Projecting China's Grains and Meats Trade: Sensitivity to agricultural productivity growth *

Allan Rae and Hengyun Ma
Centre for Applied Economics and Policy Studies
Massey University
New Zealand

Abstract

Literature from the past 20 years is reviewed to establish the range of TFP growth estimates that have been made for China's agriculture. This includes some studies that have focussed on either the crops or livestock subsectors. The dispersion of these estimates is used as an input to a slightly-modified GTAP model in order to determine the sensitivity of China's projected grains and meats trade balances to agricultural productivity growth. For many variables, results indicate a high degree of sensitivity, and a number of ways are suggested by which such projections might be enhanced through improved productivity measurement.

* Presented at International Agricultural Trade Research Consortium Annual General Meeting, session on Research Plan and Reports, San Antonio, Texas, 14-16 December 2003. Financial support from the Massey University Academy of Business Research Fund and FRST contract number IERX0301 is gratefully acknowledged.

Introduction

China's agricultural output has expanded rapidly since the economic reforms of the late 1970s, reflecting both productivity growth and mobilisation of inputs. Over the 1980-2000 period wheat output has doubled and that of maize has risen by about 70%. Among livestock products, output of poultry has increased tenfold, egg output has increased sixfold and that of pork by three times. Over the same period China's rapid economic growth and urbanisation have pushed consumption patterns towards increased consumption of high-value foodstuffs including livestock products. Will China's food output expansion be able to match consumption growth in the future? Urban and rural industrialisation is drawing labour, capital and land away from agricultural employment, and growing environmental awareness could increase pressures to moderate the use of fertilisers and pesticides. Further, the current land tenure system hinders the achievement of scale economies and constrains the expansion of labour-saving agricultural technologies. The above question, along with China's heightened involvement in global food markets as both an importer and exporter, has spurred debate over whether or not China will be able to feed itself, and if not what might be the consequences for global markets?

Perhaps the most (in)famous and pessimistic projection was that of Brown while others (e.g. Fan and Agcaoili-Sombilla) have shed considerable doubt on his scenario of soaring prices and widespread starvation. Nevertheless, several studies have since projected emerging grain deficits in response to population and income growth, urbanisation, a shift in comparative advantage from land-intensive to labour-intensive commodities, and increased demands for livestock feedstuffs. Turning to meats, China has been a net exporter (in value terms) of pigmeat and poultry, a net importer of beef, and overall a net exporter of fresh and prepared meats. Is this likely to continue? Rosegrant *et al*. projected meat imports rising from near trade balance in 1997 to a 4 million tonne deficit by 2020. Delgado *et al*. projected a decline in pork net exports but an increase in the case of poultry by 2020. In contrast, both Rutherford and Huang *et al.* (2000) projected continuing Chinese self-sufficiency in meats.

Given possible policy and resource constraints, achievement of the Chinese government's goal of food self-sufficiency would appear to have to rely on continuing improvements in agricultural productivity. It follows that the measurement of agricultural productivity will become crucial for estimating the future supply of domestic agricultural commodities and in turn for predictions of future grain and meat trade balances. However, the estimation of China's past productivity growth, let alone the formulation of future projections, has also been controversial. The following section reviews past studies, and it will be apparent that the range of measured productivity growth rates is wide. While this reflects in part the variety of estimation techniques and differences in the definition of outputs and inputs, considerable doubt has been cast on the reliability of the underlying agricultural statistics. Only recently have some researchers made efforts to adjust for discrepancies in existing data series or to access alternative data sources. The paper then makes use of a CGE model to illustrate the sensitivity of China's future grains and meats trade balances to current measurements of productivity growth rates.

Review of some Chinese agricultural productivity studies

Agricultural productivity in China stagnated over the two decades prior to 1978 – a net decline of around 25 percent from 1952 to 1977 according to Wen and Tang, while Kalirajan found negative productivity growth in nearly all provinces during the 1970-78 period (Table 1). Several studies are in general agreement over the impact of de-collectivisation in increasing agricultural productivity. Communes were disbanded and the household was made the primary production unit under the Household Responsibility System (HRS), from 1979. This saw the introduction of private property incentives while leaving land ownership in state hands. Grain quota and above-quota prices were increased, with such price increases spreading to other farm products and livestock. Farmers were given greater freedom to choose their production mix, and by the mid-1980s were able to sell produce in a growing number of free markets. Over the late 1970s to mid 1980s, productivity increased rapidly according to several studies. Estimates from the literature vary quite widely, however, depending on the methodology employed and the sectoral coverage. Using the gross value of agricultural output[1], TFP annual growth rates include 1.3% (Kalirajan *et al.* and Lambert and Parker[2]), 5.8% (McMillan *et al.*) and between 7.2% and 8.9% (Wen). Fan (1997) obtained TFP growth of 5.1% for the crops, livestock and fisheries aggregate, Mead estimated growth of 5.6% (crops and livestock) while for crops (grains and cash crops) Lin estimated a TFP annual growth rate of 3.4%. Colby *et al.* estimated a 5.4% annual growth of TFP for the rice, wheat, maize and soybean aggregate while Jin *et al.*'s estimates for rice, wheat and maize range from 6.5% to 8%. Institutional change (HRS) over this period, innovation induced by price increases, and increased use of modern inputs such as improved crop varieties, were seen as important drivers of this productivity growth. Not only did the production frontier move outwards, but institutional innovation enabled production to return to the frontier through the elimination of institutional constraints that had caused serious resource misallocations.

Productivity growth appeared to slow over the latter half of the 1980s. When GVAO is used as the measure of output, reported TFP annual growth rates include 0.5% to 1.4% (Wen), 0.9% (Kalirajan *et al.*) and -0.45% and -0.5% (Lambert and Parker, and Hsu *et al.*, respectively, excluding sideline activities from output). For grains and cash crops Lin obtained annual TFP growth of 0.7%, Jin *et al.* reported static productivity for rice, wheat and maize and Mead's TFP estimate was -0.4% per year. What might have caused this apparent slowdown? From 1979, the state began to allow rural enterprises (TVE – town and village enterprises) to enter markets once the sole domain of mainly urban state-owned enterprises, so as to provide jobs for labour released by the de-collectivisation of farming. The HRS innovation may have largely run its course by the mid-1980s so efficiency gains had diminished, and since then the rapidly expanding TVEs have attracted relatively skilled and more-motivated rural

[1] GVAO = crop farming, animal husbandry, forestry, fisheries and sideline activities.
[2] GVAO less sideline activities.

labour from traditional farm employment which could have impacted negatively on productivity (Lambert and Parker). Jin *et al*. note that Chinese debate on the causes of the slowdown has focussed on land rights, commodity pricing policy, input availability and pricing, and rural industry expansion. They also mentioned the closing gap between potential and actual crop yields as improved varieties became generally adopted. This may imply that technological progress was stagnating, which is consistent with the observed agricultural productivity measurements. In addition, influenced by the declining marginal productivity in the agricultural sector, total investment in agriculture slowed down between 1985 and 1990, and actually fell in real terms over this period (Carter *et al.*).

During the 1990s, the evidence again points to a period of faster productivity growth in the first part of the decade, flowed by a period of slower growth. During the early 1990s, Lambert and Parker estimated TFP annual growth rates (crops, animals, fisheries and forestry) of 2.5% (1990-92) increasing to 5.97% over the 1993-95 period, Jin *et al.* obtained TFP growth of almost 4% for wheat and a little less for maize and rice over 1990-95, and Mead estimated an annual growth of 1.9% (crops and livestock) over 1989-96. In contrast, for the latter part of the 1990s productivity growth rates of 0.8% were obtained by Colby *et al.* (crops, 1995-97), 0.2% by Mead (1996-99 , crops and livestock) and 0.3% by Hsu *et al.* (crops, animals, fisheries and forestry, 1993-99). What might be some reasons for the increased productivity growth in the early 1990s? In 1992, the Chinese government announced its intention to transform the country into a ‘socialist market economy’. Then followed a liberalisation of the grains market and abolishment of the grain rationing system, and farmers have been allowed to lease use-rights to land to encourage more investment in land. According to Lambert and Parker, these new policies were revolutionising China’s rural economy. In 1993, more than 90% of all agricultural produce was sold at market-determined prices, and would have been expected to have impacted on farmers’ allocative efficiency. A return to greater state involvement in the grains sector was signalled by introduction of the provincial governor’s grain responsibility system from late-1994, to promote grain production and self-sufficiency at the provincial level. This resulted in a shift towards supporting grain production with various subsidies, and the contribution of TFP to output growth decreased (Colby *et al.*). Mead attributed the slowdown in productivity growth in the late-1990s (and also in the latter part of the 1980s) to policy uncertainty and flux, for example returning to government monopoly control over grain distribution in 1998 and uncertainty over the impact of China’s accession to the WTO.

While several of the above studies included livestock in their measure of aggregate output, none examined productivity specifically in the livestock sector. Recently, efforts have begun to address this shortcoming. Animal husbandry in China has traditionally been a ‘backyard production’ activity, so would likely not have been as directly affected by the introduction of the HRS as was the crop sector, but innovation in this sector could have been encouraged by the move to free markets and higher relative output prices during the 1980s. Other major policy interventions have also focussed on China’s crop sector rather than livestock, so livestock production may not have been subject to the same political uncertainties that some authors have claimed had a negative impact on productivity growth in the crops sector.

Nin *et al.* (2004) used output per animal (from FAO data) as a partial productivity measure, and obtained growth rates over the 1990s of 3% for hogs and over 11% for poultry. Such partial measures could well be biased estimates of TFP, however, since increased use of other inputs such as feed could contribute to increased output per animal. Nin *et al.* (2003) estimated TFP growth, again with FAO data, but developed the use of directional distance functions that recognised allocatable and non-allocatable inputs. Output was measured as two separate aggregates (crops and livestock); feed, animal numbers and pasture land were inputs allocated to livestock production while fertiliser, labour and tractors were defined (due to incomplete information) as unallocatable inputs. Their graphed results for China show that both crop and livestock TFP declined from 1965 to the late 1970s. Crop TFP increased over 1980-85, was static over the remainder of the 1980s, but increased again between 1990 and 1994. This pattern of TFP development is not inconsistent with several of the previous findings. For livestock however, TFP appeared to have increased steadily over the entire period, and averaged around 6.5% annual growth during 1980-94, compared with almost 4% growth in TFP for crops. Jones and Arnade used data from the same source as Nin *et al.* (2003) and similar methodology, although it is not clear whether allocatable inputs were distinguished from non-allocatable. For the periods 1981-90 and 1991-99, their annual growth rates for TFP were 0.10% and 5.75% respectively for crops, and the higher rates of 4.38% and 10.82% for livestock. While these estimates indicate much lower productivity growth in the 1980s than the 1990s, the apparently static productivity over the latter half of the earlier decade (revealed by several of the above studies) would bring down the average growth rate over the entire 1980s period.

Ma *et al.* (2003) estimated TFP growth rates for each of hogs, eggs, milk and beef over various time periods, depending on data availability. By employing data from the national farm cost and return surveys, data on feed and labour inputs specific to these types of livestock production could be obtained, which is not possible with the data published in the official statistical yearbooks. Efforts were made to correct for the over-reporting of livestock statistics in the official yearbooks (Fuller *et al.* ; Xu; Ma *et al.* 2004). Results suggest that livestock TFP growth was faster in the 1980s than the following decade, but that in either decade livestock TFP growth generally exceeded the estimates reported above for crops. Productivity growth in the eggs sector (8.7% in the 1980s and 4.9% in the 1990s) appeared to out-perform that in the hog sector (3.8% in the 1980s and 1.5% over the 1990s) and the evidence pointed to static productivity for hogs since the mid-1990s. Productivity growth estimates for beef and milk were made for the 1990s, and annual growth averaged 5.2% and 2.5% respectively.

While a general picture emerges from the above survey on the evolution of agricultural productivity growth in China over the past two decades, and the relative performance of crops versus livestock, many uncertainties remain, as have been noted by a number of authors. Studies that used data from the official statistical yearbooks may have included forestry and fisheries in their definition of agriculture, which could bias the estimates if they are taken as indicators of productivity growth in farming. Other studies have omitted one or both of these sectors, but without any adjustment to the input measures (as some forestry and fisheries inputs are not separately reported). Many studies specified a very limited number of inputs to agriculture – for example, of all the reviewed studies that included livestock in their aggregate measure of agriculture only Wen, Carter *et al.* and McMillan *et al.* specified feed as an input, and in each case it was aggregated with other current inputs. Biases can also result from problems in measuring changes in input quality, the number of inputs that are chosen, and the way in which inputs are aggregated (Tauer). Suspected over-reporting in the official data has been addressed in only a small number of these studies. Ma *et al.* (2003) attempted to correct for over-reporting of livestock production and animal numbers, while Mead adjusted data on the agricultural labour force since official data showed an increase in the rural labour force at the same time as labour was apparently migrating rapidly to off-farm employment. Even so, available data does not recognise different types (qualities) of labour, which could be relevant given the assertion that the development of TVEs has drawn primarily on skilled rural labour.

Problems inherent in the use of official national statistics for agricultural productivity measures are neatly illustrated by Carter *et al.* who conducted a case study in a single province (Jiangsu), comparing productivity results based on the aggregate provincial data (the source for many of the above studies) and farm-level cost and return survey data (the same data as used by Ma *et al.*2003). Both data sets gave higher productivity growth in 1978-87 than during 1988-96, but for each time period, growth rates based on the household data were lower. Over the latter time period, TFP grew at the rate of 6.7% per year using aggregate provincial data compared with just 1.9% when based on the household data. They argued that the latter result was the more plausible, casting doubt on the accuracy of using aggregate data in studying China's agricultural productivity.

The Sensitivity of China's Projected Grains and Meats Trade Balances to Productivity Uncertainty

In this section we describe our procedure for determining how such a range of Chinese productivity growth rates might impact on trade projections, and then present our results. We briefly describe the trade model, and then outline the procedure followed to define a scenario to allow projection of national and regional economies and outcomes. This includes the definition of crops and livestock productivity growth in China as random variables, and the formulation of their probability distributions.

The trade model

A slightly modified version of the GTAP applied general equilibrium model (Hertel) is used to make 10-year projections of national and regional production, consumption and trade. This is a relatively standard, multi-region model built on a complete set of economic accounts and detailed inter-industry linkages for each of the economies represented. Although GTAP is among the most sophisticated applied general equilibrium models currently available, it necessarily involves some simplifications and abstractions from the real world. While resources are heterogeneous, the GTAP production system distinguishes sectors by their intensities in just four primary production factors: land (demanded by agricultural sectors only), natural resources (extractive sectors only), capital, and labour. Some differentiation is introduced by dividing the labour resource into two classes – skilled and unskilled. In this study, labour and capital are assumed to be perfectly mobile between production sectors within each region. While GTAP allows substitution amongst the employment of these resources in any sector in response to price changes, intermediate inputs are used in fixed proportions in producing the various outputs. This assumption has been modified in this application to the extent that substitution among feedstuffs in livestock production is permitted. This is done using CES derived demand equations, with a unitary elasticity of substitution among feedstuffs. To make the model more suitable for projections, regional investment is linked to growth in regional capital stock. While all units of output from any sector in a given country are assumed identical, at least in trade products are differentiated by country of origin, allowing bilateral trade to be modelled. This formulation of the model also assumes perfectly competitive markets and constant returns to scale in production. The model is solved using GEMPACK (Harrison & Pearson). The 66 regions and 57 sectors of the version 5 GTAP database for 1997 is aggregated to nine countries/regions and 14 sectors. The latter includes, as separate sectors, rice, wheat, coarse grains, oilseeds, other crops, cattle and sheep production, nonruminant livestock, milk production, nonruminant meats, ruminant meats, dairy products and other processed foods (which includes processed animal feeds). All remaining sectors are aggregated into either manufacturing or services. All values of the trade elasticities in the standard database have been doubled as earlier studies (e.g. Liu *et al*.) have shown that this improves the fit of the model to long run structural changes in trade.

Making the Projections

We project the global economy out 10 years (from a 1997 base), so as to make projections of China's international trade in grains and meats. Because of the wide range of agricultural TFP estimates for China, our purpose is to illustrate how sensitive such projections might be to the underlying assumptions about China's future agricultural productivity growth based on agricultural TFP estimates reported in the literature. Apart from technological change in China's farm sector, what else will be happening in the global economy over our 1997-2007 period that might be captured in our projections? Changes in population, resource endowments and non-farm productivity around the world are drivers of change in the demand and supply side of each national/regional economy, and are reflected in the projections. Income growth, for example, will boost the demand for meats relative to food grains in some regions, while the accumulation of capital and skilled labour will tend to promote a shift in production away from farming to manufactures and services. China's accession to the WTO is incorporated in our analyses, through modelling of the reductions in agricultural, manufacturing and services tariffs. The agricultural TRQs for crops and wool are not modelled, however. For all other countries and regions, we assume no changes in national economic or trade policies. This is not an issue as far as the Doha multilateral round is concerned since any outcomes are most unlikely to be implemented prior to 2007. However, policy changes due to the implementation of the Uruguay Round are omitted, as are changes related to the various bilateral and regional trade agreements during the projection period.

Projections of China's agricultural productivity growth

The estimates of past Chinese agricultural productivity growth recorded in Table 1 show a wide range of values. Pooled over all shown time periods, estimates for the entire agricultural sector range from -0.5% to 8.9% per year. For crops, the range in annual TFP growth rates is 0% - 8%, and for livestock the estimates vary from 1.5% to 11.8%. Only two studies obtained negative estimates of TFP growth, both were between zero and -1%, were for the 1980s and applied to the more aggregate definition of agriculture. Therefore we choose not to project TFP at a negative rate. We assume Hicks-neutral technical change for all projections of productivity growth, whether agricultural or non-agricultural. We use the Gaussian quadrature approach to systematic sensitivity analysis proposed by DeVuyst and Preckel and automated within GTAP by Arndt and Arndt and Pearson. Triangular distributions are employed for both crops and livestock TFP growth, whose minimum and maximum values are the compounded 10-year growth rates that correspond to the ranges in annual growth rates given above. Whatever value is drawn from the crops (livestock) distribution, that TFP projection is applied to all China's crop (livestock) sectors modelled.

Agricultural productivity projections for regions other than China

For all countries and regions other than China, agricultural productivity growth projections were based on the TFP estimates of Jones and Arnade. These have the advantage of covering both crops and livestock separately, and for a large number of countries, and are all estimated with the same dataset (FAO) and methodology (distance functions). For any country other than China, our projection of either the crops or livestock TFP annual growth rate is set as the simple average of the estimated growth rates over the two periods 1981-90 and 1991-99. Such country projections were then averaged across countries to match, as nearly as possible, our regional definitions.

Macroeconomic and non-agricultural productivity projections

Projections are made through exogenous shocks to regional population, capital stock, skilled and unskilled labour supplies and technology. Consequent growth in GDP is determined endogenously. Required shocks for the population, capital and labour projections are taken directly from Ianchovichina and Martin. Productivity growth projections for the manufacturing sector were based on those from the same reference.

Productivity growth projections for the services sector were set at one-half of the manufacturing projections, based on Bernard and Jones' result that, averaged over all OECD countries, productivity growth in services was one-half that in manufacturing. The stock of farmland in each region was held constant.

Modelling China's accession to the WTO

We use a procedure based on that of Ianchovichina and Martin and tariff data from the same reference. Where necessary to match our sectoral aggregation, weighted averages of these tariffs were computed, using 1997 trade values from the GTAP database as weights. The (1997) tariff data in the version 5 GTAP database are first replaced with the 1995 applied rates. Of relevance to the present study is the finding of Huang *et al.* (2002) that some commodities in China, including livestock and meat, faced negative protection in 1995. The impact of WTO accession is then simulated through the replacement of these import tariffs with the post-accession tariffs in the projections.

Results

The 1997 base data showed China to be a net importer of all but one (coarse grains) of the commodities listed in Table 2. We project a deterioration in each of these trade balances, with China projected to be a net importer of all these products by 2007. There is considerable uncertainty surrounding these results, however, especially for grains and nonruminant meat, due to the underlying uncertainly over China's future agricultural productivity growth. By computing the 95% confidence intervals[3], the trade balances could lie within -$3,666 to $1,382 million (wheat), -$2,849 to $2,379 million (coarse grains) and -$10,047 to $8,231 million (nonruminant meats). On the other hand, the results suggest much greater certainty that China will increase its net imports of oilseeds, ruminant meat and dairy products in future.

These developments are also reflected in the export and import volume projections of Table 3. While considerable certainty can be attached to the projected increase in China's oilseed imports, the same cannot be said for either exports or imports of grains, especially wheat. This reinforces the conclusion that the range of productivity estimates available implies considerable uncertainty as to whether China will be a net exporter or importer of these commodities. Turning to the livestock products, it appears that China will continue to increase its imports of ruminant meats and dairy products irrespective of productivity outcomes. Projected changes in exports and imports of nonruminant meats, however, appear very sensitive to productivity growth rates.

Lying behind these changes in trade balances are changes in China's production and consumption of feedstuffs and livestock products. Projected mean output changes are shown in Table 4. Production of grains and oilseeds are projected to increase by between 1% and 2% annually. Considerable uncertainty surrounds these increases

[3] By applying Chebychev's inequality, the 95% confidence interval is computed as the mean result +/- 4.5 times the standard deviation.

however, and decreases in production cannot be ruled out, especially for oilseeds. Projected average growth rates for meats and milk are higher, between 4% and 8% per year. The historical growth rates in Table 7 suggest that such growth rates are not too far removed from the recent experience. The standard deviations in Table 3 also indicate that considerable confidence can be placed in these projected increases in livestock production.

Table 5 gives projected changes in China's total domestic sales of grains, oilseeds and livestock products. Sales of grains and oilseeds (including sales to livestock producers) are projected to increase by between 1.3% and 1.9% per year. The relatively high standard errors suggest that projected declines in sales cannot be ruled out, for example if productivity growth rates are such that domestic outputs of livestock products are much less than the mean projections. In contrast, domestic sales of meats and dairy products are projected to increase at annual rates between 4.2% and almost 10%, and a high degree of confidence can be placed in the projected increases in livestock product sales, especially dairy products and ruminant meats.

The modifications we made to the GTAP model allow the projection of total feed use in the cattle, nonruminant and dairy sectors, after accounting for substitution among feed components due to changes in relative prices (Table 6). The mean results suggest annual growth of just over 2% in feed use by nonruminants, but almost no change to base-period levels of feed usage in the cattle and milk sectors. These are lower than the historic growth rates given in Table 7. At least two points are relevant to explaining this result. First, the growth in the demand for feedstuffs reflects the rate of livestock productivity growth as well as that of livestock output (remember that we modelled productivity growth as Hicks-neutral technical change). Second, considerable structural change has been occurring in Chinese livestock farming. For example, backyard hog production accounted for over 91% of output in 1980, but had declined to 76% by 1999 as specialised households and commercial enterprises increased their shares. Even if total output remains constant, such structural change will impact on total feeds usage if feed conversion rates vary across production structures. The data in Table 8 suggests that at least in hog production, feedgrain conversion ratios are lowest in backyard production systems and highest in the commercial enterprises. Our projections, however, ignore such structural change and therefore its impacts on feed demands.

Conclusions

Confining attention to the modelled feedgrains, oilseeds and livestock products, then no matter what TFP growth values are drawn from our specified distributions, we can be confident[4] that the model will predict the following:

- Increased domestic sales of ruminant and nonruminant meats and dairy products;
- Increased output of milk and ruminant meat in China;

[4] Based on the 95% confidence intervals.

- Increased imports of oilseeds and dairy products; and
- China's current negative trade balances for oilseeds, ruminant meats and dairy products will worsen.

There appears to be considerable uncertainty over the direction of change in China's net exports of grains and nonruminant meats, in the domestic production of grains, oilseeds and nonruminant meats, and in total demands for livestock feedstuffs. Clearly, if an objective is to make projections of China's production, consumption and trade in feedgrains and livestock products, we have not got very far! Even for the expanding cattle and milk sectors, we cannot be confident that increased demands for feedstuffs will result from those sectors, since their productivity growth may outpace output growth. This outcome suggests that previous predictions of China's trade in grains and livestock products should be interpreted with considerable caution.

To narrow the range of projected TFP growth outcomes for Chinese agriculture, high priority ought to be given to data improvements. Many of the earlier productivity studies were based entirely on official published statistics, although some more recent analyses have turned to alternative data sources, or have made attempts to adjust the official statistics where appropriate. Future work could include surveys to gather primary data for productivity estimation, or to allow adjustment of existing data where anomalies appear to exist. More analyses of TFP growth for individual crops and livestock sectors would also be useful, since the majority of studies so far have examined agriculture, or its crops and livestock sub-sectors, in aggregate.

The review of past TFP studies has revealed that productivity growth has occurred in cycles, influenced by instances of policy and institutional reform, and also perhaps through general cycles in economic activity. This places a question mark over the relevance of historical estimates (and many of the existing studies are somewhat dated) for making projections of future productivity growth in China's agriculture, especially given the rapid transition of the Chinese economy. Hence greater understanding of how policy changes and business activity impact on productivity improvement, innovation and the uptake of new technologies would appear warranted.

A feature of the evolution of livestock farming in China continues to be the shift from backyard traditional production and feeding systems, to modern commercial enterprises. Reasons why attempts to project China's international trade in feedstuffs and livestock products ought to take account of such structural change into account include differences in feed conversion rates (Table 8) and productivity growth. The livestock productivity study of Ma *et al.* (2003) found that TFP growth rates in the hog and egg sectors were substantially slower in backyard production than in that of specialised households or commercial enterprises.

Agriculture in China will continue to be influenced by developments in the non-farm sectors, as they bid for labour and investment resources. These in turn will be influenced by non-farm productivity growth, yet there appear to be very few studies of productivity in the major manufacturing and services sectors of the Chinese economy.

Finally, we have not attempted to shed light on how the sensitivity of Chinese feedstuffs and livestock variables to agricultural TFP growth in China, is affected by uncertainty in other parameters and data of the GTAP model. For example how sensitive would be China's feedgrain trade balances to changes in assumed TFP growth, should China's future growth be slower than projected, or if economic growth was faster in other regions with growing demand for feedstuffs, or if grain TFP growth in North America was slower than we project? Restricting attention to just productivity growth, several of the above issues on improving projections of crop and livestock productivity may also be applicable to other countries, especially those that play a major role as consumers or sellers in global grains and meats markets.

Table 1 Summary of China agricultural productivity estimates

Author/s	**Sector coverage**	**Methodology**	**Time period**	**Productivity annual growth rate (%)**
McMillan *et al*. (1989)	GVAO [a]	Indexes with fixed weights	1978-84	5.8
Fan (1991)	GVAO	Stochastic production function	1965-83	2.1
Lin (1992)	Crops (grains and cash)	Cobb-Douglas production function	1978-84	3.42
			1984-87	0.68
Wen (1993)	GVAO	Indexes, various weights	1979-85	7.2 – 8.9 [b]
			1985-89	0.5 – 1.4 [b]
Kalirajan *et al.* (1996)	GVAO	Varying coefficient production frontier	1978-84	1.28
			1984-87	0.92
Mao and Koo (1996)	GVAO	Distance function / Malmquist index	1984-93 (advanced tech. provinces)	3.7
			1984-93 (low tech. provinces)	2.1
Fan (1997)	Crops, livestock & fisheries	Tornqvist index	1979-84	5.1
			1985-95	3.9

Table 1 (cont.)

Lambert and Parker (1998)	Crops, animals, fisheries & forestry	Distance function / Malmquist index	1978-84	1.28 [c]
			1985-89	-0.45 [c]
			1990-92	2.45 [c]
			1993-95	5.97 [c]
			1978-95	1.80 [c]
Colby *et al*. (2000)	Rice, wheat, maize & soybeans	Tornqvist index	1978-85	5.4
			1986-94	0.4
			1995-97	0.8
Jin *et al*. (2002)	Rice, wheat, maize	Tornqvist index	1979-85 (each crop)	6.5 – 8.0 [d]
			1985-89 (each crop)	static
			1990-95 (wheat)	Almost 4.0 [d]
			1979-95 (each crop)	3.0 – 4.1 [d]
Hsu *et al*. (2003)	Crops, animals, fisheries & forestry	Distance function / Malmquist index	1984-92	-0.5
			1993-99	0.3
			1984-99	-0.1
Nin *et al*. (2003)	All crops & all livestock (FAOSTAT data)	Directional distance functions / Malmquist index	1965-94 (crops)	0.69
			1965-94 (livestock)	1.80
			1980-94 (crops)	3.9 [d]
			1980-94 (livestock)	6.5 [d]

Jones and Arnade (2003)	Crops, livestock (FAOSTAT data)	Directional distance functions / Malmquist index		0.10
			1991-99 (crops)	5.75
			1981-90 (livestock)	4.38
			1991-99 (livestock)	10.82
Mead (2003)	Grain, other crops, livestock	Cobb-Douglas production function	1982-84	5.6 [e]
			1984-89	-0.4 [e]
			1989-96	1.9 [e]
			1996-99	0.2 [e]
Ma *et al.* (2003)	Hogs, eggs, beef, milk	Varying coefficient production frontier	1982-90 (hogs)	3.8
			1990-2000 (hogs)	1.5
			1983-1990 (eggs)	8.7
			1990-2000 (eggs)	4.9
			1993-2001 (milk)	2.5
			1991-2000 (beef)	5.2
Nin *et al.* (2004)	Hogs, poultry	Partial productivity index (output/head) FAOSTAT data	1991-97 (hogs)	3.0
			1991-97 (poultry)	11.8

a. Gross value of agricultural output, comprising crop production, animal husbandry, forestry, fisheries and sideline activities.
b. Calculated from tabled results.
c. Unweighted averages of provincial TFP growth rates.
d. Estimated from graphed results.
e. Computed as averages of tabulated annual figures.

Table 2 Mean and Standard Deviation of Changes in China's Trade Balance (millions of $1997)

	Trade Balance (exports – imports)			
	1997	2007	Mean Change	SD of Change
Wheat	-658	-1,142	-484	561
Coarse grains	303	-235	-538	581
Oilseeds	-1,003	-2841	-1,838	556
Ruminant meat	-409	-579	-170	91
Nonruminant meat	-271	-908	-637	2,031
Dairy	-206	-437	-231	13

Table 3 Means and Standard Deviations of Projected Change (1997-2007) in China's Export and Import Volumes

Sector	Exports			Imports		
	1997-2007		Equivalent mean annual growth (%)	1997-2007		Equivalent mean annual growth (%)
	Change (%)	SD of Change		Change (%)	SD of Change	
Wheat	170.7	395.0	10.5	142.0	106.9	9.2
Coarse grains	-27.4	76.3	-3.2	71.3	26.4	5.5
Oilseeds	-53.0	55.8	-7.3	211.5	44.2	12.0
Ruminant meat	-30.9	35.6	-3.6	77.2	20.5	5.9
Nonruminant meat	97.2	186.4	7.0	119.5	68.4	8.2
Dairy	-14.0	10.0	-1.5	128.9	4.1	8.6

Table 4 Means and Standard Deviations of Projected Change (1997-2007) in China's Output

Sector	1997-2007		Equivalent mean annual growth (%)
	Change (%)	SD of Change	
Wheat	21.0	11.2	1.9
Coarse grains	15.8	17.6	1.5
Oilseeds	11.3	18.8	1.1
Ruminant meat	49.1	3.6	4.1
Nonruminant meat	151.5	38.8	8.0
Milk	95.4	5.2	6.9

Table 5 Means and Standard Deviations of Projected Change (1997-2007) in China's Domestic Sales [a]

Sector	1997-2007		Equivalent mean annual growth (%)
	Change (%)	SD of Change	
Wheat	20.8	10.8	1.9
Coarse grains	18.9	14.7	1.7
Oilseeds	13.6	17.8	1.3
Ruminant meat	51.5	2.8	4.2
Nonruminant meat	156.8	25.9	9.9
Dairy	54.0	3.2	4.4

a. Includes intermediate demands, e.g. for livestock feedstuffs

Table 6 Means and Standard Deviations of Projected Change (1997-2007) in China's Feed Demands [a]

Livestock Sector	1997-2007		Equivalent mean annual growth (%)
	Change (%)	SD of Change	
Cattle & sheep	-6.1	14.7	-0.6
Nonruminant livestock	23.7	11.9	2.1
Milk	-4.2	16.6	-0.4

a. Changes in demand for composite of feedstuffs.

Table 7 Historic Growth Rates (% per year) in Livestock Production and Feed Use

	1980-90	1990-2000
Production [a]*:*		
Poultry meat	12.5	11.6
Pork	6.3	4.6
Eggs	11.2	7.5
Beef	17.3	8.0
Milk	12.5	4.0
Feedgrain consumption by production of [b]*:*		
Hogs, poultry & eggs	5.1	3.3
Beef and mutton	11.0	5.6
Milk	9.6	2.2

a. Adjusted production data (see Ma *et al.* 2004)

b. Feed grain equivalents, derived from feed/output ratios published in The Compiled Materials of Costs and Returns of Agricultural Products of China, State Development Planning Commission.

Table 8 Feedgrain Conversion Ratios[a] by Production Structure (1999-2001 averages)

	Backyard	Specialised household	Commercial
Hogs	2.0	2.3	2.5
Eggs	2.2	1.7	1.8
Broiler	1.8	1.7	1.8
Milk	..	0.4	0.4

a. Ratio of total feedgrains consumption to output of eggs or milk, or net liveweight gain of meat.

Source: The Compiled Materials of Costs and Returns of Agricultural Products of China, State Development Planning Commission.

References

Arndt, C. (1996). An introduction to Systematic Sensitivity Analysis via Gaussian quadrature. GTAP Technical Paper No. 2, July.

Arndt, C. and K.R. Pearson (1998). How to carry out Systematic Sensitivity Analysis via Gaussian quadrature and GEMPACK. GTAP Technical Paper No. 3, April.

Bernard, A.B. and C.I. Jones (1996). Comparing apples to oranges: Productivity convergence and measurement across industries and countries. *American Economic Review* 86(5): 1216-1238.

Brown. L. (1995). China: Wake up call for a small planet. World Watch Inc., Washington D.C.

Carter, C.A., J. Chen and B. Chu (2003). Agricultural productivity growth in China: farm level versus aggregate measurement. *China Economic Review* 14:53-71.

Colby, H., X.Diao and A.Somwaru (2000). Cross commodity analysis of China's grain sector: sources of growth and supply growth. Technical Bulletin No. 1884, Economic Research Service, USDA, Washington D.C.

Delgado, C., M.Rosegrant, H.Steinfeld, S.Ehui and C.Courbois (1999). Livestock to 2020: The next food revolution. Food, Agriculture and the Environment Discussion Paper 28. International Food Policy Research Institute, Washington D.C.

DeVuyst, E.A. and P.Preckel (1997). Sensitivity analysis revisited: a quadrature-based approach. *Journal of Policy Modelling* 19:175-185.

Fan.S. (1991). Effects of technological change and institutional reform on production growth in Chinese agriculture. *American Journal of Agricultural Economics* 73(2):266-275.

Fan, S. (1997). Production and productivity growth in Chinese agriculture: new measurement and evidence. *Food Policy* 22(3):213-228.

Fuller, F., D. Hayes, and D. Smith (2000). Reconciling Chinese meat production and consumption data. *Economic Development and Cultural Change* 49:23-43.

Harrison, W.J. and K.R. Pearson (1996). Computing solutions for large general equilibrium models using GEMPACK. *Computational Economics* 9:83-127.

Hertel, T.W. (ed.)(1997). Global Trade Analysis: Modeling and Applications. Cambridge University Press, Cambridge and New York.

Hsu, S-H, M-M Yu and C-C Chang (203). An analysis of total factor productivity growth in China's agricultural sector. Prepared for American Agricultural Economics Association Annual Meeting, Montreal, Canada, 27-30 July.

Huang, J, C. Chen, S. Rozelle and F. Tuan (2000). Trade liberalisation and China's food economy in the 21st century: Implications to China's national food security. Prepared for meeting of the American Association for the Advancement of Science, Washington D.C., February.

Huang, J., S. Rozelle and C. Min (2002). The nature of distortions to agricultural incentives in China and implications of WTO accession. Paper prepared for the conference WTO Accession, Policy Reform and Poverty Reduction, Beijing, 26-28 June.

Ianchovichina, E. and W. Martin (2003). Economic impacts of China's accession to the World Trade Organisation. Policy Research Working Paper 3053, World Bank, Washington D.C.

Jin, S., J. Huang, R. Hu and S. Rozelle (2002). The creation and spread of technology and total factor productivity in China's agriculture. *American Journal of Agricultural Economics* 84(4):916-930.

Jones, K. and C. Arnade (2003). A joint livestock-crop multi-factor relative productivity approach. Prepared for Southern Agricultural Economics Association Annual Meeting, Mobile, Alabama, 1-5 February.

Kalirajan, K.P., M.B. Obwona and S. Zhao (1996). A decomposition of total factor productivity growth: The case of China's agricultural growth before and after reform. *American Journal of Agricultural Economics* 78(2):331-338.

Lambert, D.K. and E. Parker (1998). Productivity in Chinese provincial agriculture. *Journal of Agricultural Economics* 49(3):378-392.

Lin, J.Y. (1992). Rural reforms and agricultural growth in China. *American Economic Review* 82(1): 34-51.

Ma, H., A.N. Rae and J. Huang (2003). The decomposition of total factor productivity growth: The case of China's livestock. Unpublished manuscript.

Ma, H., J. Huang and S. Rozelle (2004). Reassessing China's livestock statistics: Analysing the discrepancies and creating new data series. *Economic Development and Cultural Change* 52 (forthcoming).

McMillan, J., J. Whalley and L. Zhu (1989). The impact of China's economic reforms on agricultural productivity growth. *Journal of Political Economy* 97(4):781-807.

Mead, R.W. (2003). A revisionist view of Chinese agricultural productivity? *Contemporary Economic Policy* 21(1):117-131.

Nin, A., C. Arndt, T.W. Hertel and P.V. Preckel (2003). Bridging the gap between partial and total productivity measures using directional distance functions. *American Journal of Agricultural Economics* 85(4): 928-942.

Nin, A., T.W.Hertel, K. Foster and A.N. Rae (2004). Productivity growth, catching-up and uncertainty in China's meat trade. *Agricultural Economics* (forthcoming).

Rosegrant, M.W., M.S. Paisner, S. Meijer and J. Witcover (2001). Global food projections to 2020: Emerging trends and alternative futures. International Food Policy Research Institute, Washington D.C.

Rutherford, A.S. (1999). Meat and milk self-sufficiency in Asia: Forecasts, trends and implications. *Agricultural Economics* 21:21-39.

Tang, A.M. (1982). An analytical and empirical investigation of agriculture in Mainland China, 1952-80. Chung-Hua Institution for Economic Research , Taipei, Taiwan.

Tauer, L.W. (2001). Input aggregation and computed technical efficiency. *Applied Economics Letters* 8:295-297.

Wen, G.J. (1993). Total factor productivity change in China's farming sector: 1952-89. *Economic Development and Cultural Change* 42:1-41.

Xu, X. (2002). Study on some problems in estimating China's gross domestic product. *Review of Income and Wealth* 48(2):205-215.