Effectiveness of Intellectual Property Protection: Survey Evidence from China

Guanming Shi, Carl Pray, and Wenhui Zhang

This paper examines Chinese pesticide firms' use and perceptions of various means of intellectual property (IP) protection in protecting their innovations, using a unique dataset from 97 pesticide firms surveyed in 2008. These firms rate Chinese patents as quite effective in protecting their IP from infringement, although 70 percent of them state that improved enforcement is needed. Those firms that have been granted patents and those that claim their patents have been infringed upon both give lower ratings to the perceived effectiveness of patents. Trademarks are rated as less effective than patents, but firms that have had experience with patenting and infringement of patents tend to rate trademarks as more effective than those firms that do not have direct experience with the patent system. General government policies to encourage increased privatization, more private R&D, and higher education are associated with more faith in IP, but policies to strengthen IP by promoting mandatory IP training and the development of specialized IP divisions in the firms do not influence perceptions of IP effectiveness. We conclude that if the Chinese government wants to encourage innovation using IP protection, it must focus on improving the enforcement of patents.

Key Words: intellectual property rights, innovation policy, pesticide, China

Technology innovation is a driving force of today's economy, and, indeed, fostering capacity for innovation is a major policy goal for both developed and developing countries. For example, President Obama stated explicitly that "Innovation has been essential to our prosperity in the past, and it will be essential to our prosperity in the future" (USA Today 2009), while China's President Hu announced in 2006 that one of China's development goals is to become an "innovative country" by 2020 (People's Daily 2006).

Many policy tools have been proposed to increase innovation, such as reduced taxes and subsidies on research and development (R&D), public investment on R&D and education, and strengthened intellectual property rights (IPRs). Over the last three decades many governments and businesses worldwide have recognized that strengthening the laws and enforcement of IPRs is one of the most important tools for increasing innovation (e.g., Johnson and Evenson 1997, Qian 2007). Researchers have examined various types of IPRs and their effectiveness in generating innovation. However, most studies focus on innovation systems in the developed world (e.g., Mansfield, Schwartz, and Wagner 1981, Levin et al. 1987, Harabi 1997, Cohen, Nelson, and Walsh 2000). Little information is available on innovators, including firms, in developing countries, especially from direct surveys of their perceptions and use of IPRs.

Various appropriation mechanisms for returns to innovation exist, including IPRs, first mover advantage, and complementary assets and services. Researchers have found that different industries prefer and use different mechanisms (e.g., Mansfield 1986, Levin et al. 1987, Cohen, Nelson, and Walsh 2000). In general, they find that chemical industries, including the pesticide industry, rely heavily on IPRs as a means of appropriation (e.g., Cohen, Nelson, and Walsh 2000, Bessen and Meurer 2008).

Our study contributes to the literature by focusing on an industry (the pesticide industry) that uses patents extensively in developed countries to test whether similar patterns exist in an important

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developing country (China). It uses a unique, new dataset of 97 pesticide firms that are operating in China to obtain an industry perspective on the effectiveness of the IP system.[1] Most of these firms (80 percent) are private firms. The rest are state-owned firms or firms transitioning from state-owned to private, with a few firms that are joint ventures with foreign firms. About half of these firms report that they have introduced new products into the Chinese market in the last five years (2003–2007). During the same time period, one-third of the firms have applied for Chinese patents and about a quarter of all respondents have been granted with Chinese patents. According to the National Bureau of Statistics of China, China and the U.S. are the top two pesticide producers globally. Almost half of Chinese pesticide outputs have been for export in recent years, and the major markets include Southeast Asia, South America, Europe, and Africa (CCPIA Yearbook 2010). However, only five respondents in our sample report filing patent applications in foreign markets in the past five years (including the U.S., Japan, Europe, Vietnam, Australia, Brazil, South Africa, and India).

In the rest of the paper, we briefly describe China's IP system, and then present an empirical model of perceived effectiveness of IPRs based on the psychological theory. The survey data compiled and used in our analysis are described next, and then results are reported. Finally, we conclude with policy implications of our research.

Background on China's IP System and the Pesticide Industry Survey

China has substantially changed its IPR laws over the past two decades and has invested heavily in courts to enforce IPRs. China enacted its first patent law in 1985 and has amended it three times since then (first in 1992, then in 2000 and 2009). In 1963, China established trademark regulations which were enacted into a trademark law in 1983 and then amended in 1993 and 2001. Other IP laws and regulations include the copyright act and administrative protection regulations (where protection is implemented through administrative orders).

However, it has widely been viewed that while the formal written IPR laws in China have largely met the international standards, the enforcement remains an issue (e.g., Cox and Sepetys 2005, Yueh 2009). The enforcement of IPR laws and regulations in China takes two forms: one through the judicial system, the other through the administrative system. The prosecution of IPR violations can be done by right holders bringing lawsuits to the court, or by administrative agencies penalizing the infringers via fines and confiscation of infringing goods (but often not compensating the IPR owners). The effectiveness of the enforcement is highly restricted by local governments' desire to avoid short-term economic costs, corruption, and local protectionism[2] (Cox and Sepetys 2005). However, little real evidence other than anecdotal evidence is available about the effectiveness of the current Chinese IPR system and ways it could be strengthened. One way to test effectiveness of the IPR system is to ask (innovative) Chinese firms in an industry where IPRs are perceived by developed countries to be important (such as the pesticide industry) whether they believe the IPR system is effective in protecting their innovations. That is what we have done in this paper.

As part of its policies to make China an innovative country, the State Council issued the *Outline of National Intellectual Property Strategy* in June 2008. The five strategic foci include: (i) improving IP regimes, (ii) promoting the creation and use of IP, (iii) strengthening IPR protection, (iv) preventing abuses of IPRs, and (v) fostering a culture of IPRs. In response to the central government's call, the China Crop Protection Industry Association (CCPIA) surveyed its members in the fall of 2008 regarding the perceptions and use of IPRs in the Chinese pesticide industry.[3] In particular, CCPIA was interested in whether promoting man-

[1] As pointed out by an anonymous referee, IPRs may play dual roles related to innovation: the *defensive* one to protect firms' *own* innovation from being copied, or the *offensive* one to protect competitors' innovation from imitation. While it will be interesting to study both, this paper focuses on firms' perceived effectiveness of IPRs in protecting their *own* innovations, which is how the survey question is phrased.

[2] According to Chinese law, all lawsuits regarding IPRs need to be raised in local courts where the infringement occurs. This may create local bias in favor of infringers in order to protect the local economy, tax collection, and employment.

[3] The pesticide industry used to be governed by the Ministry of Chemical Industry (MCI). The MCI was dismissed in 1998, and part of its duty of regulating the pesticide industry was transferred to the National Development and Reform Commission; the administrative activities are carried out through CCPIA. Currently, CCPIA has 433 active members, which account for over 85 percent of national pesticide production.

datory IPR training and the development of specialized IPR divisions in each firm would be effective policies to achieve some of the strategic foci [e.g., (ii) and (v)]. We worked with CCPIA to develop the questionnaire and to collect and analyze the survey data that is used for this study.

Chinese invention patents and trademarks are used extensively by Chinese firms. The Chinese IPR system has three types of patents: invention, utility model, and design. We focus on the invention patent because it is similar to the U.S. utility patent, while the other two mostly cover incremental innovations (Hu and Jefferson 2009).[4] Also, invention patents are the most commonly used type of patent by the pesticide industry (Yang 2005). The effectiveness of trademarks is of interest because they are widely used in the pesticide industry; but it is unclear whether firms use trademarks for both IP protection and marketing or for marketing only.

The third and fourth means of protection (U.S. patents and Administrative Protection) are included mainly for comparison. Most Chinese firms do not have direct experience with U.S. patents, but there seems to be widespread opinion in China that obtaining a U.S. patent is a measure of success in innovation. Administrative Protection is the result of U.S.-China IP negotiations from 1989 to 1992, and only foreign firms that hold foreign patents are eligible to apply. The Chinese government provides this protection by restricting entry (via issuing no other production permits) into the production and marketing of the protected product. Foreign firms operating in China view this as one of the most effective means of protection (Shi and Pray 2010).

Empirical Model Specifications

Following the traditional psychological literature of perception (e.g., Gregory 1974), we model a firm's perception of the effectiveness of various means of IP protection as the interplay between its past experience, leaders' capacity to interpret observations, and the firm's culture. We begin with a generic specification of a firm's perception of IPR effectiveness, E, as follows:

$$E = f(EXP, COG, CUL, \mathbf{X}), \tag{1}$$

where EXP is a vector of variables reflecting a firm's past experience with the IPR system, COG are variables capturing firm managers' cognitive ability, CUL are firm culture variables, and $\mathbf{X}$ includes other firm characteristics that may potentially impact a firm's perception on the effectiveness of IPRs.[5]

Equation (1) provides a basis to evaluate the effects of different factors on IPR effectiveness as perceived by different firms. To make the analysis empirically tractable, we parameterize firms' perceived IPR effectiveness as $g(EXP, COG, CUL, \mathbf{X}; \boldsymbol{\beta})$, where $\boldsymbol{\beta}$ is a vector of parameters capturing the effects of (EXP, COG, CUL, $\mathbf{X}$) on E. It follows that equation (1) can be written as

$$E = g(EXP, COG, CUL, \mathbf{X}; \boldsymbol{\beta}) + \varepsilon, \tag{2}$$

where ε is an error term with mean zero and constant variance. Once specified, equation (2) can be estimated as a regression model.

One challenge in estimating equation (2) is to identify appropriate measures of the dependent variable E, as E is usually not observed. One option is to ask the firms directly. However, it is hard to quantify perceived effectiveness. Instead of using a cardinal measure, the survey asks respondents to rate their perceptions of the effectiveness of various means of IP protection in protecting their innovations from 1 to 7, where "1" means "not effective at all" and "7" means "very effective." In such a rating scheme, a higher rating suggests a higher level of perceived effectiveness but does not necessarily reflect a specific difference in the levels of perceived effectiveness.

To deal with the ordinal nature of the dependent variable, we chose the ordered logit model, which is a common framework for such analysis (Greene 2003, chapter 21). Following Greene

[4] For example, novelty and non-obviousness are required in the examination of an invention patent application, but not in the other two patent applications.

[5] Some independent variables may exhibit endogeneity, as a high (or low) perception of the effectiveness of IPRs could affect firms' decisions to utilize various means of IPRs, and hence may affect firms' experience, managers' cognitive ability, and firm cultures regarding IPRs. However, given limitations on available data, fully controlling such issues is prohibitively difficult.

(2003, chapter 21), the following probability function will be estimated:

(3)
$$\text{Prob}(rating = j) = F[u_j - g(\cdot)] - F[u_{j-1} - g(\cdot)],$$

where F is a cumulative logistic distribution function, and u's are the to-be-estimated cut point values for each ordered category, $u_{j-1} < u_j$ for j = 1, 2, ..., 7, and we specify a reduced-form linear function of $g(\cdot)$:

$$g(\cdot) = \beta_0 + \boldsymbol{\beta}_1 EXP + \boldsymbol{\beta}_2 COG + \boldsymbol{\beta}_3 CUL + \boldsymbol{\beta}_4 \text{X}.$$

For the experience variables, we include the number of Chinese invention patent applications filed by the firm in the past five years, the number of Chinese invention patents granted to the firm in the past five years, and a dummy variable indicating whether or not the firm's patent(s) has ever been infringed as reported by the firms in the survey. To capture potential spillover effects from foreign experience, we also include the number of patent applications filed with the trilateral patent offices in the past five years: the Japanese patent office (JPO), the U.S. patent and trademark office (USPTO), and the European patent office (EPO).

For cognition variables, we include the educational achievement of the administrative team measured by the proportion of managers with a bachelor's degree or higher, and the R&D capacity of the firm as measured by the share of R&D workers among all employees. We also include dummy variables associated with the CCPIA's proposed policies of mandatory IPR training and specialized IPR divisions: whether the firm has participated in specifically designed IPR training sessions, and whether the firm has a specialized IPR division, handles IPR through a non-specialized division, or contracts with outside IPR agencies.

For cultural variables, we use dummies for the type of firm ownership: state-owned, state-reformed, private, and foreign/joint venture. Firms with different ownership types often differ in how they receive and respond to market signals. They also have different management systems for processing information and executing decisions. "State-owned" firms are traditional government-controlled firms, which in China may still be subject to some government control even after China's transition from a planned economy to a market economy. "Private" and "foreign/joint venture" firms are standard commercial companies. "State-reformed" firms are transitioning from "state-owned" to "private." We also include variables capturing firm size and the degree of specialization of the firm in pesticide sales. For firm size we use total number of employees and total expected sales in 2008. For specialization we use the share of pesticide sales in total sales.

Finally, other firm characteristics include firm location dummies for major production regions, and number of new products the firm has introduced in the past five years. The location dummies capture potential clustering effects. The number of new products may capture firms' vulnerability or sensitivity to potential infringers.

We apply maximum likelihood estimation to equation (3) to obtain estimates of the coefficients $\boldsymbol{\beta}$ and the u's for four different types of IP protection: Chinese invention patents, Chinese trademarks, U.S. patents, and Chinese Administrative Protection. For each means of protection, we estimate the model for two types of innovation: product innovation and process innovation. Product and process innovations are the major innovation activities in the agrochemical industry. Compared to process innovations, pesticide product innovations usually require more R&D and there is less certainty about generating commercial innovations, but they may generate greater returns if the innovation is successfully developed (Cao 2006). Given the differences in the level of R&D required and expected return, we are interested in whether or not factors affecting firms' perceptions of IPR effectiveness differ across innovation types.

Data

This study uses data collected by CCPIA in 2008. The questionnaire was mailed to all 433 active members of CCPIA, and 97 firms responded. While the response rate was only 22 percent, according to CCPIA these firms are the major players in the industry in terms of R&D capacity and IPR experience. Forty-three of the respondents to our survey are listed in the 600 top Chinese pesticide firms in 2003. They account for 40 percent of total capital, 37 percent of total sales, and 50 percent of total profits for all those top 600 firms in 2003 (CCPIA Yearbook 2005). All respondents report at least

some R&D workers, suggesting a response bias towards innovative firms. However, this should not be an issue for our purpose of understanding industrial innovators' use and perception of the effectiveness of IPRs.

The majority of respondents are private firms (79.6 percent), followed by state-owned firms (10.8 percent), state-reformed firms (7.5 percent), and foreign/joint ventures (2.2 percent). Respondents are located in 22 different provinces in China, with half concentrated in three regions: Shandong province (24 percent), Jiangsu province (15 percent), and Beijing (10 percent). In terms of the proportion of the administrative team with a bachelor's degree or higher, 62 percent of the respondents report a proportion greater than 60 percent, followed by 21 percent reporting 40–60 percent, 11 percent reporting 20–39 percent, and only 6 percent reporting less than 20 percent . About 63 percent of the firms have R&D employees who participated in IPR-related training. Nineteen percent of the firms have not established specific internal divisions to handle IPRs, 21 percent have specific IPR divisions, 47 percent have IPR issues taken care of by internal divisions that are not specialized in IPRs, and the remaining 13 percent contract IPR issues to external agencies.

Table 1 summarizes the statistics of these 97 firms. About half of the firms have introduced at least one new product in the last five years (2003–2007). Respondents expect to generate total sales of 323 million RMB (or around $46.4 million) in 2008 on average, of which 92 percent would be pesticide sales. The average number of employees is 529, of which about 19 percent are R&D workers.[6]

About 34 percent of the respondents have filed Chinese invention patent applications between 2003 and 2007; among them the average number of patent applications is 12. During the same time period, about 26 percent of the respondents have been granted Chinese invention patents; the average number of patents granted to each is four. Most respondents have had no experience with patenting in the trilateral patent offices in the U.S., Japan, or EU, with only four firms filing 12 applications in total with the trilateral offices during the last five years. The data in this survey do not distinguish between patents on new products and those on new processes, but data from other sources suggest that most of these patents are on new processes: according to the State Intellectual Property Office of China (SIPO) database, 81.4 percent of all pesticide-related patent applications filed by Chinese firms between 1986 and 2005 were related to process innovations (Shi and Pray 2012).

The questionnaire asked the respondents to rate from 1 (not effective at all) to 7 (highly effective) their perceptions of the effectiveness of various means of IP protection for both product and process innovations in protecting their innovations. The mean effective ratings are not statistically different for the two types of innovations, except for the case of U.S. patents, where respondents rate the effectiveness of IP protection higher for product innovations than for process innovations. Note that although most firms do not have direct experience with U.S. patent applications, they still view the U.S. patent as the most effective in protecting both product and process innovations. They rate Chinese trademarks as the least effective means of IP, although they are commonly used by Chinese pesticide firms (Shi and Pray 2010).

Anecdotal evidence also suggests that Chinese firms are not satisfied with the current level of IPR enforcement. Indeed, if a firm gives a low rating to the effectiveness of IPR systems (reflecting a low E), this may be because of the lack of effective enforcement (meaning the firm would prefer stronger enforcement to increase the effectiveness of IPRs) or because the firm thinks IPRs are not the appropriate means of protection (meaning the firm would prefer less IPR and enforcement). To help disentangle these two different perceptions, respondents were required to report their desired level of IPR law and enforcement relative to the status quo: "much more," "more," "same," "less," or "much less." About 71 percent of respondents indicate that they would prefer stronger IPR ("more" or "much more"), while only 3 percent would prefer more relaxed IPR enforcement ("less" and "much less"); 25 percent are happy with the status quo.

In the regression analysis, we also include respondents' preferred level of enforcement. This

[6] A few dominant firms have thousands of employees, while many fringe firms have hundreds (the median number of total number of employees is 212). Indeed, the distribution is skewed for most variables reported in Table 1. The skewness of these variables should not be an issue in the ordered logistic regression, as all are explanatory variables.

Table 1. Summary Statistics

Variable		No. of Obs.[a]	Median	Mean	S.D.	Min.	Max.
No. of new products in 2003–2007		97	0	8.71	19.9	0	141
For those with non-zero count		48	7	17.6	25.4	1	141
Expected total sales in 2008 (10 million RMB)		83	75	32.3	66.2	0.15	450
Share of sales from pesticide in 2008 (%)		78	100	92	16	30	100
Total employees in 2007		96	212	529	735	10	3,500
Share of R&D employees in 2007 (%)		96	15	19	16	1.7	100[b]
No. of Chinese invention patent applications in 2003–2007		97	0	4.07	12.4	0	85
For those with non-zero count		33	3	12	19	1	85
No. of Chinese invention patents granted in 2003–2007		97	0	1	4.3	0	40
For those with non-zero count		25	2	4	8	1	40
No. of trilateral patent applications in 2003–2007		97	0	0.13	0.8	0	6
For those with non-zero count		4	2	3	2	1	6
Rating of Chinese invention patents	Product innovation	77	6	5.8	1.4	1	7
	Process innovation	77	6	5.8	1.6	1	7
Rating of Chinese trademarks	Product innovation	87	4	4.1	2.2	1	7
	Process innovation	76	4	3.9	2.4	1	7
Rating of U.S. patents	Product innovation	65	7	6.3	1.0	3	7
	Process innovation	61	6	6.0	1.2	2	7
Rating of Chinese Administrative Protection	Product innovation	73	5	5.0	1.8	1	7
	Process innovation	72	6	5.1	1.9	1	7

[a] The number of observations is less than 97 because of missing values due to non-response.
[b] One respondent reported specialization in R&D with no production and sales. This respondent is excluded from the regression analysis later.

allows us to test whether a low rating is due to lack of enforcement. If the estimation results suggest that firms which prefer stronger enforcement tend to give a lower rating of IPR effectiveness, we may conclude that the reason for a low rating is the lack of enforcement in their perception. However, if firms that preferred less enforcement gave a low rating to IPRs, it may suggest that firms do not believe the given IPR is an appropriate mechanism for protecting their innovations.

Results and Implications

The ordered logit regression results are reported in Table 2. All regressions are estimated using maximum likelihood and are estimated separately for product innovation and process innovation. To address potential multicollinearity concerns, we first compute the correlation coefficients of the explanatory variables, especially for those in the *EXP*, *COG*, and *CUL* categories. Most correlation coefficients are below 0.3, and none are above 0.8. For variables exhibiting relatively high correlations, we conduct a joint significance test to help determine whether multicollinearity would be an issue or not. Our model and results are robust to these tests.

Chinese Invention Patents

For the experience variables, if a firm's patent has been infringed upon in the past, it rates the effectiveness of Chinese invention patents lower for both product and process innovations. Firms with

Table 2. Ordered Logit Regression Results by IPR Mechanism

		Chinese Invention Patent				Trademark			
		Product Innovation		Process Innovation		Product Innovation		Process Innovation	
		Coeff.	z stat.	Coeff.	z stat.	Coeff.	z stat.	Coeff.	z stat.
EXP	Patent infringed	-4.24***	-2.72	-3.03**	2.13	1.51*	1.74	1.25	1.17
	China invention patents granted	-2.29***	-3.11	0.52***	2.70	0.20	1.53	1.01**	2.21
	China invention patents applied	0.52***	2.86	-0.31**	-2.44	-0.07	-0.84	-0.16	-1.56
	Trilateral patents applied	-0.18	-0.39	0.43	1.07	-0.01	-0.04	0.49	1.42
COG	IPR training	0.30	0.38	-0.39	-0.42	-0.42	-0.59	0.52	0.66
	External IPR agency	0.45	0.31	-0.43	-0.37	1.66	1.57	1.05	0.92
	Non-IPR internal division	-0.34	-0.34	1.05	1.01	1.26	1.46	0.75	0.74
	IPR internal division	-0.13	-0.07	0.19	0.12	1.34	1.10	1.83	1.34
	Leader education	1.51***	2.79	0.72	1.48	0.003	0.01	-0.14	-0.32
	Share of R&D employees (%)	1.65	0.55	0.09***	2.81	0.06**	2.27	0.07**	2.10
CUL	Sales in 2008 (10 million RMB)	0.001	0.02	-0.001	-0.08	-0.01	-1.23	-0.03***	-2.51
	Share of pesticide sales (%)	-0.02	-0.58	-0.07**	-2.26	-0.11***	-3.75	-0.09***	-2.82
	Total employees (1,000)	0.43	0.13	1.26	1.28	1.02**	2.00	2.13**	2.38
	State-reformed	40.0	0.00	4.12**	1.98	-3.59**	-1.98	-1.33	-0.71
	Private	0.98	0.92	2.69**	2.30	0.78	0.85	2.72**	2.05
	Foreign/joint	38.5	0.00	38.1	0.00	-0.85	-0.45	1.71	0.81
X	No. of new products	-0.11***	-2.95	0.09***	2.74	0.04**	2.08	0.06**	2.51
	Shandong	-2.66**	-2.31	0.19	0.19	-0.10	-0.15	0.05	0.06
	Beijing	-0.22	-0.22	-0.52	-0.45	-1.73*	-1.70	-2.19*	-1.84
	Jiangsu	4.19**	2.55	-2.64**	-2.30	0.66	0.69	-0.58	-0.54
Others	Much less IPR than now[a]	-40.9	-0.00	-42.2	-0.00	-35.9	-0.00	39.3	0.00
	Less IPR than now	-45.4	-0.00	-45.9	-0.00	-36.5	-0.00	-34.4	-0.00
	More IPR than now	-0.86	-0.96	-3.97***	-3.43	0.04	0.05	-1.71*	-1.74
	Much more IPR than now	-1.46	-1.58	-4.28***	-3.58	0.50	0.65	-1.52	-1.61
No. of observations		62		65		70		65	
Pseudo R^2		0.40		0.36		0.23		0.28	
LR Chi2		65.3***		56.7***		49.0***		53.5***	

[a] The benchmark is "same as now."

Note: *, **, and *** denote statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

cont'd.

Table 2. Ordered Logit Regression Results by IPR Mechanism (cont'd.)

		U.S. Patent				Administrative Protection			
		Product Innovation		Process Innovation		Product Innovation		Process Innovation	
		Coeff.	z stat.	Coeff.	z stat.	Coeff.	z stat.	Coeff.	z stat.
EXP	Patent infringed	-4.27	-1.19	-1.10	-0.74	0.01	0.01	0.20	0.24
	China invention patents granted	-7.44**	-2.36	-1.11*	-1.80	-0.66	-1.13	0.07	0.34
	China invention patents applied	1.78**	2.08	0.22	1.03	0.09	0.85	0.06	0.57
	Trilateral patents applied	6.42	1.00	4.86**	2.01	na	na	na	na
	U.S. patents applied	-24.8	-1.38	-12.1**	-2.04	na	na	na	na
COG	IPR training	-2.38	-1.55	1.04	1.09	-0.25	-0.28	-1.30	-1.60
	External IPR agency	-1.28	-0.58	-0.60	-0.38	3.63**	2.52	1.15	0.93
	Non-IPR internal division	2.57	1.49	-0.25	-0.16	3.25***	2.94	1.55	1.57
	IPR internal division	-10.0	-0.88	-0.48	-0.21	5.51***	3.16	2.68*	1.80
	Leader education	0.49	0.57	0.04	0.06	-0.87*	-1.76	-0.73*	-1.72
	Share of R&D employees (%)	0.09*	1.85	0.11**	2.54	0.05**	2.01	0.05**	2.10
CUL	Sales in 2008 (10 million RMB)	0.02	0.34	-0.002	-0.12	-0.005	-0.42	-0.03**	-2.44
	Share of pesticide sales (%)	-0.18	-1.13	-0.03	-0.48	-1.59	-0.56	0.01	0.46
	Total employees (1,000)	2.76	0.43	-0.05	-0.04	0.46	0.51	3.05**	2.51
	State-reformed	195.9*	1.81	36.6	1.62	24.2	1.25	5.68***	3.11
	Private	1.29	0.79	2.74*	1.92	2.08*	1.89	2.84**	2.54
	Foreign/joint	46.6	0.00	40.6	0.00	2.66	1.18	4.18**	1.97
X	No. of new products	-0.23**	-2.19	-0.06	-1.41	-0.03	-1.39	-0.01	-0.36
	Shandong	3.63	1.61	-2.51	-1.38	-3.01***	-2.98	-1.37	-1.46
	Beijing	1.48	0.88	0.68	0.50	-2.42**	-2.13	-0.96	-0.95
	Jiangsu	13.2**	2.05	-0.48	-0.28	0.15	0.14	-0.41	-0.39
Others	Much less IPR than now[a]	43.1	0.00	na	na	na	na	35.9	0.00
	Less IPR than now	39.6	0.00	39.6	0.00				
	More IPR than now	-2.44**	-2.29	-1.92*	-1.72	-0.86	-1.03	-0.38	-0.49
	Much more IPR than now	1.86	0.92	0.14	0.13				
No. of observations		55		53		60		61	
Pseudo R^2		0.54		0.37		0.30		0.26	
LR Chi2		59.7***		51.5***		49.2***		41.4***	

[a] The benchmark is "same as now." // Note: *, **, and *** denote statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

more Chinese invention patents granted in the past five years tend to rate their effectiveness lower for product innovations, but higher for process innovations. The pattern switches for the number of Chinese invention patents applied for, where firms with more patent applications in the past five years rate the effectiveness higher for product innovations but lower for process innovations. It seems that *a priori* high expectation of the effectiveness of IP, reflected by a firm's filing patent applications, is positively correlated with that firm's perception of the effectiveness of the patent system for its product innovations. In contrast, for process innovations the correlation is negative. Experience with foreign patent applications, while limited, does not have a significant impact on firms' ratings for either product or process innovations.

These results imply intrinsic differences between product and process innovations. Product innovations of chemical products (here pesticides) are often associated with high R&D cost, but low replication cost. They are vulnerable to infringement, and the effectiveness of IP protection mostly lies in enforcement *ex post*. Process innovations are often accompanied by technical know-how protected by trade secrets. Firms are reluctant to reveal technical know-how in the patent application. Therefore, patent protection for process innovations may be perceived as less useful than for product innovations. However, for those process innovations for which patents were applied for and granted, effective enforcement may be less problematic, as the concealed know-how reduces the need for legal enforcement because it would be difficult for would-be infringers to duplicate the technology completely.

For cognitive variables, the educational achievement of the administrative team matters: the higher the proportion of team members with at least a bachelor's degree, the more likely the firm rates perceived patent effectiveness high for product innovations. The higher the share of R&D workers, the more likely the firm rates perceived patent effectiveness high for process innovations. More educated administrative teams and employee bases (as reflected by the higher R&D capacity measured by the share of R&D workers) seem to have higher confidence in the effectiveness of patent protection. This may suggest an increasing utilization of IPRs in the long run as China's increased investment in education produces an increasing number of graduates with bachelor's degrees or higher every year.

As for the impacts of proposed policies of mandatory IPR training and the development of specialized IPR divisions, we find no statistically significant evidence that either of the proposed polices would increase the perception of the effectiveness of patents. Mandatory "rubber-stamp" policies and procedures do not seem to work in raising confidence in patents.

Firm culture variables such as firm size, scale, and ownership types do not seem to have an impact on the perceived effectiveness of the invention patent for product innovations. For process innovations, private firms and state-reformed firms tend to rate patent effectiveness higher than do state-owned firms.

The coefficient on the number of new products introduced in the last five years is negative for product innovation but positive for process innovations, both being statistically significant. This result is consistent with our findings above, in which we infer that patents may be more effective in protecting process innovations than in protecting product innovations. Thus, the more new products a firm introduced in the last five years, the lower the firm rates the effectiveness of Chinese invention patents. Location also matters. Producers in Shandong rate patent effectiveness lower for product innovation, while producers in Jiangsu give a higher rating for product innovations, but lower for process innovation. The regional differences may be due to the clustering of innovation and productivity activities. Jiangsu has a major government pesticide research institute. Thus, many producers located around that center are likely involved in product innovation activities, and the local court and enforcement system may provide more effective patent protection in this region.

Anecdotal evidence suggests that Chinese pesticide firms are more competitive in process innovations such as new formulations than in product innovations where foreign companies often dominate. As mentioned above, about 80 percent of all pesticide-related patents are related to process rather than product innovations. Our results above seem to suggest that firms are reluctant to devote resources to costly product innovation activities because they are frustrated with the cur-

rent lack of enforcement of IPRs in China on product innovation. Our results also suggest fewer enforcement issues for process innovations, likely due to the complementary role played by know-how embedded in process innovations and not revealed by their patent applications.

The survey asked additional questions on respondents' desired level of IPR and enforcement compared to the status quo. We did not find statistical evidence that a firm's desired level was related to its rate of IP effectiveness for product innovations. However, for process innovations, the firms that prefer stronger enforcement and IPR than the status quo gave lower ratings for the effectiveness of patent protection. This suggests that enforcement may still be an issue for process innovation, although earlier evidence from the experience variables suggests that it may be less problematic than for product innovations.

Chinese Trademarks

Trademarks have been widely used in the pesticide industry. However, leaders of the pesticide industry say that, compared to patents, trademarks are viewed more as a marketing tool than as an effective means of IP protection in the pesticide industry (Sun 2006). This may explain the lack of significance in the coefficient estimates for most experience and cognitive ability variables, except for patent infringement for product innovations (positive), the number of patents granted in the past five years for process innovations (negative), and the share of R&D workers in total employees for both product and process innovations (positive). The positive coefficient on the infringement in the product innovation equation may reflect firms' lack of confidence in the effectiveness of patents in protecting product innovation. This makes trademarks relatively more attractive than patents as an option for protecting IP in products.

Larger firms (in terms of greater total sales in 2008) tend to rate effectiveness of trademarks lower: coefficients are negative for both product and process innovations, but statistically significant only for process innovations. Successful pesticide products are the targets of infringers through identical or confusingly similar trademarks. Since pesticide trademark infringers are often small, anonymous producers that are hard to locate, litigation and enforcement have been widely perceived as difficult. Thus, big pesticide firms are often the victims of trademark infringement. This is consistent with our results showing that the more specialized the firm is in pesticides, the lower the effectiveness of trademark protection is for both product and process innovations. For both product and process innovations, firms give a higher rating for trademark effectiveness if they have more employees. For product innovations, the state-reformed firms give lower ratings for trademark effectiveness than do the state-owned firms, while for process innovations, the private firms tend to rate the perceived effectiveness higher than do the state-owned firms.

The coefficient of the new products variable is positive, statistically significant for both product and process innovations. As we mentioned above, trademarks are used widely for marketing. The more new products a firm introduced, the more heavily the firm will rely on trademarks. The results also suggest that firms in Beijing perceived trademarks to be less effective than did firms in the rest of the country. Firms that prefer stronger enforcement and IPR than the status quo gave lower ratings for the effectiveness of trademark protection, suggesting the lack of IP enforcement.

U.S. Patents

Although only a few firms in our sample have hands-on experience with U.S. patenting, Chinese firms in general perceive the effectiveness of the U.S. patent system as being high. The experience variables suggest spillover effects from domestic learning to IPR systems. High *a priori* expectations of IP protection, as reflected by the Chinese patent applications (or applications to the trilateral offices), are positively correlated with perceived effectiveness of U.S. patents for innovations. However, if the applications are made to the USPTO, the rating of U.S. patent effectiveness is lower. Since very few firms in our sample have U.S. patent application experience, this result should be interpreted with caution, as it may reflect the effect of some firm-specific factors that we did not observe.

For the cognitive variables, the higher the share of R&D workers, the more highly the firm rates patent effectiveness for both product and process innovations. For cultural variables, state-reformed or private firms gave a higher rating to U.S. pat-

ent effectiveness for product (or process) innovations than did state-owned firms. The new products variable was negative and statistically significant for product innovations. Finally, firms in Jiangsu differ from the rest of the sample, with a higher rating for product innovation. This may be due to the fact that Jiangsu province is the top exporter of pesticide products, accounting for more than one-third of the total exports in 2010, according to the General Administration of Customs of China (Agrochemicals Today 2010). While the exporting markets are mostly South America, Africa, and Southeast Asian countries, there might be information spillovers from foreign competitors regarding the effectiveness of U.S. patents. Also note that the firms that prefer stronger enforcement of IPRs gave lower ratings for the perceived effectiveness of U.S. patent protection for both product and process innovations. While most firms do not have direct experience with the U.S. patent system, these results suggest negative spillover effects from the lack of IP enforcement domestically to the lack of confidence in IPRs globally.

Chinese Administrative Protection

Administrative Protection is a temporary and unique means of protection for pesticide products in China, made available only to foreign firms, and the execution of protection is not through the courts and legal system. Since the majority of respondents are Chinese firms, estimated results reflect domestic firms' perceptions of the Chinese government's policy toward their foreign competitors.

As expected, since Administrative Protection is not applicable to domestic firms, none of the experience variables are statistically significant. For the cognitive ability variables, firms with some sort of specialized IPR agency do rate the effectiveness of Administrative Protection more highly than firms without an IPR office for both product and process innovations. Firms with more educated leaders, however, give a lower rating for both product and process innovations. Firms with a higher share of R&D workers rated patent effectiveness higher than other firms for both product and process innovations. Compared to state-owned firms, private firms rate this type of protection higher. Firms in Shandong and Beijing rate it lower for product innovation than do firms in other regions. Since the Administration Protection is implemented through administrative agencies rather than IPR courts and the legal system, none of the variables regarding firms' preferred level of IPR and enforcement seem to matter.

Conclusion

Although China has greatly strengthened its IPR laws and regulations, it has also been criticized heavily for its lack of IP law enforcement (e.g., Athanasakou 2007). In this study, we analyze data from a survey asking 97 Chinese pesticide firms about their perceptions regarding the effectiveness of various means of IP protection. The evidence suggests that the satisfaction of Chinese pesticide firms with the Chinese patent system is mixed. On average, Chinese firms rate the system as effective (their rating is 6 out of a possible 7), only slightly less effective than they think the U.S. system is (which they also rate about 6 out of 7). Trademarks were considered to be less useful, but may be useful for marketing new products when patent protection is weak.

Despite the fact that firms rated Chinese patents as effective, 71 percent of the firms in this survey wanted stronger enforcement of patents, while only 3 percent wanted less enforcement. Our findings from the regression analysis show that past experience with Chinese patents affects a firm's perception of IPR effectiveness negatively, implying that lack of enforcement is a problem, especially for product innovations.

Our results suggest important differences in the effectiveness of patents in protecting product and process innovations for Chinese pesticide firms. Product innovations suffer from a lack of enforcement according to anecdotal evidence, and our regression results support the anecdotal evidence. This may explain why Chinese pesticide firms are reluctant to devote resources to product innovation activities and choose to focus instead on process innovations. If the Chinese government wants to increase Chinese firms' confidence in the patent system, enforcement must be the government's primary focus.

Our evidence also suggests that private firms are more pro-IPR than are state-owned firms. Firms with more R&D capacity (measured by the

share of R&D workers in total employees) and educated leadership (measured by the proportion of managers with at least a bachelor's degree) value Chinese invention patents more highly. It seems that Chinese firms' use of IPRs will increase with China's ongoing policies that are pushing state-owned firms closer to the market, along with China's education investment policy, which produces more and more college graduates every year.

To conclude, our regression results suggest that if the Chinese government really wants to increase innovation, it will have to focus on improving firms' experiences with the IPR system through stronger enforcement. If firms continue to ask for stronger patent protection, and those that hold patents continue to rate the effectiveness of the patent system lower than do firms who do not, then Chinese pesticide firms are not likely to invest much money in developing new products. Our results suggest that policies that encourage firms to conduct more R&D could increase firms' confidence in the effectiveness of the IP system. However, policies such as mandatory IPR training and/or organizational reforms such as requiring firms to establish specialized IPR divisions, will have little impact on firms' perception of the effectiveness of IP protections and on their innovative activities.

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