Imports and Intellectual Property Rights on Innovation in China

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Abstract

In an open-economy R&D-based growth model with two intermediate production sectors, we find that strengthening intellectual property rights (IPR) has a positive effect on innovation in the sector that uses domestic inputs but both positive and negative effects on innovation in the sector that uses foreign inputs. We test these results using an empirical analysis of matching samples that combine Chinese provincial IPR data with industrial enterprises database and customs database.

JEL classification: F43, O31, O34
Keywords: Intellectual property rights; imports; knowledge spillovers; innovation

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1 Introduction

This study provides both a theoretical analysis and an empirical investigation on the effects of intellectual property rights (IPR). We develop an open-economy R&D-based growth model with two intermediate production sectors that use domestic and foreign inputs respectively. We use the model to explore the effects of IPR on knowledge spillovers and innovation. In the sector that uses domestic inputs, strengthening IPR has a positive effect on innovation. However, in the sector that uses foreign inputs, strengthening IPR has both positive and negative effects, where the latter is due to IPR suppressing knowledge spillovers from imports.

We test these results using an empirical analysis of matching samples that combine Chinese provincial IPR data with industrial enterprises database and customs database. Our regression results confirm that IPR indeed has the usual positive effect on innovation but also a negative interactive effect on innovation via imports, which is consistent with the above-mentioned suppression effect of IPR on knowledge spillovers from imports. However, importing firms still have better innovation performance than non-importing firms, which is consistent with our theoretical model. Finally, strengthening IPR first enlarges and then reduces the difference in the innovation performance between importing and non-importing firms, which is also consistent with our theoretical model.

This study relates to the theoretical literature on innovation and economic growth. The seminal study in this literature is Romer (1990). Subsequent studies in this literature use variants of the R&D-based growth model to explore the effects of IPR; see for example Lai (1998), Li (2001), Goh and Olivier (2002), Grossman and Lai (2004), Chu (2009), Furukawa (2010), Iwaisako and Futagami (2013), Yang (2013), Cozzi and Galli (2014), Zeng *et al.* (2014), Lin (2015), Huang *et al.* (2017) and Saito (2017). The current study differs from these studies by exploring a novel channel through which strengthening IPR causes a negative effect on innovation by suppressing knowledge spillovers from imports.

The study also relates to the empirical literature on the determinants of innovation. For example, Goldberg *et al.* (2010) use firm-level data to show that imported intermediate inputs increase product innovation in India. Chen and Puttitanun (2005) use country-level data to show that strengthening IPR increases innovation. Recent studies explore channels through which IPR affects innovation. For example, Ang *et al.* (2014) show that IPR stimulates innovation by improving firms' external financing ability. Naghavi and Strozzi (2015) find that IPR interacts with international migration to encourage domestic innovation by creating an environment that transmits knowledge acquired by emigrants. The current study complements these studies by exploring the effects of IPR on innovation via imports.

2 Theoretical model

We extend the small-open-economy growth model[1] in Grossman and Helpman (1991) into multiple production and R&D sectors. Also, we assume that one sector uses domestic inputs to produce differentiated products, whereas the other sector uses foreign inputs.

[1] A small open economy may not fully capture China. However, our small-open-economy model simply assumes the price of imported inputs to be exogenous. Given that this price does not affect the equilibrium allocation of R&D labor, we consider our model as a useful approximation to the analysis of IPR in China.

2.1 Household

The representative household has the following utility function:

$$U = \int_0^\infty e^{-\rho t}(\ln C_{y,t} + \gamma \ln C_{z,t})dt, \tag{1}$$

where $\rho > 0$ is the discount rate. $C_{y,t}$ is the consumption of a domestic final good chosen as the numeraire. $C_{z,t}$ is the consumption of an imported final good from abroad. Its price $p_{z,t}$ is exogenous. The asset-accumulation equation is

$$\dot{A}_t = r_t A_t + w_t l - C_{y,t} - p_{z,t} C_{z,t}. \tag{2}$$

A_t is the amount of assets. r_t is the interest rate. l denotes labor. w_t is the wage rate. From standard dynamic optimization, the optimality conditions are

$$\frac{\dot{C}_{y,t}}{C_{y,t}} = r_t - \rho, \tag{3}$$

$$C_{z,t} = \gamma C_{y,t}/p_{z,t}. \tag{4}$$

2.2 Domestic final good

Domestic final good[2] is produced by the following aggregator:[3]

$$Y_t = (X_t^d)^{0.5}(X_t^f)^{0.5}, \tag{5}$$

where X_t^d is an intermediate good that uses domestic inputs and X_t^f is an intermediate good that uses foreign inputs. Profit maximization yields the following conditional demand functions for X_t^d and X_t^f:

$$X_t^d = \frac{Y_t}{2P_t^d}, \tag{6}$$

$$X_t^f = \frac{Y_t}{2P_t^f}, \tag{7}$$

where P_t^d and P_t^f are the prices of X_t^d and X_t^f respectively.

2.3 Intermediate goods

Intermediate good $i \in \{d, f\}$ is produced by

$$X_t^i = (L_t^i)^{1-\alpha} \int_0^{n_t^i} [x_t^i(\omega)]^\alpha d\omega, \tag{8}$$

[2] It can be consumed by the household, used to produce intermediate inputs or exported abroad.

[3] Our results are robust to $Y_t = (X_t^d)^\theta (X_t^f)^{1-\theta}$; derivations available upon request. We focus on $\theta = 0.5$ for simplicity.

where L_t^i denotes domestic production labor and $x_t^i(\omega)$ denotes differentiated inputs. Profit maximization yields the following conditional demand functions for L_t^i and $x_t^i(\omega)$:

$$w_t = (1-\alpha)P_t^i X_t^i / L_t^i, \tag{9}$$

$$p_t^i(\omega) = \alpha P_t^i (L_t^i)^{1-\alpha}[x_t^i(\omega)]^{\alpha-1}, \tag{10}$$

where $p_t^i(\omega)$ is the price of $x_t^i(\omega)$.

2.4 Domestic differentiated inputs

Domestic differentiated inputs $x_t^d(\omega)$ are produced by domestic final good with an one-to-one technology. The profit function is

$$\pi_t^d(\omega) = p_t^d(\omega)x_t^d(\omega) - x_t^d(\omega) = \alpha P_t^d (L_t^d)^{1-\alpha}[x_t^d(\omega)]^{\alpha} - x_t^d(\omega). \tag{11}$$

The monopolistic price is $p_t^d(\omega) = \min\{\mu, 1/\alpha\}$, where $\mu < 1/\alpha$. As is common in the literature,[4] due to incomplete patent protection μ, the monopolist cannot charge too high a price; otherwise, an imitator will produce $x_t^d(\omega)$. The amount of profit for $\omega \in [0, n_t^d]$ is

$$\pi_t^d(\omega) = (\mu - 1)x_t^d(\omega) = \frac{\mu-1}{\mu}\frac{\alpha P_t^d X_t^d}{n_t^d} = \frac{\mu-1}{\mu}\frac{\alpha Y_t}{2n_t^d} \equiv \pi_t^d, \tag{12}$$

where the second equality uses symmetry in (8), (10) and $p_t^d(\omega) = \mu$. The balanced-growth value of an invention is

$$v_t^d(\omega) = \frac{\pi_t^d(\omega)}{r - g_\pi^d} = \frac{\mu-1}{\mu}\frac{\alpha Y_t}{2n_t^d}\frac{1}{\rho + g_n^d} \equiv v_t^d, \tag{13}$$

where g_π^d and g_n^d are the steady-state growth rates of π_t^d and n_t^d respectively.

2.5 Foreign differentiated inputs

Foreign differentiated inputs $x_t^f(\omega)$ are produced by foreign final good with an one-to-one technology. The profit function is

$$\pi_t^f(\omega) = p_t^f(\omega)x_t^f(\omega) - p_{z,t}x_t^f(\omega) = \alpha P_t^f (L_t^f)^{1-\alpha}[x_t^f(\omega)]^{\alpha} - p_{z,t}x_t^f(\omega). \tag{14}$$

The monopolistic price is $p_t^f(\omega) = \min\{\mu, 1/\alpha\}\, p_{z,t}$, where $\mu < 1/\alpha$. Once gain, due to incomplete patent protection μ, the monopolist cannot charge too high a price; otherwise, an imitator will produce $x_t^f(\omega)$. The amount of profit for $\omega \in [0, n_t^f]$ is

$$\pi_t^f(\omega) = (\mu - 1)p_{z,t}x_t^f(\omega) = \frac{\mu-1}{\mu}\frac{\alpha P_t^f X_t^f}{n_t^f} = \frac{\mu-1}{\mu}\frac{\alpha Y_t}{2n_t^f} \equiv \pi_t^f, \tag{15}$$

where the second equality uses symmetry in (8), (10) and $p_t^f(\omega) = \mu p_{z,t}$. The balanced-growth value of an invention is

$$v_t^f(\omega) = \frac{\pi_t^f(\omega)}{r - g_\pi^f} = \frac{\mu-1}{\mu}\frac{\alpha Y_t}{2n_t^f}\frac{1}{\rho + g_n^f} \equiv v_t^f, \tag{16}$$

where g_π^f and g_n^f are the steady-state growth rates of π_t^f and n_t^f respectively.

[4]See for example Li (2001), Goh and Olivier (2002), Iwaisako and Futagami (2013) and Yang (2013).

2.6 R&D for domestic differentiated inputs

The innovation process in the sector that uses domestic inputs is

$$\dot{n}_t^d = k_t^d R_t^d, \tag{17}$$

where R_t^d denotes domestic R&D labor in sector d. The productivity of R_t^d is given by $k_t^d = n_t^d$, which captures knowledge spillovers as in Romer (1990). Free entry yields

$$\dot{n}_t^d v_t^d = w_t R_t^d \Leftrightarrow n_t^d v_t^d = w_t. \tag{18}$$

2.7 R&D for foreign differentiated inputs

The innovation process in the sector that uses foreign inputs is

$$\dot{n}_t^f = k_t^f R_t^f, \tag{19}$$

where R_t^f denotes domestic R&D labor in sector f. The productivity of R_t^f is $k_t^f = n_t^f(1 + \overline{\lambda}\tau_t^f)$, where $\tau_t^f = p_{z,t}\int_0^{n_t^f} x_t^f(\omega)d\omega/Y_t$ is the value of imports (for producing differentiated inputs) as a ratio to output. This specification is consistent with Grossman and Helpman (1991) who also assume that knowledge spillovers arise from trade.[5] Imposing symmetry and using (7) and (15), one can show that $\tau_t^f = \alpha/(2\mu)$ and $k_t^f = n_t^f + \lambda n_t^f/\mu$ where $\lambda \equiv \overline{\lambda}\alpha/2$ and $\lambda n_t^f/\mu$ captures an additional knowledge spillover effect from imports. In this case, patent protection μ reduces knowledge spillovers because a larger markup reduces the demand for imports. Thus, although entrepreneurs are able to appropriate foreign technologies, this foreign knowledge spillover effect is decreasing in μ. Free entry yields

$$\dot{n}_t^f v_t^f = w_t R_t^f \Leftrightarrow (1 + \lambda/\mu) n_t^f v_t^f = w_t. \tag{20}$$

2.8 Equilibrium labor allocation

The resource constraint on labor is

$$R_t^d + L_t^d + R_t^f + L_t^f = l_t^d + l_t^f = l, \tag{21}$$

where $l_t^d \equiv R_t^d + L_t^d$ and $l^f \equiv R_t^f + L_t^f$. Substituting (6), (9) and (13) into (18) yields

$$L^d = \frac{1-\alpha}{\alpha}\frac{\mu}{\mu-1}(\rho + R^d), \tag{22}$$

which together with (21) implies that steady-state equilibrium R^d is

$$R^d = \alpha\left(\frac{\mu-1}{\mu-\alpha}\right)l^d - \rho\mu\left(\frac{1-\alpha}{\mu-\alpha}\right), \tag{23}$$

where l^d is endogenous. Substituting (7), (9) and (16) into (20) yields

$$L^f = \frac{1-\alpha}{\alpha}\frac{\mu}{\mu-1}\left(\frac{\rho}{1+\lambda/\mu} + R^f\right), \tag{24}$$

[5] See Coe and Helpman (1995) for empirical evidence that trade affects international spillovers.

which together with (21) implies that steady-state equilibrium R^f is

$$R^f = \alpha \left(\frac{\mu - 1}{\mu - \alpha} \right) l^f - \frac{\rho\mu}{1 + \lambda/\mu} \left(\frac{1 - \alpha}{\mu - \alpha} \right), \tag{25}$$

where l^f is endogenous. To solve for l^d and l^f, we use (6), (7) and (9) to obtain

$$L^f = L^d, \tag{26}$$

which together with (22) and (24) implies

$$l^f = \frac{\rho\lambda}{\mu + \lambda} + l^d. \tag{27}$$

Combining (21) and (27) yields

$$\underset{+}{l^d(\mu)} = \frac{1}{2} \left(l - \frac{\rho\lambda}{\mu + \lambda} \right), \tag{28}$$

$$\underset{-}{l^f(\mu)} = \frac{1}{2} \left(l + \frac{\rho\lambda}{\mu + \lambda} \right), \tag{29}$$

which show that stronger patent protection μ leads to a reallocation of labor from sector f to sector d because μ suppresses knowledge spillovers from imports in sector f.

2.9 Equilibrium growth rates of technologies

The steady-state equilibrium growth rate of n_t^d is

$$g_n^d \equiv \frac{\dot{n}_t^d}{n_t^d} = R^d(\mu) = \alpha \left(\frac{\mu - 1}{\mu - \alpha} \right) \underset{+}{l^d(\mu)} - \rho\mu \left(\frac{1 - \alpha}{\mu - \alpha} \right), \tag{30}$$

which is increasing in μ. Intuitively, stronger patent protection increases profit, which in turn increases R&D in sector d. Furthermore, this positive effect is strengthened by the reallocation of resources from sector f to sector d. Proposition 1 summarizes this result.

Proposition 1 *The growth rate of technology in the sector that uses domestic inputs is increasing in patent protection μ.*

Proof. Use (30). ■

The steady-state equilibrium growth rate of n_t^f is

$$g_n^f \equiv \frac{\dot{n}_t^f}{n_t^f} = (1 + \lambda/\mu) R^f(\mu) = (1 + \lambda/\mu)\alpha \left(\frac{\mu - 1}{\mu - \alpha} \right) \underset{-}{l^f(\mu)} - \rho\mu \left(\frac{1 - \alpha}{\mu - \alpha} \right), \tag{31}$$

which can be increasing or decreasing in patent protection μ. Intuitively, stronger patent protection increases profit, which is a positive effect on R&D in sector f. However, stronger patent protection also has a negative effect on knowledge spillovers and R&D in sector

f. Furthermore, this negative effect is strengthened by the reallocation of resources from sector f to sector d. Therefore, the overall effect of patent protection on the growth rate of technology in sector f is ambiguous.[6] Proposition 2 summarizes this result.

Proposition 2 *The growth rate of technology in the sector that uses foreign inputs can be increasing or decreasing in patent protection* μ.

Proof. Use (31). ∎

Finally, taking the difference between the growth rates of n_t^f and n_t^d yields

$$\Delta g_n \equiv g_n^f - g_n^d = \alpha \left(\frac{\mu - 1}{\mu - \alpha} \right) \left[\frac{\lambda}{2\mu} \left(l + \frac{\rho\lambda}{\mu + \lambda} \right) + \frac{\rho\lambda}{\mu + \lambda} \right] > 0. \tag{32}$$

The growth rate of technology is higher in sector f than in sector d due to the additional knowledge spillovers from imports in sector f. Furthermore, it can be shown that Δg_n is firstly increasing and eventually decreasing in μ. If we consider $\rho \to 0$, then Δg_n is explicitly an inverted-U function in μ. Proposition 3 summarizes these results.

Proposition 3 *The growth rate of technology is higher in the sector that uses foreign inputs than in the sector that uses domestic inputs. The difference* Δg_n *in the growth rates is firstly increasing and eventually decreasing in patent protection* μ.

Proof. Use (32). ∎

3 Empirical model

From Wooldridge (2006), the basic form of the logit model is[7]

$$P_i = P(y_i = 1|Z_i) = F(Z_i, \beta) = \frac{\exp(\beta_0 + \beta Z_i)}{1 + \exp(\beta_0 + \beta Z_i)}, \tag{33}$$

where P_i is the probability of firm i having an innovation. $F(Z_i, \beta)$ is the cumulative distribution function of the logistic distribution. Manipulating (33), we obtain

$$ln \left(\frac{P_i}{1 - P_i} \right) = \beta_0 + \beta Z_i, \tag{34}$$

where Z_i denotes a vector of explanatory variables.

We consider IPR and imported intermediate inputs as two main explanatory variables on innovation. To analyze how IPR affects importing firms' innovation, we introduce an interaction term between IPR and imports. We specify our empirical model as follows:

$$ln \left(\frac{P_{it}}{1 - P_{it}} \right) = \beta_0 + \beta_1 IPR_{pt} + \beta_2 INT_{it} + \beta_3 INT_{it} * IPR_{pt} + \theta Z_{it} + \eta_p + \eta_j + \eta_t + \varepsilon_{it} \tag{35}$$

[6]See also Goh and Olivier (2002), Iwaisako and Futagami (2013) and Saito (2017), who explore other channels through which patent breadth has ambiguous effects on innovation.

[7]Our findings in Table 1 and Figure 1 are robust to the probit model. Results are available upon request.

where $ln(P_{it}/(1 - P_{it}))$ is the log odds of firm i having innovation at time t and $P_{it} = P(NEW_{it} = 1|Z_{it})$. NEW_{it} denotes innovation of firm i in year t defined as whether firm i produces new products in year t.[8] If it does, then $NEW_{it} = 1$; otherwise $NEW_{it} = 0$. Explanatory variables include IPR_{pt}, INT_{it}, $INT_{it} * IPR_{pt}$ and other control variables Z_{it}. IPR_{pt} denotes the log level of IPR in province p of China at time t. INT_{it} is a dummy variable of whether firm i imports intermediate inputs in year t. If it does, then $INT_{it} = 1$; otherwise $INT_{it} = 0$. η_p is the province fixed effect. η_j is the industry fixed effect. η_t is the year fixed effect. ε_{it} is the error term.

$\{\beta_1, \beta_2, \beta_3\}$ respectively captures the effects of IPR on innovation, knowledge spillovers from imports, and the interaction between IPR and imports. First, β_1 captures the direct effect of IPR on innovation, which corresponds to Proposition 1. According to Proposition 1, β_1 should be positive indicating that IPR has a positive effect on innovation. Second, β_2 captures whether importing firms benefit from knowledge spillovers. If importing firms benefit from knowledge spillovers, then β_2 should be positive. Third, β_3 captures the effect of IPR on knowledge spillovers of importing firms, which corresponds to Proposition 2. According to Proposition 2, β_3 should be negative indicating that IPR hinders knowledge spillovers from imports. Finally, Proposition 3 implies

$$P(NEW_{it} = 1|INT_{it} = 1, IPR_{pt}) > P(NEW_{it} = 1|INT_{it} = 0, IPR_{pt}); \tag{36}$$

i.e., importing firms have better innovation performance than non-importing firms.

Other explanatory variables Z_{it} include the proportion of firm exports in total output (EXP), foreign capital share (FOR), the log of firm age (AGE), the log of total factor productivity (TFP) and the log of firm size measured by employment ($SIZE$) that may affect enterprise innovation. In addition, we also control for the log of per capita GDP at the provincial level ($INCOME$) and the log of the Herfindal index computed from the 4-digit Chinese Industry Classification system ($HERF$).

With the entry of China to the WTO in 2001 and the requirements of the TRIPS Agreement, the strengthening of IPR in China during that period has an exogenous nature. Therefore, we consider data from 2000 to 2007.[9] We present a description of the data and summary statistics in an online appendix.[10]

4 Regression results

Table 1 shows the regression results. From columns (1) to (3), IPR contributes to innovation at 10% significance level whereas imports INT contribute to innovation at 1% significance level. In column (4), we include an interaction term between IPR and imports of intermediate inputs. Two findings emerge. First, the coefficients of IPR and imports have the same sign but become more significant compared to those in columns (1) to (3). Second, the

[8] We measure innovation of firms by a dummy variable of new products to correspond to the theoretical model. From the law of large numbers, the probability of each firm having a new product corresponds to the growth rate of products in its sector.

[9] We consider data up to 2007 due to the incompatibility of data in the Chinese industrial enterprises database from 2008 onwards.

[10] See the Appendix.

interaction coefficient is negative at 5% significance level, which means that IPR has a significant negative effect on importing firms' innovation. These results confirm Propositions 1 and 2.

[Insert Table 1 here]

From column (4), we calculate the probability of innovation at each level of IPR. As shown in figure 1, with the improvement of IPR, importing and non-importing firms both experience higher innovation probability, but the innovation probability of importing firms is higher than that of non-importing firms. However, with stronger IPR, the gap between the two types of firms first widens and eventually narrows due to the negative effect of IPR on knowledge spillovers from imports. These findings confirm Proposition 3.

[Insert Figure 1 here]

5 Conclusion

This study develops a small-open-economy R&D-based growth model to explore the different effects of IPR on the innovation of importing and non-importing firms. We test and confirm theoretical results from the model using an empirical analysis of matching samples that combine Chinese provincial IPR data with industrial enterprises database and customs database. Our study shows that IPR has an overall positive effect on innovation in China. Furthermore, importing firms have better innovation performance than non-importing firms; therefore, the government should encourage international trade.

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Table 1: Regression results

Variable	*NEW*			
	(1)	(2)	(3)	(4)
IPR	2.342*		2.346*	2.805**
	(1.274)		(1.278)	(1.290)
INT		0.475***	0.476***	3.038***
		(0.090)	(0.090)	(1.159)
$INT * IPR$				−1.738**
				(0.779)
$SIZE$	0.543***	0.505***	0.504***	0.504***
	(0.060)	(0.054)	(0.054)	(0.054)
EXP	0.136	-0.022	-0.017	-0.009
	(0.166)	(0.151)	(0.151)	(0.154)
FOR	−0.248**	−0.425***	−0.432***	−0.421***
	(0.124)	(0.141)	(0.142)	(0.138)
TFP	0.212***	0.191***	0.199***	0.198***
	(0.035)	(0.036)	(0.035)	(0.035)
AGE	0.166***	0.168***	0.164***	0.165***
	(0.037)	(0.037)	(0.037)	(0.037)
$INCOME$	1.769	1.268	1.764	1.672
	(2.710)	(2.368)	(2.716)	(2.664)
$HERF$	0.135***	0.131***	0.132***	0.132***
	(0.017)	(0.018)	(0.017)	(0.018)
Constant	-25.914	-17.804	-25.700	-25.447
	(28.033)	(23.653)	(28.121)	(27.793)
Province fixed effect	yes	yes	yes	yes
Industry fixed effect	yes	yes	yes	yes
Year fixed effect	yes	yes	yes	yes
Observations	883793	883793	883793	883793

Notes. The brackets are the standard errors clustering at the province level. Significant at *10%, **5% and ***1%.

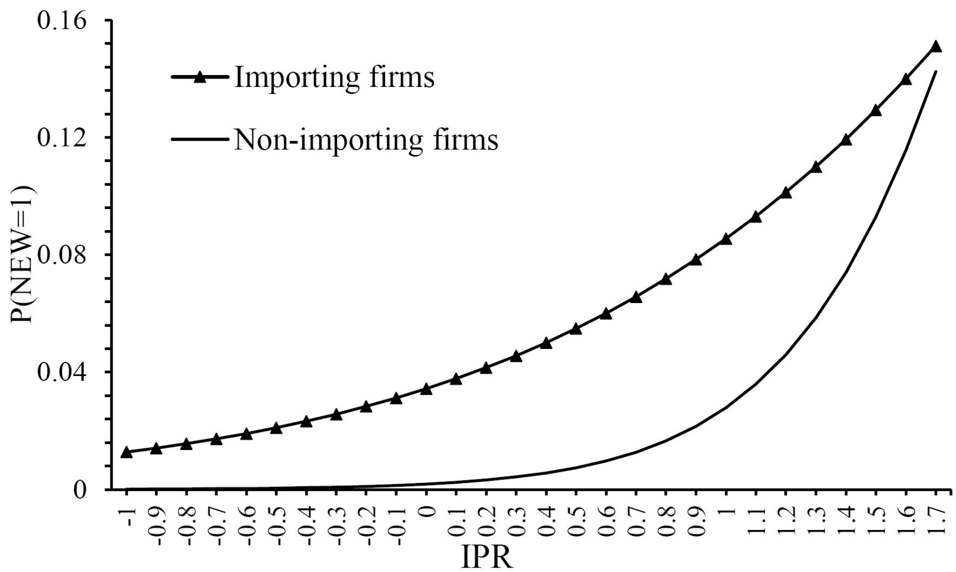

Figure 1: Firm innovation probabilities based on logit model

Notes. Stata's margins command is used to calculate the marginal effect of intellectual property rights on innovation probability. IPR is measured in log.

Imports and Intellectual Property Rights on Innovation in China: Online Data Appendix

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1 Intellectual property rights

Shen (2010) use the method in Ginarte and Park (1997)[1] to construct an annual measure of intellectual property rights (IPR) at the country level in China. We use his data from 2000 to 2007. As for the level of IPR in each province, we use information on the level of administrative protection and the level of judicial protection as follows. First, we use two indicators to measure IPR at the administrative level. (1) The importance of provincial government's emphasis on IPR. As in Ang *et al.* (2014), we use the number of articles on the protection of IPR in the newspapers of provincial authorities divided by the total number of articles in the newspapers of each province as a measure of this index. The higher the index, the more emphasis on the protection of IPR by the provincial government. (2) The degree of administrative protection of provincial patent offices. As in Wu and Tang (2006), we use the annual number of patent disputes as a ratio to the cumulative number of patent licenses in China Intellectual Property Rights Yearbook (2001-2008)[2] to calculate the administrative protection level of the State Intellectual Property Office in each of the 31 provinces in China (equal to one minus the ratio of the number of annual patent disputes to the cumulative number of patents granted). A larger value of the indicator is associated with more effective administrative protection by the provincial patent authority.

Second, we measure the provincial intellectual property judicial protection by two indicators. (1) Provincial judicial protection situation. Data on the protection of producer rights is from Fan *et al.* (2011). Based on the fairness of law enforcement and the efficiency of law enforcement agencies, this indicator measures the legal environment in each province in different years. (2) Whether the courts take the "three-in-one" trial in intellectual property cases. If the courts at all levels in a province have announced the "three-in-one" trial in intellectual property cases in a given year, then the variable is set to 1 for the year and beyond, otherwise 0. We consider this variable because China's intellectual properties are protected by both administrative protection and judicial protection. Wang and Lv (2016) consider IPR in Guangdong province and find that the "three-in-one" trial model has a significant role in promoting firm innovation by improving the quality and efficiency of trials in courts.

[1]See Papageorgiadisa and Sharma (2016) for an alternative IPR measure at the national level.

[2]Data in 2000 is based on the annual statistical report of the State Intellectual Property Office.

Ginarte and Park (1997) measure IPR by taking the arithmetic average of IPR sub-indicators to compute their aggregate index. However, the arithmetic mean may not fully reflect the difference in the relative importance of the IPR sub-indicators. Wu and Tang (2016) use principal component analysis to measure the enforcement of IPR in Chinese provinces. Principal component analysis converts a number of related indicators into a representative comprehensive indicator by dimensionality reduction. We use this method to synthesize the national protection of IPR, the provincial administrative enforcement and the provincial judicial protection to form our provincial IPR index. The eigenvalues of our five principal components are 1.7702, 1.0297, 0.9325, 0.7078 and 0.5598. Given that the first three principal components have accumulated 74.7% of the information, we construct the IPR index of each province with the first three principal components. This IPR index at the provincial level eliminates the overlap of information between intellectual property legislative protection at the national level, administrative enforcement and judicial protection at the provincial level.

2 The matching procedure of industrial enterprises database and customs database

First, we follow Brandt *et al.* (2012) in cleaning up the Chinese industrial enterprises database and constructing panel data. Second, we match Chinese industrial enterprises panel data and customs database. We begin by matching firm name, followed by zip code and the last seven digits of phone number, and finally zip code and legal person name. Accordingly, we combine industrial enterprise panel data with custom information. Then, in order to unify the import product information, we reduce product data from HS 8-digit to HS 6-digit. Also, we unify the annual HS code to HS1996 standard according to BEC classification to identify and calculate import information of intermediate products at the firm level. We delete observations with missing data on total assets, employments, total output, total assets less than the current assets, fixed assets, or accumulated depreciation less than the depreciation of current year. We follow Brandt *et al.* (2012) and Kee and Tang (2016) to exclude firms with less than 8 employees, age less than one and the total value of imported intermediates greater than the total amount of intermediate inputs. Finally, we match IPR data with industrial firms-customs matched panel based on the province-year dimension. The resulting panel includes data at the firm-level from the manufacturing sector (i.e., classification code 13 to 42 from the 2-digit Chinese Industry Classification system) in China's 31 provinces in year 2000-2007, except for 2004 because data on new products in 2004 is missing.

3 Summary statistics

Table 1 provides the summary statistics of the variables used in the empirical analysis.

Table 1: Summary statistics

Variable	Definition	Obs.	Mean	Std. Dev.	Min	Max
NEW	A dummy variable of new products	883793	0.0899	0.2861	0	1
INT	A dummy variable of importing intermediate inputs	883793	0.1421	0.3492	0	1
IPR	The log of intellectual property rights index-principal component analysis	883793	1.4533	0.1195	-0.9282	1.7003
IPP1	Intellectual property legislative protection	883793	4.3614	0.3291	3.4	4.53
IPP2	Administrative protection of provincial patent offices	883793	0.9987	0.0011	0.9697	1
IPP3	Provincial government's emphasis on intellectual property protection	883793	0.0056	0.0044	0	0.0168
IPP4	The protection of producer rights from Fan *et al.*(2011)	883793	5.2424	2.0767	-0.46	10
IPP5	A dummy variable of "three-in-one" trial	883793	0.3388	0.4733	0	1
SIZE	The log of firm size measured by employment	883793	4.8008	1.0468	2.0794	12.145
EXP	The proportion of firm exports in total output	883793	0.1566	0.3300	0	1
FOR	Foreign capital share	883793	0.0704	0.2376	0	1
TFP	The log of total factor productivity	883793	3.7289	0.9838	-6.5247	9.728
AGE	The log of firm age	883793	1.9085	0.9350	0	4.6728
INCOME	The log of per capita GDP at the provincial level	883793	9.7949	0.5833	7.9165	11.0109
HERF	The log of the Herfindal index	883793	-4.4808	1.1183	-6.5819	-0.1221

Notes. Sample is limited to state-owned enterprises and all other firms with sales above 5 million RMB in the manufacturing sector.

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