China's Food Economy to the Twenty-first Century: Supply, Demand, and Trade*

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I. Introduction

China's emergence as the world's fastest growing economy has both raised hopes that East Asia's giant can join the ranks of modernizing nations and fueled concerns that its rapid transition will upset the fragile equilibrium of global markets and institutions. The nexus of China's growth, the management of its food economy, and its potential effect on world agricultural product markets compellingly illustrates the delicate balance facing policy makers. Directed properly, China's growth provides an unprecedented opportunity for achieving major gains in its food security, poverty reduction, and nutritional improvement. Without suitable policies, China's development may wreak havoc on sectors of its own society as well as on the rest of the world.

Unfortunately, China's leadership and the international community have a limited scope for understanding future trends, evaluating socioeconomic trade-offs, and sorting through policy options. Current analytical tools are quite simple, having almost no structural basis and providing little policy guidance. Predictions have been notoriously sensitive to fundamental assumptions, creating such a wide range of forecasts that policy makers have not become enlightened but instead have felt defenseless when confronted with assertions on future supply, demand, and trade balances. The shallowness of understanding was exposed by the outrageous pronouncements by L. Brown when he projected, without any research-based underpinnings, massive food shortfalls in China by

2030.[1] The ensuing panic in China's agricultural hierarchy, however, could not be suppressed since no research team inside or outside of China could respond authoritatively.

Predictive frameworks are not easy to construct. China is a country experiencing rapid economic and social transformation. Industrialization proceeds at one of the fastest rates in the world. These forces are causing wrenching changes: market development, urbanization, environmental degradation, and budgetary stress. These factors should be expected to have as great, if not greater, an effect on supply and demand as traditional determinants such as income growth and price movements. Dealing with the challenges of managing their food sector in such a rapidly changing environment requires that China's leaders have a clear understanding of the structure of the economy, especially how supply, demand, and trade are affected by any number of key economic, technological, and social forces.

The goal of this article is to help establish a more comprehensive, transparent, and empirically sound basis for assessing the future growth of China's food supply and demand balances. We hope this article will shed light on the debate on China's future grain balance, identify the kinds of structural transformations and policy decisions that might cause large grain deficits, and show the circumstances under which China might maintain its current status as nearly self-sufficient.

To meet this goal, this article first examines China's current grain balance sheet and history of grain imports and then reviews previous efforts to project China's growth of grain supply, demand, and trade. Our own assessment of the future grain economy begins by investigating a series of factors, beyond income and prices, that may affect grain demand and supply. We develop a supply-and-demand projections model, which includes a series of important structural factors and policy variables, including urbanization and market development on the demand side and technology, agricultural investment, environmental trends, and institutional innovations on the supply side. After reviewing the baseline assumptions, we present the results of the baseline projections and examine alternative scenarios using different rates of growth in income, prices, wages, population, and investment in research and irrigation.

Although we limit our analysis to grain, some of the projections may be surprising. Even in this fairly homogeneous sector of China's food economy, socioeconomic forces act very differently on rice, wheat, and maize, the study's three major crops. Not only do we demonstrate that migration, technological change, income growth, and other trends have important effects on the future supply and demand of the commodities, but under a completely reasonable set of assumptions, we also show how there could be a complete reversal in historic global trade patterns for all three grains. Whereas since 1980 China has been a net exporter of rice and maize and the world's largest importer of wheat, under our

baseline scenario, we show that China could import rice and maize in the twenty-first century and satisfy its own demand for wheat.

II. Annual Grain Production and Utilization in China

Total grain production (in trade weight) rose to 403 million metric tons (MMT) in 1993–95 (table 1).[2] After a decline of 2 MMT in stocks (which increases current grain supply) and imports of 2 MMT of grain, China's total annual supply of grain during this period was 407 MMT. This supply was used to meet a number of needs: seed, animal feed, non-food manufacturing, and direct consumption for food. Grain used for direct food consumption took up the greatest part of total supply, about 65% in 1993–95. Animal feed accounted for 23% of utilization. On a per capita basis, the average resident in China consumed 222 kilograms of grain per year, a level quite high even in comparison to the rest of East Asia. In contrast, meat and fish consumption was relatively low. The feed supply helped provide the average resident with about 30 kilograms of meat, poultry, and fish product.

The aggregation of grain balances, however, disguises different patterns of rice, wheat, and maize utilization in terms of the use of grain for feed and food and rural-urban dietary habits (table 1, rows 2–5). China's residents consume most of the nation's rice (85%) and wheat (91%) directly as food grain. The majority (84%) of China's maize is used as feed for the livestock sector.

Even general consumption aggregates vary by sector of the economy. Urbanites eat far less rice (68 kilograms) and more meat and poultry (34 kilograms) than do their rural counterparts (103 and 20 kilograms, respectively; see table 1, rows 7–9). Wheat is more complex. Unlike the rest of East and Southeast Asia, China has a large wheat economy, and its per capita rural consumption of wheat exceeds urban intake. Although there are sharp regional variations, the average rural resident consumes 90 kilograms per year of wheat versus only 72 kilograms per person for those in cities and towns. Commodity and sectoral differences in demand patterns become important in deriving future balances, since economic forces and structural changes, as well as the size and composition of consumer groups, affect each consumer group differently.

The waxing and waning of supply and demand in the past several decades has caused imports and exports to rise and fall (table 2). When China began its reform program in 1978, policy makers decided to allow a general increase in imports to relieve the constrained demand of consumers. Several years after import restrictions on wheat and other grains were relaxed, imports grew to nearly 15 MMT (row 2). Rapid growth of grain yields in the early 1980s reversed these trends, and by 1985 China became a net exporter. With continued demand growth in the mid-1980s, poor harvests drove net imports back up to more than 10 MMT by 1989. Soft demand and a resurgence of agricultural growth allowed imports to

TABLE 1

ANNUAL GRAIN PRODUCTION, UTILIZATION AND PER CAPITA FOOD CONSUMPTION IN CHINA, 1993–95

	PRODUCTION	CHANGE IN STOCK*	NET IMPORT	TOTAL SUPPLY	DISPOSAL OF AVAILABLE SUPPLY					PER CAPITA FOOD CONSUMPTION (kg)†		
					Seed	Animal Feed	Nonfood Manufacturing	Waste	Food	Average	Rural	Urban
1. Total grain:	403	−2	2	407	17	93	16	15	264	222	242	172
2. Rice	126	−3	−0	128	4	7	1	4	109	93	103	68
3. Wheat	103	−0	8	111	3	2	2	3	101	85	90	72
4. Other grain‡	174	1	−6	167	10	84	13	8	55	44	49	32
5. Maize	105	0	−5	100	3	65	2	3	28	24	31	7
6. Red Meat										19	17	27
7. Pork										17	14	23
8. Poultry										4	3	7
9. Fish										7	5	14

SOURCE.—Computed by us.

NOTE.—All values are in million metric tons, except for Per Capita Food Consumption. Rice is in milled form (trade weight). The base year is the average of 1993–95.

* A negative number indicates a decrease in stocks, which increase total grain supply.

† Includes direct home consumption, grain purchased and consumed outside of home, and processed foods.

‡ Includes maize, other coarse grains, and soybean.

TABLE 2

INTERNATIONAL TRADE BALANCE (Million Metric Tons) OF MAJOR AGRICULTURAL COMMODITIES IN CHINA, 1985–96

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996*
1. Grain:	3.3	1.7	−8.9	−8.2	−10.1	−7.9	−2.6	2.0	7.9	4.3	−19.7	−6.1
2. Wheat	−5.4	−6.1	−13.2	−14.5	−14.9	−12.5	−12.4	−10.6	−6.4	−7.2	−11.6	−5.0
3. Maize	6.2	5.1	2.3	3.4	3.4	2.5	7.8	10.3	11.1	8.7	−5.1	−.4
4. Rice	.8	.6	.5	.4	−.7	.3	.6	.9	1.3	1.0	−1.6	−.3
5. Soybean	1.1	1.1	1.4	1.3	1.2	.9	1.1	.5	.3	.8	.1	−.2
6. Other grain	.5	1.0	.0	1.3	.9	.9	.3	.9	−.1	.0	−1.6	−.2
7. Cotton	.35	.59	.75	.43	−.25	−.25	−.17	−.14	.14	−.39	−.72	−.39
8. Sugar	−1.73	−.91	−1.38	−3.46	−1.15	−.56	−.67	.57	1.40	−.60	−2.47	−.18

SOURCES.—State Statistical Bureau, *Statistical Yearbook of China* (Beijing: State Statistical Bureau Press, 1995); Ministry of Foreign Trade, *China Customs Statistics* (Beijing: Ministry of Foreign Trade Press, January–December 1995, January–August 1996).

* Data are available only for first 6 months of 1996.

fall once again to the point where China exported grain from 1992 to 1994.[3] In the mid-1990s, the cycle repeated. Net imports reached historic highs of nearly 20 MMT in 1995 but were projected to decline in 1997.

Unlike aggregate imports, trends for specific commodities have been steadier. Despite a primary reliance on domestic sources, China imported more wheat than any other country in the world since the mid-1980s. Averaging 10 MMT of wheat per year means China accounts for 10%–15% of the world trade (table 2, row 2). In contrast, except for 1995 and 1996 (and 1989 for rice), China has exported maize and rice (rows 3 and 4). These recent trade patterns continued in 1997.

III. Alternative Projections of Grain Demand and Supply in China

Various attempts at projecting future trends in China's grain imports and exports have been published or are currently being used and periodically updated.[4] The most striking feature of the projections of grain surpluses and deficits is their wide range. At one extreme, China is predicted to become a net exporter of grain. The Chinese Academy of Agricultural Sciences forecasts that China will have the capacity to export 47 MMT in the year 2000.[5] L. Chen and A. Buckwell construct a scenario where they argue that China can move from being an importer of about 10 MMT in the mid-1980s to a net exporter of 17 MMT in the year 2000.[6]

Other analysts believe China will eventually become a net importer of grain, some predicting imports will rise gradually, others, more sharply. The medium-term forecasts of the Economic Research Service of the United States Department of Agriculture predict China will be a moderate importer through 2005.[7] K. Anderson et al. predict China's grain imports will rise to 33 MMT in the early twenty-first century.[8]

In contrast, another set of researchers predict China's grain imports will increase significantly. Other than Brown, who predicts imports could exceed 350 MMT by 2030, R. Garnaut and G. Ma project that, at per capita income growth rates of 6% to 7.2% (rates under those experienced between 1992 and 1994), China will require imports of between 50 to 90 MMT by 2000.[9] C. Carter and F. Zhong predict that consumption will outpace production, leaving a food balance deficit of more than 100 MMT by 2000.[10] Chen and Buckwell arrive at a high-growth scenario where China imports 59 MMT by 2000.[11]

Since all analysts are essentially forecasting from the same general base period, the predicted changes in the relative rates of growth of grain supply and demand lead the differences in expected grain balances.[12] Brown projects actual declines in grain production of 0.6% per year (or a 20% decline by 2030), most of which comes from a nearly 50% fall in sown area.[13] Carter and Zhong project zero growth in production, while all other estimates of grain production growth are positive, ranging from 1.1% to 1.8% for baseline or slow growth scenarios and to 2.9% for rapid growth scenarios.[14]

Variation in demand projections is similar. Several projections of demand growth are in the range of 1.0%–1.7% per year, but demand growth rates well in excess of 2% are projected by Garnaut and Ma and Chen and Buckwell.[15] The long-term projections from the Economic Research Service predict much higher cereal imports; a number of the alternative scenarios forecast food balance shortfalls of 100 MMT.[16] Given the significant variation in both supply and demand projections, it is not surprising that projected net imports differ widely. The largest import projections result from highly pessimistic supply projections (Brown; Carter and Zhong) and high demand projections (Garnaut and Ma; the Economic Research Service).[17]

Projections by commodity are much less common. S. Fan, G. Cramer, and E. Wailes predict that rice exports will continue, mainly because of their assumption that demand elasticities will continue to be positive and rice production growth will continue at current levels.[18] Unpublished projections by Fan and M. Agcaoili and recent long-range projections by the Economic Research Service forecast rising imports for wheat.[19] Their estimates, however, do not take into consideration some of the structural changes facing China's food economy.

The most difficult part of evaluating current projections results is that the sources of the parameters of the forecasting models, and forces behind the changes in important state variables (e.g., population and income growth) are not transparent. The parameters on which all of these grain projections are based (except for Carter and Zhong; and Fan, Cramer, and Wailes) are either partly or wholly synthetic.[20] There is also little scope for assessing the effect of policy variables. With the exception of the Economic Research Service and Fan and Agcaoili models, no other model can be used to systematically assess the effect of governmental policy. Fundamental forces in the economy, such as urbanization and market development, are ignored. Given the rapid structural change in China's economy-in-transition and the importance of policy in China, the omission of such important variables reduces the robustness of predictions from currently available models.

IV. Structural Change and Government Intervention in China's Agriculture

As China's economy continues to change and grow, one of the main questions facing policy makers is how future patterns of utilization can be met most effectively. China is a country in rapid transition from a socialist system to one in which an increasing proportion of its goods and services, including food, are allocated by market forces.[21] It also is a country that is rapidly developing. There are many forces arising from these development and transition processes that will affect China's food economy. Any attempt to accurately forecast future supply and demand trends of food must account for these major economic forces.

Demand Shifters: Income, Market Development, and Urbanization
On the demand side, recent changes in the urban economy have made
urban consumers almost entirely dependent on markets for their con-
sumption needs.[22] In this sector, prices and income changes most likely
will be the fundamental force driving consumption pattern changes. Real
income per capita for urban residents has risen rapidly in recent years,
jumping an average of more than 5% annually between 1985 and 1995.
At the current average level of income for most urban residents, rice and
wheat consumption rises very little with new increments in income; meat
consumption, on the other hand, is still very much influenced by income
changes.[23]

Rural residents live in a different environment than their urban
counterparts and exhibit different demand behavior. While rural incomes
have grown more slowly since the mid-1980s, the demand for food
grains and meat products has increased as incomes have risen.[24] The av-
erage rural consumer, however, will spend less of the additional income
on rice, wheat, and other staple food grains as he or she becomes richer
during the development process.

Rural consumption markets are also less complete, but as transition
improves the market environment, dietary habits may change. Farmers
in many areas face limited choices in their consumption decisions since
many of the products they desire on a daily basis, such as meat and fresh
fruit, are not always available, even as incomes rise. In a sample of
households that we drew from the national household income and expen-
diture survey, we found a strong and significant correlation between the
level of consumption of primarily purchased goods, such as meat and
fruit, and the level of market development, holding income and prices
constant.[25] Discontinuous free markets, lack of refrigeration, and gener-
ally high transaction costs for procuring food in rural areas affect rural
consumption patterns in China. Even with rapid changes in rural mar-
kets, in 1992 China's farmers still purchased only 46% of their food. As
markets develop and activity on rural consumption markets increases,
apart from changes in income and prices, consumption patterns will be
affected.

Across Asia, the behavior of consumers changes dramatically as
countries urbanize.[26] Urban dwellers consume less rice and demand
higher levels of meats, milk products, and fish than do their rural coun-
terparts, even after accounting for the differences in income and prices.
The ratio of urban to rural residents in China is changing fast. The urban
population has grown from 19% of total population in 1980 to 28% in
1992. The effects of this population shift on consumption in China have
been documented.[27] While structural transformations of the economy
should be accounted for in any predictions of future consumption pat-
terns, few projections explicitly consider the differences in the consump-
tion between rural and urban consumers.

The case of wheat in China may unfold in an unexpected pattern when compared to China's Asian neighbors, although the dietary changes from migration will differ depending on what part of the country one is examining. Other countries in East and Southeast Asia always have experienced rising wheat demand with migration, since farmers in these countries produce and consume few wheat products.[28] Migrants from southern rice-producing areas may be expected to follow this path since their current production and consumption patterns resemble those in neighboring countries. In contrast, city-bound migrants from north China consume very high levels of wheat, about 200 kilograms per capita in many northern provinces, levels that exceed or approach those of traditional wheat-producing, bread-eating nations, such as Pakistan, Turkey, and Egypt. North China migrants will cut their consumption of wheat dramatically as they adopt the dietary patterns of urban dwellers. Since the nation's average rural consumption level exceeds that of urban areas (table 1), if the same magnitude of migration occurs in both the North and the South, China's future migration most likely will have a dampening net effect on wheat demand, in contrast to its other urbanizing Asian neighbors.[29]

Supply Shifters: Technology, Investment, and Environmental Stress

On the supply side, many sharp transitions are also under way. Above all, technological change needs to be considered explicitly, since it has been the engine of China's agricultural economy.[30] China's technological base grew rapidly during both the prereform and reform periods. A breakthrough in the engineering of hybrid rice, for example, pioneered by Chinese rice scientists in the 1970s, led to significantly increased yields in many parts of the country, and its use rapidly spread to nearly one-half of China's rice area by 1990.[31] Wheat and maize enjoyed similar technological transformations.[32] China's robust growth in the stock of research capital has been significantly responsible for these dramatic changes. Recent work has shown that the contribution of technology to crop growth equaled or exceeded that of the Household Responsibility System in the early reform period. Technological change contributed almost all crop growth by the late 1980s and early 1990s.[33]

There is concern, however, that China's system may be suffering from neglect after more than a decade of reform.[34] Real annual expenditures on agricultural research fell between 1985 and 1990 before resuming real growth in 1990.[35] The slowdown in growth in annual investments in the late 1980s will result in slower growth in the overall stock of research in the 1990s and may affect production.

Historic patterns of research expenditures as well as China's investment plans affect how the supply of rice, wheat, and maize will respond to future research expenditures. Agricultural planners have traditionally invested most heavily in rice, wheat, and maize research.[36] Technological

breakthroughs and greater extension efforts in the production of rice and wheat have pushed their yields closer to their frontiers than in the case of maize. Interviews with breeders from multinational seed corporations commonly reveal that the yield potential in all crops still exists, including rice and wheat, but that it is higher in maize.

A number of other factors similarly will affect future supply. Investment in agricultural infrastructure, especially irrigation, has been another important determinant of China's agricultural growth in recent decades.[37] Irrigation investment and the stock of facilities have followed patterns similar to those for research, falling in the early reform period before recovering in recent years. Trends in environmental degradation, including erosion, salinization, and loss of cultivated land show that it may be that considerable stress is being put on the agricultural land base.[38] Erosion and salinization have increased since the 1970s, although in a somewhat erratic pattern, and these factors have affected output of rice, wheat, maize, and other agricultural products.[39]

V. A Framework for Forecasting China's Grain Supply and Demand

The major components of this article's forecasting framework include a supply model for the rice, wheat, maize, other grain, and cash-cropping sectors of the agricultural economy, while demand models are specified separately for rural and urban consumers for rice, wheat, other grain, and six animal products. Real world price projections are generated by IMPACT, a partial equilibrium global trade model developed by M. Rosegrant, M. Agcaoili, and N. Perez.[40]

Grain supply is assumed to respond to the crop's own price, prices of other crops, quasi-fixed inputs, and the off-farm wage. Output also is a function of the stock of agricultural research, the stock of irrigation infrastructure, and three environmental factors—erosion, salinization, and the breakdown of the local environment.[41] The full set of results and detailed discussion of the model can be found in J. Huang, M. Rosegrant, and S. Rozelle.[42]

Grain consumption is divided into two parts: grain that is directly consumed for food and that which is fed to animals and consumed indirectly. Direct food equations are divided into rice, wheat, and other grains.

Food Grain Demand

Rural and urban food grain demand are modeled separately for several reasons. Consumption patterns are inherently different for rural and urban consumers.[43] Income differentials, expenditure growth, rates of change of population, and other demographic factors also vary dramatically between rural and urban regions. The effect of urbanization is accounted for by multiplying per capita grain projections for each sector

by the projected changes in rural and urban populations, including the anticipated flows of rural residents into the cities.

Econometrically estimated parameters also are used for this part of the analysis. Using an Almost Ideal Demand System framework and household survey data, we estimated the demand parameters.[44] The estimated coefficients and elasticities are discussed in detail in two articles by Huang and Rozelle, and one by Huang and H. Bouis.[45] Expenditure elasticities are estimated so that they may vary according to the level of income. As projected incomes rise throughout the projection period, income elasticities fall. Urban food grain income elasticities become zero in 2000 and turn negative in 2010; those for rural residents become zero in 2010.

Feed Grain Demand

Indirect grain consumption is imputed from the underlying demand equations for pork, beef and mutton, chicken, fish, eggs, and milk. Demand parameters for the products are estimated for rural and urban residents.[46] Different sets of parameters are estimated for different types of cities. These estimates are used for the first 10 years of the projection period. Following the experience of the rest of Asia, it is assumed that after 10 years the income-demand relationship for meat by rural residents will be similar to the current expenditure pattern of small town residents. Similarly, during the first decade of the next century, demand patterns of urban consumers in small- and medium-sized cities will become more like those of consumers in large cities in the 1990s.

Once the demand for meat and other animal products is known, the implied feed demand (and hence the overall demand for grain) is calculated by applying a set of feed conversion ratios.[47] The feeding efficiency of hogs is expected to increase slightly over time. Meat is assumed to be produced in China and to be sufficient to satisfy the demand for animal products, an assumption that is relaxed later in the analysis.

VI. Baseline Assumptions

All simulations begin from 1993–95, the base period. Base-period data on production and utilization (discussed above) are 3-year averages centered on 1994. Summaries of demand and supply factors that potentially affect the future development of China's food supply are in appendixes A and B. A complete detailing of the structural elasticities and projected demographic structure of the economy can be found in Huang, Rozelle, and Rosegrant.[48]

Demand Side Assumptions

Income growth and population growth will remain important determinants of future food balance. Population growth peaked in China in the late 1960s and early 1970s. Since then, fertility rates and the natural rate

of population growth have begun to fall. Relying on the United Nation's demographic predictions, the growth rate during 1995–2000 is assumed to be 1.055% per annum. This annual rate falls during the next 2 decades to 0.740% and 0.649%, a level that is considerably below the world's projected growth rate (about 1.70%) but above recent projections by China's demographers.[49] The share of urban population will rise from 28% in the base year to 31% by 2000 and to 45% in 2020.

The baseline per capita income growth rate is forecast to average about 3% in the rural sector and 3.5% in the urban sector. The recent growth rates in the late 1980s and early 1990s were substantially above this level in the urban economy (around 6%–7%) and significantly below this in rural areas (less than 1% per year between 1985 and 1992). In recent years the overheated urban growth has slowed, however, and since 1991, the rural economy has begun to pull out of its recession, growing at 4% per year. The effect of high growth rates also is simulated to check the sensitivity of the grain projections to the alternative growth assumptions. Market factors will also change over time. Price trends are projected to follow those of world prices.[50] The rate of rural market development is expected to increase at 10% per year.[51]

Supply Side Assumptions

The supply-side assumptions are identical to those used in Rozelle, Huang, and Rosegrant; and Huang, Rozelle, and Rosegrant and will not be repeated.[52] Following the discussion above, supply will respond most sharply to new technology and irrigation investment. However, annual expenditures on research declined from 1985 to 1990, and irrigation expenditures dropped from 1975 to 1985. Because of lags, these early investment dips will keep baseline projections of investment growth below historic rates in the early projection period. The recent recovery in research and irrigation investments, together with the experience of other Asian countries and China's commitment to a strong domestic grain economy, leads to the expectation that China will sustain its recent upturn in investment funding over the long run. Erosion and salinization are expected to continue to increase at a steady but slow pace.

VII. Results of Baseline Projections

According to the analysis, per capita food grain consumption in China hit its zenith in the late 1990s. From the baseline level of 222 kilograms, food grain consumption per capita rises slightly until 2000 and falls over the remaining forecast period (app. C). The average rural resident will increase food grain consumption through 2010, before reducing demand in the second decade of the next century. The ebb of per capita rural food grain demand occurs at a time when rice and wheat income elasticities, although lower than the late 1990s, are still positive. As markets develop,

rural consumers have more choice and will move away from food grains. Urban food grain consumption per capita declines over the entire projection period.

Because of the higher quality of fine grains, total rice and wheat consumption per capita will rise slightly before stabilizing at levels near the 1994 level (app. C). Reflecting their still positive, albeit small, income elasticities, both rural and urban consumers demand higher quantities of rice and wheat as compared to other food grains. Per capita demand for other food grains falls monotonically over the projection period. Consumption per capita of all food grains is projected to be more than 5% lower in 2020 than it is for current levels.

In contrast, per capita demand for red meat is forecast to rise sharply throughout the projection period (app. D). China's consumers will more than double their consumption by 2020, from 19 to 43 kilograms per capita. Rural demand will grow more slowly than overall demand, but urbanization trends will shift more people into the higher-consuming urban areas (in the mid-1990s an urban resident consumed about 60% more red meat than his or her rural counterpart). While starting from a lower level, per capita demand for poultry and fish rise proportionally more.

The projected rise in meat, poultry, fish, and other animal product demand will stimulate aggregate feed grain demand (app. E). In the baseline scenario, demand for feed grain will increase to 240 MMT by 2020. This growth rate implies that feed grain as a proportion of total grain utilization will move from 23% in 1994 to 40% in 2020. The process of moving from an agricultural economy that produces grain primarily for food to one that becomes increasingly animal feed oriented typifies rapidly developing economies.[53]

In conjunction with the projected population rates, the projected per capita demands for food and feed grain imply that aggregate grain demand in China will reach 600 MMT (table 3), nearly 50% higher than the initial baseline demand. During this same period, rice demand will reach 147 MMT, a rate increase of only 15%. The declining importance of rice as the dominant commodity in China is apparent as its proportion of total grain demand is projected to fall from 31% in 1994 to approximately 24% in 2020. The share of wheat is expected to fall by 4% (from 27% to 24%) during the same time period.

Baseline projections of the supply of grain show that China's producing sector gradually falls behind the increases in demand (table 3). Production is expected to rise somewhat faster in the second and third decades of the forecast period. Primarily as a result of the resumption of investment in agricultural research during the forecast period, aggregate grain production is expected to reach 488 MMT in 2010, an increase of 14% during the preceding 10 years. Production will reach 569 MMT by

TABLE 3

PROJECTIONS OF GRAIN PRODUCTION, DEMAND, AND NET IMPORTS (Million Metric Tons) UNDER VARIOUS SCENARIOS WITH RESPECT TO POPULATION AND INCOME, 2010–20

ALTERNATIVE SCENARIO	2010			2020		
	Demand	Production	Net Imports	Demand	Production	Net Imports
1. Baseline:	516	488	28	600	569	30
2. Rice	142	141	1	147	153	−6
3. Wheat	133	123	10	141	141	0
4. Other grain	242	224	17	312	273	38
5. Baseline with low-population growth	501	488	13	568	569	−1
6. Baseline with high-population growth	529	488	41	625	569	56
7. Baseline with low-income growth	494	488	6	555	569	−14
8. Baseline with high-income growth	542	488	53	655	569	85

2020, an even higher percentage increase for the decade (16.6% over the 2010 level).

Under the projected baseline scenario, the gap between the anticipated annual growth rate of production and demand implies a rising deficit. Total grain consumption rises at 1.48% per year, of which 0.76% is due to the rise in population and 0.72% is due to rising per capita grain demand. Nearly all of the higher per capita grain demand stems from the increased demand for feed grain (it rises by 2.89% while aggregate demand for food is stagnant). Grain production during this period grows only 1.35% annually. Imports surge to 28 MMT by 2010 and remain at a similar level through 2020 (30 MMT, table 3).

The most surprising results of the commodity projections are those for wheat. Under the baseline scenario, the initial widening of the gap in the late 1990s implies a rising deficit. Wheat imports increase slightly in the early part of the projection period but fall back to their current levels by 2010 and by 2020 they fall to zero, implying that China will achieve self-sufficiency in wheat.

Several factors distinguish the wheat results from those of other studies. More than anything, falling wheat demand resulting from both rural to urban migration and emerging rural consumption markets allows supply to catch up. Other studies, such as those by Fan and Agcaoili and the Economic Research Service, which do not consider urbanization and market development forces, predict higher wheat imports.[54] Moreover, while there is considerable range in this study's projections for rice and even more for maize, few changes in assumptions result in predictions that China will become a significantly larger wheat importer than it currently is. Most major demand factors that appear to be inexorably increasing—urbanization, income growth (with zero or negative income demand elasticities), and market liberalization—push China's consumers to reduce wheat demand over the next 25 years.

The deficit of other grain (which is mostly maize), however, experiences a rapid rise; by 2020 almost all of China's cereal import needs will be for maize (table 3, row 4). Taste preferences for meat and rising incomes stimulate meat demand and, indirectly, feed demand to such a great extent that after maize imports begin early in the twenty-first century, they expand continuously even though the maize supply also accelerates. Major breakthroughs in maize technology (such as the adoption of varieties with Bt corn genes—genetically engineered pest-resistant maize plants—or new foreign-bred hybrids) could delay large imports.

In fact, structural change of any type, such as unanticipated shifts in cropping patterns, could drastically alter the pattern of commodity-specific forecasts. For example, rising wages could induce farmers to give up their intensive wheat-maize rotations in North China. If relative prices favored maize over wheat, large numbers of farmers might decide to stop producing winter wheat and plant a single crop of higher yielding

maize. Such a change would work against the formation of the new patterns of imports and China could end up continuing to import wheat and export (or at least not import) maize. The same type of trade-off could happen in the intense rice-wheat regions of the Yangtse Valley.

VIII. Alternative Projections

To test the sensitivity of the results to changes in the underlying forces that drive the supply and demand balances, a number of alternative scenarios are run with alterations in the baseline growth rates of the key variables, including income, wages, price, population, and investment in technology. The results indicate that low population growth rates would reduce grain demand by 32 MMT in 2020 and make China into a marginal grain exporter by the end of the projection period (table 3, row 5). With high population growth, imports increase to 56 MMT (row 6). Low-income growth causes a decline in projected total grain demand from 601 MMT to 555 MMT, resulting in moderate exports of grain in 2020, while rapid income growth causes projected imports to nearly triple to 85 MMT (rows 7–8).

Imports rise sharply to 44 MMT if real wages increase faster (e.g., 2% annually) than the baseline rate (1%—table 3, row 5). However, China still has a large, still-isolated agrarian population, of which only about one-third have off-farm jobs.[55] With rising wages, the labor force slowly is becoming integrated with the rest of the economy through emerging labor markets. The potential for an accompanying drain in the rural labor force should keep rapid real-wage increases from taking off for at least several decades. Moreover, if wage rates do rise quickly and labor begins flowing off the farm, farmers will replace lower labor input with capital-intensive inputs such as farm machinery and herbicides. Since these types of capital inputs do not exist in the structural model (owing to a lack of data), the 1% increase in wage rates should be looked on as the percentage increase rise in the wage rate over the rate of rise of the price of capital. If real-wage increases (relative to the cost of capital) approach those in Taiwan and Korea (3% annual growth), imports could increase to as much as 58 MMT.

Table 4 also illustrates the large impact of investment in agricultural research and irrigation on production and trade balances (rows 2–3), a result that is hardly surprising given the large contribution to the supply of agricultural research and the technology it produces. Increases in the growth rate of agricultural research and irrigation investment from 3.5% to 4.5% per year would transform China from an importer to an exporter by early 2010. If, instead, growth in annual investment in agricultural research and irrigation fell moderately, from 3.5% per year (as forecast under the baseline projections) to 2.5%, total production would be only 514 MMT by 2020. With no change in the demand-side assumptions, imports under such a scenario would reach a level of 83 MMT.

TABLE 4

Sensitivity of Grain Production, Demand, and Net Imports Projections to Alternative Assumptions on Public Investment, Wages, Price Trends, and Deterioration of the Environment, 2010–20

ALTERNATIVE SCENARIO	2010			2020		
	Demand	Production	Net Imports	Demand	Production	Net Imports
1. Baseline	516	488	28	600	569	30
2. Baseline with low rate of investment in agricultural research and irrigation	516	465	50	597	514	83
3. Baseline with high rate of investment in agricultural research and irrigation	518	515	3	602	631	−29
4. Wage growth:						
Low (0% per year)	517	496	21	600	584	16
High (2% per year)	516	481	36	599	555	44
5. World output price impact:						
Large (0% per year)	516	492	25	600	576	23
Small (−1%)	517	485	32	600	563	37
6. Fertilizer price growth:						
Low (0% per year)	517	501	16	601	594	7
High (2% per year)	516	476	40	598	546	52
7. Salinity and erosion growth:						
Low (0% per year)	517	491	26	600	574	26
High (0.4% per year)	516	486	31	599	565	35

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This level of grain imports could be expected only if there is continued decline in the growth of agricultural investment and if the government does not or cannot respond as imports rise with countervailing policy measures to stimulate food production growth. Agricultural research and irrigation investments, however, have already recovered in recent years. In the mid-1990s, when grain prices rose in response to short-term tightening of grain supplies, policy makers promised and have begun to deliver greater agricultural investments.[56] While most of the investments have been targeted at irrigation, improvements in the operation of research institutes has also been announced.

In addition to domestic investments, the government could also look to the international arena for technological products that would allow China time to redevelop its agricultural research system. In fact, there are currently several large international seed companies investigating the possibilities of moving into China's market for seeds. Such moves would reduce the expected decline in grain supply and also decrease the expected level of imports even if growth in public investments slowed. Weak intellectual property rights and tightly controlled and fractured domestic seed markets, however, remain a serious barrier to active participation by multinational technology firms in China.[57]

Production, demand, and imports, however, are insensitive to small changes in price trends, a characteristic that will affect projections of how China's entry into (or exclusion from) the World Trade Organization will affect food balances. Output price trends do affect China's grain balances, but the effects are small. At the baseline level, for every 0.5% increase (decline) in the annual projected grain price trend, imports fall (rise) by 7 MMT in 2020 (table 4, rows 6 and 7).[58] The baseline price assumption (an annual 0.5% world price decline as projected by both the World Bank and Rosegrant, Agcaoili, and Perez) was chosen as the most likely to be realized for two reasons.[59] Grain prices have shown a down trend in real terms during the entire twentieth century. Also, if China gains admittance to the World Trade Organization (WTO), it politically cannot support prices at the level maintained by its East Asian neighbors. Even without WTO membership, fiscal problems in China may keep it from using high price supports. In the event that China decided to adopt a protectionist policy and prices rose in real terms at 0.5 (1.0)% annually during the next 3 decades, China would import (export) about 5 MMT (7 MMT) in 2020.

Assuming a constant response of production to erosion and salinity as the level of environmental deterioration increases, slight increases in their trends (e.g., an increase of 0.2% per year from 0.2 to 0.4%) have little effect on output (a decline of only about 4 MMT in 2020; see table 4). Extrapolating from these results, substantial effects would not occur until the erosion and salinity rates accelerate to growth levels five times

greater (or to 1% per year increases in erosion and salinity). Even at this level of environmental stress, projected grain imports in 2020 only rise to 51 MMT. Unless the effect of environmental stress is exponential and the government is unwilling (or unable) to invest in rectifying the adverse aspects of the deteriorating environment, these findings indicate that Brown's pessimism is unfounded.[60]

China has other food policy alternatives, including turning to international meat markets to satisfy its food needs, instead of importing grain as feed. China currently is a net exporter of meat, mostly to Hong Kong and Southeast Asia. If the model allowed for meat imports, China might choose to buy meat on global markets, a move that would reduce projected feed grain imports but not total agricultural trade volume. If China imported a quantity of meat equal to 10% of its 2000 meat demand, grain net imports in 2020 could be reduced to 6 MMT from the baseline of 30 MMT when China relies completely on domestic sources of meat. Without good refrigeration or transportation infrastructure, however, meat imports will be constrained in the near future. In fact, many developing countries prefer to import feed grain and undertake the value-added activity in their own country. If high grain imports are unacceptable under China's current political doctrine, importing meat may be one way around such an ideological constraint.

IX. Conclusions

The purpose of this article is to examine trends in China's grain economy, review the current set of studies that project future supply and demand trends, and then, on the basis of more comprehensive and structurally sound, econometrically estimated models, explore the factors that may be behind these alternative predictions. Our framework includes a demand-side model that, in addition to the effects of income and population trends (as well as income response parameters that vary as income levels rise), accounts for the effects of urbanization and the changing level of the development of rural consumption markets. The supply response model considers the effect of prices, public investment in research and irrigation, institutional change, and environmental factors.

The projections show that, under the most plausible expected growth rates in the important factors (most of which are broadly consistent with the major projection models of the Economic Research Service; Carter and Zhong; and Rosegrant, Agcaoili, and Perez), China's imports will rise steadily throughout the next decade.[61] By 2010, imports are expected to reach 28 MMT. Increasing imports arise mainly from the accelerating demand for meat and feed grains, as well as from the continued slowing of supply due to reduced investment in agricultural research in the late 1980s. Grain imports are expected to stabilize after 2010, however, as demand growth slows because of increasing urbanization and

declining population growth rates. Supply growth is meanwhile sustained with the ongoing recovery of investment in agricultural research and irrigation. China's dynamic economy and rapidly changing structure may cause changes in the historic patterns of food trade. By 2010, for example, China could import rice and by 2020 become self-sufficient in wheat and one of the world's largest importers of maize.

There is considerable range in the projections, however, when baseline assumptions are varied in both the short and long run. Different rates of agricultural investment create some of the largest differences in China's expected imports, but this is what should be expected from the factor that has the largest marginal output response. While there are a few scenarios where projected levels of imports are somewhat large, from both the viewpoint of China's own domestic needs and relative to the size of current world market trade, there are factors that may keep China from becoming too large of a player in world markets. First, world grain prices would certainly rise in the face of large Chinese imports, a tendency that would dampen Chinese grain demand and stimulate domestic supply. Second, there may be major foreign exchange constraints to importing such large volumes of grain—either government policy makers will not allocate foreign exchange for additional grain imports or exchange rate movements will discourage imports. Third, limitations on the ability of China's ports and other parts of the nation's transportation and marketing infrastructure to handle large quantities of grains may constrain import levels.

Finally, and perhaps most important, many political economy influences may force China's leaders to react to increasing grain shortages. Regardless of China's comparative advantage, government leaders have been historically, and continue to be, concerned with maintaining near self-sufficient domestic agricultural production capacity. National defense, pride, and ideology will necessarily put a premium on maintaining a rough balance between domestic demand and supply.

On the basis of the results presented here, it appears that China will neither empty the world grain markets nor become a major grain exporter. It does seem likely, however, that China will become a more important player in world grain markets as an importer in the coming decades. Both potential exporters outside of China and those charged with managing China's food needs through domestic production and imports need to be ready. Exporting nations—especially those dealing with wheat (in the short run) and maize (in the long run)—will undoubtedly be the beneficiaries of these trends. If China's policy makers believe the projected levels of imports are too high (either politically or because they see some other physical or economic constraint), they will need to devise an investment strategy soon because of the long lags between the period of expenditure and the time when such investments can affect production. Investment in facilities and institutions needed to handle the in-

creased volume of incoming grain will smooth the shock of production shortfalls and reduce the time and expense of importing grain. China's foresight in dealing with the upcoming challenge will most likely determine whether the production-demand gap turns into a major agricultural crisis or whether it will become an opportunity to more effectively develop the nation's food economy.

Appendix A

TABLE A1

ASSUMPTIONS ON THE GROWTH OF FACTORS AFFECTING GRAIN DEMAND IN CHINA, 1994–2020

	ANNUAL GROWTH RATE (%)		
FACTORS	Low	Baseline	High
Total population:			
1995–2000	.933	1.055	1.165
2000–2010	.491	.740	.932
2010–2020	.374	.649	.844
Rural:			
1995–2000	.218	.343	.461
2000–2010	−.515	−.252	−.047
2010–2020	−.873	−.606	−.413
Urban:			
1995–2000	2.633	2.750	2.842
2000–2010	2.424	2.650	2.825
2010–2020	2.158	2.450	2.658
Per capita real income:			
Rural	2.0	3.0	4.0
Urban	2.5	3.5	4.5
Prices:			
Rice	−1.0	−.5	.0
Other Grain	−1.0	−.5	.0
Meat	−.5	−.5	−.5
Rural market development:			
2000	.60	.60	.60
2010	.70	.70	.70
2020	.80	.80	.80

NOTE.—The shares of urban population under baseline assumption are 28, 31, 38, and 45% for 1995, 2000, 2010, and 2020, respectively. Population estimates are based on the United Nations, *World Population Prospects, 1994 Revisions* (New York: United Nations, 1995). Output prices are based on simulation analysis performed in collaboration with the IMPACT model developed by the International Food Policy Research Institute (M. Rosegrant, M. Agcaoili, and N. Perez, ''Global Food Projections to 2020: Implications for Investment,'' 2020 Vision Discussion Paper no. 5 [International Food Policy Research Institute, Washington, D.C., 1995]). Figures for the rural market development are index numbers for the year indicated; see J. Huang and S. Rozelle, ''Market Development and Food Demand in Rural China,'' *China Economic Review* (in press).

Appendix B

TABLE B1

Assumptions on the Growth of Factors Affecting Grain Supply
in China, 1994–2020

	Annual Growth Rate (%)		
Factors	Low	Baseline	High
Output and input prices:			
Rice	−1.0	−.5	.0
Other grain	−1.0	−.5	.0
Fertilizer	0	1.0	2.0
Land and labor:			
Land opportunity cost	1.0	1.0	1.0
Wage	.0	1.0	2.0
Agricultural research expenditure	2.5	3.5	4.5
Irrigation expenditure	2.5	3.5	4.5
Environmental factors:			
Salinity	.0	.2	.4
Erosion	.0	.2	.4

Note.—Agricultural research and irrigation expenditures are extrapolated from recent trends and are adjusted based on Li Peng, *National Economy and Social Development for the Ninth Five-Year Plan and 2010 Long Term Goals* (Beijing: People's Press, 1996). The ''land opportunity cost'' growth rate is an extrapolation from trends in State Price Bureau, *Compendium of Cost of Production Data* (Beijing: State Price Bureau Press, 1988–95). Land opportunity cost is assumed to be the return to grain cropping (total revenues) net of expenditures for labor (including own labor valued at the market wage), farm chemicals, and other cash expenses. Output price trends are based on simulation analyses performed in collaboration with the IMPACT model reported in M. Rosegrant, M. Agcaoili, and N. Perez, ''Global Food Projections to 2020: Implications for Investment,'' 2020 Vision Discussion Paper no. 5 (International Food Policy Research Institute, Washington, D.C., 1995). Fertilizer price trends are similar to those used by the World Bank, *Agriculture to the Year 2000,* a World Bank Country Study (Washington, D.C.: World Bank, 1990), ''Annex 2 to China: Long-Term Development Issues and Options.'' The trends in the deterioration of the environment are based on extrapolations of past trends.

Appendix C

TABLE C1

PROJECTED ANNUAL PER CAPITA FOOD GRAIN
CONSUMPTION UNDER ALTERNATIVE INCOME
GROWTH SCENARIOS IN CHINA,
1994–2020

ALTERNATIVE SCENARIO	PER CAPITA FOOD GRAIN CONSUMPTION (kg)		
	1994	2010	2020
Baseline:			
Total grain:	222	219	210
Rural	242	246	243
Urban	172	174	168
Rice:	93	93	90
Rural	103	107	109
Urban	68	69	68
Wheat:	85	87	86
Rural	90	95	95
Urban	72	76	75
Other grain:	44	38	34
Rural	49	44	40
Urban	33	29	25
Low-income growth:			
Total grain:		216	208
Rural		243	241
Urban		173	169
Wheat		86	84
Other grain		39	35
High-income growth:			
Total grain:		221	211
Rural		249	246
Urban		174	167
Rice		95	92
Wheat		89	87
Other grain		37	32

Appendix D

TABLE D1

PROJECTED ANNUAL PER CAPITA CONSUMPTION OF MEAT
AND FISH UNDER ALTERNATIVE INCOME GROWTH
SCENARIOS IN CHINA, 1994–2020

| | PER CAPITA MEAT CONSUMPTION (kg) | | |
ALTERNATIVE SCENARIO	1994	2010	2020
Baseline:			
Red meat:	19	32	43
Rural	17	26	33
Urban	27	40	52
Poultry:	2	5	8
Rural	1	3	4
Urban	5	8	12
Fish:	8	17	28
Rural	5	9	14
Urban	14	28	43
Low-income growth:			
Red Meat:		27	34
Rural		22	27
Urban		34	42
Poultry:		4	6
Rural		2	3
Urban		7	9
Fish:		14	20
Rural		8	10
Urban		22	30
High-income growth:			
Red Meat:		36	53
Rural		30	41
Urban		46	65
Poultry:		6	10
Rural		3	5
Urban		10	16
Fish:		21	40
Rural		12	19
Urban		35	61

Appendix E

TABLE E1

DEMAND FOR FEED GRAIN UNDER ALTERNATIVE
POPULATION AND INCOME GROWTH SCENARIOS
IN CHINA, 2010–20

| | DEMAND FOR FEED GRAIN (Million Metric Tons) | |
ALTERNATIVE SCENARIO	2010	2020
Baseline population growth:		
Low-income growth	147	197
Base-income growth	166	240
High-income growth	189	294
Low population growth:		
Low-income growth	143	186
Base-income growth	161	226
High-income growth	183	277
High population growth:		
Low-income growth	151	205
Base-income growth	171	250
High-income growth	194	308

NOTE.—Total feed grain is 93 million metric tons in the base year (1993–95).

Notes

1. L. Brown, ''How Could China Starve the World? Its Boom Is Consuming Global Food Supplies,'' *Washington Post* (August 28, 1994), ''Outlook'' section.

2. Grain includes rice in milled weight, wheat, maize, other coarse grains, and soybeans.

3. An alternative explanation for the seeming contradiction of declining imports along with rising meat demand has been suggested by Fred Crook of the USDA's Economic Research Service. He believes that grain production may be underestimated by as much as 10%, some of which may have contributed to growing farm stocks in the 1980s that were used as feed and food in the early 1990s.

4. S. Fan and M. C. A. Agcaoili, ''Why Do Projections on China's Food Supply and Demand Differ?'' Environment, Production, and Technology Division Discussion Paper no. 22 (International Food Policy Research Institute, Washington, D.C., 1997).

5. Chinese Academy of Agricultural Sciences, ''Abstract of the Compre-

hensive Report on Study of the Development of Grain and Cash Crops Production in China,'' in *Study of the Development of Grain and Cash Crop Development in China,* vol. 4, ed. Chinese Academy of Agricultural Sciences (Beijing: Chinese Academy of Agricultural Sciences, 1985).

6. L. Y. Chen and A. Buckwell, *Chinese Grain Economy and Policy* (Wallingford: C.A.B. International, 1991).

7. Economic Research Service of the U.S. Department of Agriculture, ''Projections Model for Predicting Agricultural Output: An Introduction,'' in *Research in China—Issues and Data Sources,* Proceedings of Western Regional Coordinating Committee 101 (Washington, D.C., April 21–22, 1995).

8. K. Anderson, B. Dimaranan, T. Hertel, and W. Martin, ''Asia-Pacific Food Markets and Trade in 2005: A Global, Economy-Wide Perspective,'' *Australian Journal of Agricultural and Resource Economics* 41, no. 1 (1997): 19–44.

9. R. Garnaut and G. Ma, *Grain in China: A Report* (Canberra: Department of Foreign Affairs and Trade, East Asian Analytical Unit, 1992).

10. C. Carter and F. Zhong, ''China's Past and Future Role in the Grain Trade,'' *Economic Development and Cultural Change* 39 (July 1991): 791–814.

11. Chen and Buckwell.

12. Alternatively, if the baseline starting points differ, significant variations in predictions can occur, even if the projection frameworks are alike in all other aspects. In fact, because of differences in estimates of meat consumption, one of the factors that causes the largest differences among the models is that some analysts use per capita meat production figures as a starting point for their baseline take-off point, while others use figures based on consumption figures. Unfortunately, because of overreporting of production figures (caused by double counting and local leader exaggeration) and underestimation of consumption (because of the fact that current enumeration techniques overlook much of the consumption activities that occur outside of the household—e.g., in restaurants), production-based estimates of demand have grown to be more than 200% higher than estimates based on consumption data. In a recent conference, the postconference workshop on ''China's Food Economy in the 21st Century,'' at the annual meetings of the American Agricultural Economics Association, Toronto, July 31, 1997, the baseline level of meat demand projections was determined to be one of the single most important factors distinguishing the various predictive models.

13. Brown (n. 1 above).

14. Carter and Zhong.

15. Garnaut and Ma; Chen and Buckwell.

16. Economic Research Service.

17. High import projections for supply-side reasons come from Brown and Carter and Zhong. Those for demand-side reasons are from Garnaut and Ma and the Economic Research Service.

18. S. Fan, G. Cramer, and E. Wailes, ''The Impact of Trade Liberalization on China's Rice Sector,'' *Agricultural Economics* 11 (September 1994): 71–81.

19. Fan and Agcaoili (n. 4 above); and the Economic Research Service.

20. Carter and Zhong (n. 10 above); and Fan, Cramer, and Wailes.

21. T. Sicular, ''Redefining State, Plan and Market: China's Reforms in Agriculture Commerce,'' *China Quarterly* 143 (December 1995): 1020–46; and A. Watson, ''China's Agricultural Reforms: Experiences and Achievements of the Agricultural Sector in the Market Reform Process,'' Working Paper no. 94/4 (University of Adelaide, Chinese Economy Research Unit, Adelaide, 1994).

22. S. Rozelle, A. Park, J. Huang, and H. Jin, ''Bureaucrat to Entrepreneur:

The Changing Role of the State in China's Grain Economy,'' Working paper (Stanford University, Department of Economics, Stanford, Calif., 1997).

23. Garnaut and Ma (n. 9 above); and Carter and Zhong.

24. J. Huang and S. Rozelle, ''Income, Quality, and the Demand for Food in Rural China,'' Working paper (Stanford University, Food Research Institute, Stanford, Calif., 1994); ''Urban Life, Urban Consumption'' Working paper (Stanford University, Food Research Institute, Stanford, Calif., 1995); S. Fan, E. Wailes, and G. Cramer, ''Household Demand in Rural China: A Two-Stage LES-AIDS Model,'' *American Journal of Agricultural Economics* 77 (February 1995): 54–62; and C. Halbrendt, F. Tuan, C. Gempeshaw, and D. Dolk-Etz, ''Rural Chinese Food Consumption: The Case of Guangdong,'' *American Journal of Agricultural Economics* 76 (November 1994): 794–99.

25. J. Huang and S. Rozelle, ''Market Development and Food Demand in Rural China,'' *China Economic Review* (in press).

26. J. Huang and H. Bouis, ''Structural Changes in Demand for Food in Asia,'' Food, Agriculture, and the Environment Discussion Paper no. 11 (International Food Policy Research Institute, Washington, D.C., 1995); J. Huang and C. David, ''Demand for Cereal Grains in Asia: The Effects of Urbanization,'' *Agricultural Economics* 8 (Spring 1993): 107–24.

27. Huang and Bouis.

28. Huang and David, ''Demand for Cereal Grains in Asia.''

29. In general, based on a recent work by S. Rozelle, G. Li, M. Shen, H. Li, J. Giles, and T. Low (''Poverty Networks, Institutions, or Education: Testing among Competing Hypotheses on the Determinants of Migrations in China,'' paper presented at the 1997 annual meetings of the Association for Asian Studies, Chicago, March 13–15, 1997), there are probably about an equal number of migrants coming from the North as from the South.

30. J. Huang and S. Rozelle, ''Technological Change: Rediscovering the Engine of Productivity Growth in China's Agricultural Economy,'' *Journal of Development Economics* 49 (July 1996): 337–69.

31. J. Lin, ''The Household Responsibility System Reform and the Adoption of Hybrid Rice in China,'' *Journal of Development Economics* 36 (1991): 353–73.

32. B. Stone, ''Developments in Agricultural Technology,'' *China Quarterly* 116 (December 1988): 767–822; S. Rozelle and J. Huang, ''China's Wheat Economy: Supply, Demand, Marketing, and Trade in the 21st Century'' (paper presented at Montana State University Trade Research Center's conference on ''World Wheat Economy,'' Bozeman, Mont., May 1997); J. Huang and S. Rozelle, ''Technology and Grain Supply in China,'' Working paper (Center for Chinese Agricultural Policy, Beijing, 1997).

33. Huang and Rozelle, ''Technological Change''; J. Huang, M. Rosegrant, and S. Rozelle, ''Public Investment, Technological Change and Agricultural Growth in China'' (paper presented in the final conference on the Medium- and Long-Term Projections of World Rice Supply and Demand, Sponsored by the International Food Policy Research Institute and the International Rice Research Institute, Beijing, April 23–26, 1995); and S. Fan and P. Pardey, ''Role of Inputs, Institutions, and Technical Innovations in Stimulating Growth in Chinese Agriculture,'' Working paper (International Food Policy Research Institute, Washington, D.C., 1995).

34. R. Conroy, ''The Disintegration and Reconstruction of the Rural Science and Technology System,'' in *The Reemergence of the Chinese Peasantry,* ed. A. Saith (London: Croom Helm, 1987); S. Rozelle, C. Pray, and J. Huang, ''Agricultural Research Reform in China: Testing the Limits of Commercializa-

tion-Led Reform,'' Working paper (Stanford University, Department of Economics, Stanford, Calif., 1996).

35. State Science and Technology Commission, *Zhongguo Kexue Jishu Ziliao Ku, 1985–90; 93* (China science and technology statistical yearbook, 1985–90; 93), 2 vols. (Beijing: State Science and Technology Commission, 1991, 1993).

36. S. Fan and P. Pardey, *Agricultural Research in China: Its Institutional Development and Impact* (The Hague: International Service for National Agricultural Research, 1992).

37. J. Nickum, ''Dam Lies and Other Statistics: Taking the Measure of Irrigation in China, 1931–1991,'' East-West Center Occasional Papers, Environment Series no. 18 (East-West Center, Honolulu, 1995).

38. Ministry of Water Resources and Electrical Power, *Compiled Statistics on the Development of China's Water Conservancy System* (Beijing: Ministry of Water Conservancy, 1988–92).

39. Huang, Rosegrant, and Rozelle.

40. M. Rosegrant, M. Agcaoili, and N. Perez, ''Global Food Projections to 2020: Implications for Investment,'' 2020 Vision Discussion Paper no. 5 (International Food Policy Research Institute, Washington, D.C., 1995).

41. Technology was measured in stock form and was built by aggregating past government expenditures on research according to a weighting criteria suggested by P. Pardey, R. Lindner, E. Abdurachman, S. Wood, S. Fan, W. Eveleens, B. Zhang, and J. Alston, ''The Economic Returns to Indonesian Rice and Soybean Research,'' report (Agency for Agricultural Research and Development and the International Service for National Agricultural Research, the Netherlands, November 1992). Irrigation stock was constructed by aggregating public expenditures on irrigation, subject to a depreciation rate of 4% per year, a rate used by M. Rosegrant and F. Kasryno, ''Dynamic Supply Response for Indonesian Food Crops,'' Working paper (International Food Policy Research Institute, Washington, D.C., 1994). The environmental variables have been described and analyzed in J. Huang and S. Rozelle, ''Environmental Stress and Grain Yields in China,'' *American Journal of Agricultural Economics* 77, no. 4 (November 1995): 246–56.

42. The general supply-side parameters were first estimated in Huang, Rosegrant, and Rozelle. More recent commodity specific estimates for wheat are in Rozelle and Huang (n. 32 above) and for maize are in Huang and Rozelle, ''Technology and Grain Supply in China'' (n. 32 above).

43. H. Bouis, ''Prospects for Rice Supply/Demand Balances in Asia,'' Working paper (International Food Policy Research Institute, Washington, D.C., 1989); and Huang and David, ''Demand for Cereal Grain in Asia'' (n. 26 above). The parameters relating demand behavior to rises in income use expenditure data instead of income because of the difficulty in comparing urban and rural income since the former includes large subsidies for housing, health care, etc. The analysis does not consider the effect of urban housing, education, and health reforms, which would have two effects on food consumption. If urban residents paid market rates for all goods and services, the income effect would reduce consumption of all goods, including food. The cross-price effects, however, would offset part of this drop.

44. A. Deaton and J. Muellbauer, ''An Almost Ideal Demand System,'' *American Economic Review* 70 (1980): 321–26.

45. Huang and Rozelle, ''Income, Quality, and the Demand for Food in Rural China'' (n. 24 above), and ''Urban Life, Urban Consumption'' (n. 24 above); and Huang and Bouis.

46. See F. Fuller and J. Rude, ''An Approach to Policy Analysis and Pro-

jection for the Agricultural Sector of the People's Republic of China'' (paper presented at the postconference workshop on ''China's Food Economy in the 21st Century,'' at the annual meetings of the American Agricultural Economics Association, Toronto, July 31, 1997). There is still much uncertainty about the current estimates of meat demand parameters, mainly because of data problems. In the published data, production statistics report a level of pork output that is more than twice as great as the level of pork consumption as reported in China's income and expenditure data. The discrepancy probably has a number of components. Many researchers in China believe current demand figures miss a significant part of family member consumption that occurs out of the household (e.g., dining in restaurants, etc.). It is also suspected that production figures are inflated, in part because of statistical problems (mostly a double-counting problem) and in part because local officials may have an incentive to overstate pork production, since unlike grain, monitoring of livestock production is much more difficult and the probability of being caught for exaggerating production numbers is minimal.

47. Feed conversion parameters are from the Economic Research Service (n. 7 above) and are consistent with estimates used by Chinese agriculturists found in handbooks used by Ministry of Agriculture officials. Officials, however, told us that they believed these rates were too high. This would mean that the demand for feed and imports are overestimated. However, commercialization of China's livestock industry is occurring rapidly, which would mean that conversion rates should increase over time (since farmers tend to feed scraps and other nongrain feedstuffs to hogs). Hence, any overestimation in the short run should be eliminated at some point during the study period. Our current research is centered on obtaining a better set of feed efficiency rates.

48. Huang, Rosegrant, and Rozelle (n. 33 above).

49. The baseline assumptions for population growth rates in the three study decades implies an overall projection period population growth rate of 0.89, a level slightly higher than that assumed by Rosegrant, Agcaoili, and Perez (0.74). There are many reasons to believe that, with increasing reform, the government's ability to control fertility may lessen, and future rates of population growth may be greater than the baseline rates. Rosegrant, Agcaoili, and Perez use an alternative rate of 1% per year. In this study's high-population growth scenario, it is assumed the growth rate in the first decade is 1.413; the second, 0.932; and the third, 0.844; implying an overall study period growth rate of 1.06. We present results that show the sensitivity of the conclusions to the choice of population growth rates.

50. According to J. Huang and C. David, ''Price Policy and Agricultural Incentive in China,'' a report submitted to the Food and Agriculture Organization of the United Nations (Rome, 1995), while once far out of line with world agricultural prices, in recent years China's market prices have converged with those in international markets. In an initial set of runs, we assumed constant real prices. We then simulated projected growth rates in production and demand (and thus net imports of rice and other grain) in the International Food Policy Research Institute's IMPACT model to generate projected world prices with China entering as a significant importer. We then used these projected world prices as the baseline projections for the China projections model: world grain prices should fall by 0.5% annually throughout the projection period. Meat prices should follow a similar trend. In this sense, the assumption is consistent with China's entry into the World Trade Organization where in the long run Chinese producers will not be protected or taxed by border restrictions. Since China's current grain prices are almost the same as world market prices, there is also no obvious one time effect from liberalization. The case would be different if China

went the route of its prosperous East Asian neighbors and began to protect its producers with ever-increasing prices. Severe fiscal problems, however, most likely rule out such a strategy.

51. Huang and Rozelle, ''Market Development and Food Demand in Rural China'' (n. 25 above).

52. S. Rozelle, J. Huang, and M. Rosegrant, ''How China will NOT Starve the World,'' *Choices,* no. 1 (1996), pp. 10–16; J. Huang, S. Rozelle, and M. Rosegrant, ''Supply, Demand, and Trade in China,'' a 2020 Vision Working paper (International Food Policy Research Institute, Washington, D.C., 1996).

53. P. Yotopoulos, ''Middle-Income Classes and Food Crisis: The 'New' Food-Feed Competition,'' *Economic Development and Cultural Change* 33 (April 1985): 463–84.

54. Fan and Agcaoili (n. 4 above); and the Economic Research Service.

55. Rozelle et al. (n. 29 above).

56. J. Huang, ''Agricultural Policy and China's Agricultural Performance,'' Working paper (Center for Chinese Agricultural Policy, Beijing, 1996).

57. Rozelle, Pray, and Huang (n. 34 above).

58. Import projections are not very sensitive to changes in prices for two reasons. First, our estimated supply own-price response elasticities are small, a characteristic that is commonly found in other Asian countries where the government frequently intervenes into the agricultural decision-making process. Second, on the demand side, although there are fairly large negative own-price elasticities, positive cross-price elasticities dampen the reduction (increase) in demand when prices rise (fall). Similar magnitudes are observed with changes for the price of fertilizer; by increasing (decreasing) the projected growth of fertilizer prices by 1%, imports increase (decrease) by 4 MMT. Hence, if the past trends hold—i.e., falling grain prices and rising fertilizer prices—the change in China's output to input price ratio means more imports will be required to meet the nation's projected deficit (at least through the medium run when higher imports would force prices up, offsetting part of the deteriorating output-to-fertilizer-price relationship).

59. Rosegrant, Agcaoili, and Perez (n. 40 above).

60. See P. H. Lindert, ''The Bad Earth? China's Agricultural Soils since the 1930s,'' Working paper series no. 83 (University of California, Davis, Agricultural History Center, 1995), for an analysis of soil degradation and conservation in China.

61. Economic Research Service (n. 7 above); Carter and Zhong (n. 20 above); and Rosegrant, Agcaoili, and Perez.