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The Determinants of Plant Variety Protection Applications in China

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A unique data set of the applications of plant variety protection (PVP), morphological characteristics of plants, and institutional sources of all important varieties of rice in three provinces of China have been used to estimate the determinants of PVP applications in China (China passed its Plant Variety Protection Act (PVPA) in 1997). Evidence suggests that both government and private research programmes are responding to economic and policy incentives and investing in plant variety protection as expected by economists. Analysis of the evolution of seed industry suggested that the combination of the new seed law in 2000 and the new plant variety protection regulation has changed the structure of seed industry and provided an important incentive to invest in PVPs both by public research institutes and commercial firms. Finally, there is also some preliminary evidence that private firms have lesser incentives in developing new varieties in contrast to purchasing new varieties.

Keywords: Crop, plant variety protection, China

Strong intellectual property rights (IPR) have been promoted by the United States, Europe and Japan as a way of encouraging innovation, which is an important component of economic growth. These ideas have been enshrined in the World Trade Organization (WTO), which requires its members to have and enforce a patent system and some type of plant breeders' rights legislation. These countries have argued that plant breeder's rights (PBR) will give incentives to private firms to develop varieties of crops that can not be easily made into hybrids. Crops such as maize, which are typically sold as hybrid seed, could also benefit but perhaps not as much as conventional (non-hybrid) varieties because hybrids provide some biological protection from copying.

The Chinese government permits public research institutes to earn income by commercial activities to make up for shortages of their operational budgets.[1-3] Selling plant varieties seems like a natural way for government plant breeding institutes to make money, and these sales provide government institutes with more incentive to develop and distribute varieties to meet farmers' needs. Before the new seed law was decreed in 2000, state-owned seed companies (SOSCs) were the sole legal seed marketing unit of major field crops seed.[4-5] Research institutes had to supply new seed varieties to the SOSCs. SOSCs conducted seed processing, seed marketing and sold the seeds to farmers. All new varieties had to go through a regional test by the provincial extension service to determine if the variety was qualified for extension. The varieties were supplied to province SOSCs which managed the regional test. These research institutes got very little or no revenue from their new variety development except a small amount of revenue from the production and supply of

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breeders seed to the SOSCs. Most revenue from seed marketing was earned by SOSCs.[6-12] Monopoly of the SOSCs to seed markets was formally eliminated with the adoption of the new seed law in 2000. For the first time public research institutes and private firms could participate in the seed market as stated in the law.

China approved its Plant Variety Protection Act (PVPA) in 1997 when the central government decreed the Plant Variety Protection Regulation. Two years later, the PVPA office was set up and started accepting plant variety protection (PVP) applications. PVPA was approved in part because of China's interest in joining the World Trade Organization (WTO) and in part due to the pressure from Chinese plant breeders in public research institutes who saw it as a way to increase their income and their ability to finance plant-breeding research. Economists[5,12] have also argued that stronger IPR would strengthen private plant breeding in China. They were concerned about the slow growth of government research and development (R&D) investment during the 1980s and 1990s, and the near absence of private sector research, which has been a major source of funding for plant breeding research elsewhere in the world.

Others[13] were not so positive about this new law. They were concerned that it would be used by private companies to take over the seed industry and drive up the price of seeds without inducing much change in the amount of research conducted or the amount and quality of new varieties. Some government officials and local seed companies were concerned that foreign multinational companies would use plant breeders' rights to take over the Chinese seed industry.

Past studies on these issues in developing countries were based on quantitative data. In contrast, this study analyses the impact of PVPA based on two data sets, viz. (i) details of about 1500 applications for new PVP submitted to the National Plant Variety Protection office from 1999 (when applications were first accepted) through 2004 and (ii) unique set of information on rice varieties and rice PVPs in three major rice growing areas of China. It allowed building of an econometric model of the factors that influence an institute's decision to obtain PVPs.

Pattern of PVP Applications and Grants of Protection

Tables 1-4, show the trends in PVP applications and grants from 1999 to 2004 throwing considerable light on several key issues. Tables 1 and 2 and Fig. 1 show the dominance of the public sector institutes in the number of applications. The overall trend is rapid growth through 2003 and then a slow drop off in 2004. In the first year, about one third of the applications were older hybrid maize and rice varieties that had been developed and commercialized long before 1999. The number of applications increased from just over a hundred a year in 1999 and 2000 to 349 in 2004. Most PVPs (66 per cent) were applied for by government research institutes. The provincial and prefectural research institutes, which conduct most of the plant breeding in China, applied for the bulk of applications on behalf of the government. The private sector applied for about one third of all PVPs for the entire period. After a large number of applications in 1999 when the private

Table 1 — Number of applications for plant variety rights in China, 1999-2004

	1999	2000	2001	2002	2003	2004	Total	Share of total (%)
Public	57	81	155	207	269	214	983	66
Research institutes	53	74	131	179	247	184	868	58
National	6	1	5	16	33	19	80	5
Provincial	32	43	58	82	80	66	361	24
Prefecture	11	31	65	76	129	91	403	28
County	4	-	3	5	5	8	25	1
University	4	7	24	28	22	30	115	8
Companies and individual	58	32	71	83	137	135	516	34
Seed company	56	27	56	66	115	102	424	28
Individual	2	3	9	11	20	21	66	4
Foreigners	-	1	6	6	2	12	25	2
Total	115	113	226	290	406	349	1499	100

Source: Ministry of Agriculture

Table 2 — Number of PVP applications by crop

Crop	1999	2000	2001	2002	2003	2004	Total	Share of total (%)
Maize	95	58	126	120	120	119	638	43
Hybrid varieties	61	38	94	93	88	108	482	32
Inbred lines	34	20	32	27	32	11	156	11
Rice	15	24	60	81	185	122	487	33
Conventional varieties	2	5	12	21	44	12	96	6
Hybrid varieties	4	4	17	31	52	63	171	11
Inbred lines	9	15	31	29	89	47	220	16
three line hybrids	6	14	28	24	77	44	193	14
s line	4	7	15	8	34	17	85	6
b line	-	-	-	-	3		3	1
r line	2	7	13	16	40	27	105	7
two line hybrids								
s line	3	1	3	5	12	3	27	2
Wheat	-	3	10	30	42	46	131	8
Rapeseed	-	3	5	12	18	12	50	3
Hybrid varieties	-	1	5	5	14	12	37	2
Conventional varieties	-	2	-	7	4		13	1
Soybean	-	13	4	6	7	7	37	2
Cabbage	4	1	5	-	5	1	16	1
Pepper	-	6	1	3			10	1
Peanut	-	1	5	1	3	1	11	1
Pear	-	1	6	10	1	2	20	1
Potato	1	-	2	-	3		6	1
Others[a]	-	3	2	27	22	39	93	6
Total	115	113	226	290	406		1499	100

Source: Ministry of Agriculture

[a] Others include watermelon, tomato, garden sorrel, ornamental flowers, etc.

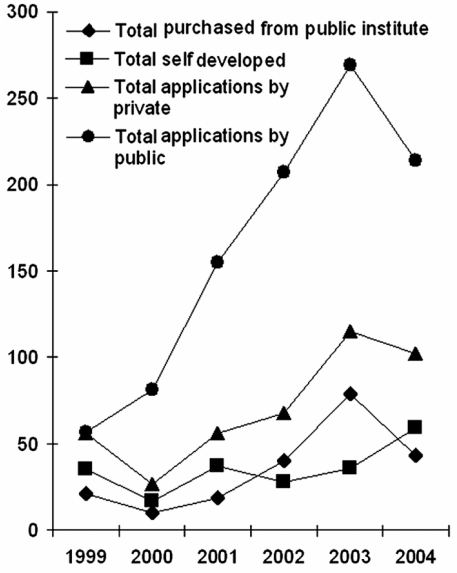

Fig.1 —Applications for PVPs by public and private institutions

sector share was 50 per cent including some old varieties, its share went down to 28 per cent in 2000 and then increased to 39 per cent in 2004.

Foreign companies and individuals played a very limited role in PVP applications – accounting for only 2 per cent of total applications. Some of these applications were by South Korean seed companies. Of large multinational seed companies, only the CP Group, a Thai multinational firm, made few applications for PVPs by the end of 2004.

The trends in applications for crops and types of cultivars are shown in Table 2 and in the applications granted in Table 3. The most striking finding in these tables is the high incidence of applications for hybrids and inbreds for making hybrids compared to a limited number for protection of conventional varieties. Seventy three per cent of all the applications were for hybrids or inbred lines for hybrids. The applications

Table 3 — Number of granted PVP applications by crop

Crop	2000	2001	2002	2003	2004	Total	Share of total (%)
Maize							
hybrid	26	6	55	91	32	210	44.4
Non-hybrid	7	1	29	33	2	72	14.7
Rice							
three-lines							
s line	1		5	15		21	4.3
r line		1	6	10	8	25	5.1
two-lines							
s line	1		1	2		4	0.7
Hybrid	2	1	5	17	13	38	7.7
Non-hybrid	2		3	10	4	19	3.8
Wheat			2	19	7	28	5.7
Soybean			3	16		19	3.8
Cabbage		1	4	2	1	8	1.5
Rapeseed hybrid			3	2		5	1.0
Non-hybrid				6		6	1.2
Pepper				1	2	3	0.5
Peanut				5	1	6	1.2
Pear			1	7	1	9	1.8
Potato			1			1	0.2
Others				8	4	12	2.4
Total	39	10	118	244	75	486	100.0

Source: Ministry of Agriculture

Table 4 —Number of PVP applications by private firms during 1999-2004 of purchased and self-developed varieties

Crop	1999	2000	2001	2002	2003	2004	Total
Maize hybrids and inbreds							
Purchased from public	21	6	10	21	33	29	120
Self-developed	32	13	32	25	23	44	169
Rice							
Conventional varieties							
Purchased from public			3	3	6	1	13
Self-developed		1			3	3	7
Hybrid varieties							
Purchased from public			2	6	16	5	29
Self-developed		2	1		5	5	13
Inbred lines							
Purchased from public		1	4	1	16	5	27
Self-developed		0	1	2	1	2	6
Wheat							
Purchased from public		1		6	5	3	15
Self-developed					3	4	7
Others							
Purchased from public	0	2	0	3	3		8
Self-developed	3	1	3	1	1	1	10
Total purchased from public	21	10	19	40	79	43	212
Total self-developed	35	17	37	28	36	59	212
Total	56	27	56	68	115	102	424

Source: Ministry of Agriculture

Table 5 —Number of new released varieties for rice, wheat, and maize in China, 1991-2003

	Rice			Wheat	Maize
	Sub-total	Non-hybrid	Hybrid	Non-hybrid	Hybrid
1990	150	44	106	102	79
1991	93	19	74	66	58
1992	104	25	79	90	70
1993	125	32	93	54	59
1994	122	39	83	71	63
1995	99	22	77	67	53
1996	101	31	70	55	56
1997	133	53	80	83	66
1998	150	64	86	94	86
1999	180	78	102	86	115
2000	275	162	113	111	172
2001	233	121	112	82	190
2002	242	116	126	106	249
2003	356	183	173	146	397

Source: Ministry of Agriculture

were mainly for maize (a total of 43 per cent of applications, which accounted for 60 per cent of granted PVPs) and rice (33 per cent of applications, 20 per cent granted PVPs). Besides 8 per cent applications were for wheat, rapeseed, soybeans whereas, other crops accounted for less than 3 per cent of the applications.

One reason for the concentration of PVPs in hybrids is that before the Act was passed, the only way that cultivars could be protected from copying was as hybrids. Thus, most of the private and public institutes invested their money in hybrid research. Thus, when the PVPA came along, they had more hybrids ready. In addition, since the PVPA enforcement system in China is still not strong[13] breeders seek to give their hybrid varieties double protection with PVPs and biological protection as hybrids.

In terms of the actual development of new varieties, the public sector is more dominant as shown in Table 1, since most of the private applications and PVPs actually are for varieties which were developed by public breeders. Table 4 shows that half the applications were for cultivars developed by the public sector and then licensed to private firms which then made the PVP application. This reflects the early stage of development of the private seed industry in which the private firms had to rely on cultivars developed by the public research institutes until they are able to develop their own cultivars. It is important to note that the number of cultivars developed by the private sector has been steadily rising since 2000 which indicates that their research programmes are now producing proprietary varieties. The publicly developed varieties are dominated by rice and wheat. Of the 26 rice hybrid applications by private firms, 24 were on hybrids developed by the public sector. Of the non-hybrid rice varieties 12 of 16 varieties were developed by the public sector. Maize is one crop in which there was much private plant breeding which developed and protected their own hybrids.

The decree and implementation of PVP regulation has stimulated development of new varieties. Table 5 shows a sharp increase for new released varieties of hybrid rice and maize since 1999 when PVP application was accepted by the PVP office. The number of newly released rice hybrid varieties increased from 78 in 1999 to 162 in 2000. The number of newly released maize varieties also increased sharply from 86 in 1998 to 115 in 1999 and 172 in 2000.

Protected and Unprotected Rice Varieties

Another way to analyse why institutes and companies protect varieties using PVPA is to examine all varieties of one crop and create a model to understand why they protect some varieties and hybrids but not others. For this data was collected on all rice varieties that farmers grew on more than 100,000 mu (6,667 ha) in Guangdong, Hunan, and Zhejiang provinces during 1999-2002. Rice was selected because of its importance to Chinese agriculture and because about half of the rice area is planted as hybrids and half as conventional varieties. It is also the crop where Koo *et al.*[14] found many more varieties have been protected than seems to be justified by economics. Guangdong, Hunan, and Zhejiang were chosen as the study area because they are large rice producing and important rice research institutes are located in these provinces.

The Model of Protection

Previous researchers on IPR have focused most of their attention on the impacts of IPRs on private investment in agricultural R&D.[9-11] Koo *et al.*[14] is the only study that has looked at the incentives to apply for IPR protection in China and the determinants of these applications. Koo *et al.*[14] assume that the institutions that are applying for PVPs are profit maximizing firms. However, as mentioned above only one-third of the applications were from private firms whereas, two thirds were from government institutes that may be acting as profit maximizers when applying for PVPs, but in addition may also be influenced by other factors that do not influence private firms.

The expected returns for applying for PVPs will depend on the expected sales and price premiums over what the firms could earn selling unprotected varieties, probability that the variety will be successful, and the discount rate. The expected sales, price premiums, and probability of success will be determined by the characteristics of the new variety such as the yields and grain quality. Expected sales and prices will also be influenced by whether the new variety is a hybrid or not. If it is, it will be more difficult for farmers and companies to copy and so innovators may expect larger markets for their seed for longer and may be able to charge a higher price premium.

In addition to the characteristics of the varieties, the characteristics of the institution could influence their expected costs and benefits. For example, private firms were officially allowed to sell rice hybrids until the new seed law in 2000 and they began to establish their seed marketing network during that time. Public research institutes had already established their own seed marketing and information channels in the different regions. The provincial level public research institutes have extended their new developed variety information within the province. The prefecture level public research institutes first extend their new developed variety information in the prefecture.

Finally, provincial governments may have different policies that encourage or discourage public institutes from applying for PVPs in their province. For example, in Guangdong besides the policy that government subsidizes breeders' research budget based on their varieties' sown, breeders receive 1.5 Yuan/ha for their research budgets for the varieties they develop. Part of the budget goes to the breeders' income as bonus. This policy stimulates the scientists to work hard on the variety extension and apply PVPs, in other promote research in the area. In addition, dummy variables for different provinces may capture other unidentified differences in provinces where the varieties were produced.

The conceptual model can be expressed as follows

$$PVP_i=f(X_i, Institution_i, Policy_i, Region_i, T_i,), \quad \ldots(1)$$

Where *PVP* is a variety variable, which equals 1 if an institute applied for a PVP, otherwise the variable is zero, *X* is a vector of the variety's characteristics such as yield, grain quality, hybrid, and type such as *indica* or *japonica*, *Institution* provides information as to whether it is a private or public institution and if public whether it is national, provincial, prefectural institution or university, *Policy* variable corresponds to three policies – probablility of PVPs at the time of release of variety, probablility for private seed companies and seed companies owned by research institutes to sell hybrid rice seed, and the type of institute producing the hybrid, viz., a provincial or prefectural institute in Guangdong, *Region* variable imposes controls arising due to differences in the province in which the varieties were developed and finally, the time variable *T* corresponds to the year in which the variety was first approved for commercial use.

Data and Methodology Adopted in the Current Study

The data consists of observations on 357 varieties that were planted by the farmers in the three study provinces between 1999-2002. The varieties were classified as protected with PVP or unprotected (a hybrid variety was counted as PVP if either an inbred parental line or the hybrid itself was protected). The characteristics included in the data set were varieties' yield potential, grain quality, growing season, rice type (*indica*, *japonica*, and *glutinous*), and variety type (conventional variety and hybrid variety). The variety's yield potential and grain quality data came from the variety's regional experiment results. Grain quality includes normal grade (including poor quality and normal quality), high quality grade, and super quality grade. The growing seasons were early season rice, middle season rice, or late season rice.

Information was also collected on the variety's source (breeders). Public research institutes included national level research institutes (China's National Rice Research Institute, CNRRI, and Hunan Hybrid Rice Research Center, HHRRC), provincial level rice research institutes, prefecture level research institutes, and universities. The private sector included seed companies (public and private), individuals, and county level research institutes. Here, it is to be noted that most county level institutes operate as private plant breeding and seed companies and receive almost no money from county governments. PVPs which were applied for by companies but bred by public research institutes, were counted as private varieties because application and maintenance fees are normally paid by seed companies.

Estimation Procedure

Because the value of PVP variable is 0 and 1, the probit model is adopted in the estimation. To estimate the PVP function, yield is the only continuous

variable. Quality is rated from medium, to high and finally super quality for *indicas* and *japonicas*. High and super quality is given the value 1 with average as the base. The hybrid and *indica* variables are dummies with value of 1. There are more control variables for the different types of public research institutes including national level, provincial level, prefectural level, and universities with private as the base. The private sector includes seed companies and individuals but since individuals have fewer PVP applications, they have been merged with seed companies. As mentioned above, private also includes a few county seed companies because they are essentially private enterprises. The PVPA/seed policy variables are included as one of the variables because PVPA regulation implementation and as a consequence of which research institutes and private firms were allowed to market their own hybrids occurred in the same year 2000. The variety is assigned a value of 'one' if the variety was developed after 1999 when the PVPA regulation was implemented; otherwise it was assigned a value of 'zero'. The location where the variety was bred was also included, with Hunan, Zhejiang and other provinces as 1 and Guangdong as 0.

Estimation Results

The results of the PVP application equation as shown in Table 6 demonstrate reasonable accuracy of the model. The summary statistics are quite good for model estimation. Most of the signs of the estimated coefficients are statistically significant and have signs that conform to expectations. The analysis showed that research institutes when deciding to apply for a PVP, take into consideration the characteristics of the varieties that will decide the adoption and the price premium of the protected variety. Higher yield and super quality are both positively related to the probability of application. *Indica* varieties which generally receive lower prices in China than *japonicas* have a negative influence on the probability of applications. Finally, hybrids, which increase the value of seed sales over conventional varieties by encouraging farmers to purchase seed every year, have a large positive impact on the probability of application. In addition, hybrids make it somewhat

Table 6 —Estimation of plant protection application model by probit method

	Model I		Model II	
	Coefficients	Standard Err	Coefficients	Standard Err
Constant	-5.38***	1.33	-5.01***	1.20
Variety morphological characteristics				
Yield (tonne/ha)	0.35**	0.16	0.37***	0.14
Grain quality				
High grain quality	0.09	0.24	0.10	0.23
Super grain quality	1.44***	0.37	1.50***	0.36
Rice type				
Middle rice	0.25	0.34		
Late rice	0.56**	0.26		
Hybrid variety (by variety type)	2.16***	0.44	2.27***	0.43
Indica (by rice type)	-0.35	0.52	-0.51	0.50
Institutions (private co.=0)				
National	0.74**	0.33	0.79**	0.33
Provincial	-0.45	0.31	-0.50*	0.31
Prefecture	-0.05	0.31	-0.14	0.30
University	-0.07	0.36	-0.17	0.35
Policy dummies				
PVP/Seed policy	1.18***	0.24	1.19***	0.23
Variety source (Guangdong=0)				
Hunan	-0.74**	0.38	-0.83**	0.37
Zhejiang	-2.18***	0.58	-2.19***	0.57
Other provinces	-0.39	0.30	-0.51*	0.28
Observations	357		357	
Pseudo R	0.4005		0.3867	
Log likelihood	-105.9		108.36	
LR Chi	141.54***		136.65***	

The figures in the parentheses are t ratios of estimates. ***, **, * denote significance at 1%, 5% and 10%, respectively. The model includes two province dummy variables to control for province-specific effects, but the estimated coefficients are not included for brevity.

more difficult for other companies to copy, produce and market the hybrids that you developed. Since PVPA regulation enforcement in China was weak during the period covered by this research, breeders probably viewed PVPA protection as supplemental to hybrid protection, which was their primary means of protecting their intellectual property.

The regression analysis also showed some differences in the propensity to apply between different breeding organizations. The positive and significant coefficient on the national level public research institute implied that compared to seed companies, the Hunan Hybrid Rice Research Center and the Chinese National Rice Research Institute are more likely to apply for protection than private companies or other types of public research institutes. The coefficients of provincial institutes, prefecture level research institute and university are negative and statistically insignificant.

Not surprisingly, the coefficient of PVPA/seed policy variable is positive and highly significant reflecting that the PVP policy stimulates breeders to apply PVP for new developed varieties. Other two coefficients, Hunan and Zhejiang province dummies were all negative and insignificant in comparison to Guangdong. This implies that holding everything else constant Guangdong institutions still had a higher propensity to seek PVPs than scientists in other provinces because they had double incentives to apply PVPs.

Conclusion

The above analysis has suggested that both government and private research programmes are responding to economic and policy incentives and investing in plant variety protection as economists would expect profit maximizing firms to invest, although it is not apparent if such investment is optimal. This suggests that these institutions would also respond to the incentives provided by the PVPA and invest in research and technology development.

It is also implied that the combination of the new seed law in 2000 and the plant variety rights law has changed the structure of the seed industry and provided an important stimulus to investments in plant breeding research and seed production and marketing by both public research institutes and Chinese commercial firms.

The tabular analysis of the PVP application data on all crops up to 2004 suggests the following: (i) research institutes and firms are responding to these incentives, (ii) PVP applications from the private and public sector are growing rapidly, (iii) public sector is still the major developer of new cultivars in all crops except maize, where local private firms dominate and (iv) since most of the applications are for hybrids, PVPA is not yet stimulating much research on conventional varieties.

The regression analysis of the use of PVPA to protect rice varieties shows that although most of the varieties were developed by the public sector, they are more likely to apply for protection for varieties that have higher yields, higher quality, and are hybrids. The national level rice research institutes are more likely to apply for protection than private companies or institutes from other levels of government. This may also be rational economic behaviour because as national institutes they expect to have much larger markets for their varieties than other institutes. This expectation is based on the fact that they have national markets for their varieties already and are expecting to have national markets for future varieties. The regression analysis also shows that institutes respond to policy incentives such as the incentives for applications by the Guangdong government.

The evidence available at this early stage, post implementation of PVPA, suggests that Chinese research institutions are investing money in response to the economic incentives. This may also lead to investing their marketing and research money so that in future PVPs will lead to the development of new, improved varieties of crops.

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