The Australian Journal of Agricultural and Resource Economics, 41:2, pp. 169–190

Why projections on China's future food supply and demand differ†

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This article analyses the macroeconomic assumptions, demand and supply parameters, and structures of the models used in projecting China's future food supply, demand and trade. Projections vary greatly, from China being self-sufficient in grain to being a net importer of 369 million metric tons of grain in 2030. The differences stem mainly from the approaches chosen to model China's grain production and, in particular, the combined effects of land decline and yield growth. The article also points out improvements needed in future work on modelling China's grain economy, which include accounting for the links between agriculture and other sectors, technical change in the livestock industry and infrastructure constraints on grain imports.

1. Introduction

Since the economic reforms took place in China at the end of the 1970s, China's national economy has grown at more than 10 per cent per year. This rapid economic growth is expected to continue which will lead to significant changes in China's future food supply and demand balances. On the demand side, shift in food preferences are bound to take place, with demand for processed foods and high value products continuing to increase at high rates. On the supply side, greater difficulty will be encountered in further increasing agricultural production as the comparative advantage of the sector continues to decline and resources like labour, land and water move out of the agricultural sector.

Great concerns are now looming about China's future food security. This led to the development of various projection models by many

†The authors acknowledge helpful comments on earlier versions of this paper from David Nygaard, Philip Pardey, the participants of the international conference on *Food and Agriculture in China: Perspectives and Policies* held in Beijing, China on 7–9 October 1996, and two anonymous journal reviewers.

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economists (both domestic and abroad) aimed primarily at determining the future prospect of China's food situation and its impact on the world food market. The more popular of these projections are those made by Brown (1995), Rosegrant, Agcaoili-Sombilla and Perez (1995), Huang, Rozelle and Rosegrant (1995), US Department of Agriculture (USDA), the Overseas Economic Cooperation Funds of Japan (OECF) (1995), and the World Bank.[1] Projection results from these models are reported in several publications. This article considers their most recent published results. Brown's projections primarily come from the book entitled *Who Will Feed China? Wake-Up Call for a Small Planet* which was published in 1995. The main source for the projections by Rosegrant *et al.* is the IFPRI discussion paper entitled *Global Food Projections to 2020: Implications for Investment* (1995). The projection results are generated by the International Model for Policy Analysis of Agricultural Commodity and Trade (IMPACT). Projections made by Huang *et al.* also come from another IFPRI discussion paper entitled *China's Food Economy to the 21st Century: Supply, Demand, and Trade* (1997). USDA projections are taken from the ERS/USDA staff paper entitled *Long-Term Projections for International Agriculture to 2005* (No. 9612, August 1996). The OECF projections come from a research study conducted by the Research Institute of Development Assistance of OECF, the results of which are published in a discussion paper entitled *Prospects for Grain Supply–Demand Balance and Agricultural Development Policy in China* (OECF Discussion Paper No. 6, 1995). The World Bank projections were made by Donald Mitchell and Merlinda Ingco and are published in *The World Food Outlook* (1993).

Projection results from the models mentioned above generally indicate that China will continue to increase its grain imports. The magnitude of such import increments, however, differ between the models. There are at least three factors that account for these differences, namely, the macroeconomics assumptions, the demand and supply parameters, and the model structures. The objective of this article is to compare the different models based on these three factors and to determine how they have influenced the projection results. This information is very valuable to policy-makers

[1] Various other models which also project China's food supply and demand are not included in this comparison primarily because their structure and assumptions are not explicit in their respective reports. These models include those of FAPRI (1996) and the FAO's World Food Model (FAO 1995), Garnaut and Ma (1992), Simpson, Xu and Miyazaki (1994), and the Chinese Academy of Agricultural Sciences (Mei 1995). There are also a whole range of projection studies (e.g. Anderson *et al.* 1996; Yang and Huang 1996; and Yang and Tyers 1989) using a general equilibrium approach such as the Global Trade Analysis Project. These studies were also not included simply because their comparison would be undertaken on a much wider dimension.

as it will provide a clearer understanding as to why projections for a single country, like China, vary. More importantly, it will evoke caution in the use of the results for policy purposes.

The article is organised as follows. The second section reviews the results of the different model projections on China's supply, demand and trade of grains. The third and fourth sections compare the assumptions and parameters used respectively by each of the models. In the fifth section, differences in the model structures are described and analysed. Finally, the article concludes with the authors' observations and views on the projection results *vis-à-vis* more recent trends and developments in China's agricultural sector. In addition, recommendations are specified on the direction of similar modelling efforts in the future.

2. Projections of China's food supply, demand and trade

Before comparing the results of the different projection models, two important adjustments are made to start the results on a common basis. The first adjustment pertains to the definition of grains which differ among the models. USDA's definition of grain includes wheat, rice (measured in milled form), corn, sorghum, millet, barley, and oats. Brown, Huang *et al.*, and the World Bank use this definition. Rosegrant *et al.* use the FAO definition where grain covers paddy rice, wheat, maize and other coarse grains but with rice converted into a milled form using an average conversion ratio of 65 per cent. OECF uses the definition of the Chinese agencies. Grains, according to these agencies, include not only those covered in the USDA definition but also potatoes (converted to grain equivalent using a 5 to 1 ratio), soybeans, pulses, and other grains like buckwheat. Unlike the USDA definition, rice used in the Chinese definition is in paddy form. The article uses a standard definition of grains based on that of the USDA to properly compare the results. Grain quantities in the various models are, therefore, adjusted upward or downward depending on whether they include fewer or more commodities in their grain definition compared to USDA. In the Rosegrant *et al.* study, grain quantity is adjusted upward by 1.06.[2] OECF grain quantities, on the other hand, are adjusted downward by a factor of about 0.76. This factor is estimated based on the difference between the 1990 OECF production figure and the average grain production level reported by USDA for 1990.

The other adjustment is on the projection period covered by each model.

[2] The discrepancy possibly comes from difference in the conversion factor used to convert paddy rice to milled basis.

Brown projects supply, demand, and trade to the year 2030, Rosegrant *et al.* and Huang *et al.*, to the year 2020, the World Bank and OECF to the year 2010, and USDA to the year 2005. In most studies, results were reported only for the base year and that for the final projection year. Linear extrapolation is used to bring projection results of USDA to 2010 and to derive results every five years between 1995 and 2010 for the other models.

Tables 1, 2 and 3 present the adjusted projection results on production, demand and trade from the different models. The figures for 1980, 1990, and 1995 are actual, while the bold numbers are projection estimates reported by the different studies. The italicised numbers are linear extrapolations made by the authors to enable a trend comparison of results for the projected years.

Note the extreme results particularly on production (table 1). Brown projects that China's grain production will decline by 11 per cent, from 355 million metric tons (mmt) in 1995 to 317 mmt in 2010. On the other hand, World Bank, Huang *et al.*, and Rosegrant *et al.* project that China's grain production will continue to grow between 1.7 and 1.8 per cent annually to reach levels ranging from 450 to 480 mmt in 2010. Note that these three projection results are very close despite differences in their assumptions and model structures as will be described in the succeeding sections. USDA and OECF production projections fall between that of Brown's and the rest of the models mentioned above. USDA projects that China's grain production will pose a growth rate of 1 per cent per year

Table 1 Projections of grain production in China (mmt)

Year	Brown	Rosegrant *et al.*	Huang *et al.*	USDA	WB	OECF
1980	238	238	238	238	238	238
1990	345	345	345	345	345	345
1995	355	355	355	355	355	355
2000	*342*	*385*	**426**	**362**	**411**	**367**
2005	*329*	*418*	*455*	**382**	*445*	**382**
2010	*317*	**453**	**486**	*403*	**483**	**389**
2020	*294*	**541**	**570**	n.a.	n.a.	n.a.
2030	**272**	n.a.	n.a.	n.a.	n.a.	n.a.

Notes: [a] Figures for 1980, 1990, and 1995 are actual, while those in bold are projected by the different studies. The italicised figures are estimated by the authors using linear extrapolation.
[b] Grains in the table are defined using USDA's definition, which includes wheat, rice (milled basis), corn, sorghum, millet, barley and oats. China's State Statistical Bureau definition of grain includes those covered in the USDA definition plus potatoes converted to grain equivalent (ratio of 5 to 1), soybean, pulses and other grains such as buckwheat. Brown, Rosegrant *et al.*, World Bank and Huang *et al.* employ the USDA definition while OECF and all Chinese institutions use the SSB definition.

Table 2 Projections of grain demand in China (mmt)

Year	Brown	Rosegrant *et al.*	Huang *et al.*	USDA	WB	OECF
1980	250	250	250	250	250	250
1990	355	355	355	355	355	355
1995	375	375	375	375	375	375
2000	*405*	**403**	**450**	**387**	**420**	**385**
2005	*437*	*434*	*480*	**414**	*459*	**435**
2010	*472*	**468**	**513**	*443*	**502**	**492**
2020	*549*	**565**	**594**	n.a.	n.a.	n.a.
2030	**641**	n.a.	n.a.	n.a.	n.a.	n.a.

Note: See table 1 for explanation of the figures in this table.

and would reach 403 mmt in 2010. The OECF projects a much slower rate of growth (about 0.44 per cent per year) such that grain production will only reach 389 mmt in 2010. At this rate, projected production shows a very modest increase of 10 per cent from the current production level.[3]

Grain demand projections for China depict much smaller variations compared to those in production, both in terms of rates of growth and levels (table 2). USDA shows the lowest rate of increase at 1.4 per cent per year, such that grain demand will only reach a level of 443 mmt in 2010. Huang *et al.* show the largest demand projection of 513 mmt in 2010. The other projections, including that of Brown, fall between those resulting from the above two models.[4]

The variability of grain import projections comes primarily from the supply side. Brown and OECF project that China will have a grain deficit of more than 100 mmt (20–30 per cent of total consumption) in year 2010 (table 3). The large import projection by Brown and OECF mainly comes from a very pessimistic outlook on grain production in China. Much more modest imports are projected by Rosegrant *et al.*, Huang *et al.*, USDA and the World Bank, the levels of which are very close. These projections

[3] The FAO model projects that production would reach 398 mmt in 2000. The Simpson, Cheng and Miyazaki (1994) projection results for 2000 ranges between 370 mmt under a sluggish economic growth scenario to 378 mmt under a more robust economic growth scenario, 421–428 mmt for 2010, and 437–467 mmt for 2025. FAPRI's (1996) projection is 386 mmt in 2005.

[4] The FAO model projects grain demand to reach 415 mmt in 2000, and FAPRI's projection is 410 mmt for 2005. Brown's grain demand reported here is based on the assumption of a per capita consumption of 400 kg per year. His other demand scenario is based on a lower per capita consumption of 300 kg.

Table 3 Projections of grain imports in China (mmt)

Year	Brown	Rosegrant *et al.*	Huang *et al.*	USDA	WB	OECF
1980	12	12	12	12	12	12
1990	10	10	10	10	10	10
1995	20	20	20	20	20	20
2000	*63*	*18*	**24**	**25**	**11**	**18**
2005	*108*	*16*	*25*	**32**	*14*	**52**
2010	*155*	**15**	**27**	*39*	**22**	**104**
2020	*256*	**24**	**25**	n.a.	n.a.	n.a.
2030	**369**	n.a.	n.a.	n.a.	n.a.	n.a.

Note: See table 1 for explanation of the figures in this table.

indicate that in year 2010 China will only need to import from the international market between 15 to 39 mmt of grains, or roughly between 3–9 per cent of the total domestic demand.[5]

3. Macroeconomic assumptions

Macroeconomic assumptions play an important role in determining projections of grain production, consumption, and trade of countries modelled. Those reviewed in this study are the population and income growth assumptions.

The differences in the population growth assumptions are small among the models (table 4). The outlier would be that of OECF which assumes population growth rates at 1.46 per cent per year between 1990 and 2000 and 1.22 per cent per year between 2000 and 2010. All other projection models assume population growth rate close to 1 per cent per year. Brown projects China's population to reach 1.5 billion in year 2017 and 1.6 billion in year 2030. These figures indicate that population will grow at 1 per cent per year from 1994 to 2017, and 0.5 per cent per year from 2017 to 2030. Rosegrant *et al.* also used a 1 per cent per year population growth rate. Huang *et al.*, USDA and the World Bank used the same 1 per cent per year population growth rate up to year 2000 and a slower rate of less than 1 per cent per year in the years after.

The assumptions on per capita income growth are quite diversified among the models. A pessimistic view is that taken by Huang *et al.* which assumes that China's per capita income will grow only at 3.0 to 3.5 per

[5] Import projections by FAO is 17 mmt for 2000 and that by FAPRI is 25 mmt for 2005.

Table 4. Macroeconomic assumptions in various models

Projection period	Brown	Rosegrant *et al.*	Huang *et al.*	USDA	WB	OECF
Annual population growth (%)						
1990–2000	1	1.0	1.28	1	1.3	1.46
2000–2010	1	1.0	0.74	0.66	0.7	1.22
2010–2020	1	1.0	0.65	n.a.	n.a.	n.a.
Annual per capita GDP growth (%)						
1990–2000	n.a.	6.0	3–3.5	7.8–8.0	7.1	8.06
2000–2010	n.a.	6.0	3–3.5	6.8–7.7	7.7	8.06
2010–2020	n.a.	6.0	3–3.5	n.a.	n.a.	n.a.

Notes: [a] Brown stated that population in China will be 1.5 billion in 2017, and 1.6 billion in 2030 implies that population will grow at 1 per cent per year from 1994 to 2017, and 0.5 per cent per year from 2017 to 2030.
[b] OECF assumes per capita income will increase at a rate equal to that achieved between 1984 and 1993.

cent per annum. These rates are even lower than those achieved during the period of the Cultural Revolution. The optimistic view is that taken by the OECF which assumes that China's economy will continue to grow at 8.1 per cent per year, a rate which is equivalent to that achieved between 1984 and 1993. Per capita income growth assumptions in Rosegrant *et al.*, USDA, and the World Bank are more modest ranging from 6 to 8 per cent per year.[6]

The large demand projection by Huang *et al.*, despite their relatively low assumption of per capita income growth rates, comes primarily from the incorporation of urbanisation parameters in the model. As mentioned earlier, urbanisation influences the shift in demand primarily towards meat and other livestock products. The projected indirect demand of grains for feed use accounts for 31 per cent of the study's total demand projection in 2010.

4. Model parameters

Supply and demand elasticities are important parameters in any projection model as they also account for differences in results. These elasticities reflect those of prices and income. Table 5 shows the respective income elasticities employed in the different projection models being compared in this article. Setting up a similar table for the price elasticities was not easy

[6] Macroeconomic assumptions used in other models are also within the range of values used by Rosegrant *et al.*, USDA and the World Bank.

Table 5 Comparison of income elasticities used in the various models

			1990–2000	2000–2010	2010–2020
Brown			n.a	n.a	n.a
Rosegrant *et al.*	Grains		–0.03 to 0.003	–0.03 to 0.003	–0.03 to 0.003
	Wheat		0.2	0.2	0.2
	Maize		–0.19	–0.19	–0.19
	Other Grain			–0.16	–0.16
–0.16					
	Rice		–0.04 to 0.03	–0.04 to 0.03	–0.04 to 0.03
Huang *et al.*	Rural		0.15	0.00	–0.05
	Urban		0.00	–0.05	–0.10
USDA					
		Rice	–0.10 to 0.11	–0.11 to –0.15	n.a.
	Urban	Wheat	–0.05 to 0.06	–0.06 to –0.01	n.a.
		Coarse grain	–0.14 to 0.17	–0.17 to –0.25	n.a.
		Rice	0.10 to 0.02	0.02 to 0.00	n.a.
	Rural	Wheat	0.12 to 0.20	0.10 to 0.12	n.a.
		Coarse grain	–0.10 to 0.12	–0.12 to –0.20	n.a.
WB			n.a.	n.a.	n.a.
OECF	Food		–0.034 to –0.238	–0.034 to –0.170	–0.034 to –0.170
	Feed		0.346 to 0.907	0.346 to 0.907	0.346 to 0.907
	Processing		0.446 to 0.924	0.446 to 0.924	0.446 to 0.771

Note: OECF income elasticities represent those for 2000, 2005 and 2010. USDA's elasticities are calculated by the authors from the CPPA model.

as these parameters are not readily available for all the models.[7] For the supply side of the models, projected yield and area growth rates are compared instead as shown in table 6. All models, except the Huang *et al.* model, express the supply component as the combined effect of area planted and yield.

As can be noted from table 5, income elasticities of grain demand for food use are generally small, with some of them negative. These values imply that growth in grain for food will continue to slow down and/or decline as shown in most of the projection results. In some models, grains actually become an inferior good. The small income elasticities further indicate that food demand of grains will come primarily from population

[7] Effort was exerted by the authors to get these parameters directly from the model developers but some hesitancy was encountered.

increases. On the other hand, income elasticity for feed and for other uses are definitely larger in response to growth in demand for livestock products and other processed foods.[8]

The great variations in the production projections follow from the variations in the effective growth rate estimates for area and yield and/or the perception of the respective modellers on the future trend of these variables. Brown projects that area planted to grain in China will decline by almost half between 1990 and 2030. This is equivalent to a rate of decline of about 1.58 per cent per year (table 6). His yield growth projection, which is estimated from the respective projections of area and production, is 1.1 per cent per year. This rate is relatively high considering

Table 6 Comparison of projected growth rates in yield and area harvested

	Areas (annual change in %)			Yield (annual change in %)		
	1990–2000	2000–2010	2010–2020	1990–2000	2000–2010	2010–2020
Brown	–1.58	–1.58	–1.58	1.09	1.09	1.09
Rosegrant *et al.*						
Grain	0.27	0.27	0.03	1.32	1.32	1.33
Wheat	0.53	0.53	0.04	1.43	1.43	1.60
Maize	0.54	0.54	0.07	1.70	1.70	1.48
Other grains	0.03	0.03	0.10	1.03	1.03	1.39
Rice	–0.10	–0.10	–0.04	0.98	0.98	0.95
Huang *et al.*	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
USDA						
Grain	–0.18	0.19	n.a.	1.45	1.42	n.a.
Wheat	–0.36	0.02	n.a.	1.50	1.12	n.a.
Rice	–0.70	–0.31	n.a.	0.96	1.08	n.a.
Coarse grain	0.63	0.86	n.a.	1.85	1.82	n.a.
WB	–0.03	0.00	n.a.	1.90	1.70	n.a.
OECF	–0.62	–0.51 to – 0.58	n.a.	1.46	0.84 to 1.4	n.a.

Note: Brown indicated that the grain area harvested in China declined from 90.8 million hectares in 1990 to 85.7 million hectares in 1994. He uses this trend to project that grain land in 2030 will be reduced to 48 million hectares. Brown's 2030 grain production and land in grain imply that the grain yield would reach 5.7 tons which is 54 per cent higher than the 3.7 tons in 1990.

[8] Income elasticities of demand for feed use and other processed products are reported between 0.346 and 0.907 by the OECF. Other models are not explicit on their assumptions for these parameters.

Brown's pessimistic outlook on prospects for increasing grain yields. The projected high yield growth does not offset the projected area decline, however.

OECF is also very pessimistic about the future growth in land area for grain cultivation in China. OECF projects that planted area to grain production will decline by 0.62 per cent per year from 1993 to 2000, 0.51 per cent per year from 2000 to 2005, and 0.58 per cent per year from 2005 to 2010. Like Brown, the projected drastic reduction in area growth offsets the relatively high growth rate initially projected for yield, which is 1.5 per cent per year between 1990 and 2000. Projected yield growth rate in the OECF model declines slightly after year 2000 to 1.4 per cent per year between 2000 and 2005, and further to 0.84 per cent per year between 2005 and 2010.

World Bank, on the other hand, projects that area for grain production will only decline slightly at the rate of 0.3 per cent per year between 1990 and 2000, after which area is assumed to stay unchanged. Similarly, USDA assumes that China's planted area will decline at 0.18 per cent per year from 1990 to 2000, and then will increase slightly from 2000 to 2010. On yield changes, World Bank assumes that it will increase 1.9 per cent per year from 1990 to 2000, and 1.7 per cent per year from 2000 to 2010, while USDA's projected rate of increase is 1.45 per cent per year from 1990 to 2000, and 1.42 per cent from 2000 to 2010.

Projected area growth rate in grains in the Rosegrant *et al.* study is most optimistic as it indicates slight land expansion (0.27 per cent per year between 1990 and 2010 and 0.03 per cent per year between 2010 and 2020), although this varies by commodity. Largest expansion is expected in maize and wheat, while some contraction is seen in rice. Projected growth rate in grain yield is more modest, however, at only about 1.3 per cent per year between 1990 and 2020. Similarly, yields in wheat and maize are projected to be more rapid than the rest of the grains including rice.

5. Model structures

The following section reviews the different model structures used by the various projections. This is where most of the variations lie. Some models simply employ value judgment using past trends and/or the experiences of other countries to predict the future. Other projections are more rigorous in that they are expressed in terms of equations that model different market forces and government policies as they affect supply and demand of commodities. Sophistication of a model is determined by the market forces and government policies that would be incorporated. These levels of

Table 7 Comparison of commodity and country coverages

	Brown	Rosegrant *et al.*	WB	Huang *et al.*	USDA	OECF
Commodities						
Demand	1 (grain)	17	3	2 (rice, other grains)	42	5
Production	1 (grain)	17	3	2 (rice, other grains)	42	5
Trade	1 (grain)	17	3	2 (rice, other grains)	42	5
Countries/ regions	1 (China only)	35	24	1 (China only)	Global	1 (China only)
Periodicity	Calendar	Calendar	Crop year	Calendar	Calendar	Calendar
Base data	1994	1987-89	1990	1991	1995	1993

Note: Among all these models, only Rosegrant *et al.*, and USDA incorporated a livestock sector module in their models. CPPA/USDA model is capable of modelling any single country or group of countries as well as the global market for agriculture.

sophistication are exemplified in the various projection models being compared in the article, all of which are primarily focused on the agriculture sector. Table 7 shows the extent of coverage in terms of countries/ regions and commodities. Table 8 provides a brief comparison of the projection structure and framework used.

5.1 Brown's projections

Brown's projections are not based on any explicit demand and supply modelling effort, but primarily on certain assumptions about growth in population, demand per capita and production. He closely analysed the experiences of other East Asian countries (or regions), namely Japan, Taiwan, South Korea and Hong Kong. He then argued that China in the mid-1990s may now be where Japan was in the early 1960s when it starts to face the problems of rapid loss of resources for production.

Since Brown does not have a structural model, interactions among producers, consumers, and government are not captured in his projections. For example, increase in grain price due to high demand and low supply will not evoke any response from producers, consumers, research institutions, and government.[9]

[9] Various comments on Brown's projection methodology and results are discussed in more detail in Alexandratos (1996), Crook (1994), Johnson (1995), Paarlberg (1995, 1996), Smil (1995, 1996) and Crosson (1996).

5.2 The World Bank econometric simulation model

The World Bank model is a non-spatial, partial equilibrium, net trade model. The model has 24 countries (including China) modelled individually and the remaining countries grouped into nine regions. The commodities included in the model are wheat, rice, and coarse grains. Individual models are estimated for each commodity and country or region with cross-linkages between commodities.

Production for each country (or region) is determined as the product of separately estimated harvested area and yield equations. Harvested area is determined using a two-stage process. First, total area harvested is projected as a function of the aggregate grain revenue from the previous year, the total carry-over stocks, and a trend variable. This is then allocated among the three grain crop categories by regressing individual crop area on total crop area, the relative revenues of alternative crops, and a trend variable. Yields are estimated as functions of lagged crop prices, fertiliser prices, the proportion of area planted to high yielding varieties and a trend variable.

Domestic demand equation in this model is formulated differently for net importers and net exporters of grains. For net importing countries, per capita imports of each commodity are estimated as a function of income, prices and some shift variables which include domestic supply. Total consumption is then calculated as the residual of production, net imports and stocks. Ending stocks are expressed in terms of consumption and prices which apply both to importers and exporters. Consumption in the exporting countries is estimated as a function of population, income and prices. Net exports then are the residual of domestic supply, demand and stocks. The model is solved simultaneously for world prices which equate net imports with net exports.

The major weakness of the model is its limited coverage of commodities with only three crops modelled. This is explained by the fact that the model has been developed primarily to focus on grains which comprise the major component of food especially in the developing countries. Significant development and growth in many countries are rapidly changing this demand trend. But the model cannot capture the interactions among the grain crop, cash crop and livestock sectors.

5.3 IMPACT model of Rosegrant *et al.*

The global food model called the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) was developed by Rosegrant, Agcaoili-Sombilla, and Perez at the International Food Policy

Research Institute (IFPRI). IMPACT is (1) partial equilibrium with its focus on the agriculture sector; (2) global, covering 35 countries and regions, and seventeen commodities; (3) non-spatial; and (4) synthetic, because of its use of elasticities derived from other studies. Despite its primary focus on agricultural commodities, relationship has been incorporated in the model to link income growth in the agriculture and non-agricultural sectors. The model uses a system of supply and demand elasticities, incorporated into a series of linear and non-linear equations, to approximate the underlying production and consumption functions. The general specifications of the supply and demand equations are shown in table 8. Sectoral growth multipliers are used to determine the intersectoral effects of changes in income in agriculture and non-agricultural sectors. A typical country or regional sub-model consists of a set of these equations for each commodity, as well as the equations that link the agriculture and non-agricultural sectors. Inter-country and inter-commodity linkages in the world market are achieved through trade at which prices are also determined.

The model has a wider coverage in terms of commodities and it does capture the linkage between the crop and livestock sectors as well as the agriculture and non-agricultural sectors, although the latter is done through simple multiplier effect relationship. The weakness lies in the inadequacy to capture the impact of technical and structural change, especially in the livestock sector which would have a big impact on future grain supply.

5.4 USDA CPPA model

The CPPA model of USDA is also a multi-commodity, multi-country partial equilibrium simulation model focused on the agricultural sector. It is primarily used as a tool to generate vigorous, theoretically consistent annual, long-term projections of supply, demand and trade for major commodities. It is synthetic, like IMPACT, with its use of elasticities and parameters derived from other studies. Commodity coverage is very extensive which includes both primary and processed products.

The standard structural framework of the CPPA model is country-based where world prices are given. Mechanisms are provided to link the country models to create a comprehensive model of world agriculture. In such a global model, equilibrium world prices for each of the commodities are then endogenously determined when market clears. More advanced versions of CPPA are possible where policies, prices and incomes are, likewise, endogenously determined.

The sub-model for China includes the most detailed representation of

Table 8 Comparison of modelling approaches

	Brown	Rosegrant *et al.*	Huang *et al.*	USDA	WB	OECF
Production			f (prices, quasi-fixed and variable inputs off-farm wage, stock of ag research, stock of irrigation, infrastructure and three environmental factors)			
Crop area	Based on past trends — declining rapidly due to shift in land use, degradation, etc.					Time trend
total		Sum of crop areas		Sum of crop areas	f (revenue, stocks, time)	Time trend
by crop		f (producer price, trend)		f (producer prices, production shifters)	f (total area, area to grain crop, revenue, time)	Time trend
Yield	Past trends — generally declining	f (producer price, input price, trend)		f (research stock)	f (ratio of output price to fertiliser price, area, area planted to HYV, time)	Time trend
Livestock no.	None	f (producer price, feed price, trend)	None	f (producer price, feed price, trend)	None	None
Demand	400 kg per capita per year in 2030		Modelled separately for urban and rural consumers as follows:	f (consumer prices, demand shifters including income and population growth, rate of feed use)	Importers: identity (production, net imports, stocks)	

Food		f (consumer price, income)	f (prices, income, rural markets)		Exporters: f (income, prices)	f (income)
Feed		f (livestock number, feed price)	Indirect demand using feed conversion ratios		Exporters: f (income, prices)	f (income)
Seed		Proporation of food and feed demand			None	Areas × seed use per hectare
Waste			Proporation of food and feed demand		None	
Stocks		None			f (prices, demand)	
Net imports	Identity	Identity	Identity	Identity	f (prices, income, demand shifters)	Identity
Net exports	Identity	Identity	Identity	Identity	Identity (supply, stocks, demand)	Identity
Price determination	None	Market clearing	World prices exogenously determined	Market clearing	Market clearing	None
Price transmission	None	Exchange rate x world price + margins + subsidies		Exchange rate x world price + margins + subsidies	Exchange rate x world price	None
Policies	None	Producer subsidy equivalent, consumer subsidy equivalent, area set asides, input quotas, etc.		PSE, CSE, set asides, quotas, deficiency payments	Implicit	None
Parameters	Synthetic	Synthetic	Econometric estimation	Synthetic	Econometric estimation	Synthetic

Note: f( ) indicates that the row variable is modelled as a function of the variables within the parentheses.

the Chinese agricultural sector among all the models reviewed. It disaggregates the country into six regions (Northeast, North, Northwest, East, Central, and South), each with their own supply and demand structure and trade is undertaken between them and with the international market. The major weakness of the model is its nature of partial equilibrium focused on only agricultural sectors.

5.5 Huang *et al.* China grain model

In contrast to IMPACT, the World Bank model, and the CPPA/USDA, the model developed by Huang *et al.*, also at IFPRI, covers only China but is based on a relatively detailed country modelling effort. The model's supply relationship includes that for rice, other grains, and cash crops, while the demand relationship covers more commodities which include rice, grain, meat, and six other animal products. The latter is also specified separately for urban and rural consumers, which is a very important feature considering the influence of urbanisation on food demand. Real world price projections are exogenous and are taken primarily from IMPACT. In addition to income and prices, a number of structural and policy variables are incorporated in the supply and demand relationship which include those that represent the impact of irrigation development, strengthening research and extension, and environmental degradation.

The major handicap of the Huang *et al.* model lies in its limited coverage of commodities. Furthermore, it is based on a single country and one sector (crop sector), therefore, the model has limited ability to analyse the effects of broader policy issues in other sectors, as well as in other countries, on China's grain supply and demand.

5.6 OECF model

The OECF model is primarily a country model. The projection framework is based on a multi-commodity, multi-region (province) model. Supply and demand are estimated independently and trade is the residual. The model explicitly assumes the absence of price effects on supply and demand as both are primarily estimated using past trends. The projected supply comes from projected yield and acreage. Projected area for each crop is based on the following two assumptions: (1) crops whose acreage has steadily increased in the last ten years are assumed to maintain their 1993 planted acreage for future years; and (2) crops whose acreage has declined in the last ten years are assumed to continue the same rate of contraction in the future. Yield increases are projected using trends achieved from 1984 to 1993. Yields are allowed to increase but only up to the current highest yield levels achieved in China and/or other countries. Government policies, technological changes and price effects on both supply and demand are ignored in projection estimates which therefore account for its deficiency.

6. Conclusions: why projections are different

As mentioned earlier, research exercises of this kind are strongly influenced by the judgment of the analysts, but it is difficult to say how much of the difference is due to this. But, in addition, model difference on the basis of the factors discussed in the previous sections account for the great variations in the results. To summarise the comparisons made on the basis of the macroeconomics assumptions, parameters, and structures, the following points should be noted.

First, clearly, all the studies indicate that China will remain a significant net importer of grains. The bulk of these imports will be wheat, followed by maize and other feed grains. This reflects shifts in taste preferences towards wheat and livestock products, and away from rice, with continued growth in income and China's rapid increase in its urban population. Projected levels of grain demand are very close in all models. This comes from their almost consistent assumptions on population growth which will primarily account for grain demand increases for food in the future as the income elasticity parameters are generally small.

The supply side of any food balance sheet is always the most difficult to project. The large variations in the projected levels of output primarily come from the analysts' perception of prospects for technological change and other factors affecting growth of cultivated area and productivity. Brown and OECF projections of grain production are lowest. Projection results by Rosegrant *et al.*, Huang *et al.*, and the World Bank for supply are very close, leading to almost identical effective growth rates in area and yield. Net trade is generally the residual of supply and demand. The large variations in projected import volumes primarily come from the production side.

Second, Brown's low projections of grain production in China mainly come from his pessimistic view on future grain production, as land area available to grain production will be reduced by half for industrial and urban use while yield levels do not increase fast enough to offset the effect of land contraction. OECF's low projections of grain production come from the same argument.

It should be noted, however, that China's cereal production continued to grow at an annual rate of 2 per cent between 1986 and 1995, even after the positive impact of the institutional and policy reforms in the late 1970s had been reaped. There are reasons to believe that higher productivity growth can still be promoted in China as the average grain yields are not so high as previously reported, because official data on land area have been reportedly understated by as much as 30 per cent.[10] With proper price incentives, grain yields can be raised further in Chinese farms. The effect of prices not only on Chinese producers but also on consumers is important especially since China is rapidly moving towards a full market and private economy. As supply becomes tighter in the future, the government will also respond by increasing investment in agricultural R&D and public infrastructure to increase crop yield. The improved exchange of scientific information, germplasms, and other research materials between Chinese scientists and those in other countries and international agricultural research centres will further enhance productivity of crops and animals in China.

Both the Brown and OECF models ignore the influence of prices that could trigger policy changes as well as the contribution of research systems that provide technology advancements. These two projections only serve to set off an alarm for the worst case scenario when all other things fail to respond to changes in the environment. These studies should therefore not be taken seriously, especially in the formulation and evaluation of effective policies to direct the course of future food balances.

Finally, the rest of the models, which are based on more elaborate specifications of demand and supply behaviour, remarkably arrived at almost consistent figures for the levels of production, demand and trade in 2010 despite some differences in assumptions and parameters. This seems to indicate the strength of well-formulated econometric models because of their ability to capture the responses of various sectors and components to changes in the economic environment. As they are now, the model structures are already complex. But some of the more important variables and forces that will influence China's grain economy in the future are still missing in most of them. These forces arise not only from the fact that China is expected to maintain its strong economic growth but also from its undergoing the transition process from a centralised system to a market-oriented economy.

7. Future research

While this study has provided an initial framework for answering the question as to why projections on China's grain situation differ, it does no

[10] The current official figure for cultivated land is 96 million hectares (from State Statistical Bureau). But a recent report by the Land Administration indicates that China's cultivated land is actually 124 million hectares (Ke 1996). This is the first time a revision has been made on China's cultivated land data by another government agency.

more than point the way in which future research should be expanded to capture more accurately the country's complex agricultural market situation and government policies. The following issues should be addressed and considered in any future modelling efforts of the Chinese agricultural sector:

7.1 On the endogeneity of government policies

D. Gale Johnson lamented that China does not have a grain problem but a series of policy problems (1994). Despite its move towards more privatisation, China's government remains deeply involved in guiding the nation's development process. It is critical to understand the response of government to the new economic environment as this would have great impact on future trends of food supply and demand. The impact of new policies and institutional reforms on efficiency in agricultural production and marketing should be assessed in terms of their ability to allocate scarce resources effectively and promote better input and output market adjustments.

7.2 On the linkage of agriculture with the non-agricultural sector

China is undergoing rapid transformation in its national economy. Comparative advantage of agriculture is declining, and resources like water, labour, land, etc. are rapidly moving out of the agricultural sector. None of the models reviewed considered the effects of the prospective rigidities of factor inputs on food supply and demand brought about by more rapid development of the commercial and industrial sectors. A more general equilibrium framework which incorporates intersectoral linkages should be able to capture these effects.

7.3 On the effects of the WTO

Another important issue that needs to be considered in future modelling efforts is the impact, on the global grain economy as a whole, of the inclusion of China in the World Trade Organization.[11] China is an important player in the international market of grains, being a major producer and consumer of grains. Even a small change in China's imports

[11] Limited efforts have been made by several economists in modelling the welfare impact of the Uruguay Round reform, self-sufficiency of grains, and China's entry to WTO using a general equilibrium approach (Yang and Tyers 1989; Yang and Huang 1996: and Anderson *et al.* 1996). But these models often have very aggregated sub-agricultural sectors.

or exports can have a significant impact on the international grain market (Tuan 1994). Information on these potential effects will help policy-makers in both China and other countries develop their strategies to prevent any instabilities in both domestic and international grain markets.

7.4 On the technical and structural change in the livestock sector

The livestock sector deserves much more attention than currently afforded by any of the models. Most of the models do not have a livestock sector. In models where livestock sector is included, the structure is very simplified. The rapid structural change in the livestock industry (moving from back yard to commercial production) will have large impact on future food security in China. The move towards the improvement of feed–meat ratio from these technical and structural changes can save a huge amount of feed grains.

7.5 On the constraints of infrastructure on grain imports

The models reviewed in the article have all ignored a very crucial factor in determining China's future grain imports, i.e., constraints of port capacity and other infrastructure like domestic transportation. According to Chinese government officials, current port capacity can only import up to a maximum of 20 mmt of grains. To increase grain imports from the current 10–20 mmt to even the modest projection of 40 mmt in 2010 would require substantial amount of investment in infrastructure development. The question being raised now is whether it is more economically efficient to pour investment into the development of infrastructure facilities or to improve further the productivity of the agriculture sector through strengthening the agricultural research.

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