National and International Agricultural Research and Poverty: Findings in the Case of Wheat in China

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Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Montréal, Canada, July 27-30, 2003

1. Introduction

Agricultural research played an important role in agricultural production and productivity growth in many developing countries. One of the most prominent outcomes of agricultural research was the release of high-yielding varieties by national and international agricultural research centers during the Green Revolution, which substantially increased crop production and consequently farmer's income in many Asian countries.

While there have been many studies on the impact of the Green Revolution on production and productivity growth, there have been few attempts to link agricultural research investments to rural poverty reduction. In addition, what role the CGIAR (Consultative Group on International Agricultural Research) centers have played as a partner in this process has not been well documented and understood. This study is designed to fill the gap in our knowledge using the case of wheat in China. Information on poverty effects of agricultural research investments will help national and international policy makers in mobilizing resources and in setting priorities for agricultural research in the future.

The objectives of this study are the following ones: (i) to evaluate the total benefits from wheat varietal improvement research in China; (ii) to analyze how CIMMYT (International Maize and Wheat Improvement Center) varietal improvement research contributed to productivity gains in Chinese wheat production; and (iii) to assess how wheat varietal improvement research has contributed to rural poverty reduction in China.

We present in the next 2 sections an overview of rural poverty, a scope of wheat production, and a historical account of wheat breeding in China. Following the presentation of the methodology and the empirical findings, we provide some concluding remarks.

2. Rural Poverty in China

The late 1970's marked a turning point in China's economic development with the country's transition towards a market-based economy. A series of policy and institutional reforms introduced in 1978 resulted in the formation of rural enterprises and private businesses, the liberalization of foreign trade and investment, and the relaxation of state control over some prices. The reforms were particularly successful in developing the rural economy. Consequently, per capita income in rural areas grew by at an average rate of 7.9% per year over the past two decades, from 220 yuan (1990 price) in 1978 to 1,169 yuan (1990 price) in 2000. During the same period, the number of rural poor declined dramatically. Using the government poverty line, China's rural poor fell from 260 million (33% of the rural population) in 1978 to 36 million (3.7% of the rural population) in 2000 (table 1) [1].

Despite the increasing trend in the number of urban poor, poverty remains largely a rural phenomenon in China. In 1998, China's urban poor accounted for only 2% of the total urban population (Fang, Zhang, and Fan 2002) whereas the proportion of rural poor in total rural population was 4.8% for that same year.

[1] Chinese official poverty line is based on a minimum daily intake of 2100 calories per person and is equivalent to about two-third of the World Bank $1 per day poverty line. Poverty estimates based the World Bank $1 per day show greater number of rural poor in China in absolute terms but the declining trend in poverty is still confirmed.

Rural poverty is concentrated in mountainous areas, primarily in the several ranges and high plateaus that define the western boundary of traditional Han agriculture (World Bank 2000; Park, Wang, and Wu 2001). According to official data, more than 60 percent of the rural poor in 1996 lived in border provinces such as Gansu, Yunan, Sichuan, Guizhou, Guangxi, Qinghai, Ningxia, Inner Mongolia, and Xinjiang. Given the low population density in these areas, the poverty incidence was much higher than the national average. For example, 23 percent of the rural population in Gansu and 27 percent in Xinjiang lived under the poverty line in 1996. Another pocket of poverty is the Northern China Plain, where the poor accounted for 22 percent of the total rural population. This area includes Henan, Hebei, Shaanxi, and Shanxi, where meager natural resources, particularly poor soil and scarce water, contribute to rural poverty.

3. Wheat Production and Wheat Research

Wheat in China. China is the largest producer of wheat in the world and was responsible for 16% of the world wheat production in 2002. In that same year, India was the second leading grower with 71.4 million metric tons (13% of world production), while by the Russian Federation occupied the third place with 50 million metric tons of wheat produced (9% of world production). Together these top three countries of production accounted for 38% of the world wheat production.

In terms of harvested area and production, wheat is the third most important cereal in China after rice and maize. In 2002, wheat accounted for 29% of Chinese total cereal production and for 22% of the total area harvested to cereal[2]. About 85% of the wheat produced in China is winter wheat, which is grown mainly in the North China Plain and the Sichuan Basin. Spring wheat, on the other hand, is produced primarily in Helongjiang and Inner Mongolia. Wheat production is highly concentrated in China: only three provinces, Henan (22.4%), Shangdong (18.7%), and Hebei (12.1%) accounted together for 53% of the total wheat production in China. Table 2 shows the production of wheat by province ranked by their 1980 and 2000 production shares.

Wheat output has increased significantly in China, from 14 million tons in 1961 to 89 million tons in 2002, or an average growth rate of 4.96% per annum. Much of this increase was a result of yield gains. From 1961 to 2002, wheat yield grew at an average annual rate of 4.56%, whereas area expanded by only 0.39% per year. The genetic improvement of wheat varieties in conjunction with irrigation and the greater use of modern inputs (such as fertilizer and pesticide) have been instrumental in achieving the substantial increase in yield.

Wheat is an important food crop in China. According to FAO food balance sheet, about 90% of the domestic wheat supply was used for food in 2000, while the remaining 10% was apportioned to animal feed, seed, processing, waste, and other uses.[3] That same year, wheat provided nearly 20% of Chinese daily caloric intake. Thus, wheat is not only a significant source of income and employment for many Chinese farmers, particularly those in the Northwest, Northeast, and Northern China Plain, but also an important source of calories.

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[2] Cereal includes the following grains: rice, wheat, maize, millet, sorghum, barley, buckwheat, rye, oats, and triticale.

[3] Over 90% of wheat grain is used to make steamed bread and noodles (He, 2001).

Wheat breeding. Yan and Smale (1996) and He et al (2001) provide a detailed account of the history of wheat breeding and varietal replacement in China. Prior to the founding of the People's Republic of China in 1949, several universities, missionaries of agricultural agencies, and the National Agricultural Bureau were responsible for wheat breeding. In these early days, farmers used mostly landraces. During the 1950s and 1960s, selections of farmers' landraces, new introductions, and improved materials developed in China and abroad gradually replaced landraces. A number of foreign cultivars from Italy (Villa Glori, Mentana), Chile (Orofen), the U.S. (Minn 2761, Triumph, Early Premium), and Australia (Quality) contributed significantly to the parentage of advanced Chinese lines.[4] By the late 1970s, selected and improved cultivars with high yield potential, resistance to rust, and early maturity prevailed in farmers' field. Following the market reforms introduced in 1978, farmers were given more autonomy in choosing which crops and varieties to plant. Consequently, an increasingly large number of varieties were released and grown during the 1980s and 1990s*,* whereas a few number of varieties dominated farmer's fields prior to the reforms. With a greater turnover of varieties in the post-reform period, the area shares occupied by the top wheat varieties have declined over the past 2 decades (table 3). In 1982, the top 10 varieties accounted for about 40% of total wheat area compared with 31% in 2000. Table 3 also shows that the number of wheat cultivars planted in China increased substantially over the past 2 decades, from 174 wheat varieties in 1982 to 497 varieties in 2000.

According to Dalrymple (1986), the first CIMMYT varieties were introduced in China from Pakistan in the late 1960s. In the 1970s, a number of CIMMYT semi-dwarf

[4] Foreign cultivars played a significant role in developing improved wheat varieties in China. Between 1950 and 1986, more than half of the varieties released were developed from crosses between imported varieties and Chinese landraces or their derivatives (He et al, 2001).

varieties such as Yecora F70, Alondra "s", Veery, and Tanori F71, were present in China. These varieties did not adapt well: they were prone to rust, sprouted before harvest, and matured later than local varieties. However, Chinese breeders crossed the CIMMYT cultivars with local wheat and developed a number of varieties (e.g. Kehong 16, Ningchun 4, Jinan 17), which adapted well in southwestern and southern China. Following the economic reforms and the establishment of the Chinese Plant Germplasm Institute in 1978, China became increasingly involved in exchanging germplasm with CIMMYT and other countries. Nowadays more than 35 Chinese institutes participate in CIMMYT wheat international nurseries (He, 2001). Further, scientific exchange, training courses, and wheat breeding meetings between Chinese and CIMMYT scientists occur on a regular basis.

3. Methodology

Estimation of Benefits. In contrast to the traditional econometric approach proposed by Griliches (1957), this study uses extensive data on the adoption and yield performance of wheat varieties used by Chinese farmers to estimate the benefits from wheat varietal improvement research. The economic benefits from such research result mostly from the productivity gains that farmers experienced after adopting improved varieties. Typically, measuring these benefits is based on comparing a "with research" scenario to a counterfactual "without research" scenario (Heisey and Morris 2002, Alston et al 1996, Pardey et al 1996, Pardey et al 2002).

The first step towards measuring these benefits is to determine the gain in yield resulting from the development and adoption of improved varieties. To isolate the genetic contribution to yield increases from other factors, we collected experimental yield data of adopted wheat varieties in China. Experimental yields have the advantage of holding many of the variables influencing yields constant, and hence may provide a good approximation of the genetic contribution to yield gains.[5] Using the experimental yield data, we select numeraire varieties specific to each province. We then compute the yield gains of newer adopted varieties against the numeraire varieties.[6] [7] Ideally, the numeraire should be a variety widely adopted in China—thus well known by farmers— before the Chinese wheat research system was set up. Table 4 presents the numeraire varieties we used for each province.

The benefits for each variety are calculated by multiplying the estimated yield gains by price, and by the area sown to the variety. The total benefit is obtained by summing the estimated benefit of each variety. This approach assumes that increased wheat production from wheat varietal improvement research does not affect wheat price. Further as discussed in Pardey et al (1996), this approach is equivalent to using a model in which a perfectly inelastic supply curve shifts out against a perfectly elastic demand curve. According to the authors, this measure attributes all the benefits to the producers— in the form of the change in producer profit caused by the reduction in unit cost from adopting improved varieties—but nevertheless provides a good approximation

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[5] Empirical evidence shows that absolute yields achieved in experimental trial are higher than those in farmers' fields. However, it is uncertain whether relative yields gains in trials are also greater (Heisey and Morris 2002; Pardey et al 1996). Here we assume that the proportional gains achieved in experimental trials are representative of the gains realized by farmers.

[6] We use the chain rule in estimating the yield premium of various varieties over the numeraire variety. For example, before variety B was released, it was tested against numeraire A. The yield premium of variety B is Yb/Ya. But before variety C was released, variety B was used as a check variety. The yield premium of variety C over B is Yc/Yb′. Note that Yb and Yb′ are not equal since they are the yields of the same variety tested at a different time and location. The yield premium of variety C over numeraire variety A is therefore (Yc/Yb′) × (Yb/Ya).

[7] Under neutral technical change with fixed factor proportions, the percentage increase in experimental yield translates into an equal, proportional, rightward shift of industry supply in the quantity direction (Alston et al 1995).

of the total benefit.[8] Under more plausible assumptions about elasticities, the benefits would be shared between producers and consumers.

Varietal Spillovers. The study relies on pedigree information to analyze how CIMMYT varietal improvement research contributed to productivity gains in Chinese wheat production. The impact of CIMMYT wheat breeding research in China occurs through: 1) the direct use of CIMMYT varieties by farmers; and 2) the use of CIMMYT varieties as parents in local breeding programs. To assess the contribution of CIMMYT to the estimated benefits, we followed the approach described in Pardey et al (1996). The authors developed various rules to attribute benefits to a specific research or breeding program, in this case to CIMMYT research. These rules take into consideration various factors involved in varietal development such as recent versus past breeding efforts versus heritability of traits. The binary-parents rule gives full credit to CIMMYT if the two parents of a variety or any of its ancestors were CIMMYT-released. If only one set of parents was CIMMYT-released or has CIMMYT ancestry, the variety was considered 50% CIMMYT. The all-antecedents rule assigns equal weights to the variety and each of its ancestors. Thus, if we trace the pedigree back to the grandparent level, the variety and each of its ancestors is given a weight of 1/7 if released by CIMMYT. The geometric rule assigns higher weight for the recent generations and lower weight for the early generations. The all-credit-to-last-cross rule takes only the last cross into account, so, if the variety was released by CIMMYT, it gets all credit, otherwise none. Finally, the any-ancestor rule gives credit to CIMMYT if a variety or any of its ancestors was released by

[8] Although this method provides a good approximation, it is likely to overstate the benefits if input use has increased after adopting the new varieties and if supply is not perfectly elastic (Pardey et al 1996).

CIMMYT. The all-credit-to-last-cross rule and the any-ancestor rule represent polar cases: the former is the most conservative rule and the latter is the least conservative.

Poverty Impact. New technology resulting from agricultural research can improve farmers' income and consequently helps to alleviate poverty. Following the releases of new and improved cultivars, farmers can produce more output at the same cost or the same level of output at a lower cost (Kerr and Kolavalli, 1999).

To estimate the impact of wheat varietal improvement research on poverty allevation, we use some poverty impact parameters reported in Fan et al (2002). Fan et al estimated a system of econometric equations to calculate the impact of different types of government spending on agricultural growth and rural poverty reduction in China using provincial level data from 1970-97. The model is structured to enable the identification of the various channels through which different types of government expenditures affect the poor. Increased output from agricultural research affects the poor directly in the form higher income, and indirectly through increased rural wages, greater employment opportunities, and changes in food prices. The estimated poverty equation in Fan et al shows that with every 1% increase in agricultural production or productivity growth, the total number of rural poor in China would be reduced by 1.924% as a result of all direct and indirect effects.

Using this total elasticity, we calculate the marginal impact on poverty alleviation. This measure gives the number of rural poor reduced per unit increase in the value of agricultural production. As the estimated research benefits represent the value of the additional output from adopting improved varieties, we can easily calculate the total number of poor reduced due to wheat varietal improvement research. Finally, we use

CIMMYT's share of total wheat research benefits estimated from the geometric attribution rule to calculate the contribution of CIMMYT wheat to rural poverty alleviation. These are lower bound estimates since the geometric rule is one of the most conservative attribution rules.

4. Results

Benefits. Our preliminary results indicate that wheat varietal improvement research has contributed significantly to increases in wheat production in China (table 5). The benefits from wheat breeding research increased sharply, from 1.1 billion (measured in constant 2000 price) in 1982 to 6.1 billion $US in 1998, or an average annual growth rate of 11% per year. These research benefits represented 11.9% to 22.7% of the total value of wheat production in 1982 and 1998 respectively.

Benefit-cost analysis helps policy makers to evaluate investments and judge alternative projects. A cost-benefit analysis of varietal improvement research compares the benefits from a set of new varieties to the costs of developing these varieties. Thus, to match the stream of benefits to the corresponding costs one must carefully account for all the cost involved in developing the new varieties. These include: (i) the costs of the work undertaken by plant breeders as well as the appropriate shares of agronomy, plant pathology, entomology and other scientific staff; and (ii) the indirect or overhead costs relating to physical capital, management, and research support costs (Pardey et al 1996). Unfortunately, such detailed cost data were not available. Therefore, we compare in table 5 the benefits from wheat breeding research to China's total investment in agricultural research and to CIMMYT wheat research costs. Over the period of study, the benefits from wheat breeding research largely exceeded both the total investment to agricultural research in China and CIMMYT expenditures on wheat research. In 1982, the additional wheat production from the introduction of new wheat varieties was worth $1,132 million (2000 prices), thus 4.6 times larger than the total budget for agricultural research ($246 million) and 54.2 times larger than CIMMYT wheat research cost ($20.9 million). In 1999, the estimated benefits ($4.629 million) were 7 times greater than the total agricultural research expenditure in China. These findings suggest that the investments in wheat breeding research have been very profitable in China.

CIMMYT contribution. To gain some insights on China spillover benefits from CIMMYT 's wheat varietal improvement research, we examined the share of wheat area sown directly to CIMMYT varieties or to varieties that have CIMMYT ancestry. Table 6 show that the share of wheat area sown to varieties with CIMMYT ancestry declined from 14% in 1982 to 3% in 2000. Table 6 also shows that the impact of CIMMYT in China occurred mostly though the use of CIMMYT varieties rather than through direct adoption.

These trends are confirmed in table 7, which presents the proportion of the total wheat research benefits attributable to CIMMYT varieties. Overall, CIMMYT's contribution to the total gains declined over the past 2 decades. With the any-ancestor rule, CIMMYT accounted for 16% of the wheat research benefits in 1982 and for only 2.4% in 2000. With the most conservative scenario (all-credit to last-cross rule), which gives all the credit to the breeding program responsible for developing the variety, CIMMYT account for practically none of the research benefits over the period of study. This is expected given that CIMMYT varieties were mostly used as breeding material and not directly planted in farmers' field. In between these two extremes, the geometric attribution rule takes into account recent versus past breeding efforts. According to this rule, CIMMYT varietal improvement research contributed to 1.3% to 0.3% of wheat research benefits in 1982 and 2000 respectively. Under the binary parents and the all antecedents attribution rules, CIMMYT's shares of the benefits ranged from 0.4% to 8% over the period of study. However, these results may underestimate CIMMYT's contribution since we had only partial pedigree information that is back to the grandparents level. Moreover, these results mask important variations across provinces within China. Offspring of CIMMYT varieties are mostly planted in Southwestern and Southern China, which are minor producing zones (Yang and Smale 1996). They are also found in Northeastern and Northwestern China. Using the any ancestor rule for example, CIMMYT's contributed for over 40% of the total benefits in Inner Mongolia and Ningxia in 2000. With the geometric rule, CIMMYT's accounted for about 6% of the total benefits in these two provinces in 2000.

Table 8 compares the benefits and costs of CIMMYT's research. The benefits attributed to CIMMYT from the geometric attribution rule are presented next to CIMMYT's total budget and to China's financial contribution to CIMMYT. Even using this conservative rule, the benefits from CIMMYT wheat in China is worth 236 times China's contribution to CIMMYT in 1998.

Poverty reduction effects. Increases in wheat production from improved varieties helped to reduce rural poverty in China (table 9). About 3.2 million and 1.7 million of rural poor were lifted above the poverty line as a result of wheat varietal improvement research in 1982 and 1998 respectively. These reductions in the number of poor represented respectively 2.4% and 4% of the total number of rural poor in China in 1982 and 1998. Table 9 also shows the contribution of CIMMYT wheat varieties to poverty alleviation. According to our estimates, the number of poor that came out of rural poverty as a result of CIMMYT wheat varietal improvement research ranged between 6,523 and 42,582 over the period of study. In relative terms, these represent less than 2% of the total number of rural poor over the 1982-1998 period. However, the impact of CIMMYT may vary widely provinces. As we discussed earlier, progeny of CIMMYT varieties are mostly adopted in Southwestern, Northeastern and Northwestern China. Therefore a provincial level analysis would probably show greater impact on poverty alleviation from CIMMYT varieties in provinces such as Liaoning, Inner Mongolia, and Xinjiang.

5. Conclusion

The green revolution characterized by the adoption of high yielding varieties resulted in very high economic payoff, and contributed to alleviate hunger in many Asian countries, as evidenced by many studies. However, questions are whether the green revolution technology still has positive economic returns today, and how it has helped to reduce rural poverty. Using varietal adoption and performance data, this study calculated the total benefits from wheat varietal improvement research in China for the past two decades. We then used pedigree information to estimate the contribution of CIMMYT to the total benefits. Finally, we used reported elasticity of poverty reduction with respect to agricultural output growth to assess the effects of national and international research on poverty reduction in rural China.

The results indicated that wheat varietal improvement research has contributed to increase in wheat production in China. From 1982 to 1998, the benefits from wheat varietal improvement research represented between 10% and 30% of the total value of wheat production. Further, the estimated benefits were on average 6.6 times higher than the total investment in agricultural research in China.

Wheat varietal improvement research helped to reduce rural poverty. Our estimates show that the total number of rural poor lifted above the poverty line added up to nearly 39 million from 1982 to 1998 as a result of the productivity gains from adopting improved wheat varieties.

However, most of these benefits are the results of research conducted in the 1960s, ’70s, and ’80s. Agricultural research investment is relatively low in China representing only 0.3% of the total agricultural gross domestic product (AgGDP). For comparison purposes, the corresponding shares are in the range of 0.5% to 1% for other low-income Asian countries, and 2% to 4% for developed countries.

Today, there are still more than 1 billion poor in the world and most of them depend on agriculture. It has been established that national and international agricultural research not only promotes productivity growth but also helped to alleviate poverty. Therefore increased and stable funding for national and international agricultural research is a must to reduce both rural and urban poverty in the future.

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Table 1: Per capita income and incidence of poverty in rural China

Year	Per capita income		Poverty	
	Yuan per person	Percentage of urban residents	Absolute number	Percentage of population
	1990 prices	*%*	*million*	*%*
1978	220	42	260	32.9
1979	263	43	239	30.0
1980	306	44	218	27.1
1981	349	49	194	24.3
1982	414	55	140	17.5
1983	467	59	123	15.2
1984	522	58	89	11.1
1985	593	58	96	11.9
1986	612	51	97	12.0
1987	644	51	91	11.1
1988	685	49	86	10.4
1989	674	44	103	12.4
1990	686	49	97	11.5
1991	700	42	95	11.1
1992	741	39	90	10.6
1993	765	39	80	9.4
1994	803	38	70	8.2
1995	846	41	65	7.6
1996	922	44	58	6.7
1997	964	40	50	5.8
1998	1,122	40	42	4.8
1999	1,147	38	34	3.9
2000	1,169	36	30	3.7
Annual growth rate (%)				
1978–84	15.49	5.53	–16.36	–16.59
1985–89	3.26	–6.67	1.78	1.03
1990–00	5.48	–3.07	–11.07	–10.68
1978–00	7.89	–0.71	–9.35	–9.44

Source: The China Statistical Yearbook and China Agricultural Development Report (various years)

Table 2: Wheat production by province in China

1980			2000	
Province	Production share		Province	Production share
	(%)			*(%)*
Henan	16.4		Henan	22.4
Shandong	14.1		Shandong	18.7
Jiangsu	9.4		Hebei	12.1
Sichuan	8.7		Jiangsu	8.0
Heilongjiang	7.3		Anhui	7.1
Hebei	7.1		Sichuan	6.4
Anhui	6.3		Shaanxi	4.2
Hubei	4.9		Xinjiang	4.0
Gansu	4.4		Gansu	2.7
Shaanxi	4.2		Hubei	2.3
Xinjiang	3.9		Shanxi	2.2
Shanxi	2.2		Inner Mongolia	1.8
Inner Mongolia	1.5		Yunnan	1.5
Zhejiang	1.5		Guizhou	1.0
Yunnan	1.4		Heilongjiang	1.0
Qinghai	1.0		Ningxia	0.7
Ningxia	0.9		Beijing	0.7
Beijing	0.7		Tianjin	0.6
Guizhou	0.6		Zhejiang	0.6
Tianjin	0.5		Qinghai	0.4
Hunan	0.5		Liaoning	0.4
Guangdong	0.4		Tibet	0.3
Fujian	0.4		Shanghai	0.2
Shanghai	0.4		Hunan	0.2
Tibet	0.3		Jilin	0.2
Jilin	0.3		Fujian	0.1
Jiangxi	0.2		Jiangxi	0.1
Liaoning	0.1		Guangdong	0.0
Guangxi	0.0		Guangxi	0.0
Total	*100*		*Total*	*100*

Source: Compiled by authors from various issues of *China Agricultural Yearbook*.

Table 3: Area share by top wheat varieties and number of cultivars planted

Rank	Variety	1982	Variety	2000
		%		%
1	Taishan 1	9.8	Yumai 18	7.3
2	7023	5.8	Jinan 17	3.6
3	Jinan 13	3.6	Mianyang 26	3.3
4	Fengchan 3	3.5	Yumai 49	3.2
5	Shannongfu 63	3.0	Yangmai 158	2.9
6	Fan 6	2.9	Jimai 19	2.7
7	Yangmai 3	2.8	Han 4564	2.4
8	Mianyang 11	2.8	Lumai 21	2.0
9	Bainong 3217	2.6	Jingdong 8	1.9
10	Changle 5	2.6	Miannong 4	1.8
11	Zhengyin 1	2.3	Yumai 34	1.8
12	Taishan 5	2.0	Wanmai 19	1.7
13	Dongfanghong 3	1.9	Yumai 70	1.7
14	Aifeng 3	1.8	Yumai 54	1.6
15	E mai 6	1.7	Yumai 69	1.6
16	Zhengzhou 761	1.6	Jinmai 47	1.5
17	Kehan 6	1.5	Jinan 16	1.4
18	A Fu	1.5	Lumai 23	1.3
19	7422	1.4	Mianyang 28	1.3
20	Kefeng 2	1.4	Xuzhou 25	1.3
	Top 5	25.7		20.3
	Top 10	39.5		31.2
	Top 20	56.6		46.4
	Number of wheat cultivars planted	174		497

Source: Compiled by authors

Table 4: Numeraire varieties by province

Province	Check Variety	Year of Release
Anhui	Wumai 1	1968
Beijing	Nongda 139	1969
Fujian	Youyimai	n.a.
Gansu	Fengchan 3	1965
Guizhou	Abbondanza	Introduced in 1956
Hebei	Nongda 139	1969
Heilongjiang	Kefeng 1	1968
Henan	Zhengyin 1	1965
Hubei	Youyimai	n.a.
Inner Mongolia	Kefeng 1	1968
Jiangsu	Zhengyin 1	1965
Shaanxi	Changwu 702	n.a.
Shandong	Zhengyin 1	1965
Shanxi	Nongda 139	1969
Sichuan	Fan 6	1969
Xinjiang	Doudi 1	1969
Yunnan	Fan 6	1969
Jiangxi	E mai 6	1973
Jilin	Kefeng 1	1968
Liaoning	Fengkang 2	1983
Ningxia	Doudi 1	1969
Qinhai	Abbondanza	Introduced in 1956
Shanghai	Wumai 1	1968
Tianjin	Nongda 139	1969
Zhejiang	Wumai 1	1968

Notes: n.a.: not available.
Due to data limitation, we chose Abbondanza an introduced variety from Italy, as the numeraire variety for Guizhou and Qinhai.

Table 5: Benefits from wheat breeding research

	Benefits	Share of production value	Agricultural research expenditures	Wheat research cost CIMMYT
	(millions of 2000US$)	*%*	*(millions of 2000US$)*	
1982	1,132	11.9	246	20.9[1]
1983	1,182	9.9	306	n.a.
1984	1,231	10.2	349	n.a.
1985	1,609	12.7	342	n.a.
1986	1,457	11.6	347	n.a.
1987	1,759	14.7	328	n.a.
1988	1,754	14.5	384	n.a.
1989	2,212	15.1	399	n.a.
1990	2,114	15.0	361	20.3
1991	2,191	18.1	387	n.a
1992	2,603	19.5	454	n.a
1993	2,489	19.4	473	16.4
1994	3,320	24.6	506	n.a
1995	4,010	26.8	503	n.a
1996	5,004	27.1	522	n.a
1997	5,763	25.3	483	n.a
1998	6,097	29.8	573	n.a
1999	4,629	23.5	660	n.a
2000	3,383	22.7		n.a

Source: All figures except for CIMMYT wheat research cost were compiled by authors. CIMMYT wheat research cost data are from Pardey et al (1996, p.45).

Note: Wheat research cost is the sum of breeding and non-breeding wheat research costs.

[1] 1980 data.
n.a. not available

Table 6: Area planted to varieties with CIMMYT parentage in China

Year	Direct adoption	With CIMMYT ancestry	Total
		(percent)	
1982	0.44	13.59	14.04
1983	0.55	12.34	12.89
1984	0.13	8.18	8.31
1985	0.43	5.97	6.40
1986	0.30	4.20	4.49
1987	0.25	8.19	8.44
1988	0.13	7.06	7.20
1989	0.15	7.17	7.32
1990	0.11	7.57	7.68
1991	0.14	6.81	6.95
1992	0.15	8.00	8.16
1993	0.10	8.65	8.75
1994	0.10	8.98	9.08
1995	0.07	7.96	8.04
1996	0.00	6.78	6.78
1997	0.00	6.89	6.89
1998	0.00	5.23	5.23
1999	0.00	3.99	3.99
2000	0.00	2.98	2.98

Source: Compiled by authors

Table 7: CIMMYT's contribution to research benefits

	Binary Parents	All Antecedents	Quadratic	All Credit to Last Cross	Any Ancestor
			(percent)		
1982	8.0	2.4	1.3	0.4	15.5
1983	3.7	1.5	1.1	0.6	6.8
1984	2.9	1.0	0.5	0.1	5.6
1985	2.8	1.2	0.8	0.4	5.0
1986	3.0	1.2	0.7	0.2	5.1
1987	4.0	2.2	1.3	0.2	6.9
1988	3.3	1.5	0.8	0.2	5.5
1989	3.3	1.4	0.8	0.2	5.4
1990	3.6	1.7	1.0	0.1	5.9
1991	2.9	0.9	0.5	0.2	4.6
1992	3.6	1.4	0.7	0.1	6.4
1993	4.2	1.5	0.8	0.1	7.8
1994	3.3	1.2	0.6	0.1	6.2
1995	3.3	1.1	0.6	0.1	5.8
1996	2.3	0.8	0.4	0.0	4.4
1997	2.2	0.8	0.4	0.0	4.2
1998	1.9	0.7	0.4	0.0	3.5
1999	1.7	0.6	0.4	0.0	3.1
2000	1.3	0.4	0.3	0.0	2.4

Source: Estimated by the authors.

Table 8: CIMMYT wheat research benefits and cost

	Research benefits contributed by CIMMYT	CIMMYT total expenditures	China contribution to CIMMYT
		millions 2000 US$	
1982	14.7	33.1	
1983	12.5	32.0	
1984	6.7	37.3	
1985	13.0	36.2	
1986	10.2	38.7	
1987	22.3	39.2	
1988	14.1	44.3	
1989	18.0	43.3	
1990	20.8	40.8	
1991	11.5	41.1	
1992	19.2	39.3	
1993	18.8	37.3	
1994	20.5	32.4	
1995	24.3	29.6	0.09
1996	20.7	32.4	0.09
1997	24.8	31.9	0.08
1998	23.6	33.4	0.10
1999	16.5	38.2	0.12
2000	9.1	39.0	0.41

Source: Research benefits are compiled by the authors. CIMMYT expenditures from 1981 to 1997 are from the CGIAR secretariat; 1998 to 200 expenditures are taken from the CGIAR 199 financial report and the 2000 annual report respectively. China's contribution to IRRI from 1995 to 2000 are from CIMMYT annual report available on line << http://www.cimmyt.org/index.htm>>.

Note: The research benefits reported in the table were computed using the geometric rule

Table 9: Rural Poverty Impact of Wheat Research in China

	Total number of rural poor	Number of rural poor reduced from wheat research	Number of rural poor reduced from CIMMYT research
	(million)	*(million)*	*(person)*
1982	140	3.29	42,582
1983	123	2.75	29,129
1984	89	1.86	10,163
1985	96	2.59	20,931
1986	97	2.24	15,597
1987	91	2.30	29,158
1988	86	1.94	15,592
1989	103	2.87	23,291
1990	97	2.32	22,804
1991	95	2.36	12,443
1992	90	2.57	18,991
1993	80	2.07	15,611
1994	70	2.02	12,463
1995	65	1.98	12,035
1996	58	2.13	8,787
1997	50	2.00	8,597
1998	42	1.68	6,523

Source: Estimated by the authors.