
The Engines of a Viable Agriculture: Advances in Biotechnology, Market Accessibility and Land Rentals in Rural China

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**THE ENGINES OF A VIABLE AGRICULTURE:
ADVANCES IN BIOTECHNOLOGY, MARKET ACCESSIBILITY
AND LAND RENTALS IN RURAL CHINA***

Scott Rozelle, Jikun Huang and Keijiro Otsuka

China's rural economy faces many serious problems. The revenue available to local rural governments has not been sufficient to provide adequate public services for villagers.¹ The rural banking system has not been able to reform itself and is hampering the rural sector.² The government's programs to help develop impoverished villages have not effectively reached much of the poor who reside in remote, resource-poor and ethnic-minority areas.³ If the rural sector is to grow and become a more equal partner in China's economic development, it is imperative that fundamental changes are made to these and other institutions that affect the lives and livelihoods of China's rural residents.⁴

But while the rural political economy faces sobering challenges, the record of agricultural production nevertheless has exhibited impressive gains during the reform era. In the 1990s per capita grain output reached a level similar to that in

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¹ Christine Wong, *Financing Local Government in the People's Republic of China* (Hong Kong: Oxford University Press, 1997).

² Christopher Findlay, Andrew Watson, Enjiang Cheng and Zhu Gang (eds), *Rural Financial Markets in China* (Canberra: Asia Pacific Press, 2003), pp. viii-xiii.

³ World Bank, *China: Overcoming Rural Poverty* (Washington: World Bank, 2001).

⁴ CCICED [China Commission International Cooperation for the Environment and Development], *China's Agricultural and Rural Development in the New Era: Challenges, Opportunities and Policy Options: An Executive Summary of Policy Report* (Beijing: China Commission International Cooperation for the Environment and Development, Agricultural and Rural Development Task Force, September 2004).

most developed countries.⁵ Rising food exports between 1983 and 2003 demonstrate that China's farmers are now able to compete in international markets.⁶ Rural incomes have risen significantly, increasing by around 4 per cent annually since 1990.⁷ Hundreds of millions among the rural population have escaped poverty during this time. And while inequality in inter-household rural incomes rose sharply during the 1980s and early 1990s, these disparities in household incomes have actually begun to narrow after the late 1990s.⁸

We believe that three vital ingredients that underpin the continued progress of China's agriculture have not received adequate attention. These are the emergence of a well-financed, effective system of agricultural research and development (R&D), including the capacity to produce biotechnology breakthroughs; major improvements in agricultural commodity markets; and increasingly effective, albeit nascent, land rental markets. With China's farmers today increasing their productivity through new seed varieties, specialization and marketing, and securing more effective access to cultivated land (rural China's most scarce commodity), the signs are excellent for continuing gains in the agricultural sector in the years to come. This paper will therefore focus on how the three vital elements are having a positive impact on farmers' livelihoods.

Agricultural Technology and Increased Productivity

Scientists and policy-makers, in both developing and developed countries, recognize the importance of agricultural technology in promoting increased productivity. Researchers have documented the importance of this in raising total factor productivity (TFP) in the agricultural sector in the US and in Japan's development.⁹ In the developing world, Rosegrant and Evenson have documented

⁵ *Zhongguo nongye nianjian* (China Agricultural Yearbook) (henceforth, *ZGNYNJ*) (Beijing: Nongye Chubanshe, 2001).

⁶ Jikun Huang and Chunlai Chen, *Effects of Trade Liberalization on Agriculture in China: Institutional and Structural Aspects* (United Nations ESCAP CGPRT Centre, Bogor, Indonesia, 1999).

⁷ Martin Ravallion and Shaohua Chen, "China's (Uneven) Progress against Poverty since the Early 1980s", Working Paper, World Bank, Washington DC, 2004.

⁸ Carl Riskin and A. R. Khan, "China's Personal Income Distribution in 2002", Paper presented in Workshop, "Paying for Progress: Public Finance, Human Welfare and Inequality in China", St Anne's College, Oxford, 21–23 May, 2004.

⁹ In the economics literature, TFP is the most comprehensive measure of productivity. It is measured as the increase in output after the level of all inputs is controlled for. Various elements can cause changes in TFP, including changes in efficiency, increases in the quality of inputs and new output-increasing technologies. Julian Alston, *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting* (London: CABI Publishing, 1998); Zvi Griliches, "Hybrid Corn: An Exploration of the Economics of Technological Change", *Econometrica*, Vol. 25, No 4 (1957), pp. 501-22; Yujiro Hayami and Vernon Ruttan, "Factor Prices and Technical Change in Agricultural Development: The

the importance of new plant varieties and extension efforts on Indian total factor productivity, while Pingali, Hussein and Gerpacio have reviewed the contributions made by the Green Revolution elsewhere in South and Southeast Asia.¹⁰

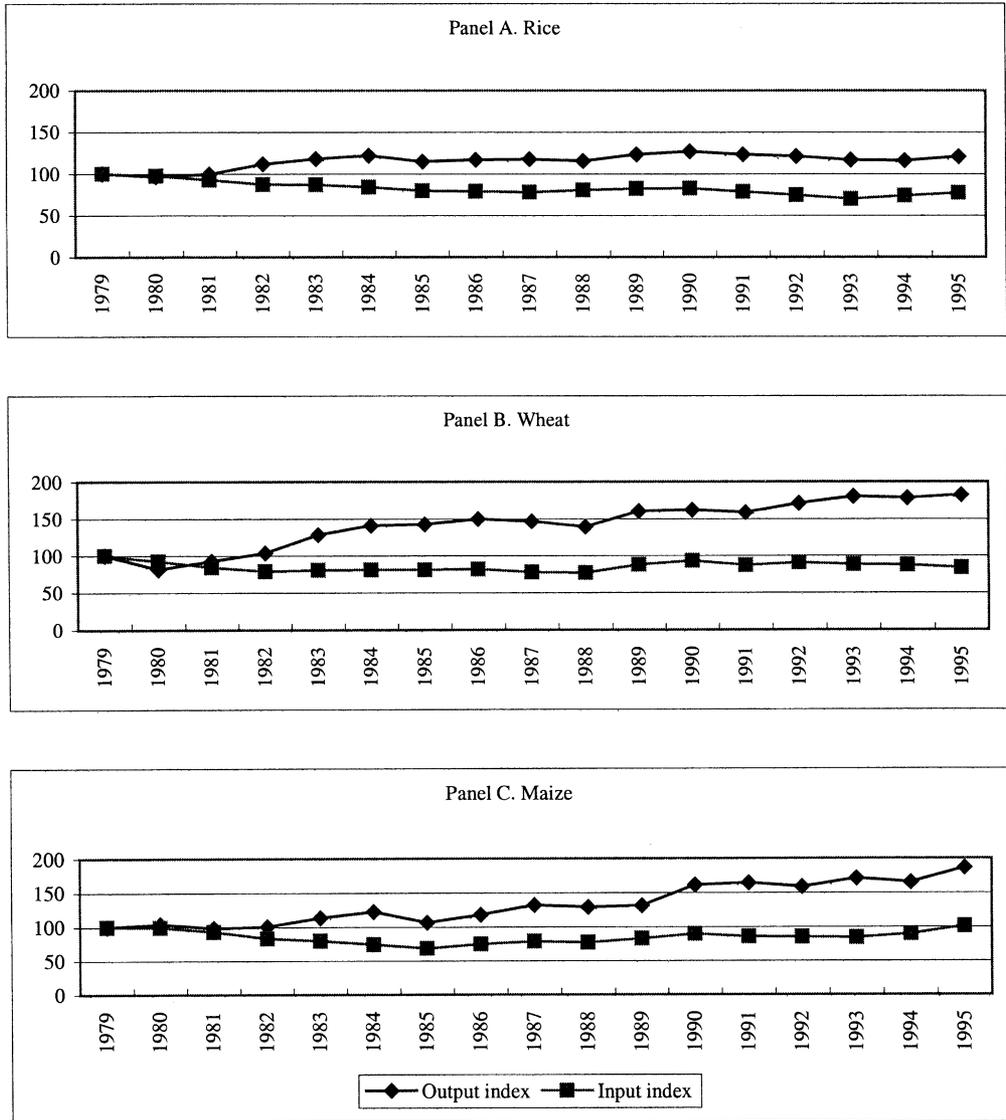
While important in the rest of the world, less is known about the overall productivity of China's agricultural economy; instead, more attention has been given to the rise in partial productivity measures, such as yields and output. During China's reform period, the rapid and monotonic expansion of the yields of major food crops have ranked as one of the nation's great achievements.¹¹ The output of rice, wheat and maize rose sharply between 1982 and 1995 (Figure 1, upper line on each graph). Rice production increased by 20 per cent, wheat by 80 per cent and maize by 95 per cent during the 1980s and early 1990s. While cultivated land and inputs of labor fell during the early 1980s before stabilizing during the late 1980s and 1990s, material inputs, including fertilizer and pesticides rose sharply, increasing at an annual rate of 32 per cent for rice, 26 per cent for wheat and 30 per cent for maize.¹²

An analysis of the more recent trends in input levels and their prices underscores the importance of understanding the role of technology (Figure 1, lower line). While the rise in material inputs accounts for a substantial part of the increase in output during the earlier part of the reform era,¹³ the annual rise in the use of fertilizer and pesticide began slowing during the 1990s. By the early 2000s high levels of fertilizer and pesticide were already in use in many regions of the country. Other correlates of development, such as rising industrial wage rates

United States and Japan, 1880 to 1960", *Journal of Political Economy*, Vol. 78, No. 5 (September–October 1970), pp. 1115-41, among others, have argued that in the long run the most fundamental driving force of TFP rise is technological change. It is for this reason that we focus on the role of technology.

- ¹⁰ Mark Rosegrant and Robert E. Evenson, "Agricultural Productivity and Sources of Growth in South Asia", *American Journal of Agricultural Economics*, Vol. 74, No. 3 (August 1992), pp.757-61; Prabhu Pingali, Mahabub Hossein and Roberta Gerpacio, *Asian Rice Bowls* (London: CAB Publishing, 1997).
- ¹¹ Bruce Stone, "Basic Agricultural Technology under Reform", in Y. Y. Kueh and Robert Ash (eds), *Economic Trends in Chinese Agriculture: The Impact of Post-Mao Reforms: A Memorial Volume in Honour of Kenneth Richard Walker, 1932-1989* (Oxford: Oxford University Press, 1993), pp. 311-59.
- ¹² *Zhongguo tongji nianjian* (China Statistical Yearbook) (henceforth, *ZGTJNJ*) (Beijing: Zhongguo Tongji Chubanshe, 2000); Justin Y. Lin, "The Household Responsibility System Reform and the Adoption of Hybrid Rice in China", *Journal of Development Economics*, Vol. 36, No. 2 (1991), pp. 353-73; Jikun Huang and Scott Rozelle, "Technological Change: Rediscovery of the Engine of Productivity Growth in China's Rural Economy", *Journal of Development Economics*, Vol. 49, No. 2 (1996), pp. 337-69.
- ¹³ Shenggen Fan, "Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture", *American Journal of Agricultural Economics*, Vol. 73, No. 2 (1991), pp. 266-75.

Figure 1. Output and Input Indices for Major Rice, Wheat and Maize Growing Provinces in China, 1979–95



Note: Authors' calculations based on Divisia-Tornquist Formula.

Source: For a complete description of the data and methods, see Songqing Jin, Jikun Huang, Ruifa Hu and Scott Rozelle, "The Creation and Spread of Technology and Total Factor Productivity in China", *American Journal of Agricultural Economics*, Vol. 84, No. 4 (November 2002), pp. 916-30.

(which raises the opportunity cost of working on the farm), environmental awareness and resource limitations mean that there will be pressures on farmers to reduce inputs more in future. When the agriculture of countries approaches a plateau in inputs, further expansion of output must rely increasingly on technological change.

The Contribution of Technology to Agriculture's Total Factor Productivity(TFP)

Estimates of China's cropping TFP in the literature have been controversial, arriving at significantly different conclusions.¹⁴ Poor data and *ad hoc* ways of aggregating inputs may account for the debates and for the uncertainty in pre- and post-reform productivity studies.¹⁵ To overcome this problem, we have carried out a statistical analysis of the costs of production, using information collected for the past twenty years by the State Price Bureau (SPB).¹⁶ Enumerators collected data from a sample of more than 20,000 households on their production costs for the inputs of all of China's major crops (including land, labor, fertilizer, pesticides, seeds, machinery, hired services and other miscellaneous costs). Each farmer also reported on the quantities of all their major inputs and on the yields and the total revenues earned from each crop.¹⁷

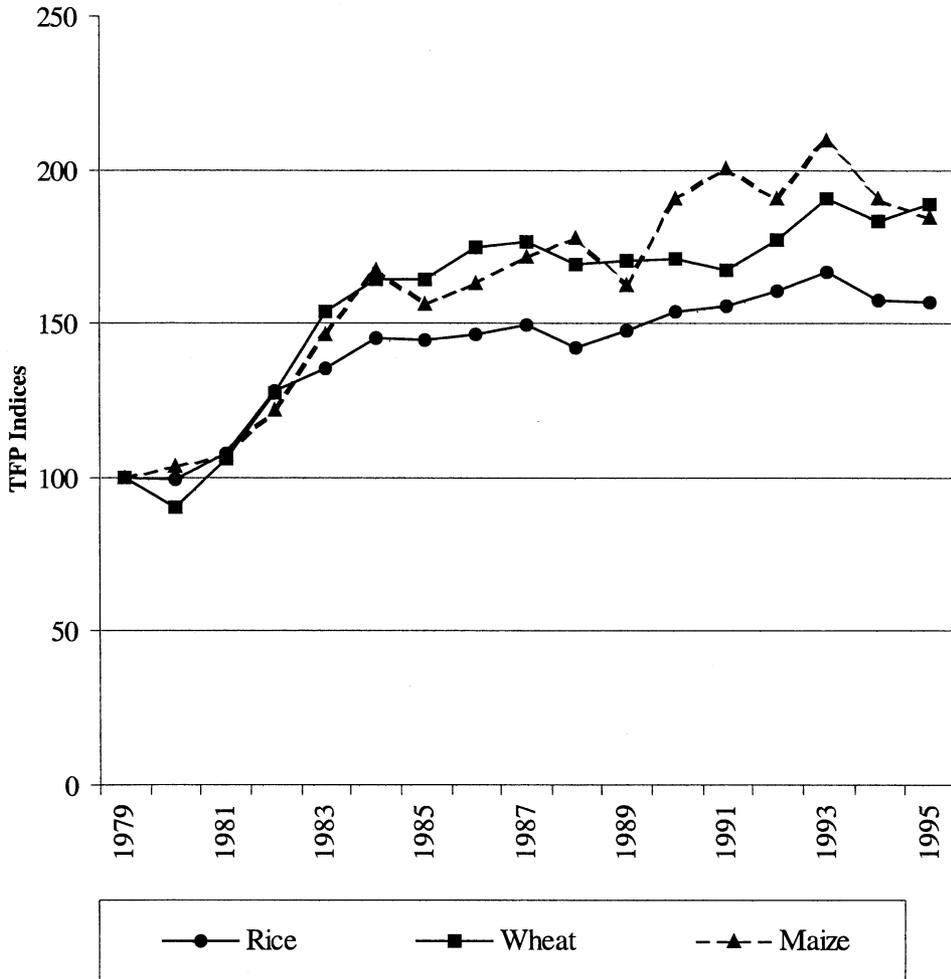
¹⁴ Guangzhong Wen, "Total Factor Productivity Change in China's Farming Sector: 1952-1989", *Economic Development and Cultural Change*, Vol. 42, No. 1 (1993), pp. 1-41; Shenggen Fan and Philip G. Pardey, *Agricultural Research in China: Its Institutional Development and Impact* (The Hague: International Service for National Agricultural Research, 1992).

¹⁵ The best discussion of TFP during the pre-reform era is in Anthony Tang and Bruce Stone, *Food Production in the People's Republic of China* (Washington: International Food Policy Research Institute [IFPRI] Report, May 1980). In the past, researchers gleaned data from a variety of sources, and warned readers of the poor quality of many of the input and output series.

¹⁶ We have used standard methods to calculate TFP trends for China's agriculture. Our methodological approach is similar to that of Mark Rosegrant and Robert E. Evenson, "Agricultural Productivity and Sources of Growth", in that we use standard Divisia index methods to calculate TFP. In essence, TFP measures the difference between aggregate output and aggregate inputs. It can be thought of as the rise in output that is not accounted for by inputs, and as such, is a measure of productivity from all (or total) factors. For more details see Songqing Jin, Jikun Huang, Ruifa Hu and Scott Rozelle, "The Creation and Spread of Technology and Total Factor Productivity in China", *American Journal of Agricultural Economics*, Vol. 84, No. 4 (November 2002), pp. 916-30.

¹⁷ During the last several years, these data have been published by the State Price Bureau [SPB] *The Compiled Materials of Costs and Profits of Agricultural Products of China* (Beijing: SPB, 1988-1998). The data have previously been used in analyses on China's agricultural supply and input demand (Jikun Huang and Scott Rozelle, "Technological Change: Rediscovering the Engine of Productivity Growth"; Jikun Huang, Scott Rozelle and Mark Rosegrant, "China's Food Economy to the Twenty-first Century: Supply, Demand, and Trade", *Economic Development and Cultural Change*, Vol. 47, No. 4 (July 1999), pp. 737-66; The World Bank, *At China's Table: Food Security Options* (Washington: The World Bank, 1997).

Figure 2. Total Factor Productivity Indices (Sown Area Weighted Average) for Rice, Wheat and Maize in China, 1979–95



Note: For a complete description of the data and methods, see Songqing Jin, Jikun Huang, Ruifa Hu and Scott Rozelle, “The Creation and Spread of Technology and Total Factor Productivity in China”, *American Journal of Agricultural Economics*, Vol. 84, No. 4 (November 2002), pp. 916-30

Although there are differences over time and across regions,¹⁸ in general China’s TFP has risen at a healthy rate of about 2 per cent per year during the

¹⁸ The TFP growth trends of our various sample provinces vary. For example, TFP for wheat rose 3 to 4 per cent annually in Hebei and Shandong Provinces, but by less than 1.5 per cent

reform era (Figure 2).¹⁹ A growth rate of 2 per cent is above the rate of population growth and is considered strong by international standards, about the same as the US during the 20th century and Japan in the post-World War II period. The rates in China have varied over time. TFP for all crops rose rapidly in the early 1980s (above 5 per cent annually), but such an unparalleled rise in TFP could not be sustained. In fact, for a period of five years in the late 1980s, TFP growth stagnated—the average TFPs of our sample provinces were at about the same level for all crops in 1990 as they were in 1985. In the 1990s, however, TFP growth restarted.

In order to measure the importance of various sources of productivity growth, we decompose TFP growth over two sub-periods, 1981–84 and 1984–95.²⁰ Although institutional change was certainly important (it is part of the residual in column 3 and 4, row 6 of Table 1), the rice decomposition results show that technology was one of the key factors that drove the sharp increase in TFP during the early 1980s. It contributed the largest share, augmenting the annual growth rate of TFP by 6 per cent (63.6 per cent of the total growth rate). This positive contribution of technology to the growth of TFP during the period is underscored by the deterioration of China's agricultural extension services and irrigation systems during the early 1980s. Our analysis suggests that these problems (perhaps related to the breakdown of the collectives)²¹ negatively affected TFP by 3 per cent (column 4, rows 2 and 5).

Subsequently, between 1984 and 1995 (Table 1, columns 5 to 7) technology was the only factor that underlay the positive growth of TFP. Technological improvements would have caused TFP to grow by 2.2 per cent (row 1), instead of the overall actual rate of growth 1.1 per cent (row 7), had not other factors, such as problems in the upkeep of irrigation systems, significantly reduced the growth of TFP (row 5).

annually in Sichuan and Shanxi. While we use these differences among provinces in order to measure the relationships between the determining factors (for example, technology and extension), for reasons of brevity we do not attempt to explain the trends of individual provinces.

¹⁹ According to the work of Songqing Jin *et al.*, "The Creation and Spread of Technology", between 1981 and 1995 the TFP of China's rice (Table 1), wheat and maize (not shown for the sake of brevity) increased on a per annum basis by approximately 2.0 per cent.

²⁰ In order to decompose TFP, we first had to estimate econometrically the relationships between TFP and its determining factors (including technology, extension, irrigation level, and two indices—one for floods and one for drought). We then used the estimated coefficients (which represent the relationships between the factors and TFP) and multiplied them by the changes in the factor over the period of analysis and estimated the change in TFP during the period of analysis due to the change in that one factor. When doing so for all of the factors in our model, we then put them on a percentage basis and completed the decomposition.

²¹ Justin Y. Lin, "The Household Responsibility System Reform and the Adoption of Hybrid Rice"; and Louis Putterman, *Continuity and Change in China's Rural Development* (New York: Oxford University Press, 1993).

Table 1. Decomposition of the Sources of Rice TFP Growth in China

	TFP elasticities ^a	1981-84			1984-95		
		Annual growth rate ^b	Sources of growth		Annual growth rate	Sources of growth	
			Rate ^c	Per cent ^d		Rate	Per cent
Varietal Turnover (VT2)	0.28	21.47	6.01	63.61	7.81	2.19	197.01
Extension	-0.02	2.03	-0.04	-0.43	3.96	-0.08	-7.14
Flood Index	-0.01	29.02	-0.18	-1.93	9.26	-0.06	-5.19
Drought Index	-0.02	-13.17	0.21	-2.26	1.24	-0.02	-1.80
Irrigation Index	-0.34	0.70	-0.24	-2.58	1.29	-0.44	-39.50
Residual Actual growth rates			1.21	56.62		-0.30	-143.94
			9.45	100		1.11	100

^a TFP elasticity with respect to each factor is calculated on the basis of coefficients from Rice Model in Table 5.

^b TFP and factor growth rates are computed by a least square estimate.

^c Growth rate contributed by each factor is calculated by multiplying factor growth rate (column 2) by elasticity (column 1).

^d The percentage of total TFP growth explained by each factor is the corresponding figure in column 3, divided by the total growth rate of TFP (which for the period of 1981-90 was 9.45 per cent).

For a complete description of the data and methodology, see Songqing Jin, Jikun Huang, Ruifa Hu and Scott Rozelle, "The Creation and Spread of Technology and Total Factor Productivity in China", *American Journal of Agricultural Economics*, Vol. 84, No. 4 (November 2002), pp. 916-30.

Findings from the decomposition analysis for wheat and maize are similar to those for rice. In both the early 1980s and the 1990s, technology in China has been the engine of the growth of agricultural productivity.²²

New Seed Varieties

While the record of growth of TFP in the past demonstrates the strength of China's agricultural technology development, future TFP growth is likely to depend even more on China's program of agricultural research and development and, more particularly, on whether it is able to generate new plant varieties. In this section, we will first examine the quantity of varieties already being produced by China's agricultural research system to try to identify the source of TFP growth and its potential for continued improvement. We will then look at the quality. Finally, we will estimate the propensity of farmers to adopt the new varieties.

Building on one of the strongest research systems in the developing world,²³ during the 1980s and 1990s China's agricultural scientists and agricultural extension system developed and disseminated technology throughout the People's Republic.²⁴ Reform-era breeders have turned out a constant stream of rice, wheat and maize varieties (Table 2).²⁵ For example, each year in each of China's rice-growing provinces, plant breeders have produced seeds for more than 20 rice varieties.

²² See Songqing Jin *et al.*, "The Creation and Spread of Technology". In our paper we have only examined the growth of TFP for the cropping sector. While it is possible to do so for the livestock and fishery sectors, problems with China's data preclude such an analysis. Allan Rae, Hengyun Ma, Jikun Huang and Scott Rozelle, "Livestock in China: Data Revision and Total Factor Productivity Decomposition", *American Journal of Agricultural Economics*, forthcoming; Hengyun Ma, Jikun Huang and Scott Rozelle, "Reassessing China's Livestock Statistics: Analyzing the Discrepancies and Creating New Data Series", *Economic Development and Cultural Change*, Vol. 52, No. 2 (2003), pp. 445-74 contain discussions of the way that the outputs of these sectors are overstated. Using data that are known to be inflated would lead to an upward bias in the estimates of TFP.

²³ Bruce Stone, "Basic Agricultural Technology under Reform"; Shenggen Fan and Phillip G. Pardey, *Agricultural Research in China*.

²⁴ Justin Y. Lin, "The Household Responsibility System Reform and the Adoption of Hybrid Rice"; Bruce Stone, "Basic Agricultural Technology under Reform"; Jikun Huang and Scott Rozelle, "Technological Change".

²⁵ A "major" variety in our sample is any variety that covers at least 10,000 *mu* (or 667 hectares) in a province. Since our data base is built on this concept, we do not have full coverage. However, the coverage is almost complete. For the rice-, wheat-, and most of the maize-growing sample provinces, the proportion of area covered by "major" varieties exceeds 90 per cent in each province.

Table 2. Total and Average Number of Major Varieties Planted by Farmers in China's Rice, Wheat and Maize Growing Provinces, 1982-95

	Rice		Wheat		Maize	
	Total	Average per Province	Total	Average per Province	Total	Average per Province
1982	379	24	211	15	130	10
1983	333	21	274	20	130	10
1984	380	24	277	20	130	10
1985	424	27	313	22	156	12
1986	419	26	303	22	156	12
1987	373	23	313	22	156	12
1988	381	24	301	22	130	10
1989	365	23	337	24	143	11
1990	412	26	333	24	156	12
1991	395	25	350	25	156	12
1992	403	25	338	24	156	12
1993	392	25	341	24	182	14
1994	416	26	330	24	182	14
1995	391	24	311	22	208	16

Notes: These are totals for the 16 rice-growing provinces, 14 wheat-growing provinces and 15 maize-growing provinces in our sample. The 16 rice-growing provinces are Heilongjiang, Jilin, Liaoning, Hebei, Jiangsu, Anhui, Hubei, Hunan, Jiangxi, Zhejiang, Fujian, Guangdong, Guangxi, Yunnan, Guizhou and Sichuan. Together the 16 rice-growing provinces comprise more than 90 per cent of China's rice-sown area and output in 1995. The 14 wheat-growing provinces are Hebei, Shanxi, Jiangsu, Anhui, Shandong, Henan, Sichuan, Gansu, Guizhou, Heilongjiang, Hubei, Shaanxi, Yunnan and Xingjiang. The 14 wheat-growing provinces account for 92 per cent of China's wheat-sown area and 95 per cent of its output in 1995. The 13 maize-growing provinces include Guangxi, Hebei, Heilongjiang, Henan, Jiangsu, Jilin, Liaoning, Shanxi, Shandong, Shaanxi, Sichuan, Xingjiang and Yunnan. The maize-growing provinces account for more than 89 per cent of China's maize-sown area and 92 per cent of its output in 1995.

Source: Authors' data gathered from the Ministry of Agriculture.

Although in the wheat- and maize-growing regions the number of varieties is somewhat less, it is rising gradually over time.²⁶

China's plant breeding efforts have also enhanced the quality of its seed stock. Using experimental station yields of each major variety during the year that were certified, a measure of quality was developed, a variable we call the "yield frontier". The yield frontier is created by using the highest experimental yield of any one major variety in the field, in each province, during a given year. The trend over time in the yield frontier is a measure of the ultimate yield potential of the current technology used by farmers.²⁷ According to our measure, on average, the yield frontier is moving up at about 2 per cent annually.

Perhaps surprisingly, given the breakdown of the agricultural extension system during the reform era, not only have China's researchers produced new varieties, but farmers have also adopted them. In fact, their adoption of new technologies is at a rate that is usually only seen in the most advanced agricultural economies. To examine this, we use a varietal turnover variable, which measures the proportion of the average farmer's sown area that is planted to a new variety each year.²⁸ During

²⁶ The data on major crop varieties come from the Ministry of Agriculture. Agricultural extension station personnel in conjunction with the local seed companies collect the data and report them up through the Ministry of Agriculture hierarchy. The data have been used in the past in a number of studies, including Songqing Jin *et al.*, "The Creation and Spread of Technology"; Ruifa Hu, Jikun Huang, Songqing Jin and Scott Rozelle, "Assessing the Contribution of Research System and CG Genetic Materials to the Total Factor Productivity of Rice in China", *Journal of Rural Development*, Vol. 23, No. 3 (Summer 2000), pp. 33-70; Funing Zhong, "The Comparative Advantage and Domestic Resources Cost of China's Staple Grain Products and Study of Regional Difference", Research Report of the Social Science Committee of the Ministry of Agriculture, Beijing, 1999; Jikun Huang and Scott Rozelle, "Environmental Stress and Grain Yields in China", *American Journal of Agricultural Economics*, Vol. 77, No. 4 (1995), pp. 853-64.

²⁷ These data were collected by the authors by examining a number of sources. The selection of varieties included in this study is based on the Ministry of Agriculture's varietal data base. The characteristics of each variety are recorded in China's regional variety demonstration trials conducted by the provincial agricultural bureau. If one variety passes the trial, which shows its advantages in yield, resistance and benefits of other traits compared to the check varieties, the variety receives certification and it is allowed to be commercialized. We collected these data from several sources: sometimes from the research institutes in which the varieties were developed, sometimes in the library of the Chinese Academy of Agricultural Sciences (CAAS), and sometimes from the internal documents kept by the Ministry of Agriculture and CAAS. The maximum yield data for a given variety are part of the record of a variety's certification process.

²⁸ In this paper, varietal turnover (VT) is defined as:

$$VT_t = 1 \text{ for } t=1, \text{ and}$$

$$VT_t = VT_{t-1} + \sum_k [V_{kt} = W_{kt} - W_{k,t-1} \text{ if } W_{kt} - W_{k,t-1} > 0, \text{ otherwise } V_{kt}=0] \text{ for } t > 1,$$

the 1980s and 1990s China's farmers were replacing the seed types in about 20 to 25 per cent of their sown area during each cropping season. In other words, about every four to five years, China's farmers are completely turning over their technology portfolios. Although such information is not widely reported in other countries, interviews with extension agents in the US found that farmers in some of the most progressive states typically turn over their technology baskets about every 3 to 4 years, much like China's households. In contrast, according to interviews with national research administrators in India, the typical Indian farmer changed the entire varietal basket about every 8 to 10 years. The rapid turnover of varieties in the fields of China's farmers is consistent with the data from household-level studies.²⁹

Plant Biotechnology Research

As the world debates the promises and dangers of plant biotechnology, swinging between the optimism generated by a long list of breakthroughs and the backlash of consumer reticence in many parts of the world, a new source of plant biotechnology discoveries is emerging in what initially appears to be a most unlikely place: China. And the discoveries being made are more than cosmetic transformations. China's research community has made a major investment to understand the structure and function of the rice genome, the use of agrobacterium to transform cotton and rice plants, and new methods of transforming other crops.³⁰

Although China started its national plant biotechnology program only in the mid-1980s, a number of years after most of the developed countries, its program has grown rapidly.³¹ Unlike the rest of the world, where most plant biotechnology research is financed privately, China's government funds almost all of the research. According to

where V_k is the area share change for those varieties that have positive sign, and W_k is the area share of k^{th} variety in the *total sown area* for VT_1 . The equation defines varietal turnover as the extent to which newly introduced varieties replace existing varieties. The data used for calculating varietal turnover are the same as those used for Table 2 and come from the MOA varietal data base. Songqing Jin *et al.*, "The Creation and Spread of Technology", use VT as a measure of new technology, under the assumption that farmers replace varieties if and only if the new variety is of a higher "quality" than the variety it is replacing, where quality can be cost-reducing, yield-enhancing, or include some new taste characteristic.

²⁹ Melinda Smale, Erica Meng, John P. Brennan and Ruifa Hu, "Determinants of Spatial Diversity in Modern Wheat: Examples from Australia and China", *Agricultural Economics*, Vol. 28, No. 1 (2003), pp. 13-16.

³⁰ E. Rubenstein, "China's leader commits to basic research, global science", *Science*, Vol. 288, No. 5473 (16 June 2000), pp. 1950-53; Biotechnology Research Institute (BRI), "Research Achievements of Biotechnology", Working Paper, BRI: Chinese Academy of Agricultural Sciences, 2000; J. Yu *et al.*, "A Draft Sequence of the Rice Genome (*Oryza sativa* L. ssp. *Indica*)", *Science*, Vol. 296, No. 5565 (5 April 2002), pp. 79-108.

³¹ Jikun Huang, Carl Pray, Scott Rozelle and Qingfang Wang, "Plant Biotechnology in China", *Science*, Vol. 295, No. 5555 (25 January 2002), pp. 674-77.

information that we received during visits to plant biotechnology laboratories, the Ministry of Science and Technology increased investment in plant biotechnology from 16 million yuan in 1986 to 93 million yuan in 1999. It is estimated that China's total investment in plant biotechnology in 1999 was US\$112 million in purchasing price parity (PPP) terms.³² In 1999, China outspent all other developing countries combined.

In more recent years China has increased its commitment to plant biotechnology. In 2000 China's top leadership decided to more than quadruple funding between 2000 and 2005. By 2003, according to a recent survey by the Center for Chinese Agricultural Policy, China was spending about US\$350 million in plant biotechnology and US\$570 million in total agricultural biotechnology (plant, animal and microorganism) in PPP terms.³³ In short, the government is spending more than a half a billion dollars per year and is close to outspending the US government in plant biotechnology research.³⁴

Using the funds, China's scientists have applied advanced biotechnology tools to the synthesis, isolation and cloning of new plant genes and genetic transformations. After the initiation of a research program on rice functional genomics in 1997, researchers have used AC/DS transposons³⁵ and T-DNA insertion methods to create rice mutagenesis pools. Biotechnologists also have initiated functional genomics research for Arabidopsis.³⁶ Our survey of China's plant biotechnology laboratories demonstrated that by 2000 there were over 50 different plant species and more than 120 functional genes which have been used in plant genetic engineering. China has emerged as a global leader in the production of GM plants (although almost certainly the PRC lags behind the industrialized world in functional genomics research).

China's scientists have also generated an impressive array of new technologies. Between 1996 and 2000, China's Office of Genetic Engineering Safety

³² See *ibid.*

³³ Jikun Huang, Ruifa Hu, Scott Rozelle and Carl Pray, "Genetically Modified Rice, Yields and Pesticides: Assessing Farm-level Productivity and Health Effects in Pre-production Trials in China" (Beijing: Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, 2004).

³⁴ Although the governments of China and the US are spending about the same amount on plant biotechnology, the overall spending on plant biotechnology research in the US is much higher. According to Julian Alston, Phil Pardey and J. Roseboom, "Financing Agricultural Research: International Investment Patterns and Policy Perspectives", *World Development*, Vol. 26, No. 6 (1998), pp. 1057-72, the private sector in the US invests almost 4 times as much in plant biotechnology as does the public sector.

³⁵ A transposon is "a segment of DNA that can become integrated at many different sites along a chromosome (especially a segment of bacterial DNA that can be translocated as a whole)" (<http://hyperdictionary.com/dictionary/transposon>).

³⁶ Arabidopsis: small annual weed of the Brassicaceae family, occurring throughout temperate regions. "It has no economic or agronomic utility, but is useful for genetic and biological research". See further <http://arabidopsis.info/AboutASCA/Arabidopsis.html>.

Administration approved 251 GM plants, animals and microorganisms for field trials, environmental releases or commercialization. In recent years the pace of commercialization has slowed, but in part this is a reflection of caution, to allow China's new regulatory system time to catch up with the rapid breakthroughs in the laboratories.

Whereas in the rest of the world over 40 per cent of trials involve GM maize, in China the government's concern for food security is reflected in major research on crops and problems that have received little attention elsewhere. Transgenic rice resistant to stem borers and planthoppers (using Bt and CpTI genes) and bacterial leaf blight (Xa21), three of China's major rice pests, has already passed through at least two years of successful field-level trials.³⁷ In late 2004, China's Bio-safety Management Committee certified that a number of the rice varieties are scientifically ready for commercialization. Researchers have also developed BYDV-resistant³⁸ GM wheat to the point that it is undergoing field and environmental release trials. Scientists are experimenting with GM potatoes, peanuts and horticultural varieties such as cabbage—crops that private companies elsewhere in the world have shown little interest in due to their more limited commercial value. The nation's public-dominated research system has given researchers a strong incentive to produce GM crops that increase yields and prevent pest outbreaks. In industrialized countries, 45 per cent of all field trials are for herbicide tolerance and improving product quality; only 19 per cent are for insect resistance.³⁹ By contrast, in China more than 90 per cent of field trials target insect and disease resistance.

Although the commercialization of crops is still limited to Bt cotton, the experience of cotton shows that genetically modified crops can lead to significant rises in productivity. Since its initial adoption in 1997, more than 5 million Chinese farmers have adopted genetically modified cotton.⁴⁰ Moreover, unlike some criticisms of the Green Revolution that suggest that most gains were enjoyed by richer farmers, the gains of Bt cotton have been shared by almost all farmers. For example, more than 80 per cent of the adopted area of Bt cotton in China was planted by farmers holding less than half a hectare of crop land.⁴¹ More than 75 per

³⁷ Jikun Huang, Ruifa Hu, Scott Rozelle and Carl Pray, "GM Rice in Farmers' Fields: Assessing Productivity and Health Effects in China", *Science*, forthcoming 2005.

³⁸ Barley yellow dwarf virus.

³⁹ A. Courtmanche, Carl E. Pray and R. Govindasamy, "The Importance of Intellectual Property Rights in the International Spread of Private Sector Agricultural Biotechnology. Report to the World Intellectual Property Organization" (New Brunswick: Department of Agricultural, Food, and Resources Economics, Rutgers University, 2001).

⁴⁰ Carl Pray, Cunhui Fan, Jikun Huang, Ruifa Hu, Caiping Zhang and Scott Rozelle, "Intellectual Property Rights, Regulations, and Openness to Foreign Investment in the Seed Industry in China" (Beijing: Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, 2004).

⁴¹ Carl Pray, D. Ma, Jikun Huang and Fangbin Qiao, "Impact of Bt Cotton in China", *World Development*, Vol. 29, No. 5 (2001), pp. 813-25.

cent of the adopted acreage was by farm households earning less than US\$2 per capita per day in PPP terms. Moreover, not only did the production costs of farmers fall and their yields rise, but in addition their falling levels of pesticide use led to a significant reduction in the self-reported health problems of cotton farmers.⁴² In recent preproduction trials for genetically modified rice, similar patterns of productivity and health gains for farmers were found.⁴³

The Emergence of Commodity Markets

Price and market reforms have been key components of China's effort to shift from a socialist to a market-oriented economy. However, the policies have only been implemented in a gradual way.⁴⁴ For example, the initial reforms initiated in the late 1970s were only aimed at raising farm procurement prices and allowing a small amount of local trade. These specific reform policies included gradual increases in agricultural procurement prices toward market prices, reductions in procurement quota levels, and flexibility in the marketing of surplus production of all categories of agricultural products.

Over time the government's position on market reform has gradually evolved. As officials in charge of the overall economic reforms became committed to using markets as the primary means to allocate resources in the general economy, the commitment to allowing markets in agriculture also deepened.⁴⁵ Since the 1980s, China's reformers allowed farmers increasing freedom in their marketing decisions and have gradually commercialized the state grain system, reduced the rules prohibiting trade across provinces and increasingly allowed the entry of private traders.⁴⁶

The special status that many leaders accord to agriculture and its role in national food security, however, has made China's grain policy variable across time.⁴⁷ In fact, there have been at least three cycles between the mid-1980s and the late 1990s during which officials liberalized commodity markets and then

⁴² Although with rising production and sown area the price of cotton did fall, the rise in productivity far outpaced the fall in prices. Jikun Huang, Ruifa Hu, Carl Pray and Scott Rozelle, "Five Years of Bt Cotton in China: The Benefits Continue", *The Plant Journal*, Vol. 31, No. 4 (September 2002), pp. 423-30. Farmers have been shown to have benefited the most; consumers were second; the seed companies were third.

⁴³ Jikun Huang *et al.*, "GM Rice in Farmers' Fields: Assessing Productivity and Health Effects in China".

⁴⁴ Terry Sicular, "Redefining State, Plan and Market: China's Reforms in Agriculture Commerce", *China Quarterly*, No. 143 (December 1995), pp. 1020-46.

⁴⁵ *Ibid.*

⁴⁶ Albert Park, Hehui Jin, Scott Rozelle and Jikun Huang, "Bureaucrat to Entrepreneur: The Changing Role of the State in China's Transitional Commodity Economy", *Economic Development and Cultural Change*, Vol. 48, No. 2 (2000), pp. 227-52.

⁴⁷ Scott Rozelle and Johann Swinnen, "Success and Failure of Reform: Insights from the Transition of Agriculture", *Journal of Economic Literature*, Vol. 42, No. 2 (2004), pp. 404-56.

retrenched. China's top leaders have encouraged the development of inter-provincial grain markets and have then reversed gears and blockaded grain shipments between provinces. Policies have urged specialization and structural change during some periods and promoted self-sufficiency during others. And even though private traders became a fixture in the countryside and cities during the 1990s, they were nonetheless legally prohibited from trading as late as 1998. So while the overall policy of China was to encourage marketization, it needs to be clarified whether the roller-coaster policies have hindered the development of well-functioning markets today.⁴⁸ This is important to our topic because efficient markets—whether they are classic competitive ones or whether they are some workable substitute—facilitate trade and crop specialization and thereby enable farmers to raise their incomes.

Market Integration in China

We can use data on prices from the State Market Administration Bureau and the Jilin Provincial Oil and Grain Information Center to examine how prices over time have shifted in tandem across markets in the same geographic region and across markets separated by long distances.⁴⁹ Statistical-based tests can be employed to examine the degree of market integration in rural China's commodity markets in different time periods and the extent to which prices in different pairs of markets converge over time—the early 1990s, the late 1990s and post-2000, using our price series for rice, maize and soybeans.⁵⁰ According to these price data, despite the stop-and-start nature of marketing policies, China's markets have functioned increasingly well.

⁴⁸ On the question of administrative constraints on local rural markets, see Scott Rozelle, Jikun Huang and Vincent Benziger, "Continuity and Change in China's Rural Periodic Markets", *The China Journal*, No. 49 (January 2003), pp. 89-115.

⁴⁹ The price data from both sources are collected by personnel in each unit that have established permanent reporting stations in multiple markets throughout China. At predetermined timing intervals (for example, once or twice a week or once every 10 days), the reporting stations fax or phone the prices that they are observing in the markets. Prices are always quoted FOB. These data have been used by a number of researchers, including: Laping Wu, "Food Price Differences and Market Integration in China", in Chunlai Chen and Christopher Findlay (eds), *China's Domestic Grain Marketing Reform and Integration* (Canberra: Asia Pacific Press, ANU, 2004), pp. 194-211; Albert Park, Hehui Jin, Scott Rozelle and Jikun Huang, "Market Emergence and Transition: Transition Costs, Arbitrage, and Autarky in China's Grain Market", *American Journal of Agricultural Economics*, Vol. 84, No. 1 (2002), pp. 67-82; and Yuping Xie, "WTO and China's Agricultural Trade and Impact on Domestic Markets", Unpublished Masters Thesis (Beijing: Center for Chinese Agricultural Policy, Chinese Academy of Sciences, 2002). Typically, the data after 1995 are more complete than in earlier years.

⁵⁰ Our results for the years after 1995 can be compared with those in Albert Park *et al.*, "Market Emergence and Transition", which examined integration in the early 1990s, because we use the same techniques and the same type of data set.

Comparing the results between market cointegration analysis for the late 1980s/early 1990s and a similar analysis for the late 1990s (Table 3), it is found that in the middle years of the reform era (1988 to 1995), a time when markets were starting to emerge, between 20 and 25 per cent of the markets showed signs of prices moving in tandem.⁵¹ In the late 1990s, we find a significant increase compared to the mid-1990s. For maize, for example, in 89 per cent of the cases the prices in one market shifted at the same time as in another (Table 3, column 2). This is up from only 28 per cent in the early 1990s. A similar increase in price integration is also found for soybeans, japonica rice and indica rice (rows 2 to 4).

Table 3. Percentage of Market Pairs that Test Positive for Being Integrated based on Dickey Fuller Test, 1989 to 2000

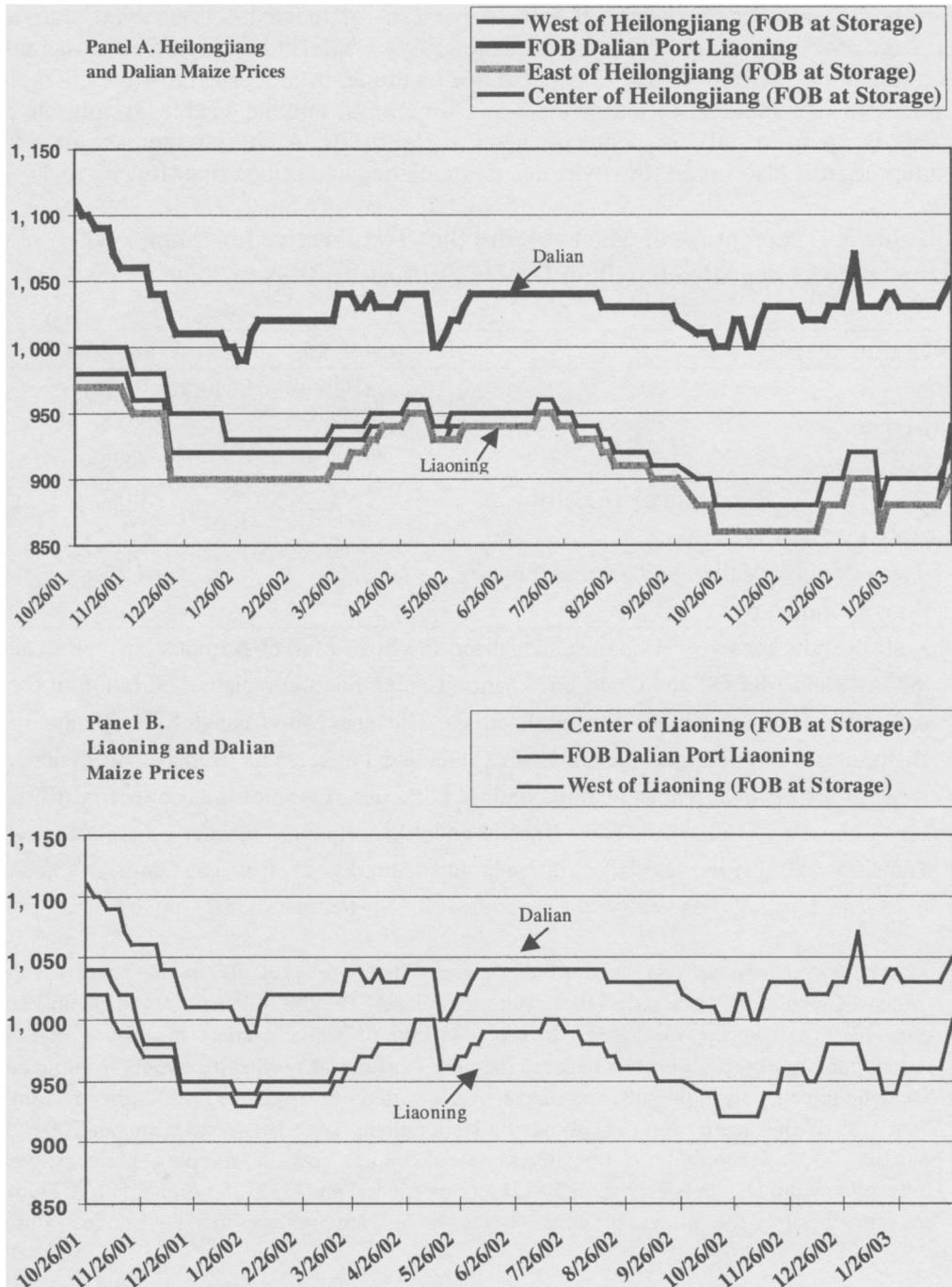
Commodity	1989–95	1996–2000
	(Percent of Market Pairs)	
Maize	28%	89%
Soybeans	28%	68%
Rice, Yellow River Valley (mostly japonica rice)	25%	60%
Rice, Yangtze Valley and South China (mostly indica rice)	25%	47%

Note: Results for two periods use data from the State Market Administrative Bureau (SMAB) and Jilin Oil and Grain Information Center. For a complete description of the data after 1995, see Jikun Huang, Scott Rozelle and Min Chang, “The Nature of Distortions to Agricultural Incentives in China and Implications of WTO Accession”, *World Bank Economic Review*, forthcoming. For a description of the data before 1995, see Albert Park, Hehui Jin, Scott Rozelle and Jikun Huang, “Market Emergence and Transition: Transition Costs, Arbitrage, and Autarky in China’s Grain Market”, *American Journal of Agricultural Economics*, No. 84 (February 2002), pp. 67-82.

These trends have continued to the present day. For example, maize prices within northeast China today track each other even more closely (Figure 3, Panels A and B). In Panel A we have plotted the local price in the port city of Dalian versus the prices in three Heilongjiang market sites chosen because they are the furthest northeast markets from Dalian. While the price levels in the different markets have varied over time, the Dalian price remained about US\$127 per metric ton (mt) above the Heilongjiang price between December 2001 and February 2003. According to our interviews, the total cost of shipping grain between Heilongjiang and Dalian is between US\$126 per metric ton and US\$128 per metric ton. During the same period, the prices in each of the three Heilongjiang markets moved almost

⁵¹ Ibid.

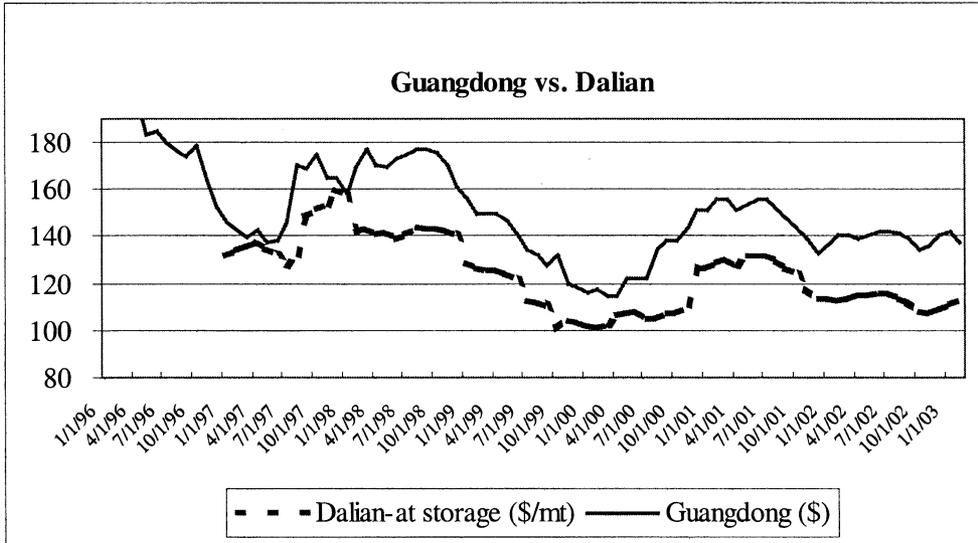
Figure 3. Maize Prices in Heilongjiang, Liaoning and Dalian (Yuan/mt), October 2001 to February 2003



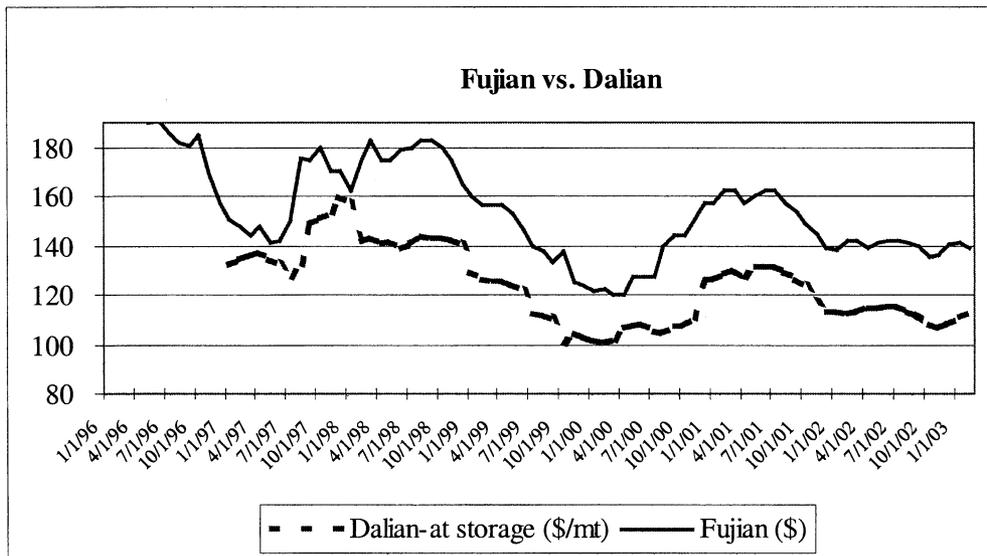
Source: Jinlin Oil and Grain Information Center

Figure 4. Maize Prices in Guangdong, Fujian and Dalian (Yuan/mt), 1996 to February 2003

Panel A. Guangdong and Dalian Maize Prices



Panel B. Fujian and Dalian Maize Prices



Source: Jilin Oil and Grain Information Center

in perfect concert with one another. Similar patterns in price movements are found to exist between the two markets in western and central Liaoning Province and the port city of Dalian (Panel B). In fact, the prices in the two Liaoning grain-producing areas track each other even more closely than the markets in Heilongjiang Province, a finding that is not surprising since Liaoning is a smaller province with better transportation and communication infrastructures.

The patterns of price movements between markets at greater distances display similar patterns of close co-movements (Figure 4, Panels A and B). Prices have moved in tandem since the mid-1990s between Dalian in northern China and Guangdong and Fujian Provinces in south China, and the tracking among these markets became even closer in recent years. Almost every turning point in prices (a shift from low to high or high to low) in Guangdong and Fujian can be found in the Dalian market. The data in Figure 4, Panels A and B, when linked with those from Figure 3, strongly suggest that prices in Heilongjiang, in the far north of China, depend on shifts in feed demand and maize availability in Guangzhou and Fujian, in the south of China. Similar patterns occur with soybeans and other crops.⁵²

Transaction Costs and Transportation Gradients

When examining spatial price relationships across China, we can create transportation gradients. These gradients plot prices according to the distance of each market from one of the nation's major ports. For example, Figure 5, Panel A, shows the relationship between the price of maize in the northeastern port city of Dalian and in the three northeastern provinces—Liaoning, Jilin and Heilongjiang—during the post-WTO-accession period of December 2001 to February 2003. The downward sloping gradient (high in the port and lower as markets move away from the port) illustrates a price contour that is consistent with the existence of a properly functioning market. For instance, the price in a market 1000 kilometers away from Dalian (for example, the Jilin market) is, on average, about .70 yuan per metric ton lower (6 per cent lower) than the price in Dalian, and the price in Heilongjiang is even lower. The same pattern occurs when examining rice prices in south China (Figure 5, Panel B). In fact, a similar pattern applies for all crops for any time period.⁵³

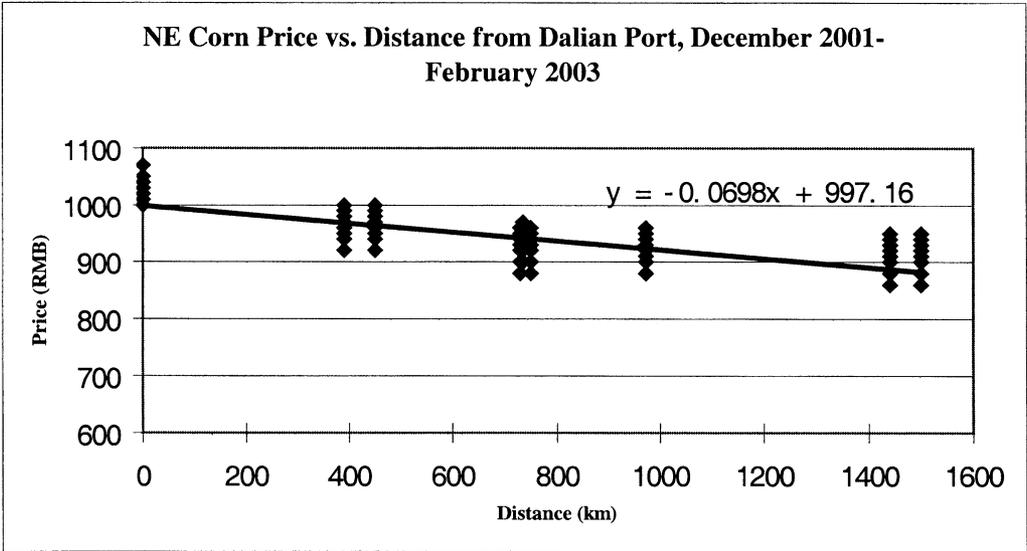
Using the transportation gradients, we can produce two additional pieces of evidence that are relevant to showing that China enjoys increasingly efficient markets and transportation networks. First, if we divide the price data by year between 1998 and 2000, the transportation gradients are becoming less steep over time (Table 4, rows 1 to 3). Second, the results show that the transportation gradients in China are similar to those found in the US (Table 4, rows 1 to 3 versus row 4). When plotting similar data and running similar regressions on corn in the

⁵² Scott Rozelle and Jikun Huang, "The Emergence of Agricultural Commodity Markets in China" (Beijing: Center for Chinese Agricultural Policy Working Paper, 2004).

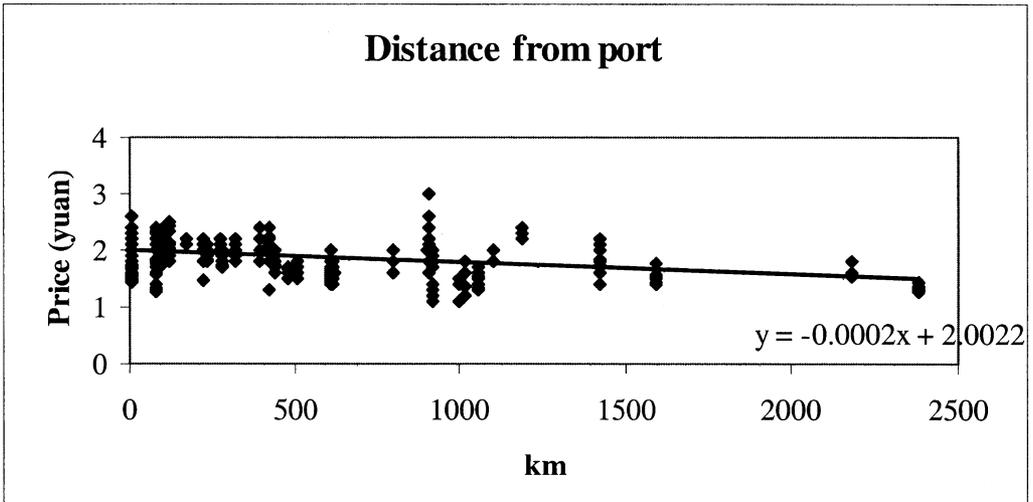
⁵³ Jikun Huang, Scott Rozelle and Min Chang, "The Nature of Distortions to Agricultural Incentives in China and Implications of WTO Accession", *World Bank Economic Review*, Vol. 18, No. 1 (2004), pp. 59-84.

Figure 5. Changes in Maize Prices across Northeast China as Markets Increase in Distance from the Port of Dalian, 2000–03

Panel A. Transportation Gradient, for Maize in Northeast China, 2002



Panel B. Transportation Gradient, for Rice in Northeast China, 2002



Source: Jilin Oil and Grain Information Center. For a complete description of the data, see Jikun Huang, Scott Rozelle and Min Chang, “The Nature of Distortions to Agricultural Incentives in China and Implications of WTO Accession”, *World Bank Economic Review*, Vol. 18, No. 1 (2004), pp 59-84.

Table 4. Changes in Maize, Soybean and Rice Prices across China and the US as the Distance of the Market Increases (by 1000 kilometers) from the Nearest Major Port, 1998–2000

	Maize	Soybean	Rice
China			
1998	-4%	-10%	-10%
1999	-4%	-11%	-9%
2000	-3%	-8%	-7%
United States			
2000	-5%	-3.5%	-8%

Source: Jilin Oil and Grain Information Center. For a complete description of the data, see Jikun Huang, Scott Rozelle and Min Chang, “The Nature of Distortions to Agricultural Incentives in China and Implications of WTO Accession”, *World Bank Economic Review*, Vol. 18, No. 1 (2004), pp. 59-84.

Mississippi Valley we find a pattern of spatial price spreads similar to those in China. In other words, assuming our findings are representative of average transportation gradients in China and the US, these results show that the time when China’s inland grain baskets were isolated by poor transportation and other infrastructural weaknesses has been ended, as China’s aggressive investment in roads and other infrastructure projects have come on line.

Another major contribution to the rising market efficiency has been the entry of private traders.⁵⁴ During the planning era marketing sales and purchases were planned.⁵⁵ Most of the commodity flows into cities were routed through the state marketing system. Wholesale and retail shops were officially sanctioned and geographically segmented. In recent years, however, there has been a veritable explosion of private trading activities. Although the extent of private trading is difficult to measure, especially since official statistics are not kept, a 2001 survey of wholesalers, importers, retailers and grain officials by the authors elicited their estimates of the number of wholesalers who were engaged in grain trading in some of the main coastal cities. The numbers were enormous. According to the survey, more than 5000 rice traders were doing business in Guangzhou; more than 3000 wheat traders were trading in Shanghai; and more than 3000 maize traders were operating in Beijing.⁵⁶ According to our interviews, with such stiff competition the

⁵⁴ Albert Park *et al.*, “Market Emergence and Transition”.

⁵⁵ Terry Sicular, “Redefining State, Plan and Market”.

⁵⁶ These numbers—all exceed 1000—can be compared to numbers in the United States where there are fewer than 10 major players in the entire grain economy.

price margins between the procurement and sales prices differed by only pennies more than the transportation cost.

According to these findings, the situation in China is consistent with that observed by John McMillan: China's gradual market reform has been one of entry-driven competition.⁵⁷ In other words, as more and more traders have entered the market, the markets have become more and more competitive and officials have responded by relaxing the rules for the former state-owned grain enterprises. The relaxation has come about both through the commercialization of the state grain bureaus and the emergence of the private trading sector. In the process, China has enfranchised tens of thousands of individuals who have become involved in commodity trade. At the same time that this produced a rise in market integration and a fall in transaction costs, it has also eroded the power of the state to control markets using traditional command and control methods (for example, by setting prices or allowing a single government organ or group of individual traders to handle all of the commodities from an area). Our findings suggest that if the nation's leaders want to control markets in the future, they are going to have to devise new ways to intervene (for example, through price floor programs such as those used in the US) that use indirect methods instead of trying to suppress traders.

Rental Markets in Land

In order for the rural economy to reap fully the benefits of better commodity markets and work-migration opportunities,⁵⁸ well-functioning land rental markets are essential.⁵⁹ Migrant families need to be able to rent out their land, and households that have not been able to move into the migrant labor force need a means to gain access to additional land. But open, active, efficient land rental markets do not always exist. In various countries there are barriers to effective land rental markets arising from high transaction costs and from government constraints.⁶⁰ Internationally, inasmuch as efficient rental markets for cultivated

⁵⁷ John McMillan, "Markets in Transition", in David Kreps and Kenneth F. Wallis (eds), *Advances in Economics and Econometrics: Theory and Applications*, vol. 2 (Cambridge: Cambridge University Press, 1997), pp. 210-39.

⁵⁸ Alan de Brauw, Jikun Huang, Scott Rozelle, Linxiu Zhang and Yigang Zhang, "The Evolution of China's Rural Labor Markets during the Reforms", *Journal of Comparative Economics*, Vol. 30, No. 2 (June 2002), pp. 329-53.

⁵⁹ This need for land markets is especially true in the light of China's WTO accession. In other East Asian countries the returns to land could be raised by trade protectionist policies. Such policies were able to raise rural incomes even if households could not get access to more land for farming. But China's leaders cannot raise trade barriers. Renting in land will benefit the household depending on the size of the rent. However, in an economy in which land is scarce and employment opportunities are limited, having access to additional land at a reasonable rent, which is the situation in China today, will benefit the renter.

⁶⁰ Alain de Janvry, Marcel Fafchamps and Elizabeth Sadoulet, "Peasant Household Behaviour with Missing Markets: Some Paradoxes Explained", *The Economic Journal*, Vol. 101, No. 409 (November 1991), pp. 1400-17.

land have not emerged in many developing countries, they have had little impact on the reduction in poverty.⁶¹

In the first decade and a half of reform, China's record in cultivated land rental markets was dismal, and households in the rural areas were rarely able to gain access to additional cultivated land.⁶² According to a nationwide survey of more than 200 representative villages, few households rented cultivated land either in or out.⁶³ In fact, in 1988 only one half of 1 per cent of households rented land. Even by the mid-1990s, less than 3 per cent of the agricultural land was rented. While there was a debate about why it is that farming households were not renting more land, the fact remained that markets were doing little to shift land from those with an excess of cultivated land to those with a positive demand.⁶⁴

Since 1995, however, the emergence of cultivated land rental markets has quickened. Between 1995 and 2000, the proportion of cultivated land that was rented in and out more than doubled to around 7 per cent.⁶⁵ After 2000 the pace of

⁶¹ World Bank, "Rural Development in China: New Challenges in a New Landscape", World Bank, Washington DC, Report Written for the Government of the People's Republic of China, July 2004.

⁶² Farmers can also get access through the periodic free administrative reallocations of land that have been discussed at length in the literature (Loren Brandt, Jikun Huang, Guo Li and Scott Rozelle, "Land Rights in China: Facts, Fictions and Issues", *The China Journal*, No. 47 (January 2002), pp. 67-97; Dwayne Benjamin and Loren Brandt, "Property Rights, Labor Markets and Efficiency in a Transition Economy: The Case of Rural China", Working Paper, University of Toronto, 2000. Although administrative reallocations are shown to help efficiency, they are less effective than market-based transactions. Moreover, by law they are not allowed more often than once every 30 years.

⁶³ The main data for examining rentals in 1988 and 1995 come from a national representative survey (China National Village Survey—CNVS) of 228 villages in 7 provinces (Liaoning, Hebei, Shaanxi, Sichuan, Hubei, Zhejiang and Yunnan). In the survey we asked village leaders to provide information on land transactions in their village during the years 1995 (the most recent year) and 1988 (a year that was similar in that grain prices were equally high in real terms). For more information in the survey and a more complete discussion of land rights and cultivated land rental markets during the late 1980s and mid-1990s, see Loren Brandt *et al.*, "Land Rights in China: Facts, Fictions and Issues".

⁶⁴ Dwayne Benjamin and Loren Brandt, "Property Rights, Labor Markets and Efficiency"; James Kung, "Equal Entitlement versus Tenure Security under a Regime of Collective Property Rights: Peasants' Preference for Institutions in Post-reform Chinese Agriculture", *Journal of Comparative Economics*, Vol. 21, No. 1 (1995), pp. 82-111; Michael Carter and Yang Yao, "Property Rights, Rental Markets, and Land in China", Working Paper, Department of Agricultural and Applied Economics, University of Wisconsin-Madison, 1998.

⁶⁵ The national point estimate for 2000 comes from a national representative, household- and village-based survey (China Rural Land Survey—CRLS) of 1199 households and 60 villages. Although the villages were different from the CNVS survey, the households were chosen from the same 6 provinces (Liaoning, Hebei, Shaanxi, Sichuan, Hubei and Zhejiang). During the survey, sit-down, pre-coded questionnaires were executed at the village level and household

increase continued. According to a nationwide survey by the China National Statistical Bureau (CNSB), in 2002 9.5 per cent of households rented in cultivated land.⁶⁶ In 2003, more than 10 per cent rented in land.⁶⁷ In fact, in some provinces the rate of land rental was much higher. For example, in Zhejiang, according to our survey, more than 25 per cent of the cultivated land was rented.⁶⁸

Rental markets for cultivated land, then, have emerged fairly robustly, though not yet enough to satisfy all of the demand.⁶⁹ In fact, despite having had almost no rental activity as recently as the late 1990s, China is already moving towards a level

level and were focused, among other things, on the evolution of land transactions, including cultivated land renting in and out. The results of the cultivated land rental transactions in 2000 are reported in more detail in CCICED, *China's Agricultural and Rural Development in the New Era*.

⁶⁶ Before 2002, the China National Statistical Bureau's Household Income and Expenditure Survey did not include questions on cultivated land rental transactions. In conjunction with the authors and the World Bank, a pilot set of questions were added and a part of the rural household data set were made available for the authors. The survey (2002 CNSBPlus) uses a two-stage sampling procedure. In the first stage, sample villages are drawn randomly for the survey. In 2001 these were located in 26 provinces. In the second stage, 10 households were drawn from each administrative village in the sample using an equal distance sampling methodology. (According to the National Statistical Bureau, the sampling error for the survey does not exceed 3 per cent at a 95 per cent confidence level.) The survey contained a one-time set of questions related to the household's land rental activities. In particular, households were asked whether they rented land in or out and, if they did, the size of the rental transaction. We were given access to the 2001 data at the community level. For our analysis we use a mixture of panel data and cross-sectional data. For more details on the 2002 CNSBPlus Survey, its coverage and content, see Klaus Deininger, Songqing Jin and Scott Rozelle, "Rural Land and Labor Markets in the Process of Economic Development: Evidence from China", Working Paper, Washington, DC: World Bank Research Department, 2004.

⁶⁷ See the previous footnote for a description of the survey data. In 2003, the same questions were added and a similar data set (2003 CNSBPlus Survey) was made available to the authors. These data included information from 2002 and were provided to the authors at the household level. For more details on the results of the overall 2003 survey, see Klaus Deininger, Songqing Jin, Xude Xuan and Scott Rozelle, "Implementing China's New Land Law: Evidence and Policy Lessons", Working Paper, Washington, DC: World Bank Research Department, 2004.

⁶⁸ The Zhejiang figure is based on the CNVS survey. For more details, see CCICED, *China's Agricultural and Rural Development in the New Era*.

⁶⁹ Cultivated land rental markets are not perfect. In a recent paper using panel data that followed households from Hunan, Guizhou and Yunnan provinces for 5 years, Klaus Deininger and Songqing Jin show that (despite increases in renting) there is still unmet demand for cultivated land by households. See their "Land Rental Markets as an Alternative to Government Reallocation? Equity and Efficiency Considerations in the Chinese Land Tenure System", *Journal of Development Economics* (forthcoming).

that is can be considered normal, at least in terms of its neighbors in Asia and in terms of China's historical past. The level of cultivated land rental for all of China (10 per cent) is only 6 percentage points behind the average for all of Asia (16 per cent).⁷⁰ Moreover, in some prosperous parts of the country, such as Zhejiang Province, where many families are leaving farming for other income-earning activities, the rentals of cultivated land are becoming close to the rental rates that existed during the 1920s and 1930s (between 30 and 40 per cent).⁷¹ Hence, although rental markets for cultivated land were at a negligible level one and a half decades ago, they have become more common and in some places are providing farmers with access to as much land as they need.

Efficiency and Equity Effects

In addition to merely growing in size, there also are indications that cultivated land markets are beginning to play a role that could promote economic development by improving efficiency, and currently do not have adverse effects on equity.⁷² In particular, we are interested in seeing if those engaged in migration or who are working off the farm locally (that is, those who are relatively labor-short on the farm) are more inclined to rent land out. Similarly, we want to see if households which principally engage in farming are increasingly renting in extra land.

Table 5 provides information at the community level for all of China and by region, showing the village's average household income composition, the participation of the village members in different types of economic activities, their land endowments and rental market participation.⁷³

⁷⁰ Keijiro Otsuka, Hiroyuki Chuma and Yujiro Hayami, "Land and Labor Contracts in Agrarian Economies: Theories and Facts", *Journal of Economic Literature*, Vol. 30, No. 4 (December 1992), pp. 1965-2018.

⁷¹ John Buck, *Land Utilization in China* (Nanjing: Jinling University Press, 1937).

⁷² There are many situations in the world in which land rental markets either do not exist or do not have efficiency- or equity-increasing effects. In many cases, transactions costs are so high (for policy-based and economic-based reasons) that those with excess land and those demanding land are unable to complete cultivated land rental transactions. In other cases, richer households are the ones able to rent in more land through rental markets. Hence, *ex ante*, it is not clear whether or not China's land rental markets will exist or whether or not they will involve relatively poor households. For good references on this topic outside of China, see: C. M. Shackleton, S. E. Shackleton and B. Cousins, "The Role of Land-Based Strategies in Rural Livelihoods: The Contribution of Arable Production, Animal Husbandry and Natural Resource Harvesting in Communal Areas in South Africa", *Development Southern Africa*, Vol. 18, No. 5 (2001), pp. 581-604; I. Shivji, *Not Yet Democracy: Reforming Land Tenure in Tanzania*, (London: International Institute for Environment and Development, 1998); and Colin Thirtle, L. Lin and J. Piesse, "The Impact of Research-Led Agricultural Productivity Growth on Poverty Reduction in Africa, Asia and Latin America", *World Development*, Vol. 31, No. 12 (2003), pp. 1959-75.

⁷³ Importantly, the descriptive statistics in Table 5 help establish the representativeness of our data. The average rural per capita income for China (2,681—row 1) is almost the same as in

Table 5. Key Indicators of Labor and Land Market Activity in China's Main Regions, from 2002 CNBSPlus data set

	All China	North & Northwest	Coast	Central	South West
No of households in sample	54,590	12,390	14,680	14,860	12,660
Mean per capita income (Yuan)	Y2,681	Y2,646	Y3,894	Y2,392	Y1,794
Agricultural Production (%)	37%	38%	28%	41%	41%
Wage employment (%)	25%	28%	31%	21%	19%
Remittances (%)	9%	6%	10%	13%	8%
Non-farm self-employment (%)	29%	28%	31%	25%	32%
	100%	100%	100%	100%	100%
Households with non-farm enterprise (%)	10.7%	7.3%	14.4%	11.1%	9.2%
Households which migrate (%)	37%	25%	35%	47%	37%
Months in non-farm activity	10.0	8.3	13.7	9.2	7.6
Months spent in migration	4.1	2.3	4.5	5.4	3.6
Land (mu)	1.62	2.14	1.00	1.31	1.37
Percentage of households renting in (%)	9.5%	7.1%	9.4%	10.4%	7.5%
Ratio of own land to rented land	0.51	0.48	0.59	0.50	0.44

Source: Own computation from the community-level part of the NBS national 2001 household survey as included in Klaus Deininger, Songqing Jin and Scott Rozelle, "Rural Land and Labor Markets in the Process of Economic Development: Evidence from China", Working Paper, Washington, DC: World Bank Research Department, 2004.

The North and Northwest Region includes the provinces of Hebei, Shanxi, Liaoning and Henan; the Coastal Region includes Jiangsu, Zhejiang, Fujian, Shandong and Guangdong; the Central Region includes Anhui, Jiangxi, Hubei, Hunan and Guangxi; and the Southwest includes Sichuan, Guizhou, Yunnan, Shaanxi and Gansu.

the 2002 statistical yearbook, as are the national shares of income from agricultural production (37 per cent) and landholdings per capita (1.62 *mu*), two variables also reported regularly in published statistical sources (*ZGTJNJ*, 2000 to 2004). Our data also show how diversified China's rural income sources were in 2001. Although agriculture still made the largest contribution to overall rural household income (37 per cent), it was followed by income from local wage employment and migration (25 and 9 per cent) and local non-farm self-employment (29 per cent).

Above all, across China's major regions, the communities in regions with the highest levels of migration (the central and coastal regions) also show the highest levels of rentals (rows 8 versus 10).⁷⁴ Rental markets tend to be more active in the provinces in which migration is most common (for example, Jiangxi, Henan, Hubei, Hunan and Anhui). Correlations between the share of family members in the migrant labor force and the share of cultivated land that is rented come to more than 0.80, and is more than 0.90 when including other types of off-farm activities. This means that in villages in which there is a lot of migration and off-farm employment, there is a greater propensity for land rentals.

Examining the differences among households (Table 6) that rent in land (column 2), rent out (column 3) or do not rent land in or out (autarkic households—column 4) shows that the emergence of land markets has been of help to the households with less land. Those renting in land have been able to increase their area of cultivation significantly above the average (row 3) even though their original land endowment was significantly below the mean (row 2). T-test results also show that households which rent out land spend significantly more time in labor migration than those which rent in land (row 12 to 15)⁷⁵ and, as expected, that households renting out land earn a higher share of their income from non-farm sources (rows 9 and 10).⁷⁶ Thus, land rentals are making the agricultural sector more efficient by providing land to the households that are more focused on farming, have sufficient labor to farm effectively, and most need the land.

⁷⁴ The evidence at the regional level also is supported by province-level data (not shown for the sake of brevity), where the aggregate correlation coefficient between migration and land rentals is 0.54.

⁷⁵ Specifically, the members of households that rent out land cumulatively spend, on average, 4.7 and 12.2 months in migration and in non-agricultural self-employment as compared to 3.6 and 8.7 months for households that rent land in. The number of months in the migration and/or off-farm workforce can exceed 12 months for a household since there may be more than one family member working off the farm.

⁷⁶ Those who rent in land receive the most important share of their income from agriculture (52 per cent), while only earning 39 per cent (27+12) from non-farm employment and less than 10 per cent from remittances (column 2, rows 8 to 11). In contrast, those who rent out land obtain 56 per cent of their income from local non-agricultural sources (35+21), 13 per cent from remittances and only 31 per cent from agriculture (column 3, rows 8 to 11). Importantly, in multiple regression analysis using the same data, Klaus Deininger, Songqing Jin and Scott Rozelle, "Rural Land and Labor Markets in the Process of Economic Development", construct a variable measuring the efficiency of households in farming (from an agricultural production function using panel data on the same households) and show that, everything else being equal, farm households that are more efficient at farming rent in more cultivated land while those that are less efficient at farming rent out more cultivated land. The opposite is true for the level of human capital that in China is increasing associated with higher wages in the off-farm labor market; those households with higher education level tend to rent out more land while those with lower human capital rent in land. These results, it is argued, show that, in multivariate analysis, rental markets for cultivated land are also shifting land in a way that will increase efficiency.

Table 6. Asset Holdings and Economic Activities of Households Renting In and Renting Out Land in 2001, from the 2003 CNBSPlus Dataset

	All households	Households renting in land	Households renting out land	Autarkic
Number of households	15,873	3,332	2,590	9,951
Family's allotted land per capita (<i>mu</i>)	1.44	1.35	1.65	1.43
Land planted per capita (<i>mu</i>)	1.50	1.98	1.09	1.43
Value of own agricultural assets (yuan)	Y775	Y812	Y740	Y772
Value of own non-farm assets (yuan)	Y419	Y237	Y557	Y450
Households owning draft animal (%)	31%	38%	26%	31%
Per capita income (Y/person)	Y2,686	Y2,582	Y3,024	Y2,636
Income from Agriculture (%)	38%	52%	31%	40%
Income from local wages (%)	33%	27%	35%	31%
Income from non-farm self-employment (%)	17%	12%	21%	18%
Income from remittances (%)	11%	9%	13%	11%
Months spent as migrant	3.7	3.6	4.7	4.0
Number of months in on-farm activities	10.0	8.7	12.2	9.9

Source: For a complete description of the data, see Klaus Deininger, Songqing Jin, Xude Xuan and Scott Rozelle, "Implementing China's New Land Law: Evidence and Policy Lessons", Working Paper, Washington, DC: World Bank Research Department, 2004.

A number of factors point to the fact that cultivated land rental markets not only increase efficiency but also may be enhancing equity. For example, there is a difference in the asset bases of households which rent in land and those which rent out land (Table 6). Those households with fewer non-farm assets (237 yuan per capita among the families renting in cultivated land versus 557 yuan per capita for

those renting out) rent in more cultivated land (row 5). Households that rent in are also endowed with less cultivated land (1.35 *mu* per capita) than those that rent out (1.65 *mu*—row 2). The equity effects can be seen even more clearly when examining income. Households renting in cultivated land have lower per capita incomes (2,582 yuan per capita) than those renting out cultivated land (3,024 yuan). Indeed, given the nature of China's income distribution,⁷⁷ to the extent that rental transactions raise the agricultural incomes of those households that rent their plots in, at least in some small way, cultivated land rental markets are leading to falling inequality.

Conclusions

In examining China's agricultural sector, we have focused on whether or not China's current biotechnology is able to raise productivity, provide a marketing environment that will allow for specialization and a rational allocation of resources, and create markets for cultivated land that will allow migrant households and households that have not shifted to off-farm work to exchange land through a rental market.

In looking at these three aspects of the agricultural sector, we believe that China is capable of generating long-run sustained growth. China's agricultural R&D system has become more than capable of generating both new conventional technologies and those created by GM biotechnology, and technology-driven growth has become one of the main means of raising the returns in agriculture. The analysis of commodity markets demonstrates that they are becoming remarkably integrated across regions: between the coast and inland and between county market seats and villages, even in remote areas. Finally, although the emergence of land markets has been fairly recent, in the past decade they have begun to develop fairly quickly, with beneficial effects in terms of allocative efficiency and equity. Land across China has begun to shift to the households which concentrate largely on farming and away from those in the migrant labor force. In summary, according to all three indicators—agricultural productivity; the emergence of commodity markets; and the emergence of markets in cultivated land—China is making strong progress.

Of course, development also requires the transfer of capital to poorer, agricultural areas, much of which will not flow through markets. It is here that there is a role for government. At similar points in their development, the governments of Japan, Korea and Taiwan launched enormous rural development campaigns aimed at making rural areas better places to live. Billions of dollars were invested through government-led investment programs. In order for these funds to be spent rationally, the investments were typically managed by the village itself and this required a transparent, accountable fiscal system. These and other Asian countries also developed ways to make rural banks and other financial markets more responsive to farmer demands. In other words, improvements in

⁷⁷ Scott Rozelle, "Stagnation Without Equity: Patterns of Growth and Inequality in China's Rural Economy", *The China Journal*, No. 35 (January 1996), pp. 63-96.

technology and the rise of markets, while necessary for development, are not sufficient.

The literature is fairly clear that in rural China many of the most basic institutions that are needed to deliver basic public goods and services are weak or missing. Hence, the strength of China's R&D system and the improvements in commodity markets, while certainly needed for healthy agricultural development, are not enough. If China is to continue to make progress in its rural development agenda, leaders must not only rely on a steady supply of technology or well-functioning commodity and cultivated land rental labor markets; further reforms and government investment in village-level infrastructure are also needed.

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