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THE ECONOMICS OF GENERATING AND MAINTAINING PLANT VARIETY RIGHTS IN CHINA

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ABSTRACT

Notwithstanding the ambiguous research and productivity promoting effects of plant variety protections (PVPs), even in developed countries, many developing countries have adopted PVPs in the past few years to comply with their Trade-Related Aspects of Intellectual Property Rights (TRIPS) obligations. Seeking and maintaining PVPs reserves options to an expected revenue stream from the future sale of protected varieties, the value of which varies for a host of reasons. In this paper we empirically examine the pattern of plant variety protection applications in China since its PVP laws were first introduced in 1997. We place those PVP rights in the context of China's present and likely future seed markets to identify the economic incentives and institutional aspects that influence decisions to develop and apply for varietal rights.

Key Words: intellectual property rights, crop improvement, option value, seed markets

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1. INTRODUCTION

The development and spread of new and improved seed varieties has been the basis for productivity improvement in agriculture since crops were first domesticated about 10 millennia ago. For most of that time, new varieties were largely treated as common property, shared freely among farmers and countries and generating billions of dollars of benefits worldwide.[5] The era of free and unencumbered access to new crop varieties appears to be passing.

Since the coming into force of the World Trade Organization's (WTO) Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement on January 1, 1995, 120 countries lodged notifications of their compliance with all or part of the Agreement by late 2002 (WTO 2002).[6] Nonetheless, many of the world's poorer countries are yet to

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[5] Nonetheless, a few countries sought to monopolize some genetic resources as described by Wright (1997).
[6] Developed countries were required to implement most provisions of TRIPS within one year of the Agreement taking affect. Developing countries were given a five-year period to comply while the least developed countries had 10 years to put the provisions in place, subject to review. Any country failing to enact and enforce the required forms of property protection is subject to trade sanctions under the reciprocity and trade settlement dispute clauses in the WTO Agreement. Even now, under national patent law, trading products with a country that is in violation of local forms of property protection makes the trade subject to sanctions and fines within that local jurisdiction (Binenbaum et al. 2003).

be TRIPS compliant, and the 30 least-developed WTO member countries have until January 2006 to become so.[7]

While many rich countries focused on the copyright, trademark, and the pharmaceutical patent aspects of the TRIPS Agreement, the intellectual property (IP) provisions concerning agricultural innovations, especially those involving crop varieties, were of special interest to developing countries. Under TRIPS, the status of plants as patentable subject matter is unclear and controversial. Moreover, members may exclude from patentability "plants and animals other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes."[8] In fact, only the United States and a few other countries have opted so far to extend the scope of utility patents to encompass plants.[9] Protection of plant varieties, however, must still be provided "either by patents or by an effective *sui generis* system or by any combination thereof."[10]

Like many other countries, China has, at least for now, taken the *sui generis* route to TRIPS compliance, passing a plant variety protection law in 1997. At this early stage of its implementation, a substantial number of questions arise. What is the specific nature

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[7] The WTO distinguishes between developed, developing, transition and least-developed countries. Member countries declare for themselves if they are "developed" or "developing" subject to challenge of other WTO members. (There are 70 developing and transition country members as of January 2003.) Least-developed countries are those countries so designated by the United Nations Conference on Trade and Development (UNCTAD). There are currently 49 least-developed countries on the UNCTAD list, 30 of whom are members of WTO.

[8] Article 27(3)(b) of TRIPS Agreement, which is currently being reviewed by members of the WTO.

[9] Henson-Apollonia (2002) estimates that by October 2002, there were 114 patents with claims to novel plants issued in the United States so far that year.

[10] *Ibid.* Plant varietal or breeders' rights are examples of so-called *sui generis* rights: that is, rights designed for a specific field of technology. These property rights are harmonized internationally through the UPOV (International Union for the Protection of New Plant Varieties) Convention. The number of UPOV members increased rapidly in the 1990s after the TRIPS Agreement came into force, from 20 members at the end of 1992 to 51 members by October 2002 (about half of whom are non-OECD countries).

of these intellectual property rights and the institutional arrangements in China to confer and protect them? To what extent are intellectual property rights on crop varieties being sought, and by whom? And what are the likely long-term effects of these rights on the amount, structure and conduct of agricultural R&D in China? Answers to these questions have potentially profound long-run consequences on the rate and direction of inventive activity in China's agriculture. While all of these questions are amenable to empirical investigation, unfortunately data are sparse, not least because the history of implementing varietal rights in most developing countries, including China, is short.[11]

Our intent here is to document the emergence and current status of plant varietal rights in China and assess their likely longer-term effects. We include, but go beyond, a consideration of the legal aspects of varietal rights in China to provide an empirical assessment of their extent and the institutional context that lay behind this form of property protection. An economic assessment of China's seed markets is also provided as a basis for investigating the incentives to seek and maintain varietal protection for new crop varieties.

2. ECONOMICS OF VARIETAL PROTECTION

Establishing, maintaining and exercising varietal rights is an economic decision made by breeders of new varieties subject to intellectual property protection. Plant breeders will seek or maintain intellectual property protection if the expected rent from a variety exceeds the cost of securing and exercising the rights to that variety. If

[11] Prior attempts to analyze the economic effects of PVP legislation deal mainly with the United States and include Perrin et al. (1983), Butler and Marion (1985), Knudson and Pray (1991), and Alston and Venner (2002). Diez (2002) analyzes the situation in Spain.

information on the future stream of revenues from selling a variety were complete, plant breeders would simply calculate the present value of the expected rent and the corresponding present value of the costs to make a one-time, up-front decision about securing and maintaining varietal rights.

While the costs of gaining and securing plant variety protection are known with reasonable surety, the sequence of future returns from a varietal right is highly uncertain for many reasons. There are uncertainties about the size of the appropriable seed market for a given crop, the probability of commercial success of the protected variety, and the extent of enforcement of assigned property rights. Consequently, breeders typically make annual renewal decisions, preserving the right to pay renewal fees and exercise their exclusionary rights in future periods. Thus applying for (and subsequently renewing) PVP rights is a way of reserving the rights to potential future revenues, even if revenues in the short term are negligible.

The expected value of holding plant variety rights consists of the current returns captured from the coming year and the option to renew the right in the subsequent year. If the right is not renewed, it lapses and the value of the variety to the breeder (but not necessarily others) is zero. Following Pakes (1986), the decision problem of a breeder to apply for or renew a varietal right at the beginning of the t^{th} period is expressed as

$$\Pi(t) = \max\{0, r(t) + \beta E[\Pi(t+1) \mid I(t)] - c(t)\} \qquad \text{for} \quad 1 \le t < T \tag{1}$$

where $\Pi(t)$ is the expected discounted value of varietal protection at the beginning of the t^{th} period, $r(t)$ is the return from the right during the coming t^{th} period, β is the discount factor, $I(t)$ is the information held at time t about the appropriable revenues from

maintaining rights to the variety in the future, $c(t)$ is the costs of reserving the exclusionary rights (i.e., the application fee or the subsequent costs of renewing and exercising ones exclusionary rights), and T is the statutory limit to PVP lives. If the total benefit from holding the varietal right (the sum of current returns and the discounted value of the option) is greater than the cost $c(t)$, breeders will opt to apply for or renew varietal rights.[12] Option values are zero at the end of year T when the right expires.

Plant breeders often apply for or renew protection even if the current return $r(t)$ is negligible because they expect the potential revenue from the varietal right to be higher in future years. A distinguishing aspect of most PVP laws is the "breeders' exemption," making it possible for others to use the protected variety in their own breeding programs and thus undermining the potential future revenue streams of the protected variety (as desired traits from the protected variety are incorporated into new and in some aspects, superior varieties). In contrast, it is an infringement subject to legally enforced penalties to use varieties protected by patents to breed new varieties, absent assignment of use rights by the patentee. Thus holders of PVP rights have less control and surety over the revenue streams realized from their rights than patent holders.

The current return depends on the currently appropriable size of the seed market and the seed price premium of the protected variety over other varieties of the same crop. The option value placed on future revenue streams depends on the expected size of the appropriable seed market, the probability of successfully commercializing and appropriating rents from the protected variety, the rate of varietal obsolescence, and the

[12] Generally, the option value from renewing varietal rights is non-negative and decreases over time as uncertainty regarding the appropriable stream of future revenues is reduced with better information. See Pakes (1986) for technical details.

discount rate. Varietal obsolescence has both biological and economic-cum-institutional dimensions. Biologically, varietal performance (in terms of pest or disease resistance as well as resilience to abiotic stresses) tends to deteriorate over time,[13] while the economic and institutional aspects of varietal obsolescence involve the extent of legal reuse of farmer saved seed and the illegal spread or piracy of reproduced versions of the protected seed and vary among geopolitical and legal jurisdictions. Varietal obsolescence (or, conversely, the superiority of the protected variety over others) affects both the size and longevity of the price premium commanded by the protected variety, while effectively enforced PVP rights determine the overall magnitude of the rents that can be appropriated by varietal right holders.

3. GENERATING, REGULATING, AND MARKETING IMPROVED SEED

CHANGING R&D MARKETS[14]

Agricultural research in China has been and continues to be dominated by public agencies, staffed, operated, and largely financed by government.[15] Provincial institutes account for more than one-third of the government agencies and over half the public spending, with the remaining public expenditures almost evenly divided between national and prefectural institutes. Some private research is conducted by local and multinational firms, but is still embryonic.

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[13] This diminution in yield (or, more generally, productivity) performance may not occur uniformly in all locations, so the relative superiority of a variety can, and usually does, have strong agro-ecological determinants.

[14] Fan and Pardey (1992, 1997) describe developments in Chinese agricultural R&D through to the early 1990s. Fan et al. (2003) and Huang et al. (2002) provide some details of the more recent developments.

[15] The amount of public research spending in China is significant in global terms, accounting for about 10 percent of public agricultural R&D spending worldwide in the mid-1990s (Pardey and Beintema 2001).

As part of a broader effort to rein in government spending as well as encourage the development and commercialization of new technologies, the Chinese government launched a series of reforms concerning the funding and management of agricultural research in the mid-1980s. Public research institutes that hitherto relied solely on direct funding from government, almost entirely in the form of block grants, were now required to compete on a project-basis for some of their funding. They were also encouraged to raise some of their own revenues, giving rise to the establishment of "development firms" owned and operated by the respective research institutes. Initial efforts were fraught with management problems, exposed research institutes to potentially ruinous business risks, and often involved institute staff in undertakings only remotely related to research.[16] Since the mid-1990s many public research agencies began more concerted efforts to exploit their research base to commercialize new technologies involving seeds, livestock vaccines, agricultural chemicals, machinery and so on.

Some institutes have forsaken commercializing their own technologies via development firms, opting instead to focus on research and using others to bring their innovations to market, often on a contractual basis. Other institutes have evolved their commercial companies beyond in-house operations to limited liability shareholding companies, many times retaining controlling interests in these companies although some of the larger firms have recently been floated as public offerings to mobilize additional

[16] For instance, the nationally recognized research institutes of Taihu and Lixiahe in Jiangsu province produced mineral water and set up a plant manufacturing auto spare parts, respectively. In 1988, the China National Rice Research Institute in Hangzhou launched a business to manufacture monosodium glutamate that lost more than 10 million yuan, saddling the institute with many legal battles as a result (Fan et al. 2003).

capital.[17] The companies spun-off from public research institutes now compete against other agribusiness firms, mainly state-owned seed, food, agricultural, chemical and machinery enterprises facing similar, if not even more intense pressures to wean themselves from government funding. Some of the state-owned agencies have also become shareholding companies in their own right, and a few have even begun developing their own research capacities—the beginnings of domestic private agricultural R&D in China.[18] The amount of R&D collectively conducted by these firms is not known with any precision but is thought to be comparatively small, perhaps less than 5 percent of total agricultural R&D.

Although it appears technologies developed by foreign firms played a key role in promoting agricultural productivity in some sectors such as chemicals and machinery (Rozelle et al. 1999), their investment in locally conducted, seed-related research has been small, mainly because of constrained commercial seed markets, ineffectual intellectual property rights, and various government regulations. Monsanto and Delta and Pine Land established joint ventures with local operations but are only authorized to sell genetically modified (GM) cotton varieties in Hebei and Anhui provinces.[19] Pioneer Hi-Bred International (now part of Dupont) began operations in China about a decade ago, opening a breeding station and then setting up a seed company in Northeastern China about five years ago to screen, adapt, and demonstrate maize and soybean varieties

[17] For example, the seed company of the Institute of Vegetable and Flower (IVF) of the Chinese Academy of Agricultural Science established in 1990 takes promising hybrid vegetables lines developed by IVF and conducts varietal demonstrations targeted to various markets, then produces and markets the seed commercially. Since 1990 the seed company has earned more than 10 million yuan annually, returning 90 percent of its earnings to IVF, which in turn allocates 10 percent of this income to commercially successful breeders with the rest used to cover general research or operational costs (Fan et al. 2003).

[18] Government has selectively encouraged moves toward shareholding companies by way of exempting some firms from some taxes and providing low-interest loans.

[19] Notably, cotton is not included in the list of crops subject to PVP protection in China.

(although apparently with no commercial releases to date), while the Cha Thai Group from Thailand set up a joint venture in Hubei province to develop and market improved hybrid maize and rice varieties. However, these operations are hampered by government refusal to allow foreign firms and their local affiliates to directly compete with domestic seed companies in certain provinces. Foreign firms are also presently prohibited from importing and directly selling hybrid rice and maize seeds produced outside of China.[20] However, indications are the government will continue liberalizing these markets, perhaps becoming fully WTO compliant in four to five years, after which local seed suppliers will be exposed to significant competitive pressure from foreign firms. The little local agricultural R&D done to date by multinational firms is limited to hybrid vegetable and sunflower seeds and genetically modified cotton.

CHANGING SEED REGULATIONS AND MARKETS

Developments in China's commercial seed market are inextricably intertwined with changes in the supporting R&D markets and regulations. Prior to the 1989 Seed Administration Regulation, agricultural seed markets were almost the sole purview of state-owned seed agencies. These seed agencies monopolized all seed-related operations, including seed testing, production, quality control, and the distribution of new seeds typically obtained free of charge from public research institutes. They were also responsible for administering seed regulations in their respective local jurisdictions, meaning that the structure of the Chinese seed market until the 1980s can be characterized as a series of regional monopolies under state government control.

[20] Vegetable seeds can be imported and sold directly, as can hybrid maize and rice varieties developed outside China but bulked up within China. Presently, foreign firms can only operate as a minority partner with a Chinese controlled joint-venture firm.

Although the market is still dominated by state-owned seed companies, the general agricultural market reforms introduced during the 1980s along with the 1989 Seed Administration Regulations significantly changed the market opportunities for input suppliers, including those producing and distributing seed, and began to erode the local monopoly positions held by the state agencies (Pray et al. 1998). First, the regulatory roles of the former seed agencies were separated from their seed business operations, which are now handled by state-owned seed companies or various other types of agribusiness firms. In addition, a plethora of private seed companies (usually small-scale family operations) restricted to selling vegetable seeds also emerged during the 1990s.[21]

The 1989 Seed Administration Regulations also gave legal status to the seed development firms emerging from the provincial, prefectural, and some national research institutes, although initially their roles were restricted. For example, seed development firms were initially restricted to selling the hybrid varieties of rice and maize developed by their respective research institutes. Many of these firms lacked sufficient land, expertise, and operating capital to economically produce and distribute their own seeds and thus relied on state-owned seed companies or large farms for these operations. This is still so, although the relationship between the research institutes and the state-owned seed companies is changing considerably. Notably, the state-owned seed companies no longer have generally free access to the new varieties emanating from the public institutes. As a result, some of the state-owned seed companies (and especially those operating at the county and township levels) have opted simply to produce commercial quantities of seed

[21] We estimate there were around 2,700 state-owned seed companies in 2000, and about twice as many private (usually small-scale) seed companies.

on a contract basis, leaving the sale of that seed to others. Others, mainly but not exclusively operating at the provincial level, are specializing in seed marketing and distribution, and a few of the seed companies have also begun their own breeding programs.

Market barriers were lowered even further with the implementation of the 2000 Seed Law that supercedes the 1989 Seed Administration Regulation. The 2000 Seed Law involves no restrictions on the production of seeds other than a requirement for a license to produce hybrid maize and rice seed issued by a provincial or national agency.[22] Seed development firms or private seed companies can now compete with state-owned seed companies in many types of crops, and several firms have grown rapidly and command sizable market shares. This growth, including the merger or consolidation of various operations, has led to specialization among some firms (in terms of functions like seed production, marketing, or distribution) and the scale economies that brings, and restructuring and integration on the part of other firms seeking scale and scope economies.[23] Some of the bigger firms have become shareholding companies hoping to become more competitive with or engage in joint ventures involving multinational companies, thereby providing access to more advanced management skills and research capacity.[24]

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[22] The intent of these licenses is to maintain seed quality, and so licenses are restricted to larger seed operations with in-house technical support. The provision of vegetable seed does not require a license.
[23] For instance, several years ago the Delong Group, with interests in machinery, financial services and telecommunications, began purchasing several state-owned seed companies in Anhui, Xinjiang, Shandong, and Inner Mongolia provinces, and in the process become one of the country's largest seed companies.
[24] For example, the Hunan Academy of Agricultural Sciences founded a seed company three years ago, Yuan Longping High-tech Agriculture Co. Ltd. (trading on the name of their renowned senior scientist, Yuan Longping, often called the "father of hybrid rice" in China), which purchased the seed distribution systems of several state-owned seed companies. This company has now evolved into a shareholding

4. PLANT VARIETY PROTECTION IN CHINA

INSTITUTIONAL ASPECTS

Spurred by preparations for entry to the WTO, China began significantly revising its laws regarding patents, copyrights, trademarks, and other forms of intellectual property about a decade ago, including signing on to various international intellectual property conventions (Maskus and Dougherty 1998). Among the latest in a series of policy and legislative reforms affecting agriculture[25] and agricultural R&D in China over the past several decades is the extension of intellectual property rights to include agricultural innovations. China became a member state of the UPOV Convention on April 23, 1999 after enacting its "Regulations of the People's Republic of China on the Protection of New Varieties of Plants" law (hereafter the PVP law) in March 1997. The law came into legal force on October 1, 1997 and PVP applications were accepted beginning April 1999.

China's PVP law conforms to the 1978 Act of the UPOV Convention. Like similar laws implemented elsewhere, the Chinese PVP law grants protection to varieties that are new, distinct, uniform and stable.[26] Holders of a PVP certificate have the legal right to exclude others from commercializing protected varieties for a prescribed length of time: 20 years since the date of grant for vines, forest trees, fruit trees, and ornamental

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company, and moved well beyond its initial focus on hybrid rice to specialize on pepper seed which presently accounts for the preponderance of the firm's income.

[25] Perkins (1988), Sicular (1988), Lin (1990), and Fan et al. (2003) provide perspectives on the considerable policy changes affecting Chinese agriculture, beginning with the moves to de-collectivize production initiated in late 1978.

[26] More specifically, to qualify for PVP protection in China a variety must be part of the botanical genera and species in the national list of protected varieties, not have been sold prior to the filing date of the application, be noticeably distinguishable from other known varieties, be uniform in relevant features or characteristics after propagation, breed true to type after repeated propagation, and have an adequate denomination (i.e., complies with compulsory seed certification and registration requirements).

plants, and 15 years for all other plants, including food, oil and fiber crops. Exceptions to the exclusionary rights are made, however, for both breeding and other scientific research (breeders' exemption) and for the use of seeds saved by farmers for replanting (farmers' exemption).

Two separate administrative authorities implement China's plant variety protection laws. The State Forestry Administration is responsible for forestry including forest trees, bamboo, woody plants and dry fruit trees, while the Ministry of Agriculture is responsible for all agricultural plants, including grains, vegetables, edible fungi, and grasses. On April 27, 2000, the State Forest Administration published its first and so far only "Gazette for Protection of New Varieties of Plants (Forestry)," which included information on 13 PVP applications for forest trees. Since then information on the applications for and granting of these PVP rights are scattered throughout various journals and newspapers.[27] In contrast, the Ministry of Agriculture has published a "Variety Protection Gazette for Agricultural Plants" on a bi-monthly basis since April 1999.[28] This study deals with the protection of agricultural plant varieties, drawing on data compiled from various issues of the Ministry of Agriculture's PVP Gazette.

Upon receiving an application, the relevant authority is required by law to complete a preliminary examination within six months. If an application is then deemed acceptable, information such as the date of application, crop type, description of the variety for which protection is sought, and the names of the applicants are published in

[27] By early 2002, about 190 applications were filed for the varietal protection for forest trees, of which 48 applications were granted (Faji Huang, Deputy Director of the PVP Office for Forest, personal communication).

[28] In July 2000, the gazette was renamed from "Plant Variety Protection Gazette" to "Variety Protection Gazette for Agricultural Plants," hereafter called the PVP Gazette.

the PVP Gazette. For those applications passing preliminary examination, the authority conducts a substantive examination of the distinctness, uniformity, and stability of the variety in question. The granted rights prevail from the date of issuance of the PVP certificate, and like PVP laws prevailing in many other countries, each new right pertains to a single new variety.

Administrative procedures for protecting agricultural plants are handled by the Office of Variety Protection for Agricultural Plants within the Ministry of Agriculture. In early 2002, the office had a total of 12 full-time employees handling basic assessment and administrative tasks, with four staff involved in pre-examination activities and the rest engaged in testing and substantive examination.[29] The office devolves most of its biological evaluation to various testing centers, one main center located in Beijing plus 14 other testing sites scattered throughout the main agricultural areas of China. Other procedures such as rejection of application, denomination of new varieties, and re-examination of applications are handled by an ad-hoc committee, the Plant Variety Re-examination Committee, which is convened when needed by senior administrators of the Ministry of Agriculture (Chen 2002).

Once a PVP certificate is issued, the right holder is required to pay a series of annual fees over the period of protection to maintain the rights. The 1999 fee schedule administered by the Ministry of Agriculture (Table 1) is still the applicable fee schedule for agricultural plants. Establishing and maintaining protection for a full 15 years costs

[29] By way of comparison, in 2001, the PVP office of the United States employed 12 staff, including a commissioner, 9 examiners and 2 support staff.

the right holder 47,089 yuan or US$5,687 for each plant variety right granted (excluding the administrative and other costs of submitting an application). More than 85 percent of the total fee is for maintaining the right. Establishing and maintaining PVP rights in China is costly, even by rich country standards. For example, PVP fees in the United States totaled US$2,450 per variety (including a $300 application fee and a $2,150 examination fee) in 1999 and there is no annual maintenance fee.[30]

Table 1--Costs of establishing and maintaining plant variety rights in China

Fees	Chinese yuan	U.S. dollars	
		Official market exchange rate[a]	Purchasing power parity rate[b]
Establishing Rights			
Application fee	1,800	217	994
Examination fee	4,600	556	2,541
Maintaining Rights			
		(*cost per year*)	
Years 1-3	1,500	181	829
Years 4-6	1,950	236	1,077
Years 7-9	2,535	306	1,401
Years 10-12	3,295	398	1,820
Years 13-15	4,283	517	2,366
Years 16-18	5,567	672	3,076
Years 19-20	7,237	874	3,998
Total maintenance fee (15 years)	40,689	4,914	22,480
Total maintenance fee (20 years)	71,864	8,679	39,704
Total cost			
Agricultural plants (15 years of protection)	47,089	5,687	26,016
Forestry (20 years of protection)	78,264	9,452	43,240

Source: China Ministry of Agriculture (1999)
a. The 1999 exchange rate used here was US$1 = 8.28 yuan.
b. The 1999 purchasing power parity rate is US$1 = 1.81 yuan World Bank (2001).

[30] Similarly, Brazil charges US$348 to establish PVP rights and US$2,609 to maintain these rights for 15 years (Koo et al. 2003).

Given the substantial differences in price levels between the United States and China, purchasing power parities (PPPs) instead of market exchange rates provide an alternative and somewhat more realistic basis for comparing PVP costs internationally. Using PPPs to denominate costs in terms of international dollars (rather than the U.S. dollars obtained when market exchange rates are used), the total cost of establishing and maintaining PVP rights in China for a single variety for 15 years is $26,010 in 1999 prices (Table 1, right-hand column). This is almost five times more than the corresponding costs when using official market exchange rates to convert currencies, and more than ten times the corresponding costs in the United States. Although insufficient time has elapsed to examine the renewal behavior of rights holders, the exceptionally high maintenance costs suggest that right holders in China will maintain their rights only if significant revenue is expected from the protection in the future.

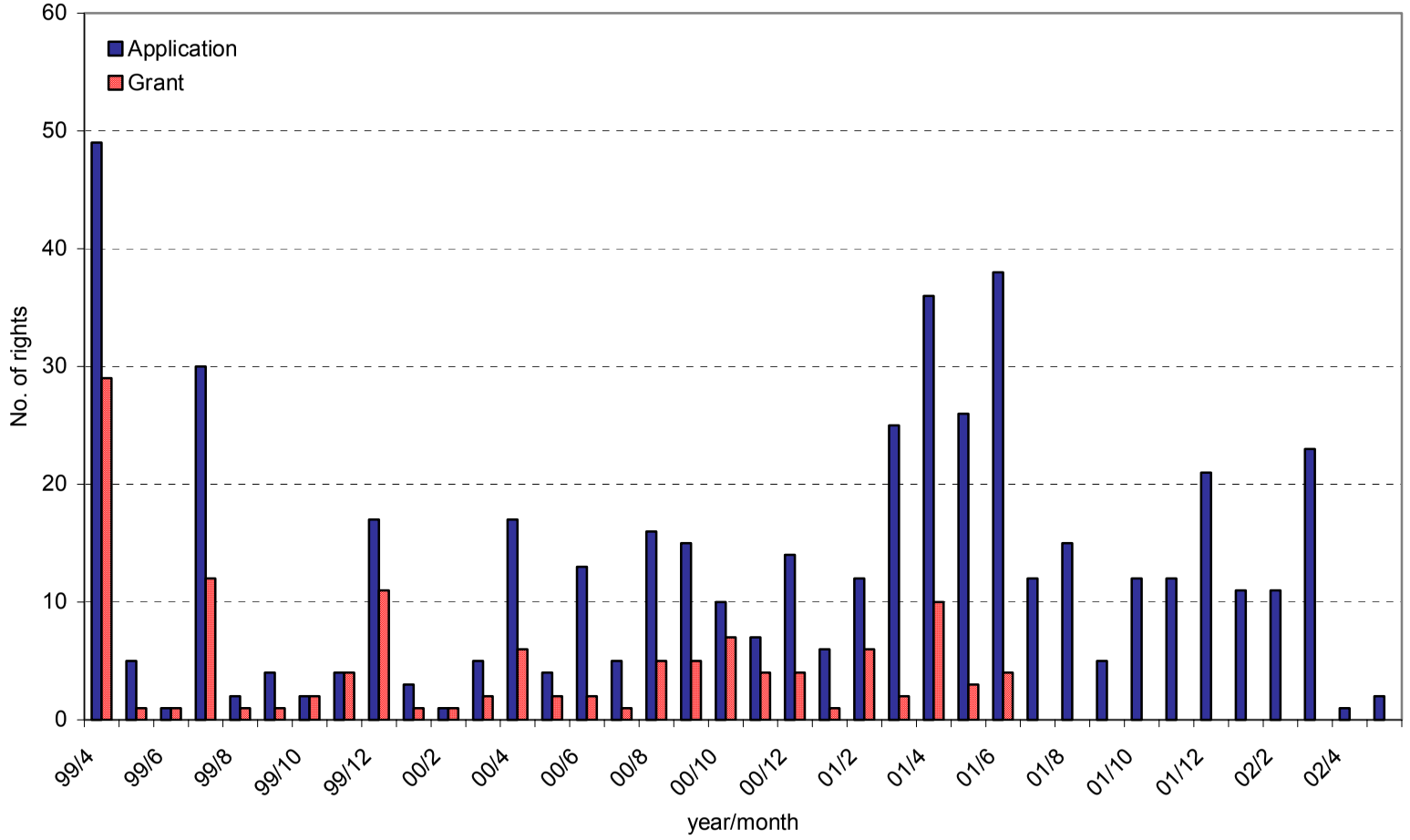
THE PATTERN OF VARIETAL PROTECTION

A total of 492 PVP applications for agricultural plants were lodged and published in the PVP Gazette through September 2002. Figure 1 shows the number of PVP rights sought and granted on a monthly basis from April 1999 (when the first application was lodged) to May 2002 (the last published application for which we have data). An average of 13 applications were made monthly, but with substantial variation around the average and indications of an upward trend over time. The initial spike of 49 applications in April 1999 most likely reflects the latent demand for varietal rights for material developed prior to the implementation of the PVP law. The reported reduction in the number of applications in early 2002 may be more apparent than real, reflecting lags between the

date of application and its publication (which averaged about 6 months in our sample). Only 128 PVP rights, about 26 percent of the total of 492 applications, were granted by September 2002. Almost half the applications lodged in 1999 are yet to be granted, although some may have been rejected or withdrawn in the interim.[31] The average grant lag for granted applications is about 17 months from the date of application.

[31] By way of comparison, during the period from January 1971 to December 2001, a total of 7,199 PVP applications were made in the United States, of which 4,960 certificates were granted for more than 190 crops.

Figure 1--Monthly applications and grants of plant variety rights



Source: Compiled by authors from China Ministry of Agriculture (various issues)

Based on an assessment of the early wave of PVP applications, Tong (2002) argued that the number of applications in China was limited because of a lack of appreciation of the role of property rights in a market economy, the high cost of gaining protection, the uncertain scope of protection, and complicated and costly enforcement processes. Some of these concerns are supported by our data, others are moot given the rapid changes afoot in the Chinese seed sector and some are questionable. In particular, the basic premise that the initial number of PVP applications was unduly constrained by Chinese-specific factors is debatable and the number is not out of line with the historical experience in the United States. Although there were an average of 347 PVP applications per year in the United States during the past ten years, there were only 121 applications per year for the decade following the passage of the U.S. Plant Variety Protection Act in 1970 (compared with 156 per year for China).

Plant variety rights were sought for 15 different crops since 1999, and the number of crops for which varietal protection was sought has increased over time (Table 2).[32] Applications were lodged for only 5 crops during the first 13 months of our sample, and for 12 crops during the last 12 months, reflecting in part the expanded number of crops eligible for protection. About 61 percent of the total number of applications was for maize, followed by rice (21 percent), wheat (4 percent), and soybean (3 percent). Most applications are made to protect grain crops, with the share of applications for vegetable and fruit crops being less than 5 percent. Perhaps surprisingly, the preponderance of the protection sought is for hybrid, not open-pollinated, maize and rice varieties, including

[32] In September 1999 a total of 10 species were eligible for protection, growing to 30 species by March 2002 (including 5 major cereals, 2 oil crops, 2 roots and tubers, 10 vegetables and fruits and 11 flowers and grasses).

both the inbred lines and the final hybrid seed. The institutional arrangements for producing finished seed and the state of legal recourse for piracy may account for this apparent anomaly. The common practice in China is for research institutes or seed development firms to outsource the production of commercial quantities of seed, often to state-owned seed companies who in turn contract with individual growers to produce the seed. Under these circumstances, the technology owner (i.e., seed development firm or research institute) runs the real risk of piracy or theft of its hybrid seed and even its in-bred lines, so that plant variety protection certificates provide an additional legal avenue of recourse beyond that offered by contract law.

Table 2--PVP applications by crop

Crop	Number of applications				
	First 13 months of sample[a]	Middle 13 months of sample[a]	Last 12 months of sample[a]	Total	Share of total
		(*count*)			(*percent*)
Maize					
Hybrid	77	71	62	210	43
Non-hybrid	39	35	15	89	18
Rice					
Hybrid	13	25	36	74	15
Non-hybrid	5	17	8	30	6
Wheat	0	5	14	19	4
Soybean	0	16	1	17	3
Cabbage	4	1	5	10	2
Rapeseed	0	3	7	10	2
Pepper	0	7	2	9	2
Peanut	0	3	4	7	1
Pear	0	2	5	7	1
Potato	1	2	0	3	1
Others[b]	1	2	4	7	1
Total	***140***	***189***	***163***	***492***	***100***

Source: Compiled by authors from China Ministry of Agriculture (various issues)
a. The first thirteen month of the sample includes April 1999 – April 2000; the middle 13 month, May 2000 – May 2001; the last 12 month, June 2001 – May 2002.
b. Others include pink flower (2), watermelon (2), tomato (1), garden sorrel (1), and an ornamental flower (1).

By way of comparison, state trade secret laws in the United States effectively protect the theft of hybrid in-bred lines. For example, in 1994 Holden Foundation Seeds were judged liable for misappropriating Pioneer Hi-Bred's in-bred hybrid corn lines under Iowa trade secret law. They were ordered to pay $46 million to Pioneer Hi-Bred

International, an estimate of the profits forgone by illegal use of these in-bred lines.[33] Utility patents provide an additional means of protecting in-bred lines in the United States. As a consequence, the share of hybrid varieties for which plant variety protection is sought is very small in the United States. Among the more than 190 crops for which PVP protection was sought during the past 30 years in the United States, open pollinated crops accounted for the lion's share of applications. For example, soybeans accounted for 1,022 applications (20 percent of the total) and wheat for 472 (10 percent) of the applications. Only 12 percent of the total applications were for corn varieties.

The majority of PVP applications (72 percent of the total) were filed by national, provincial, and prefectural public research institutes and universities (Table 3). Among these institutes, more than half the applications were made by provincial institutes, nearly one-third by prefectural institutes, 12 percent by universities, and only one percent by national research agencies such as the Chinese Academy of Agricultural Sciences (CAAS). These institutional shares are roughly consistent with the corresponding shares of overall investments in agricultural research. Both publicly-held seed development firms and state-owned seed companies accounted for about 10 percent of the applications, with another 14 percent made by the shareholding companies spun off from these firms. The demarcation between the public and private sectors in China is sometimes difficult to discern, but we estimate that 82 percent of the PVP applications are lodged by public agencies (i.e., excluding shareholding companies). This contrasts markedly with the United States where the public-sector share of PVP applications is only 15 percent.

[33] Pioneer Hi-Bred International. v. Holden Found. Seeds, 35 F.3d 1226, 1240 (8th Cir. 1994). See Goss (1996) for more details.

Notably, multinational companies accounted for few filings in China (two for potatoes, one for pepper, and one for an ornamental flower), a reflection of restrictive government regulations.

Table 3--Plant variety protection by type of applicant[a]

Type of applicants[b]	Number of applications	Share of total
	(*count*)	(*percent*)
Public research institution		
National	4	1
Provincial	189	38
Prefectural	116	24
University	43	9
Seed development firm (by research institute)	14	3
State-owned seed company (agribusiness firm)	34	7
Shareholding company	72	15
Multinational	4	1
Individual	13	3
Others (foreigners)	3	1
Total	***492***	***100***

Source: Compiled by authors from China Ministry of Agriculture (various issues)
a. Joint applications (a total of 45) are assigned according to the name of the first applicant.
b. This classification structure taken from Fan et at. (2003).

Table 4 gives more detail regarding individual applications and the crops involved. More than 120 different applicants applied for protection during the sample period, but the distribution is highly skewed toward a few applicants. Just 10 applicants account for more than 40 percent of the total applications—13 percent were made by the Jilin Academy of Agricultural Science (AAS), 5 percent by Laizhou AAS, 4 percent by Dandong AAS, and 3 percent by Sichuan AAS. A further 20 percent of the total applications were lodged by 74 applicants who each filed less than 2 claims.

Interestingly, institutions located in just five of China's 31 provinces (Jilin, Liaoning, Shandong, Sichuan, and Henan) accounted for more than 55 percent of the total number of applications.

Table 4--PVP applications by applicant and type of crop

Applicant	***Applications***		Crop						
	Share	Number	Maize	Rice	Wheat	Soybean	Cabbage	Peanut	Others[b]
	(percent)	*(count)*	*(count)*						
Jilin AAS[a]	13	62	49	2		11			
Laizhou AAS	5	24	21				3		
Dandong AAS	4	18	16	2					
Sichuan AAS	3	17	3	14					
Chengde Greatwall Seed Ltd.	3	15	15						
Henan AAS	3	13	6		2		4	1	
Hunan AAS	3	13		9					4
Shandong Denghai Seed Ltd.	3	13	13						
Jiangsu AAS	2	12	4	7	1				
Sichuan Agricultural University	2	11	3	7	1				
China Agricultural University	2	9	9						
Heilongjiang AAS	1	8	8						
Other applicants	58	277	152	63	15	6	3	6	32
Total	***100***	***492***	***299***	***104***	***19***	***17***	***10***	***7***	***36***

Source: Compiled by authors from China Ministry of Agriculture (various issues)
a. AAS denotes Academy of Agricultural Science.
b. Others include rapeseed (10), pepper (9), pear (7), potato (3), pink flower (2), watermelon (2) tomato (1), garden sorrel (1), and ornamental flower (1)

While there is a reasonably close correspondence between the patterns of overall R&D spending and PVP applications, the links between research and the intellectual property sought by an individual research institute is less clear-cut. The Jilin AAS is a relatively large provincial research institute with a total of 1,055 staff in 2000 (including

404 scientific researchers) focusing on maize and soybean research. Sichuan AAS and Jiangsu AAS are also large institutes, comparable to Jilin AAS, with 1,530 and 1,200 staff respectively, and an emphasis on rice, cotton, and wheat research. Not surprisingly, these three institutes sought significant numbers of PVP certificates and the crop orientation of their PVP applications aligns with their respective research emphases. What is surprising is that some smaller research institutes like Laizhou AAS (a prefectural institute in Shandong province with 380 staff engaged heavily in maize breeding) and Dandong AAS (a similarly sized prefectural institute in Liaoning province) also sought varietal rights comparable in number to the larger institutes mentioned above. At the other extreme is the Chinese Academy of Agricultural Science (CAAS), a national institute with a large staff (about 9,000, split evenly between scientists and support staff) and a research budget of about $35 million in 2001, which sought only 4 PVP certificates through to May 2002.[34]

Financial factors seem relevant regarding the decision to apply for PVP protection. The comparatively large number of PVP applications from financially strapped agencies such as Heilongjiang AAS, Dandong AAS, and Laizhou AAS are indicative of their interest in reaping the potential rewards from commercializing their technologies. Other institutes with comparatively abundant resources, like CAAS, have made less effort to protect varieties for revenue raising purposes. Moreover, commercial

[34] In late 2002 CAAS began implementing a radical restructuring program that will take several years to complete. The intent is to reduce staff on core government support to 2,800 (down from the current 9,000) without a commensurate reduction in funding so that salaries can rise sufficiently to retain and recruit good scientists, and to remove excess support personnel and less productive scientific staff. Those staff not supported by government, are to be paid from revenue earning operations run by CAAS or retired, although in the later case the lack of a national social security program means that CAAS is saddled with paying all retirement costs.

successes prior to the passage of the PVP Law in 1999 may account for the application behavior of some institutes. For example, the commercial success of the "Yedan" series of hybrid maize seeds developed by Li Denghai, now president of Laizhou AAS, might have stimulated subsequent PVP application by the institute. Personal traits can also be important in understanding the pattern of applications: the presidents of Jilin AAS and Laizhou AAS are known to be well versed in intellectual property matters and attuned to the commercialization prospects of new technologies. However, the most important factor may be the overly optimistic expectation of breeders or research administrators about the appropriable size of the Chinese seed market, as analyzed below.

ECONOMIC EVALUATION OF CHINA'S PVP APPLICATIONS

The current and expected size of commercial seed markets in China is both affected by and provides incentives for generating, acquiring, and maintaining intellectual property rights over seeds. Decisions to establish and protect intellectual property involve economic choices about the costs and benefits of doing so. As demonstrated above, PVPs in China are especially costly, even by developed-country standards. Expectations about the future size of commercial seed markets in China and the appropriability of rents in relation to those future markets circumscribe the PVP costs that rights holders are likely to incur. Crops for which the propensity to use saved or informally (often farmer to farmer) exchanged seed is high and likely to persist provide few opportunities to recoup the cost of developing and protecting property rights to new seed varieties. Higher valued crops and those with significant market transactions give a greater incentive to acquire and maintain the rights to new varieties.

According to ISF (2002), worldwide seed sales are US$30 billion, of which China's domestic market accounts for about 10 percent. The basis for these figures is not revealed, nor are crop specific values reported. Thus, combining data obtained from publicly available databases with additional information gained from numerous interviews of those engaged in or familiar with Chinese seed markets, we estimated the size of the commercial seed market for 14 principal crops (and additionally hybrid and non-hybrid varieties for four of those crops) (Table 5). Present values of the future sale of seed are then used to investigate the incentives to develop and protect new seeds in commercially important segments of the Chinese market.

Table 5--Size of domestic seed markets for commercially important crops in China, 2000

	Area sown	Average sowing rate	Total seed consumption	Average seed price	Seed replacement rate	Commercial seed sales	
	(1000 ha)	*(kg/ha)*	*(1000 kg)*	*(Yuan/kg)*	*(percent)*	*(1,000 yuan)*	*(1,000 US dollar)*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Food crop							
Maize							
Hybrid	21,903	45	985,644	6	100	5,913,864	714,235
Non-hybrid	1,153	80	92,224	2	15	27,667	3,341
Rice							
Hybrid	14,981	15	224,715	8	90	1,617,948	195,404
Non-hybrid	14,981	45	674,145	2.5	30	505,609	61,064
Wheat	26,653	170	4,531,010	2	30	2,718,606	328,334
Soybean	9,307	90	837,630	3	50	1,256,445	151,745
Potato	4,723	9	42,507	1	20	8,501	1,027
Millet	1,250	15	18,750	1	20	3,750	453
Sorghum	889	15	13,335	5	90	60,008	7,247
Total			*7,419,960*			*12,112,398*	*1,462,850*
Vegetable/fruit							
Chinese cabbage	2,023	3.5	7,081	120	100	849,660	102,616
Pepper	1,309	2	2,618	100	95	248,710	30,037
Cucumber	1,168	2	2,336	200	100	467,200	56,425
Tomato	1,032	0.5	516	800	90	371,520	44,870
Watermelon	1,617	2	3,234	1000	100	3,234,000	390,580
Total			*15,785*			*5,171,090*	*624,528*

Table 5--Size of domestic seed markets for commercially important crops in China, 2000 (continued)

	Area sown	Average sowing rate	Total seed consumption	Average seed price	Seed replacement rate	Commercial seed sales	
Oil and other crop							
Rapeseed							
Hybrid	2,998	3	8,993	35	100	314,748	38,013
Non-hybrid	4,496	3	13,489	7	50	47,212	5,702
Cotton							
Hybrid	404	20	8,082	60	100	484,920	58,565
Non-hybrid	2,829	60	169,722	5	30	254,583	30,747
GM	808	20	16,164	40	50	323,280	39,043
Total			*216,450*			*1,424,743*	*172,070*
Total (15 crops)						***18,708,231***	***2,259,448***

Source: Data for the area sown are from China National Bureau of Statistics (2001). Estimates of the sowing rate, seed price, and seed replacement rate are national averages obtained from consulting Chinese experts. Pray et al. (1998) also contain useful information to help calibrate these simulations.

a. The ratio of hybrid to non-hybrid is 9.5:0.5 for corn, 5:5 for rice, 4:6 for rapeseed, and 1:7:2(GM) for cotton.
b. Commercial seed market in US dollar is derived using US$1 = 8.28 yuan.

Total seed consumption by farmers for important crops and vegetables is reported in column 3, obtained by multiplying the area sown for each crop (column 2) by its average sowing rate (column 1). This represents the total seed planted, irrespective of its source. For many non-hybrid crops farmers save seeds for use in subsequent plantings so only a fraction of the seed consumed is traded in commercial markets.[35] Column 4 gives the consensus estimates we obtained of the rate of seed replacement, defined here as the proportion of sown seed purchased through commercial markets.[36] Seed replacements rates, seed consumption and average prices were then used to estimate the value of China's commercial seed market for selective crops in local (column 6) and U.S. dollar (column 7) units.

The total value of commercial seed sales in 2000 for the 14 crops in table 5 is about US$2.3 billion, including $1.5 billion for the 7 major food crops we valued, $0.6 billion for vegetable and fruit crops, and $0.2 billion for oil and other crops. In 2000, the area cropped for agriculture totaled 156.3 million hectares, of which 108.4 million hectares were for food crops, 15.2 million for vegetables and fruits, and the rest for rapeseed and other oil crops, cotton, tea, and so on (China National Bureau of Statistics 2001). The crops included in table 5 accounts for about 90 percent of the total area sown to food crops, 50 percent of the area in vegetables and fruits, and 35 percent of the area in other crops. Using the respective area shares to recalibrate the crop seed values directly

[35] For our baseline estimates in table 5 we took the extent of informal seed exchange among farmers to be negligible, thus these estimates represent an upper-bound indication of the current value of the commercial seed market in China.

[36] Hybrid varieties of corn, rice, and vegetables have comparatively high seed replacement rates (almost 100 percent), whereas self-pollinated crops such as wheat and millet have lower rates, deemed to be in the 20 to 30 percent range in 2000.

estimated in table 5, we figure the value of the Chinese seed market for all agricultural crops in 2000 was about US$3.4 billion (or 28.7 billion yuan).

Plant breeders base their decisions on whether to develop and protect new varieties on the present and expected future size of the appropriable commercial seed market. If the present value of the expected return from the variety exceeds the present value of the cost of R&D and IP protection, then breeders will opt to invest in varietal development. Expanding on the reduced form of the decision problem described by equation (1), the present value of benefits from developing and protecting a representative crop variety can be expressed as

$$PV(\Pi) = f(Q_d, \Delta, \rho, \beta) \qquad (2).$$

The quantity of seed demanded, Q_d, is itself a function of the average share of sown area for each variety, the seed sowing rate per hectare, and the rate of seed replacement per season per crop. The seed price premium, Δ, paid for improved seed over the price of current varieties depends both on the quality of the seed, which affects the *potential* size of the price premium, and the strength of intellectual property rights, which affects the share of the potential premium appropriable by the breeder. Well-enforced property rights limit the scope of illegal reproduction and sale of protected seed so that a larger share of the potential price premium accrues to breeders. The probability of commercial success of the variety, ρ, depends both on the productive quality of the seed and market structure aspect that effect the intensity of competition in a given locale for a given crop. The effective commercial life of the variety is affected by the rate of release of competing varieties and the rate of biological obsolescence, while the discount factor β affects the size of the present value of the benefit stream.

The inherent uncertainty of estimating future benefit streams compounded by the lack of relevant data makes estimating the present value of the expected return problematic. Nonetheless, we compiled sufficient information to develop order-of-magnitude estimates of these present values for representative varieties of maize, rice, wheat, soybean, and potato for China (Table 6). The intent here is to demonstrate how variations in the strength of property protection–i.e., the degree of appropriability of the price premium and the effective life of the varietal rights–affect the incentive to develop and protect improved varieties, and to compare the economically rational number of PVPs with the actual number of PVPs sought over a recent 12 month period.[37]

[37] Building on the estimates provided in table 5, the results in table 6 assume that the representative variety for each crop included occupies 1 percent of the total sown area for each crop; there is a 2 percent reduction per year in this sowing rate due to improvement of seed quality over time; the probability of research success is one percent; the present value of research costs for each variety is 10,000 yuan; the effective life of a variety is 7 years; and discount rate is 6 percent (i.e., $\beta = 0.95$). In addition, we assumed that farmers' rate of seed replacement and the area sown to each crop are constant over time. Costs include only the government charges and exclude the private costs of preparing PVP submission and exercising exclusionary rights.

Table 6--Indications of the extent of varietal protection under different IP regimes

Category	Hybrid maize	Hybrid rice	N-hybrid rice	Wheat	Soybean	Potato
Present value of revenue			(yuan per variety)			
Effective length of protection (7 years)						
Weak IPR	337,848	92,430	28,884	155,309	71,778	486
Intermediate IPR	1,689,238	462,151	144,422	776,544	358,891	2,428
Strong IPR	3,378,476	924,302	288,845	1,553,087	717,783	4,857
Statutory length of protection (15 years)						
Weak IPR	565,098	154,603	48,313	259,776	120,059	812
Intermediate IPR	2,825,489	773,013	241,567	1,298,878	600,296	4,026
Strong IPR	5,650,977	1,546,026	483,133	2,597,757	1,200,593	8,123
Present value of cost(a)						
Effective length of protection (7 years)	27,311	27,311	27,311	27,311	27,311	27,311
Statutory length of protection (15 years)	43,289	43,289	43,289	43,289	43,289	43,289
US cost structure (no maintenance fee)	16,400	16,400	16,400	16,400	16,400	16,400
Number of annual PVP applications			(PVP count per year)			
Chinese cost structure						
Effective length of protection (7 years)						
Weak IPR	12	3	1	6	3	0.0
Intermediate IPR	62	17	5	28	13	0.1
Strong IPR	124	34	11	57	26	0.2
Statutory length of protection (15 years)						
Weak IPR	13	4	1	6	3	0.0
Intermediate IPR	65	18	6	30	14	0.1
Strong IPR	131	36	11	60	28	0.2

Table 6--Indications of the extent of varietal protection under different IP regimes (continued)

Category	Hybrid maize	Hybrid rice	N-hybrid rice	Wheat	Soybean	Potato
US cost structure (no maintenance fee)						
Effective length of protection (7 years)						
Weak IPR	21	6	2	9	4	0.0
Intermediate IPR	103	28	9	47	22	0.1
Strong IPR	206	56	18	95	44	0.3
Statutory length of protection (15 years)						
Weak IPR	34	9	3	16	7	0.0
Intermediate IPR	172	47	15	79	37	0.2
Strong IPR	345	94	29	158	73	0.5
Actual annual number of PVP applications	**62**	**36**	**8**	**14**	**1**	**0.0**

Source: Calculated by authors

a. Include the costs of developing the variety and the administrative costs of seeking and maintaining varietal protection.

Table 6 gives an indication of the likely present values of the returns accruing to Chinese breeders of a representative maize, rice, wheat, soybean, and potato variety based on our best estimates of the future value of the respective seed markets in China (from table 5) and the institutional and IP realities facing crop breeders (see footnote 33 for details). Here we analyze the effects of different intellectual property regimes by simulating a range of returns to breeders based on variations in varietal protection. The upper panel involves a set of simulations in which returns are appropriated for only 7 years or the legal limit of the right (15 years), while the appropriable price premium varies from 100 percent of the average price in table 5 for "strong" rights to 10 percent for "weak" rights (plus an intermediate case when the premium equals 50 percent of the average price). The central panel gives an indication of the present value of the cost of developing and protecting a new variety under different IP regimes and under the U.S. cost structure with no annual maintenance fee. For each of these IP and cost regimes, the bottom panel of table 6 provides an estimate of the number of varieties for which IP protection makes economic sense.

Comparing among crops, it is clear that market size is an important determinate of the economically rational extent of intellectual property protection. Given the costs of varietal development and protection, the comparatively small size of the Chinese market for potato seed provides little incentive to protect new potato varieties presuming the current low rate of commercial seed replacement persists. Conversely, with plausible assumptions regarding the effective life of a varietal right (see lower panel of table 6), it makes economic sense to protect upwards of 124 new varieties of hybrid corn each year. The economic extent of protection is also sensitive to the price premium appropriated by

breeders; a tenfold increase in the premium (comparing weak versus strong rights) results in a proportionate increase in the number of varietal rights.

Because the costs of maintaining varietal rights in China increases along with the benefits as the varietal life lengthens, the economic extent of protection is less sensitive to variations in the life of the right than changes in the price premium appropriated by breeders. In fact, lengthening the effective life of varietal rights in China (comparing the results of 7- to 15-year lives) marginally increases the number of varieties for which protection is economically justified. Indeed if China were to adopt a U.S. style cost profile by eliminating its annual maintenance fee, the present value of IP costs are diminished relative to the costs of research such that the economic number of protected varieties increases substantially. In table 6, for example, the number of hybrid maize varieties for which protection is rationally sought increases from 124 to 206 varieties per year under a strong IP regime if a U.S. cost structure were adopted. Clearly this result is especially sensitive to assumptions about the costs of research. Finally, a comparison of our simulation results with the actual extent of protection are consistent with the notion that breeders perceive that China's IP regimes give more protection (or are likely to do so in the future) than the institutional evidence suggests is currently the case.[38]

[38] Alternatively it could be that crop breeders in China expect the overall value of domestic seed markets to grow substantially larger than we predicted when forming these estimates.

5. CONCLUSION

Keeping with the general structure of research in China, public agencies account for the majority of total PVP applications (more than 80 percent), in contrast to the situation in the United States where more than 85 percent of the applicants are private firms. Given its longer history, the institutional interest in PVP protection is naturally much greater in the United States (with more than 600 entities applying for protection since 1971) than China (with about 120 entities seeking protection), although the pattern of institutional protection is similar. In both countries, the top 5 applicants account for about one-third of the total number of applications, with the remaining applications being lodged by a large number of other entities.

In line with the general patent literature (as surveyed by Jaffe 2000 and Gallini 2002), we find that the economically rational extent of PVP protection in China is more sensitive to appropriability conditions in a given year (analogous to the "scope" of protection) than the extent of appropriability over time (i.e., the length of protection). In part, this stems from the structure of PVP protection in China that requires the payment of annual fees that increase with time to maintain options over varietal rights, in an analogous way to the structure of patent costs generally. In contrast, the structure of PVP costs in the United States requires an up-front payment with no recurring maintenance fees. We demonstrate that if China adopted the U.S. pattern of PVP costs, the economic extent of protection would expand considerably. However, this result is sensitive to a number of assumptions, not least those regarding the present value of the costs to develop new varieties versus the costs of protecting the intellectual property embodied in them.

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