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WHY DO PROJECTIONS ON CHINA'S FUTURE FOOD SUPPLY AND DEMAND DIFFER?

Shenggen Fan and Mercedita Agcaoili-Sombilla

Environment and Production Technology Division

International Food Policy Research Institute
1200 Seventeenth Street, N.W.
Washington, D.C. 20036-3006 U.S.A.

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ABSTRACT

This paper analyzes the macroeconomic assumptions, demand and supply parameters, and structures of the models used in projecting China's future food supply, demand, and trade. Projections from these models vary greatly, from China being almost self-sufficient in grain to becoming a net importer of 369 million metric tons of grain in 2030. The differences arrive mainly in the supply projections (the combined effect of land decline and yield growth). The paper also suggests methodology improvements needed in making future projections of China's grain economy, such as endogenizing government policies, and taking into account the linkage between the agricultural with the non-agricultural sectors, technical change in livestock industry, and infrastructure constraints on grain imports.

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WHY DO PROJECTIONS ON CHINA'S FUTURE FOOD SUPPLY AND DEMAND DIFFER?

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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 percent per annum. This rapid economic growth is expected to continue which can 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 labor, 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 economists (both domestic and international) 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, Rosegrant et al., Huang et al., U.S. Department of Agriculture (USDA), the

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*Shenggen Fan is a research fellow at the International Food Policy Research Institute (IFPRI), Washington, D.C., and Mercedita Agcaoili-Sombilla is an agricultural economist at the International Rice Research Institute (IRRI), the Philippines. The authors acknowledge helpful comments on earlier versions of this paper from Peter Hazell, David Nygaard, Philip Pardey, and the participants of the international conference on *Food and Agriculture in China: Perspectives and policies* held in Beijing, China, on 7-9 October 1996.

Overseas Economic Cooperation Funds of Japan (OECF), and the World Bank.[1] Projection results from these models are reported in several publications, and the most recent published results are used here. 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 paper entitled *Global Food Projections to 2020: Implications for Investment* (1995). The projection results are generated with the International Model for Policy Analysis of Agricultural Commodity and Trade (IMPACT). Projections made by Huang et al. also come from an IFPRI 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).

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[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.

Projection results from the models mentioned above generally indicate that China will continue to increase its grain imports. The magnitude of such imports differs widely between models, creating considerable confusion for policy makers about the likely impact of China in world food markets, and the need for increased investments in agricultural production. 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 objectives of this paper are to compare the different models based on these three factors, to determine how they have influenced the projection results, and to provide a clearer understanding as to why projections for China vary so much. More importantly, it will evoke caution in the use of the results for policy purposes.

The paper is organized as follows. The second section reviews the results of the different model projections for China's supply, demand and trade of grains. The third and fourth sections compare the assumptions and parameters used in each of the models. In the fifth section, differences in the model structures are described and analyzed. Finally, the paper 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 for the direction of similar modeling 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 make the results comparable. 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 includes paddy rice, wheat, maize and other coarse grains but with rice converted into a milled form using an average conversion ratio of 65 percent. OECF uses the definition used by Chinese agencies, according to which grains include not only those covered in the USDA definition but also potatoes (converted to grain equivalent using a five to one ratio), soybeans, pulses, and other grains like buckwheat. Unlike the USDA definition, rice used in the Chinese definition is in paddy form.

This paper uses a standard definition of grains based on the USDA definition 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. 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 for the final projection year.

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

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 for production, demand and trade from the different models. The figures for 1980, 1990, and 1995 are actuals, while the bold numbers are projections reported by the different studies. The italicized numbers are linear extrapolations made by the authors to enable a comparison of results for the projected years.

Table 1 Alternative projections of grain production in China

	Projection Study					
Year	Brown	Rosegrant et al.	Huang et al.	USDA	World Bank	OECF
			(million metric tons)			
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: 1. Figures for 1980, 1990, and 1995 are actuals, while those in bold are projected by the different studies. The italized figures are estimated by the authors using linear extrapolation.

2. All projections have been adjusted where necessary to the USDA definition of grains, which includes wheat, rice (milled), corn, sorghum, millet, barley and oats. See the text for a discussion of the adjustments made.

The projected levels of grain production vary widely. Brown projects that China's grain production will decline by 11 percent, from 355 million metric tons (mmt) in 1995 to 317 mmt in 2010. On the other hand, the 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 percent annually to reach levels ranging from 450 to 490 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. The USDA and OECF production projections fall between those of Brown and the other models mentioned above. USDA projects that China's grain production will grow at a rate of one percent per annum and reach 403 mmt by 2010. The OECF projects a much slower rate of growth (about 0.44 percent per annum) with grain production only reaching 389 mmt in 2010, a modest 10 percent increase over the 1995 production level.[3]

Grain demand projections for China show much less variation than those for production, both in terms of rates of growth and levels (Table 2). USDA shows the lowest rate of increase of 1.1 percent per annum, with grain demand reaching a level of only 443 mmt in 2010. Huang et al. show the largest demand projection of 513 mmt in 2010 (growth at 2.1 percent per year). The other projections, including that of Brown, fall between those resulting from the above two models.[4]

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[3]The FAO projects that China's production will reach 398 mmt in 2000. Simpson et al. provide projections for 2000 that range between 370 mmt under a sluggish economic growth scenario to 378 mmt under a more robust economic growth scenario; they also project 421-428 mmt for 2010, and 437-467 mmt for 2025. FAPRI's projection estimate is 386 mmt in 2005 (FAPRI 1996).

[4]The FAO projects grain demand to reach 415 mmt in 2000, and FAPRI's projection is 410 mmt for 2005. Brown's projection of grain demand reported here is based on the assumption of a per capita consumption of 400 kg per year, which is higher than some of his earlier projections.

Differences in grain import projections arise primarily from differences in projected production. Brown and OECF project that China will have a grain deficit of more than 100

Table 2 Alternative projections of grain demand in China

	Projection Study					
Year	Brown	Rosegrant et al	Huang et al	USDA	World Bank	OECF
	(million metric tons)					
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.

Notes: See the footnote to Table 1.

Table 3 Alternative projections of grain imports in China

	Projection Study					
Year	Brown	Rosegrant et al	Huang et al	USDA	World Bank	OECF
	(million metric tons)					
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.

Notes: See the footnote to Table 1.

mmt (20-30 percent of total consumption) in year 2010 (Table 3). The large import projection by Brown and OECF mainly comes from a very pessimistic outlook of grain production in China. Similar but much more modest imports are projected by Rosegrant et al., Huang et al., USDA and the World Bank. These projections indicate that by year 2010, China will only need to import between 15 and 39 mmt of grains, or roughly 3-9 percent of the total domestic demand.[5]

3. MACROECONOMICS ASSUMPTIONS

Macroeconomics assumptions play an important role in determining the reported projections of grain production, consumption, and trade for China. We review the assumptions for population and income growth.

Differences in annual population growth rates are small among the projection studies (Table 4). The outlier is OECF which assumes population growth rates of 1.46 percent per annum between 1990 and 2000 and 1.22 percent per annum between 2000 and 2010. All the other projection models reported assume a population growth rate close to 1 percent per annum. Brown projects China's population to reach 1.5 billion in year 2017 and 1.6 billion in year 2030. These figures imply that population will grow at one percent per year from 1994 to 2017, and 0.5 percent per annum from 2017 to 2030. Rosegrant et al. also used a one percent per annum population growth rate. Huang et al., USDA and the World Bank all

[5]FAO projects import requirements of 17 mmt for 2000, and FAPRI projects 25 mmt for 2005.

assume a one percent per annum population growth rate up to year 2000 and then a slower rate of less than one percent per annum thereafter.

Table 4 Macroeconomic assumptions in various models

	Projection Study					
Projection Period	Brown	Rosegrant et al	Huang et al	USDA	World Bank	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: 1. Brown assumes that the population in China will be 1.5 billion in 2017, and 1.6 billion in 2030, implying that population will grow at 1% per annum from 1994 to 2017, and by 0.5% per annum from 2017 to 2030.
2. OECF assumes per capita income will continue to increase at the same rate achieved in 1984 to 1993.

The assumptions about per capita income growth are quite diverse among the projection studies. Huang et al. have the most pessimistic view and assume that China's per capita income will grow by only 3.0 to 3.5 percent per annum. These rates are even lower than those achieved during the period of the Cultural Revolution. The optimistic view is that of the OECF, which assumes that China's economy will continue to grow at 8.1 percent per annum, a rate 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 six to eight percent per annum.[6]

The large demand projection given by Huang et al., despite their assumption of low per capita income growth, comes primarily from the incorporation of urbanization parameters into their model. Urbanization leads to a greater shift in demand towards meat and other livestock products. The projected indirect grain demand for livestock feed accounts for 31 percent of the study's total demand projection in 2010.

4. MODEL PARAMETERS

Supply and demand elasticities are important parameters in any projection model, and can also account for important differences in results. Table 5 shows the income elasticities employed in the different projection models. Setting up a similar table for the price elasticities was not easy 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.

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

[7]The authors tried to obtain these parameters directly from the authors of the various models, but were unsuccessful.

Table 5 Comparison of income elasticities used in the various models

Projection Model			1990-2000	2000-2010	2010-2020
Brown			n.a	n.a	n.a
Rosegrant et al.	Grains		-0.03 - .003	-0.03 - .003	-0.03 - .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 - 0.03	-0.04 - 0.03	-0.04 - 0.03
Huang et al.	Rural		0.15	0.00	-0.05
	Urban		0.00	-0.05	-0.10
USDA					
		Rice	-0.10 - -0.11	-0.11 - -0.15	n.a.
	Urban	Wheat	-0.05 - -0.06	-0.06 - -0.01	n.a.
		Coarse Grain	-0.14 - -0.17	-0.17 - -0.25	n.a.
		Rice	0.10 - 0.02	0.02 - 0.00	n.a.
	Rural	Wheat	0.12 - 0.20	0.10 - 0.12	n.a.
		Coarse Grain	-0.10 - -0.12	-0.12 - -0.20	n.a.
World Bank			n.a	n.a	n.a
OECF	Food		-0.034 - -0.238	-.034 - -0.170	-.034 - -0.170
	Feed		0.346 - 0.907	0.346 - 0.907	0.346 - 0.907
	Processing		0.446 - 0.924	0.446 - 0.924	0.446 - 0.771

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

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

Projection Model	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.
World Bank	-0.03	0.00	n.a.	1.90	1.70	n.a.
OECF	-0.62	-0.51 - -0.58	n.a.	1.46	0.84 - 1.4	n.a.

Notes: Brown indicates 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 the grain area in 2030 will be reduced to 48 million hectares. Brown's projected grain area and production for 2030 imply that the grain yield will reach 5.7 tons, which is 54% higher than the actual 1990 yield of 3.7 tons.

As can be seen from Table 5, income elasticities of grain demand for food are generally small, and many of them are 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 for grains will come primarily from population increases. On the other hand, income elasticities for feed and other uses of grain are definitely larger in response to growth in demand for livestock products and other processed foods.[8]

The wide variations in the production projections follow from variations in the growth rates assumed for grain area and yield. 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 percent per year (Table 6). His yield growth projection, which is estimated from his projections of area and production, is 1.1 percent per annum. This rate is relatively high considering 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 future growth in land area for grain cultivation in China. They project that the area planted to grain production will decline by 0.62 percent per annum from 1993 to 2000, by 0.51 percent per annum from 2000 to 2005, and by 0.58% per annum from 2005 to 2010. Like Brown, the projected reduction in area growth offsets

[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 about these parameters.

relatively high growth rates projected for yield; 1.5 percent per year between 1990 and 2000, 1.4% per year between 2000 and 2005, and 0.84% per annum between 2005 and 2010.

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

The projected growth rate for the grain area in the Rosegrant et al. study is the most optimistic, with a slight expansion (0.27 percent per year between 1990 and 2010 and 0.03 percent per year between 2010 and 2020), although this varies by commodity. The largest expansion is expected in maize and wheat, while some contraction is seen for rice. Projected growth rate in grain yield is more modest, however, at only about 1.3 percent per annum between 1990 and 2020. Similarly, yields in wheat and maize are projected to be more rapid than for other grains, including rice.

5. MODEL STRUCTURES

This section reviews the different model structures used in the various projection studies. This is the source of most of the differences in projections. Some studies simply employ value judgments 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 the supply and demand of commodities. Sophistication of a model is determined by the range of market forces and government policies that are incorporated. These levels of sophistication are exemplified in the various projection models being compared in the paper, 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.

BROWN'S PROJECTIONS

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

Since Brown does not have a structural model, interactions among producers, consumers, and government are not captured in his projections. Thus, for example, an 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 to be found in Alexandratos (1996), Crook (1994), Johnson (1995), Paarlberg (1995, 1996), Smil (1995, 1996), and Crosson (1996).

Table 7 Comparison of commodity and country coverages in the various projection studies

	Projection Study					
	Brown	Rosegrant et al.	World Bank	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

Notes: Among the studies, only Rosegrant et al. and USDA incorporate a livestock sector module in their models. The CPPA/USDA model is capable of modeling any single country or group of countries as well as the global market for agriculture.

Table 8 Comparison of modeling approaches

	Projection Study					
	Brown	Rosegrant et al.	Huang et al.	USDA	World Bank	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 fertilizer 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		Modeled 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		Proportion of food and feed demand			None	Areas x seed use per hectare
• Waste		Proportion 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 cleaning	Market clearing	None
Price Transmission	None	Exchange rate x world price plus margins and 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	Ecomonetric estimation	Synthetic	Econometric estimation	Synthetic

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

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) modeled 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 carryover 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, fertilizer prices, the proportion of area planted to high yielding varieties and a trend variable.

The domestic demand equation in this model is formulated differently for net grain importer and net exporter countries. 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 are then 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, and its lack of a livestock sector. This is explained by the fact that the model was developed primarily to focus on food security issues in the developing countries. Significant development and growth in many countries is rapidly changing their demand patterns, yet the model cannot capture the interactions among grain crops, cash crops and livestock.

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, Sombilla, and Perez at the International Food Policy Research Institute (IFPRI). IMPACT is (1) a partial equilibrium model with a focus on the agriculture sector; (2) global, covering 35 countries and regions, and 17 crop and livestock commodities; (3) nonspatial; and (4) synthetic, because of its use of elasticities derived from other studies. Despite its primary focus on agricultural commodities, a relationship has been incorporated in the model to link income growth in the agriculture and nonagricultural sectors. The model uses a system of supply and demand elasticities, incorporated into a series of linear and nonlinear 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 the agricultural and nonagricultural sectors. A typical country or regional submodel consists of a set of equations for each commodity, as well as equations that link the agriculture and nonagricultural sectors. Intercountry and intercommodity linkages in the world market are achieved through trade at which prices are also determined.

The model has wide coverage of commodities and it does capture the linkage between the crop and livestock sectors as well as between agriculture and nonagriculture. The weakness lies in the absence of any detailed specification of supply shifter variables to capture the impact of technical and structural change, especially in the livestock sector, which will likely have a big impact on future grain supplies.

USDA CPPA MODEL

The CPPA model of USDA is also a multi-commodity, multi-country partial equilibrium simulation model of the agricultural sector. It is primarily used as a tool to generate theoretically consistent, 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 and includes both primary and processed products.

The CPPA model has a standard structural framework for each country that takes world prices as given. Mechanisms are then 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 so that the markets clear. More advanced versions of CPPA are possible where policies, prices and incomes are, likewise, determined endogenously.

The submodel for China includes the most detailed representation of 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 partial equilibrium nature that ignores the nonagricultural sector.

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., covers only China but is based on a relatively detailed country modeling effort. The model's supply specification includes equations for rice, other grains, and cash crops, while the demand specification includes 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 urbanization 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 relationships to represent the impact of irrigation development, increased 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 in analyzing the effects of broader policy issues in other sectors as well as in other countries on China's grain supply and demand.

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.

6. CONCLUSIONS

EXPLAINING THE DIFFERENCES IN PROJECTIONS

As mentioned earlier, the projection exercises reviewed in this paper are strongly influenced by differences in model assumptions and specifications. Nevertheless, several conclusions can be drawn.

1. 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, as a result of continued growth in incomes and rapid urbanization of the population. Projected levels of grain demand are very similar in all the models reviewed. This arises from their similar assumptions about population growth, which

accounts for most of the increases in future grain demand as the income elasticity parameters are generally small or negative.

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

2. Brown's low projections of grain production in China are due to his very pessimistic view about the land area that will be available for grain production; he assumes it will be reduced by half for industrial and urban uses while yield levels will not increase fast enough to offset the production losses from land contraction. OECF's low projections of grain arise from the same argument.

It should be noted, however, that China's cereal production continued to grow at an annual rate of two percent between 1986 and 1995, even after the positive impact of the institutional and policy reforms in the late 1970s has been reaped. There are reasons to believe that higher productivity growth can still be achieved in China particularly as average grain yields are not as high as previously reported (official data on land area reportedly have been understated by as much as 30 percent.[10]) With proper price incentives, grain yields can further be raised on Chinese farms. The effect of prices, not only on Chinese producers but also on consumers, are especially important since China is rapidly moving towards a full market and private economy. As supply becomes tighter in the future, the government will likely respond by increasing investments in agricultural R&D and public infrastructure to increase crop yields. The improved exchange of scientific information, germplasm, and other research materials between Chinese scientists and those in other countries and international agricultural research centers 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 are really worst case scenarios that suggest what would happen if all other things fail to respond to changes in the economic environment. These studies should not, therefore, be taken seriously, especially in the formulation and evaluation of policies to direct the course of future food balances.

3. The rest of the models, which are based on more elaborate specifications of demand and supply behavior, give remarkably consistent projections for production, demand

[10]The current official cultivated land area is 96 million hectares (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 of China’s cultivated land data by another government agency.

and trade in 2010, despite differences in assumptions and parameters. This seems to indicate the strength of well-formulated economic 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 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 the ongoing transition process from a centralized system to a market oriented economy.

FUTURE RESEARCH

While this study has provided an initial framework for answering the question as to why projections on China's grain situation are different, it also suggests ways in which future research should be directed 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 modeling efforts of the Chinese agricultural sector:

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 the move towards privatization, China's government remains deeply involved in guiding the nation's development process. It is critical to understand the response of the government to the new economic environment as this will have great impact on future trends in 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 more effectively and to promote better input and output market adjustments.

On the Linkage of the Agricultural with the Non-agricultural Sector

China is undergoing a rapid transformation of its national economy. The comparative advantage of agriculture is declining, and resources like water, labor, and land are rapidly moving out of the agricultural sector. None of the models reviewed considered the effects of the increasing scarcities in factor inputs brought about by more rapid development of the commercial and industrial sectors on agricultural investment and technology. A more general equilibrium framework which incorporates intersectoral linkages should help capture some of these effects. Also needed are more detailed specifications of how agricultural production technologies will change in response to changes in factor prices.

On the Effects of the WTO

Another important issue that needs to be considered in future modeling efforts is the impact on the global grain economy 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 or exports can have a significant impact on the international grain market (Tuan 1994). Information on

[11]Limited efforts have been made by several economists in modeling the welfare impact of the Uruguay round reform, changes in 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 have very aggregated sub-agricultural sectors.

these potential effects will help policy makers in both China and other countries develop their strategies to prevent any excessive instabilities in both domestic and international grain markets.

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 backyard to commercial production) will have a large impact on future food security in China. In particular, improvements in feed-meat ratio arising from these technical and structural changes will save huge amount of feed grains.

On Infrastructure Constraints on Grain Imports

The models reviewed in the paper have all ignored a very crucial factor in determining China's future grain imports, the constraints of port capacity and other infrastructure like domestic transportation. According to Chinese government officials, current port capacity limits grain imports to a maximum of 20 mmt of grains per year. To increase grain imports from the current 10-20 mmt per year to even the modest projection of 40 mmt by 2010 would require substantial amount of investments in infrastructure development. A key policy question is whether it is more economically efficient to pour investments into the development of infrastructure facilities to enhance greater grain imports, or to improve further the productivity of the agriculture sector through appropriate investments in agricultural research, irrigation and rural infrastructure.

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