisers have a higher conversion ratio. However, others argue that backyard raising has the smallest conversion ratio because this practice uses less feedgrains (Guo, Q. et al. 2001). It is especially difficult to estimate conversion ratios that are appropriate for backyard raising conditions. There are millions of rural households practising backyard animal-raising, and animal-raising conditions are also different between regions. To date, few researchers are in a position to suggest ratios that are representative of the three kinds of practices.

Income and income elasticities Income growth and income elasticities are believed to be most important parameters that affect demand projections (Wan 1996).While the income elasticity is crucial, its estimation, especially in the case of China, is often not an easy task. Due to data problems (see elaboration below) and different modelling techniques, estimated income elasticities of demand for the same product may be quite different. It can be seen from Table 7 that significantly different income elasticities have been produced. For example, Lewis and Andrews' income elasticity of demand for pork is four times that of Wang and Fan. In the case of aquatic products, their income elasticity is about ten times that of Wang and Fan for rural people and seven times for urban people.

[Table 7 here]

These large differences in income elasticities, holding income growth the same, will lead to different estimates of demand for animal products. For example, CAAS (1989, pp. 25, 35), Garnaut and Ma (1992, pp. 96-97), RGCFDS (1993), Huang and Rozelle (1998, p. 23) and Wang and Fan (1999, p. 52) all produced different animal product demand projections. The difference between the latter two is significant. For example, the projection for the year 2005 by Wang and Fan (1999) is even higher than the projection for year 2010 by Huang and Rozelle (1998). If the demand projections for animal products are different, demand projections for feedgrains will be different.

4.2 Supply Side

Total grain supply, the adoption of new technologies, and government policy changes are among the major factors that lead to differences in feedgrain supply projections.

Total grain supply As indicated earlier, feedgrain is a residual of total grain supply and non feedgrain usage. Non-feedgrain usage is unlikely to change drastically between years. However, total grain production can be affected by many factors such as weather conditions and input and output prices and thus may vary from year to year. This leads to uncertainty in the projections of feedgrain supply.

New technologies New technologies may increase yield and total grain supply, holding other factors unchanged. For example, since the early 1990s, plastic film has become widely adopted in corn production in China. This practice allows earlier sowing, extends the period of corn growth and as a result raises yield. However, the advent of new technologies, the scope of their adoption and their effects on output may not always be easily anticipated. This

makes it difficult to incorporate the impact of new technologies in the prediction of grain production and thus the availability of feedgrains.

Government policy changes When government policy emphasises grain production, as in 1995 with the institution of the so-called 'provincial governor grain-bag responsibility system', total grain supply is likely to increase, although at the expense of other crops. Given the fact that the Chinese government has been so sensitive about grain supply, it is likely that the government will shift its policy attention to increasing grain production whenever deemed necessary. However, it is difficult to anticipate when and to what extent the government may introduce changes to its grain production policy.

4.3 Data and Conceptual Problems

Another important aspect that contributes to projection discrepancies is data problems, including data availability, data coverage, data reliability, and conceptual problems.

Data availability Some data are simply not available. For example, the amount of feedgrain available from each year's harvest has not been collected separately. Data on proportions of the three kinds of animal feeding practices are very limited. Detailed information about feed composition for different feeding methods, especially for backyard animal raising, is hardly available. There are no well-studied feed-meat conversion ratios.

Data coverage In some studies, one cannot be sure about the exact data coverage. For example, when referring to feedgrains, exactly what products are covered or included as feedgrains is not clear. Also, in recent years, specialised household animal raising has been fast emerging. What kind of households would be treated as specialised and what is the criterion for separating specialised animal raisers from traditional backyard animal raisers? Again, this is not clear.

Data reliability It has been well known that some Chinese data are unreliable (Wu and Kirke 1994; Wu 1995; Aubert 1999). One typical example is the arable land area in China. In November 1999, the government officially acknowledged that the arable land area in China was more than previously claimed. Accordingly, the government adjusted it from 100 to 128 million hectares. This would affect the reported yield level and the sown area.

Quite often, statistics may be under- or over-reported. Zhong (1997) argues that China's meat production statistics could have been inflated by 50% or more. Lu (1998) indicates that output of meat, poultry eggs and aquatic products for 1981-95 could have been inflated by at least 40%. According to Aubert (1999), Colby et al. (1999), and Fuller et al. (2000), China's official meat production statistics have been overstated. However, Yuan (1999) disagrees with these claims and argues that the level of inflation for meat output is significantly below 40%. Jia (1999) even claims that previously published meat production statistics are reasonable and there is little inflation.

However, the gap between animal production and consumption data had been increasing since the early 1990s and became even larger by 1995 and 1996. In light of this increasing gap, in 1997 the government adjusted 1996 meat output figures downwards but without any due explanation. On the other hand, in 1998, the government adjusted 1997 meat output figures upwards and eggs and milk output downwards. The details of the adjustments of various animal products are given in Table 8. The table shows that the 1996 downward

adjustment was by 22% for all meat, with beef being the highest, 28%. Egg output for 1996 was adjusted slightly upwards, but for its 1997 output it was adjusted downwards by almost 11%, making total egg output for 1997 lower than that of 1996. After these adjustments, then, how close are the government-published output figures to the real output levels? According to Yuan (1999), for those figures prior to 1996 where no adjustment was applied, pork, beef and mutton output would remain over-estimated by about 20%, while poultry and egg output would remain over-estimated by as much as 45%. However, milk output is believed to be little inflated. Yuan (1999) believes pork, beef and mutton output figures since 1996 are reasonable, although poultry and egg output remain inflated to some extent.

[Table 8 here]

Conceptual problems The above-mentioned data coverage problem is largely related to conceptual definitions. One example is the calculation of feed-meat conversion ratios. While it is commonly held that liveweight should be used when calculating the conversion ratios, CAAS (1989, p. 43) used carcass weight instead. In addition, what feed is used as the numerator to calculate the conversion ratio? Is it all the feed material the animal eats, is it the processed industrial feed (which contains grains), or is it feedgrain only? If feedgrain only is used as the numerator, the derived conversion ratio would be lower (see, for example, CAAS 1989, p. 43).

Given the above data problems, surrogates may be used. In many other cases, data without reliability or data without clear coverage boundaries may be used. When this is the case, deviations in and discrepancies between predictions are inevitable.

5. Projecting China's Feedgrain Demand and Supply with a Regional Focus

The discussion in the above section clearly highlights the difficulties and complexities in projecting China's feedgrain demand and supply. In a project on China's feedgrain demand and supply we conducted during 2000-2003 for GRDC (Zhou and Tian 2003), we attempted to take into consideration as many as possible those challenging issues when designing our study. In addition, we also paid much attention to deal with regional differences in our project. A regional-level feedgrain demand-supply balance sheet was developed, which was the first of its kind and should contribute importantly to further studies of China's feedgrain demand and supply issues (for more details about this GRDC project, see Zhou and Tian 2003).

Based on our study, China's feedgrain demand and import requirement in 2010 is likely to be much smaller than some earlier projections. Simulations in our study reveal that technological improvements in animal raising, income growth, and the export growth of animal products all have relatively greater impacts, compared to other simulated factors, on the demand for feedgrains. Assuming technological progress and income growth maintain their current rates to 2010, China's demand for feedgrains is expected to grow by 25-30% by 2010, and so too will its domestic feedgrain supply. China's demand for feedgrain in 2010 will be around 202-207 million tonnes and the supply of feedgrains will be in the range of 198 to 203 million tonnes. The feedgrain import will be in the range of 3-4 million tonnes.

China may need to import more feedgrains if it experiences a faster per capita income growth and is able to export livestock products to the world market. Currently, consumer income growth and ability to export livestock products are the two major constraints on further

development of China's livestock industries. In addition to these two variables, whether the Chinese will consume more livestock products or aquatic products remains to be seen when their income further increases.

Assuming that there will be a faster increase in consumer income and that China can increase its livestock product export, a further 5 million tonnes of feedgrain may be demanded and imported from the world market. This would lead China's feedgrain demand in 2010 to being in the vicinity of 210 million tonnes and its import requirement to being still less than 10 million tonnes. This suggests that, by the end of this decade, China is unlikely to become a large feedgrain importer.

As shown in Table 9, China has been net exporting grains since 1997 (except 2004). Total net export continued to be substantial even in 2002 and 2003 after China had joined the WTO in late 2001. Feedgrain (chiefly, corn) was a major contributor to the increase in China's grain exports (see Table 9). However, we pointed out in our report to GRDC that China's substantial grain export would be subdued by mid of the decade because of reduced domestic grain supply. We argued that the following forces, when combined, would lead to China's reduced feedgrain export. (1) China's total grain output had been low for several consecutive years between 2000 and 2003. (2) Feedgrain export was high during the same time period. (3) Grain import was low. (4) In the meantime, domestic grain demand increased steadily. This would reduce the level of stock and China could not continue this pattern of grain distribution for too long without substantial domestic grain output increases. Indeed, following a grain price hike in late 2003, China's corn export was heavily curtailed in 2004 (see Table 9). Although corn export in 2005 increased again, the total export was significantly lower than that in 2002 and 2003.

[Table 9 here]

Taking into account China's current level of feedgrain consumption, in normal circumstances (i.e., there are no strong shocks such as severe and large-scale animal diseases that would significantly reduce livestock production activities), China's total demand for feedgrain will continue to rise at a rate largely comparable to that in the past few years. As such, the demand by 2010 would be around 200 mt. This would be significantly lower than some earlier forecasts but close to our projections. Given that China remained a net grain export in 2005 with contribution chiefly from feedgrains), we continue to hold that China's total feedgrain import is unlikely to be large by 2010 unless there were drastic changes in some key variables such as grain and livestock production, or China's ability to export livestock products.

Projections are subject to error due to many uncertainties involved. In addition to various issues we have addressed in the above sections, uncertainties regarding future changes in some key variables can result in even greater challenge for projections. In this regard, it is most useful to gain an understanding of some major factors that may affect future projections of China's feedgrain demand and supply.

6. Factors Affecting Future Feedgrain Demand and Supply Projections

Government policy If the Chinese can afford to eat more animal products, where would these products come from? Will the Chinese increase domestic animal feed production so as to produce more animal products, import feedgrains, or import animal products? The Chinese government's future policy directions and choices will have an important bearing on the

source of animal feed and animal products. It is hard to predict what choices the government will make and such choices are also influenced by many international factors. If the international agricultural trade liberalisation proceeds smoothly under the WTO guidelines, it is likely that China may import more feedgrains to raise animals. However, it is also possible that China may import more animal products should the government give priority to China's environment protection.

Income growth and changes in income elasticities Whether the Chinese will eat more animal products will be heavily influenced by their income growth. If the current rate of income growth is sustained, total demand for animal product will increase. Related to income growth are the likely changes in income elasticities. For animal products these may increase when consumers' incomes increase from a very low level. However, after income has reached a certain high level, income elasticities may decline with further increase in consumers' income. For example, Zhou (2001) reveals that the income elasticity of demand for milk tends to decline when income rises. Shono et al. (2000) also noted that income elasticities decreased as income and consumption levels of some meats increased over time.

Technological choices China's future demand for, and supply of, feedgrains can be greatly affected by technological choices. The use of crop residues to feed animals will reduce the demand for feedgrains (Guo and Yang 1997). Many believe that if the feed-meat conversion ratio is improved by a small margin, the potential savings in feedgrains can be enormous (Fan and Agcaoili-Sombilla 1997; Zhang and Lu 1997; and MOA 1998a, pp. 16-17). Many have explored the ways in which this can be achieved; for example, the use of additives, the extension of improved animal breeds, and better accommodation for animals in northern China for the winter season (see, for example, He and Wang 1993; RGCFDS 1993, pp. 44-46; MOA 1998b, pp. 58, 92). On the other hand, with the use of improved technologies, there is also potential to increase feedgrain supply (Qing 1998; Tian and Chudleigh 1999; and Tian and Wan 2000). How fast technologies will become available and to what extent they will be adopted remain to be seen.

Water availability and quality Water introduces more uncertainty into future grain and feedgrain projections. China has 22% of the world's population but only 7% of the world's fresh water (Ryan and Flavin 1995). Per capita water availability is very low, being the second lowest in the world. Over 80% of water is used for agricultural purposes. However, recent years have seen increased water being diverted to meet the needs of rapid industrialisation and urbanisation. Given that a significant portion of China's grain is grown on irrigated land, grain production will be challenged by decreasing water availability (Heilig et al. 2000; Han 2002). In addition, most of China's water is in the south, and northern China is seriously short of water. This will undoubtedly affect regional grain production which has recently attracted much attention from researchers (see, for example, Heilig et al. 2000; Yang and Zehnder 2001). Further, the water shortage problems are exacerbated by the fact that a growing share of the water is polluted. The Chinese government has taken measures to combat the water shortage and quality problems and is planning a huge project to carry water from the Yangtze River to northern China. Future regional grain/feedgrain production will certainly be affected by changes in water quality and its availability to farming.

Regional differences Being such a vast country, China has many regional variations that affect feedgrain demand and supply. For example, different climatic conditions affect both cropping patterns (thus the availability of feedgrains) and animal growth (i.e., severe or mild winter, thus affecting feed-meat conversion ratios). The availability of non-grain feed

resources in a region affects the composition of feed. Animal raising methods in different regions, especially under backyard practices, may lead to different efficiencies. Consumer preferences for meats vary from region to region. One meat may be preferred over others, or one region may prefer to have more fatty meat than lean meat. These preferences affect the kinds of feed needed and the feed-meat conversion ratios. A good understanding of regional differences may be difficult and costly to achieve, but it is essential. Without it, real insight into China's feedgrain issues will be difficult to gain.

China's access to international markets If China can export more animal products it will need to import more feedgrains. China's access to international markets is critically dependent upon the acceptance of its products by overseas consumers. At present, China's animal product exports, except for poultry meat, are limited. China has almost no access to the markets of developed countries, due to the lower safety standards of its products. How fast China can improve the safety standards is uncertain. Further, China's ability to export is also affected by the overall progress of the international trade liberalisation under the WTO arrangements and the willingness of developed countries to reduce or withdraw subsidy to their animal production and export programs.

Changes in tastes and preferences If China's economy and consumer income continue to grow as in the past two decades, changes in consumers' tastes and preferences are expected to continue. Rural consumers and urban low-income consumers are likely to consume less cereal and more animal products (Delgado et al. 1999). Higher-income consumers are likely to consume less ruminant meats but more fruits, dairy and aquatic products (Wang and Fan 1999; Shono et al. 2000). The increase in meat consumption by rural and urban low-income consumers may to some extent be offset by the reduction in red meat consumption by higher income consumers. It is not easy to gauge the speed and the extent of changes in consumers' tastes and preferences and the likely offsetting effect.

7. Concluding Remarks

The review of existing literature in this paper tends to confirm that China's future domestic feedgrain supply will not be sufficient to meet demand and thus there will be the need for feedgrain imports. However, how much to import remains a puzzle due to the vast discrepancies between projections. Clearly, further research efforts are called for. To ensure research findings are realistic and relevant to policy-making and marketing activities, in this concluding section, we offer our views about the areas to which research efforts should be devoted and also point out future research priorities.

We believe the following areas warrant further research efforts.

Regional focus Only by carefully considering regional characteristics can we gain useful insights into China's feedgrain issues. Previous studies have dealt with China's feedgrain issues largely at the aggregate national level. Studies at the regional level will make significant contributions to understanding China's feedgrain issues. The following regional characteristics are worth looking into:

- Differences between the three kinds of feeding practices across regions.
- Proportion of different feeding practices at the regional level and its change over time.
- Conversion ratios between different feeding practices and across regions.

- Income elasticities of demand for various kinds of animal products at the regional level, for rural and urban consumers, and for different income groups.
- Differences in consumer preferences between rural and urban areas, between regions, and between different income groups.

Away-from-home consumption Dining in restaurants has become increasingly popular in China. One reason that government statistics on per capita animal product consumption are lower is due to the omission of away-from-home consumption. Information on away-from-home consumption will help gain more accurate data on per capita consumption of animal products which in turn helps projection work. Carefully designed household surveys are necessary.

Feedgrain use in the farming of aquatic products Aquaculture has grown dramatically in the past two decades in China. Grain also accounts for an important portion of the feed used for aquatic farming. Currently, very limited attention has been devoted to assessing the demand for feedgrains by the aquatic farming sector.

Rural demand for animal products Given the huge size of the rural population, the potential demand for animal products by rural residents is enormous. A small increase in per capita consumption will translate into a large aggregate demand. More effort needs to be devoted to studying rural demands for animal products.

While all these research areas are important, discussions in this paper tend to suggest that the use of vastly different elasticities and conversion ratios by various studies may have contributed greatly to the different projections. Hence, in future studies, priority should be given to, in order of importance and urgency, (1) the estimation of income elasticities of demand for animal products, and (2) the estimation of feed-meat conversion ratios.

- **Estimation of income elasticities using recent data**. Earlier we pointed out that income elasticities may decrease as income and consumption levels of meats increase. Hence, new estimates of income elasticities with recent data are needed for projection work; otherwise, the future demand will be overstated. Income elasticities need to be estimated for different income groups and for different regions. Data may be collected through researchers' own household surveys. However, such exercises have become increasingly expensive in China. One alternative is to obtain household survey data from China's State Statistical Bureau, which conducts annual urban and rural household surveys. The Research Centre for Rural Economy of the Ministry of Agriculture also conducts an annual household survey but covers rural households only.
- **Estimation of feed-meat conversion ratios**. It is suspected that feed-meat conversion ratios may have declined in recent years due to, for example, improved feed diet composition and better feeding practices. Surveys may be conducted on a regional basis to collect data and to interview animal producers.

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Table 1. Estimates of feedgrains consumed (mt)

Year	Feedgrains consumed (demand approach)			Feedgrains consumed (supply approach)
	MOA	*Aubert*		
		Low	High	
1980				59.4
1981				61.8
1982				69.1
1983				77.4
1984				81.1
1985	48.7	106	118	84.6
1986	60.6	112	125	84.6
1987	73.8	114	128	93.6
1988	89.0	124	139	99.4
1989	105.2	127	142	103.4
1990	125.6	143	161	108.9
1991	132.6	151	161	114.8
1992	126.2	151	169	120.9
1993	-	162	182	127.4
1994	169.5	182	205	134.2
1995	143.6	202	227	
1996	225.6	225	254	

Sources*:* Garnaut and Ma (1992, p. 75) for demand approach estimates 1985-89; MOA, *Statistics of China's Animal Husbandry* (various issues) for demand approach estimates 1990-96; Aubert (1999) for demand approach estimates 1985-96; Cheng and Wang (1997) for supply approach estimates 1980-94.

Table 2. Comparison of the estimates of feedgrains consumed obtained by the supply approach

Author	For the year	Feedgrains consumed (mt)	Proportion out of total grains produced (%)
RGCFDS (1993, p. 180)	1987	86	21
Garnaut and Ma (1992, p. 77)	1987	92	22
	1990	115	25
Cheng and Wang (1997)	1980	59	19
	1987	94	23
	1990	109	24
	1994	132	30

Table 3. Estimated total consumption of grains in China, 1995-2005 (mt)

Year	Total	Foodgrains	Feedgrains	Other usages
1995	456.26	274.64	130.02	51.60
1996	460.50	273.25	135.73	51.52
1997	465.31	271.86	141.44	52.01
1998	469.83	274.43	143.06	52.34
1999	474.06	275.95	145.53	52.58
2000	477.05	277.80	146.70	52.55
2001	482.42	280.30	148.90	53.22
2002	488.21	282.82	151.13	54.26
2003	494.37	285.37	153.40	55.60
2004	500.08	287.94	155.70	56.44
2005	504.50	289.38	158.03	57.09

Note: 2001-2005 are projections.

Sources: Xian (2003, p. 8).

Table 4. Feedgrain consumption in China

Year	Feedgrain consumption (mt)	Total grain output (mt)	Feedgrain use as % of total grain output
1996	147.8	504.5	29.3
1997	149.2	494.2	30.2
1998	159.8	512.3	31.2
1999	162.7	508.4	32.0
2000	155.9	462.2	33.7
2001	156.2	452.6	34.5
2002	160.0	457.1	35.0
2003	163.7	430.7	38.0

Source: National Feed Industry Statistical Data from 1996 to 2005.

Table 5. Projections of China's feedgrain demand and supply

Author	Projection results (mt)			
	Year	*Demand*	*Supply*	*Balance*
Liu (1988)	2000	153.7	125	-28.7
CAAS (1989, p. 45) [a]	2000	242 (I)		
		190 (II)		
		242 (III)		
Garnaut and Ma (1992, p. 98) [b]	2000	162		
	2000	196		
RGCFDS (1993, p. 22)	2000		131	
	2020		194	
Huang and Rozelle (1996)	2000	109		
	2010	158		
	2020	232		
Cheng et al. (1997)	2000	160-170		
Zhang (1997)	2000	222	150	-72
RGCFMR (1998)	2000	150		
Findlay (ed.) (1998, pp. 11, 49) [c]	2000	239	210	-29
	2010	346	282	-64
	2020	466	378	-88
	2000	201	210	9
	2010	311	282	-29
	2020	443	378	-65
Zhu (2000, p. 4)	2000	170		
	2010	220		
	2020	280		
Guo et al. (2001, p. 25) [d]	2000	154		
	2010	223		
	2020	272		
Xian (2003)	2001	149		
	2005	158		

[a] Three scenarios are projected. I. Less cereal but relatively more animal product consumption; II. Relatively more cereal but less animal product consumption; III. Medium level cereal consumption but relatively more animal product consumption. Feedgrain demand for I and III is the same because animal product consumption is assumed to be the same for both scenarios.

[b] Two growth scenarios are assumed. Normal growth scenario (the first row): a per capita GDP growth rate of 6%; high growth scenario (the second row): a per capita GDP growth rate of 7.2%.

[c] Three sets of projections are given in their report with different assumptions. Set 1: low feeding efficiency scenario and income growth by 8%. Set 2: results under low efficiency are scaled down by 25% to reflect some improvement in efficiency. Set 3: high feeding efficiency scenario and income growth by 10%. Only Set 1 and Set 3 are used in this table.

[d] Research conducted in 1996.

Table 6. Estimates of feed-meat conversion ratios in China

Author	Conversion ratio						
	Pork	*Beef*	*Mutton*	*Poultry*	*Eggs*	*Milk*	*Fish*
Liu et al. (1988)	8	10		5	5		
MOA (1988) [a]	5.8			3	3-3.5	1	1.5
Zeng (1988)	4.5			2.2	3.2	0.4	1.5
Lu (1989) [b]	4			2.5	2.5-3		
	5-6			3.5	3-3.5		
Gao (1990) [a]	6-7	3.3		2			1.5
Yu (1991) [a]	5.1	3		3	2.8-3	0.33	2
Food Study Group (1991) [a]	5.5-6.4	4.8		2.5-3.8	3-3.5	3	
Editing Committee of MOA (1991) [a]	4-4.5	2		2.5			2
Zhou (1993)	5			2.2	2.8		
RGCFDS (1993, pp. 182-183)	5.5-6			2.5-3.5	3-3.5		
Wang and Huo (1996) [b]	3.1			1.9	2.7		
	3.5			2.2	3		
Cheng et al. (1997)	3.5	3.2	3.2	2.1	3	1.84	
NORHS (1998) [c]	3.3-3.5						
	3.24	2	1.13	2.36	2.96		
	3.47	4.01	1.34				
Guo et al. (2001, p. 23)	4	4	4	4	2.5	0.3	0.8
Minimum	3.1	2	1.13	1.9	2.5	0.3	1.5
Maximum	8	10	4	5	5	3	2
Average	4.70	4.03	2.42	2.79	3.13	1.15	1.55

[a] Taken from Garnaut and Ma (1992, p.76); beef and mutton together.
[b] Row 1: more efficient feeding practices; Row 2: on average.
[c] Row 1: for feedlots; Row 2: specialised households; Row 3: backyard raising.

Table 7. Estimates of income elasticities of demand for animal products in China

Author	Rural or urban	Year, income level	Income elasticities of demand for						
			Meat	*Pork*	*Beef and mutton*	*Poultry*	*Eggs*	*Milk*	*Aquatic products*
Lewis and Andrews (1989) [a]	Rural	1983-85		1.02		1.95			3.65
Zhu et al. (1991) [a]	-			0.57	0.57	1.46	0.66		1.34
Pinstrum-Anderson et al. (1991) [a]	-			0.63	1.23	1.16	1.18	1.71	0.86
RGCFDS (1993, p. 14)[b]	-	1995	0.580				0.936	1.400	0.468
	-	2000	0.540				0.673	1.189	0.606
	-	2020	0.426				0.553	1.100	0.472
Huang and Rozelle (1998, p. 245)	Rural	1999-2000	0.757	0.765	0.343	0.854	0.512	1.557	1.053
	Rural	2000-2010	0.835	0.782	0.789	0.985	0.455	1.637	1.244
	Rural	2010-2020	0.835	0.782	0.789	0.985	0.455	1.637	1.244
	Urban	1999-2000	0.835	0.782	0.689	0.985	0.455	1.637	1.244
	Urban	2000-2010	0.870	0.797	0.686	1.064	0.491	1.912	1.290
	Urban	2010-2020	0.870	0.797	0.686	1.064	0.491	1.912	1.290
Cai et al. (1999, p. 155) [c]	-	Low income	1.102	0.610		1.392			
	-	Medium income	1.756	0.627		0.541			
	-	High income	1.482	0.731		0.710			
Wang and Fan (1999)	Rural	1998		0.25	0.57	0.22	0.36	0.32	0.37
	Urban	1998		0.32	0.49	0.48	0.26	0.49	0.51

[a] Quoted from Garnaut and Ma (1992, p.72).
[b] No separate estimates for individual meats.
[c] Expenditure elasticities for three income groups; numbers in 'Meat' column are for ruminant meat. Based on a small sample.

Table 8. Adjustments of output figures of animal products in *China Statistical Yearbook* (mt)

Output for the year	Year of publication of the yearbook	Total meat	Pork	Beef	Mutton	Poultry meat	Poultry eggs	Milk
	1997	59.15	40.38	4.95	2.40	10.75	19.54	7.36
1996	1998	45.95	31.58	3.56	1.81	8.35	19.65	7.36
	Adjustment (%)	-22.3	-21.8	-28.1	-24.6	-22.3	0.6	0.0
	1998	51.52	34.64	4.15	2.10	9.36	21.25	7.75
1997	1999	52.69	35.96	4.41	2.13	9.57	18.95	6.81
	Adjustment (%)	2.3	3.8	6.3	1.4	2.2	-10.8	-12.1

Sources*:* SSB, various issues; Yuan (1999).

Table 9. China's grain trade 1990-2005 ('000 tonnes)

Year	Import				Export			
	Total	*Rice*	*Wheat*	*Corn*	*Total*	*Rice*	*Wheat*	*Corn*
1990	13610	49	12530	369	4890	330	...	3404
1991	13450	140	12370	1	9760	690	...	7782
1992	11750	104	10580	...	12681	950	...	10340
1993	7520	96	6420	...	14773	1430	291	11097
1994	9200	514	7300	...	10840	1520	268	8740
1995	20810	1596	11590	5180	899	50	225	110
1996	10830	761	8250	440	1240	264	565	160
1997	4170	330	1861	...	8340	938	458	6607
1998	3880	240	1489	251	8890	3745	275	4686
1999	3390	170	450	70	7380	2700	164	4300
2000	3150	240	880	3	13780	2948	188	10466
2001	3440	290	740	39	8760	1870	713	6000
2002	2850	238	632	8	14820	1990	977	11675
2003	2087	259	447	1	22004	2612	2514	16391
2004	9753	766	7256	2	4795	909	1089	2324
2005	6277	522	3544	4	10176	686	606	8644

Sources: China Customs Administration 2006.