Effects of International Trade and Intellectual Property Rights on Innovation in China

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Abstract

In this study, we develop an open-economy R&D-based growth model with two intermediate production sectors that use domestic and foreign inputs, respectively. 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 and confirm these theoretical results using an empirical analysis of matching samples that combine Chinese provincial IPR data with patent database, industrial enterprises database and customs database of China.

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1 Introduction

Intellectual property rights (IPR) serve as an important policy tool for stimulating innovation and economic growth. Seminal studies, such as Nordhaus (1969) and Judd (1985), and many subsequent studies assume that strengthening IPR stimulates innovation. However, some recent studies find that IPR may stifle innovation.[1] In this study, we use a growth-theoretic model to show that the effect of IPR on innovation depends on how IPR affects the spillovers of knowledge. Then, we confront our theory with empirics. Specifically, we develop an open-economy R&D-based growth model with two intermediate production sectors that use domestic and foreign inputs, respectively. We apply the model to explore the effects of IPR on knowledge spillovers and innovation. Our results can be summarized as follows. 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 effect is due to IPR suppressing knowledge spillovers from imports of intermediate inputs.

We test these theoretical results using an empirical analysis of matching samples that combine Chinese provincial IPR data with patent database, industrial enterprises database and customs database of China. Our regression results confirm that IPR indeed has the usual positive relationship with innovation. Furthermore, imports of intermediate inputs also have a positive relationship with innovation, suggesting that importing firms may experience a positive effect from imports on innovation. However, strengthening IPR diminishes this effect from imports on innovation, which is consistent with the above-mentioned suppression effect of IPR on knowledge spillovers from imports of intermediate inputs.

This study relates to the theoretical literature on innovation and economic growth. The seminal study in this literature is Romer (1990). Subsequent studies use variants of the R&D-based growth model to explore the effects of IPR;[2] see for example Lai (1998), Li (2001), Goh and Olivier (2002), Grossman and Lai (2004), Chu (2009a), Furukawa (2010), Chu and Pan (2013), Iwaisako and Futagami (2013), Yang (2013), Chu, Cozzi and Galli (2014), Cozzi and Galli (2014), Zeng *et al.* (2014), Lin (2015), Niwa (2016), Huang *et al.* (2017) and Saito (2017). Some of these studies also identify negative effects of IPR on innovation. However, the current study differs from these previous studies by exploring a novel channel through which strengthening IPR causes a negative effect on innovation by suppressing knowledge spillovers from imports of intermediate inputs.

This study also relates to the empirical literature on the determinants of innovation. For example, Goldberg *et al.* (2010) use Indian firm-level data whereas Chen *et al.* (2017) use Chinese firm-level data to show that imported intermediate inputs increase innovation. Chen and Puttitanun (2005) consider cross-country panel data whereas Hu and Png (2013) consider industry-country panel data, and both studies find 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 financ-

[1] See for example Lai (1998), Goh and Olivier (2002), Chu (2009a), Furukawa (2010), Chu and Pan (2013), Iwaisako and Futagami (2013), Chu, Cozzi and Galli (2014), Cozzi and Galli (2014) and Saito (2017) for theoretical studies and also Jaffe and Lerner (2004), Bessen and Meurer (2008) and Boldrin and Levine (2008) for evidence.

[2] Chu (2009b) provides a survey of this literature.

ing 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 in China via imports of intermediate inputs.

The rest of this study is organized as follows. Section 2 presents the theoretical model. Section 3 discusses the empirical framework. Section 4 shows the regression results and performs robustness checks. Section 5 concludes. Section 6 contains the data appendix.

2 Theoretical model

We extend the open-economy R&D-based growth model 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. Our open-economy model can be interpreted as (a) the small-open-economy setting in Grossman and Helpman (1991) in which the terms of trade are exogenous or (b) a large-open-economy setting in which the terms of trade are endogenous. In our model, the terms of trade neither affect the equilibrium allocation of R&D labor nor the equilibrium growth rates of technologies.

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.[3] $\gamma \geq 0$ is a preference parameter on the consumption of a foreign final good $C_{z,t}$ imported from abroad.[4] Its price is denoted as $p_{z,t}$. We assume that on the balanced growth path, $p_{z,t}$ grows at a constant rate, which can be positive, zero or negative. 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.[5] l denotes labor. w_t is the wage rate. From standard dynamic optimization, the optimality conditions are

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

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

[3] Domestic final good can be consumed by the household, used to produce intermediate inputs or exported.

[4] Imported foreign final good can be consumed by the household or used to produce intermediate inputs.

[5] Here we assume financial autarky under which the domestic financial market is not integrated to the global financial market. This assumption is reasonable given capital control in China. Under the assumption of financial autarky, it can be shown that the asset-accumulation equation ensures balanced trade.

2.2 Domestic final good

Domestic final good is produced by the following aggregator:[6]

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

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

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

where L_t^i denotes domestic production labor and $x_t^i(\omega)$ denotes domestic or foreign differentiated inputs.[7] 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

Differentiated input $x_t^d(\omega)$ is 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 $\mu \in (1, 1/\alpha)$. As is common in the literature,[8] 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

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

[6] Our results are robust to $Y_t = (X_t^d)^\theta (X_t^f)^{1-\theta}$. For simplicity, we focus on $\theta = 0.5$.

[7] It is useful to note that X_t^f is produced by combining domestic labor L_t^f and foreign input $x_t^f(\omega)$ imported from abroad. So, X_t^f is not a foreign good but a domestically produced good that uses some foreign inputs.

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

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

$$v^d_t(\omega) = \frac{\pi^d_t(\omega)}{r - g^d_\pi} = \frac{\mu - 1}{\mu}\frac{\alpha Y_t}{2n^d_t}\frac{1}{\rho + g^d_n} \equiv v^d_t, \tag{13}$$

where g^d_π and g^d_n are the steady-state growth rates of π^d_t and n^d_t respectively.

2.5 Foreign differentiated inputs

Differentiated input $x^f_t(\omega)$ is produced by imported foreign final good with an one-to-one technology. The profit function is

$$\pi^f_t(\omega) = p^f_t(\omega)x^f_t(\omega) - p_{z,t}x^f_t(\omega) = \alpha P^f_t(L^f_t)^{1-\alpha}[x^f_t(\omega)]^\alpha - p_{z,t}x^f_t(\omega). \tag{14}$$

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

$$\pi^f_t(\omega) = (\mu - 1)p_{z,t}x^f_t(\omega) = \frac{\mu - 1}{\mu}\frac{\alpha P^f_t X^f_t}{n^f_t} = \frac{\mu - 1}{\mu}\frac{\alpha Y_t}{2n^f_t} \equiv \pi^f_t, \tag{15}$$

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

$$v^f_t(\omega) = \frac{\pi^f_t(\omega)}{r - g^f_\pi} = \frac{\mu - 1}{\mu}\frac{\alpha Y_t}{2n^f_t}\frac{1}{\rho + g^f_n} \equiv v^f_t, \tag{16}$$

where g^f_π and g^f_n are the steady-state growth rates of π^f_t and n^f_t respectively.

2.6 R&D for non-importing firms

We refer to firms in the sector that uses only domestic inputs as non-importing firms. The innovation process for firms in this sector d is

$$\dot{n}^d_t = k^d_t R^d_t, \tag{17}$$

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

$$\dot{n}^d_t v^d_t = w_t R^d_t \Leftrightarrow n^d_t v^d_t = w_t. \tag{18}$$

2.7 R&D for importing firms

We refer to firms in the sector that uses some foreign inputs as importing firms. The innovation process for firms in this sector f is

$$\dot{n}^f_t = k^f_t R^f_t, \tag{19}$$

where R_t^f denotes domestic R&D labor in sector f. We assume that the productivity of R_t^f depends on n_t^f and also the volume of imports. Specifically, we consider the following specification: $k_t^f = n_t^f(1 + \overline{\lambda}\tau_t^f)$, where $\overline{\lambda} > 0$ is an import spillover parameter and $\tau_t^f \equiv p_{z,t}\int_0^{n_t^f} x_t^f(\omega)d\omega/Y_t$ is the value of imported intermediate inputs as a ratio to output. This specification is consistent with Grossman and Helpman (1991) who also assume that knowledge spillovers arise from trade.[9] Imposing symmetry and using (7) and (15), one can show that $\tau_t^f = \alpha/(2\mu)$ and hence $k_t^f = n_t^f + \lambda n_t^f/\mu$, 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 Decentralized equilibrium

The equilibrium is a time path of allocations $\{C_{z,t}, C_{y,t}, Y_t, X_t^d, X_t^f, x_t^d(\omega), x_t^f(\omega), L_t^d, L_t^f, R_t^d, R_t^f\}_{t=0}^{\infty}$ and a time path of prices $\{p_{z,t}, r_t, w_t, P_t^d, P_t^f, p_t^d(\omega), p_t^f(\omega), v_t^d, v_t^f\}_{t=0}^{\infty}$. Also, at each instance of time,

- the representative household chooses $\{C_{z,t}, C_{y,t}\}$ to maximize lifetime utility taking $\{p_{z,t}, r_t, w_t\}$ as given;
- competitive firms produce Y_t to maximize profit taking $\{P_t^d, P_t^f\}$ as given;
- competitive firms produce X_t^d to maximize profit taking $\{w_t, P_t^d, p_t^d(\omega)\}$ as given;
- competitive firms produce X_t^f to maximize profit taking $\{w_t, P_t^f, p_t^f(\omega)\}$ as given;
- a monopolistic firm produces $x_t^d(\omega)$ and sets $p_t^d(\omega)$ to maximize profit;
- a monopolistic firm produces $x_t^f(\omega)$ and sets $p_t^f(\omega)$ to maximize profit taking $p_{z,t}$ as given;
- competitive R&D entrepreneurs employ R_t^d for R&D to maximize profit taking $\{w_t, v_t^d\}$ as given;
- competitive R&D entrepreneurs employ R_t^f for R&D to maximize profit taking $\{w_t, v_t^f\}$ as given;
- the market-clearing condition for labor holds such that $R_t^d + L_t^d + R_t^f + L_t^f = l$;
- the trade account is balanced such that $Y_t - C_{y,t} - \int_0^{n_t^d} x_t^d(\omega)d\omega = p_{z,t}C_{z,t} + p_{z,t}\int_0^{n_t^f} x_t^f(\omega)d\omega$.

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

2.9 Equilibrium labor allocation

The resource constraint on labor in the domestic economy is

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

We define $l_t^d \equiv R_t^d + L_t^d$ and $l_t^f \equiv R_t^f + L_t^f$ for convenience. 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 still endogenous. Substituting (7), (9) and (16) into (20) yields

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

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 still 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

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

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

which show that stronger patent protection μ leads to a reallocation of labor from importing firms in sector f to non-importing firms in sector d because μ suppresses knowledge spillovers from imported inputs in sector f.

2.10 Equilibrium growth rates of technologies

The steady-state equilibrium growth rate of technologies n_t^d for non-importing firms 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 importing firms in sector f to non-importing firms in sector d. Proposition 1 summarizes this result.

Proposition 1 *The growth rate of technologies for non-importing firms in the sector that uses only domestic inputs is increasing in patent protection μ.*

Proof. Use (30). ■

The steady-state equilibrium growth rate of technologies n_t^f for importing firms 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 importing firms in sector f to non-importing firms in sector d. Therefore, the overall effect of patent protection on the growth rate of technologies n_t^f for importing firms in sector f is ambiguous.[10] Proposition 2 summarizes this result.

Proposition 2 *The growth rate of technologies for importing firms in the sector that uses some 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 technologies is higher among firms in sector f than firms in sector d due to the knowledge spillovers from imports in sector f. Proposition 3 summarizes this result.

Proposition 3 *The growth rate of technologies is higher for firms in the sector that uses some foreign inputs than firms in the sector that uses only domestic inputs.*

Proof. Use (32). ■

[10] 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.

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. The intuition behind this non-monotonicity can be explained as follows. When there is insufficient patent protection (e.g., $\mu \to 1$), there will be no innovation by firms in the two sectors; in this case, $\Delta g_n \to 0$. Therefore, Δg_n must first increase given that it is positive. Eventually, the additional negative effect of μ on g_n^f will reduce the difference between g_n^f and g_n^d causing Δg_n to fall.

3 Empirical specification and data

In this section, we specify our econometric model and describe the data that we use.

3.1 Empirical specification

Our theory analyzes the effects of IPR, imported intermediate inputs and their interaction on innovation. Motivated by our theoretical results, we estimate the following logit model:

$$\Pr\left(y_{i,t+1} > 0\right) = \Phi\left(\beta_1 IPR_{pt} + \beta_2 INT_{it} + \beta_3 INT_{it} * IPR_{pt} + \theta Z_{it} + \eta_p + \eta_j + \eta_t\right) \quad (33)$$

where y_{it+1} is firm i's new products or patent applications in year $t+1$ to measure innovation output.[11] 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 $INT_{it} = 0$. Therefore, to be consistent with our theoretical model, we explore the different innovation performance of importing firms versus non-importing firms and how this difference in the innovation performance between the two groups of firms is affected by IPR. 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 capture the effects of IPR on innovation, knowledge spillovers from imports, and the interaction between IPR and imports. First, β_1 captures the effect of IPR on innovation of non-importing firms, which corresponds to Proposition 1. According to Proposition 1, β_1 should be positive indicating that IPR has a positive relationship with innovation of non-importing firms. Second, β_2 captures the impact of knowledge spillovers from imports, which corresponds to Proposition 3. According to Proposition 3, β_2 should be positive.[12] Third, β_3 captures the relationship between IPR and knowledge spillovers on importing firms, which corresponds to Proposition 2. According to Proposition 2, β_3 should be negative indicating that IPR hinders knowledge spillovers from imports.

Other control variables Z_{it} include firm's productivity (TFP), capital intensity (capital-labor ratio), firm size (measured by total employment), firm age, firm export ratio, and

[11] Because new products and patent applications reflect the output of innovation that is subject to delay, we measure them using data in year $t+1$ instead of year t as suggested by the referee.

[12] More specifically, $\beta_2 + \beta_3 * IPR_{pt}$ should be positive. This term provides information on the relative innovation performance between importing and non-importing firms, which in turn relates to Proposition 3. Given that $\beta_3 < 0$ and $IPR_{pt} > 0$, β_2 should be positive and sufficiently large. Indeed, this is what we find in Section 4.

state-owned capital share.[13] In addition, we also control for the log of population and the log number of colleges and universities at the provincial level. Finally, we control for the Herfindahl index (HHI) computed at the 4-digit CIC (Chinese Industrial Classification) industry level. The data appendix provides their summary statistics and data sources.

3.2 Data

To investigate the effects of IPR, imported intermediate inputs and their interaction term on innovation, we use four databases in China: (1) firm-level production data, (2) firm-product-level trade data, (3) the State Intellectual Property Office (SIPO) patent application data, which contains detailed information on each patent filing, and (4) a provincial-level measure of IPR protection. The sample period is between 2000 and 2006. With the entry of China to the World Trade Organization (WTO) in 2001 and the requirements of the TRIPS Agreement, the strengthening of IPR in China during that period has an exogenous nature.

The data source for the firm-level production data is the annual survey of Chinese manufacturing firms, which was maintained by the National Bureau of Statistics (NBS). This database has been widely used by previous studies; see for example, Cai and Liu (2009) and Fan, Li and Yeaple (2018) among others. This dataset contains detailed firm-level information of Chinese manufacturing enterprises and complete information on the three major accounting statements. Of all the information contained in the NBS database, we are mostly interested in the variable on new product sale and other control variables, such as firm's productivity.

In order to construct the import dummy variable, we need to merge the NBS database with the product-level trade data. The firm-product-level trade data, provided by China's General Administration of Customs (CGAC), covers the universe of all Chinese exporters and importers in 2000-2006. It records detailed information of each trade transaction, including import and export values, quantities, quantity units, and contact information of the firm. We match these two databases based on the contact information of firms, because there is not a consistent coding system of firm identity between them. Our matching procedure is done in three steps. Our matching procedure is done by company name first, and next by both zip code and telephone number, and lastly by telephone number and contact person name together; see the detailed description of the matching process in Fan, Lai and Li (2015). Our merged sample covers 42% of total import value reported by the customs database.

The third data source is SIPO. The SIPO dataset contains detailed information on each patent filing since 1985, including the date of filing, company name and address of the applicant, name of the patent, and the patent type (i.e., invention, utility model, or design) according to the Patent Law of China. As Liu and Qiu (2016) mentioned, China's patent filing is a good alternative measure of innovation output. As in Liu and Qiu (2016), we match firm-level NBS and SIPO data using the company names and then double-check the matched outcomes using location information of firms.

The fourth data set is a measure of IPR protection in each province, which is calculated based on information on the level of administrative protection and the level of judicial protec-

[13] Following Fan, Li and Yeaple (2015, 2018), our TFP measure is estimated based on the augmented Olley-Pakes method, as in Amiti and Konings (2007). We leave the detail discription of TFP measure in Appendix B. The results are robust to other different approaches of estimating TFP.

tion. We use two indicators to measure the level of the administrative level: (1) 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; and (2) one minus the ratio of annual number of patent disputes to the cumulative number of patent licenses in China Intellectual Property Rights Yearbook (CIPRY). Also, we use two indicators to measure the level of provincial intellectual property judicial protection: (1) provincial judicial protection situation from Fan *et al.* (2011); and (2) whether the courts take the "three-in-one" trial in intellectual property cases. Appendix A provides the detail description on how we construct our IPR index based on these four indicators. Finally, we match the measured IPR index with firm-level NBS data based on the province-year dimension.

4 Regression results

This section reports empirical results on the impact of IPR, imported intermediate inputs and their interaction term on new products and patent applications to test the theoretical results.

4.1 Main results

Table 1 shows the main regression results. Results of columns (1) and (2) indicate that both the import dummy and patent protection are positively associated with innovation, and the former one is at 1% significance level whereas the latter is at 10% significance level, which are consistent with Chen and Puttitanun (2005), Goldberg *et al.* (2010), Hu and Png (2013) and Chen *et al.* (2017). Column (3) reports the result for the case in which we control both the import dummy and patent protection, and it shows that both variables continue to be positively and significantly correlated with innovation. Next, in column (4), we include our novel interaction term between patent protection and the import dummy. Interestingly, we find that although the import dummy and patent protection are still positively significant, their interaction term is significantly negative. To be more specific, two findings emerge. First, the coefficients of the import dummy and patent protection are still positively significant. Second, the coefficient of the interaction term is negatively significant at 1% significance level, which means that compared with non-importing firms, patent protection has an additional negative effect on the innovation of importing firms. All these empirical results are consistent with our theoretical predictions.

In Table 1, other firm level characteristics such as firm's productivity (*TFP*), capital intensity (*K/L* measured by the capital-labor ratio), firm size (*Firm Size* measured by employment), firm age (*Age*), firm export ratio and stated-owned capital share (*SOE Share*) are also controlled in the regression. We also control the province and industry level variables, which are the log of population (*Pop*) and the log number of colleges and universities (*GGXX*) at the provincial level and the Herfindahl index (*HHI*) computed at the 4-digit CIC level. We add year fixed effect, industry fixed effect and province fixed effect in the regression. All the results are clustered at the province level.

Table 1: Imports and IPR on new products

	(1) new	(2) new	(3) new	(4) new
Import Dummy X Patent Protection				-0.542***
				(0.149)
Import Dummy	0.209***		0.207***	1.362***
	(0.057)		(0.057)	(0.339)
Patent Protection		0.458*	0.455*	0.520**
		(0.235)	(0.235)	(0.240)
$\log(TFP)$	0.207***	0.217***	0.208***	0.207***
	(0.030)	(0.030)	(0.030)	(0.030)
$\log(K/L)$	0.208***	0.219***	0.208***	0.207***
	(0.028)	(0.027)	(0.028)	(0.028)
$\log(Age)$	0.146***	0.148***	0.148***	0.148***
	(0.047)	(0.046)	(0.046)	(0.046)
$\log(Firm\ Size)$	0.536***	0.547***	0.537***	0.537***
	(0.056)	(0.055)	(0.056)	(0.056)
$\log(Pop)$	-1.465	-1.867	-1.944	-1.714
	(5.614)	(5.682)	(5.689)	(5.636)
$\log(GGXX)$	-0.835	-0.909	-0.916	-0.915
	(1.076)	(1.064)	(1.066)	(1.060)
Exp Ratio	-0.110	-0.069	-0.110	-0.107
	(0.110)	(0.112)	(0.110)	(0.109)
SOE Share	-0.060	-0.073	-0.061	-0.057
	(0.082)	(0.083)	(0.082)	(0.082)
HHI	1.523***	1.550***	1.530***	1.504***
	(0.160)	(0.160)	(0.159)	(0.161)
Year fixed effect	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes	Yes
Observations	763586	763586	763586	763586
Probability (mean) of y	0.095	0.095	0.095	0.095

Notes: The number of the observations in this table is smaller than that of Table 2, since the data of New product in 2004 are missing. Standard errors in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. All the results are clustered at province level.

4.2 Patent applications

In this section, we consider patent applications instead of new products as the dependent variable and repeat the main regression estimation of column (4) in Table 1. As shown in column (1) of Table 2, the coefficient of the interaction term continues to be negative and significant at 5% significance level. Also, according to the Patent Law of China, patent can be classified into three categories, namely, invention, utility model, and design.[14] Compared with utility model patents and design patents, invention patents are the most suitable measure of innovation output. Therefore, it is reasonable to find that the aforementioned effects exist in all three types of patents but the coefficient of the interaction term is more significant and larger in magnitude for invention patents. In summary, considering the different types of patents, our main findings still hold and are consistent with the theoretical results.

Table 2: Imports and IPR on patent applications

	(1) patent	(2) invention	(3) design	(4) utility
Import Dummy X Patent Protection	-0.333**	-0.447***	-0.343*	-0.317**
	(0.161)	(0.173)	(0.200)	(0.159)
Import Dummy	1.185***	1.443***	1.186***	1.193***
	(0.357)	(0.365)	(0.451)	(0.370)
Patent Protection	0.076	0.059	0.084	0.180
	(0.158)	(0.220)	(0.198)	(0.156)
Other control variables	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes	Yes
Observations	887490	887490	887490	887490
Probability (mean) of y	0.019	0.010	0.012	0.016

Notes: Standard errors in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. All the results are clustered at province level. Other control variables include firm's productivity, capital insensity (measured by capital-labor ration), firm size (measured by the number of total employment), firm age, firm export ratio, and satated-owned capital share. We also control the provincial and industry level variables, the log total population and the log number of college and university at the provincial level, and Herfindahl index computed at 4-digit CIC level.

4.3 Robustness checks

In this section, we perform two more robustness checks. First, we use year-province fixed effects in the regression instead of the province fixed effect. Second, we consider the probit model. We use year-province fixed effects to capture time-varying provincial characteristics. As shown in Table 3, the coefficients of the interaction term from columns (1) to (5) are still negative and significant at least at 10% significance level.

[14] Detailed description on these three types of inventions can be found in Liu and Qiu (2016).

Table 3: Effects of imports and IPR (within province-year)

	(1) new	(2) patent	(3) invention	(4) design	(5) utility
Import Dummy X Patent Protection	-0.303**	-0.384**	-0.495***	-0.401*	-0.375**
	(0.138)	(0.172)	(0.185)	(0.212)	(0.157)
Import Dummy	0.847***	1.296***	1.549***	1.314***	1.318***
	(0.312)	(0.377)	(0.394)	(0.474)	(0.363)
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes
Province-year fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	763586	887490	887490	887490	887490
Probability (mean) of y	0.095	0.019	0.010	0.012	0.016

Notes: Standard errors in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. All the results are clustered at province level. Other control variables include firm's productivity, capital insensity (measured by capital-labor ration), firm size (measured by the number of total employment), firm age, firm export ratio, and satated-owned capital share. We also control the provincial and industry level variables, the log total population and the log number of college and university at the provincial level, and Herfindahl index computed at 4-digit CIC level.

Table 4 reports the empirical results for the probit model. From columns (1) to (5) in Table 4, the coefficients of the interaction term are still significantly negative and the coefficients of the import dummy and patent protection are positive. This means that our findings under the logit model are robust to the probit model.

Table 4: Effects of imports and IPR (probit model)

	(1) new	(2) patent	(3) invention	(4) design	(5) utility
Import Dummy X Patent Protection	-0.299***	-0.151**	-0.157**	-0.145*	-0.144**
	(0.085)	(0.074)	(0.074)	(0.079)	(0.072)
Import Dummy	0.749***	0.561***	0.548***	0.522***	0.553***
	(0.188)	(0.165)	(0.157)	(0.179)	(0.170)
Patent Protection	0.250**	0.030	0.011	0.032	0.068
	(0.122)	(0.065)	(0.083)	(0.075)	(0.061)
Other control variables	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	763586	887490	887490	887490	887490
Probability (mean) of y	0.095	0.019	0.010	0.012	0.016

Notes: Standard errors in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. All the results are clustered at province level. Other control variables include firm's productivity, capital insensity (measured by capital-labor ration), firm size (measured by the number of total employment), firm age, firm export ratio, and satated-owned capital share. We also control the provincial and industry level variables, the log total population and the log number of college and university at the provincial level, and Herfindahl index computed at 4-digit CIC level.

5 Conclusion

This study develops an open-economy R&D-based growth model to explore the different effects of IPR on the innovation performance of importing and non-importing firms. We test our theoretical results from the model using an empirical analysis of matching samples that combine Chinese provincial IPR data with patent database, industrial enterprises database and customs database of China. In summary, the conditional correlations that we found in the data are consistent with our theory. However, we acknowledge that these correlations do not necessarily represent causal relationships and leave this interesting issue to future research.

6 Data appendix

6.1 Provincial intellectual property rights

For the level of IPR protection 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 the level of the administrative protection. (1) The importance of provincial government's emphasis on IPR (IPR1). 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 (IPR2). As in Wu and Tang (2016), we use the annual number of patent disputes as a ratio to the cumulative number of patent licenses in China Intellectual Property Rights Yearbook (2001-2006) 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).[15] 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 (IPR3). 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 (IPR4). 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.

Ginarte and Park (1997) measure IPR by taking the arithmetic average of IPR subindicators to compute their aggregate index. However, the arithmetic mean may not fully

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

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 synthesize two indicators of provincial administrative enforcement and two indicators of provincial judicial protection to form provincial IPR execution strength.[16] Shen (2010) use the method in Ginarte and Park (1997) to construct an annual measure of intellectual property rights (IPR5) at the country level in China. Similar to Hu and Png (2013), we construct the IPR index of each province by multiplying the provincial IPR execution strength and IPR5.[17]

6.2 Firm-level productivity

To capture firms' productivity as a control variable in our regression analysis, we estimate total factor productivity (TFP). We use a Cobb-Douglas production function as estimation specification:[18]

$$Y_{ft} = A_{ft} L_{ft}^{\beta_l} K_{ft}^{\beta_k} \tag{34}$$

where production output of firm f at year t, Y_{ft}, is a function of labor, L_{ft}, and capital, K_{ft}; A_{ft} captures firm f's TFP in year t. We use firm's value-added to measure production output, and deflate firms' inputs (e.g., capital) and value added, using the input price deflators and output price deflators from Brandt, Van Biesebroeck and Zhang (2012).[19] Brandt, Van Biesebroeck and Zhang (2012) construct the output deflators using "reference price" information from China's Statistical Yearbooks and then calculate the input deflators based on output deflators and China's national input-output table (2002). The real investment variable is constructed via the perpetual inventory method. To capture the depreciation rate, we use each firm's real depreciation rate provided by the Chinese NBS firm-level data.

Our TFP measure uses the method of Olley-Pakes (Olley and Pakes, 1996) that has been augmented to account for additional firm-level decisions. We take into account firm's trade status in the TFP realization, as in Amiti and Konings (2007), by including two trade-status dummy variables–an export dummy (equal to one for exports and zero otherwise) and an import dummy (equal to one for imports and zero otherwise). In addition, we include a WTO dummy (one for a year after 2001 and zero for before) in the Olley-Pakes estimation to capture the effect of China joining WTO since the WTO accession was a positive demand shock for China's exports. Besides, our results are also robust to alternative measures of TFP, including the OLS method and the Ackerberg-Caves-Frazer augmented Olley-Pakes and Levinsohn-Petrin (Levinsohn and Petrin, 2003) methods (Ackerberg, Caves and Frazer, 2015).

[16] The weights of IPR1, IPR2, IPR3 and IPR4 are 0.1367, 0.5351, 0.2426 and 0.0856, respectively. We use the eig function in MATLAB to compute these weights.

[17] Using the IPR execution strength directly would not affect our results. Data on the provincial IPR index is available upon request.

[18] Using a trans-log production function leads to similar estimation results.

[19] We do not include intermediate inputs (materials). Including intermediate inputs (materials) in the estimation of TFP does not alter the results of our empirical results.

6.3 Summary statistics

Table A1 provides the summary statistics of the variables in the empirical analysis.

Table A1: Summary statistics of the key variables

Variables	(1) Observations	(2) Mean	(3) S.D.	(4) Min	(5) Max
New Product Dummy	763,586	0.095	0.293	0	1
Patent Dummy	887,490	0.019	0.136	0	1
Invention Dummy	887,490	0.009	0.097	0	1
Design Dummy	887,490	0.012	0.107	0	1
Utility Dummy	887,490	0.016	0.125	0	1
Patent Protection	887,490	2.059	0.360	0.568	2.625
Import Dummy	887,490	0.092	0.288	0	1
log(TFP)	887,490	3.778	1.130	-7.538	11.11
log(K/L)	887,490	3.562	1.320	-6.986	10.46
log(Age)	887,490	2.004	0.898	0	7.602
log(Pop)	887,490	3.950	0.591	0.948	4.576
log($GGXX$)	887,490	4.153	0.404	1.099	4.736
log(Firm Size)	887,490	4.854	1.121	0	11.99
Exp Ratio	887,490	0.192	0.357	0	1
SOE Share	887,490	0.211	0.384	0	1
HHI	887,490	0.018	0.033	0.0005	1

Notes: The number of the observations of New Product is smaller since the data of New product in 2004 are missing.

Table A2: Data sources of the key variables

Variables	(1) Definition	(2) Data source
New Product Dummy	A dummy variable of new products	NBS
Patent Dummy	A dummy variable of patent applications	SIPO
Invention Dummy	A dummy variable of invention patent applications	SIPO
Design Dummy	A dummy variable of design patent applications	SIPO
Utility Dummy	A dummy variable of utility-model patent applications	SIPO
Patent Protection	The log of IPR index	From IPR1 to IPR5
IPR1	Government's emphasis on IPR	Provincial newspapers
IPR2	Administrative protection of provincial patent offices	CIPRY
IPR3	The protection of producer rights from Fan *et al.* (2011)	Fan *et al.* (2011)
IPR4	A dummy variable of "three-in-one" trials	The provincial court
IPR5	Intellectual property legislative protection	Shen (2010)
Import Dummy	A dummy variable of imports	CGAC
log(TFP)	The log of total factor productivity	NBS
log(K/L)	The log of the capital-labor ratio	NBS
log(Age)	The log of firm age	NBS
log(Pop)	The log of population at the provincial level	NBS
log($GGXX$)	The log number of colleges and universities	NBS
log(Firm Size)	The log of firm-level employment	NBS
Exp Ratio	The proportion of firm exports in total output	NBS
SOE Share	Stated-owned capital share	NBS
HHI	Herfindahl index computed at the 4-digit CIC level	NBS

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