Competition, Openness and Innovation in Emerging Economies:

The Roles of Technology and Ownership

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Abstract
This paper examines innovation response of firms with different technology and ownership to domestic and openness-induced competition in emerging transition economies. Using a firm-level panel dataset from China and linked trade tariff data for the period 1998-2010, we find that an inverted-U relationship between domestic competition and innovation regardless of levels of technology and types of ownership although the high-technology and private firms demonstrate greater resilience in innovation. However, their innovation responses to openness-induced competition differ. The decrease of sectoral input tariff significantly stimulates innovation in all types of firms. FDI exhibits the same effect except in the high-technology firms. The decrease of sectoral output tariff promotes innovation in privately-owned and high-technology firms but depresses innovation in the state-owned and low-technology firms. A mixed ownership, ie. increasing state-ownership in privately-owned firms and reducing that in state-owned firms, increases innovation in Chinese firms.

Key words: Innovation, competition, openness, ownership, technology, China

JEL classification codes: O31; F13; L22

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1. Introduction

Competition has been regarded as one of the key factors that affect firms’ innovating behavior (Schumpeter, 1942; Geroski, 1990; Aghion et al., 2005). On one hand, monopoly power ensures the rents from innovation which incentivize firms to invest in the costly and risky research and development (R&D) activities (Schumpeter, 1942). Fierce competition thus reduces innovation (e.g., Jadlow, 1981; Lunn, 1986; Kraft, 1989; Hashmi, 2013). One the other hand, competition encompasses all forms of rivalry, instruments of rivalry (such as price, advertising, and merge and acquisition), and objects of rivalry (such as profits, market share, and survival) (Vickers, 1995). Therefore, competition will force firms and individuals to improve productivity and work efforts, and also to allocate resources to more productive activities and firms (Nickell, 1996). Geroski (1990) finds no support for the role of monopoly in stimulating innovation and Blundell et al. (1999) find that "less competitive" industries have fewer aggregate innovations. Recent studies find an inverted-U relationship between competition and innovation (Aghion et al., 2005; Im et al., 2015).

In addition to the competition among firms in the domestic market, foreign competition induced by imports also impacts on innovation behavior in domestic firms. Trade liberalization intensifies domestic competition, thus reducing profits and R&D (Long et al., 2011). Liu and Rosell (2013) find that import competition reduces firms’ basic innovation in the US. While Imports from China are found to explain 13.9% of the increase in patents in 12 European countries during the period 2000-2007 (Bloom et al., 2016). Moreover, the competition effect on firms’ innovation will be influenced by the distance of firms’ productivity from the productivity frontier (Aghion et al., 2005). Evidence from Mexico confirms that the effect of trade liberalization on firm’s productivity growth depends on its distance from the frontier (Iacovone, 2012).

However, although the previous literature explored the effect of domestic competition and openness on innovation separately, they didn’t place domestic competition and foreign competition in an integrated framework. Moreover, this literature mainly focused on developed
countries where the majority of market players are private firms. However, state owned enterprises (SOEs) are pervasive in transition economies like China (Berkowitz et al., 2017). SOEs and non-SOEs are different in respect of efficiency and financial constraints (Jiang et al., 2013; Song et al., 2015; Berkowitz et al., 2017). Openness does not always bring competition, productivity spillovers through trade and investment are important sources of innovation in developing countries (Pamukcu, 2003; Crescenzi and Rodríguez-Pose, 2012). Our understanding is limited concerning the effect of competition and openness on innovation in emerging transition economies and how the effect varies with firm’s technology and ownership. These are important questions awaiting systematic analysis.

This paper aims to fill the gap in the literature by examining the impact of competition and openness on Chinese enterprises’ innovation in an integrated framework and how such innovation effect of competition varies between firms of different technology levels and ownership types, using a firm level panel dataset from China and linked trade tariff data. China has experienced significant improvement in innovation in the past twenty years. According to the World Intellectual Property Organization, the number of patent applications from resident in China increased from 30,038 in 2001 to 1,204,981 in 2016, with an annual growth rate of 28%. Over the same period, China’s accession to the WTO greatly reduced import tariff and attracted the bulk of FDI; another reason for this was reform of SOEs that gradually opened market access and raised market competition. China hence provides a very good case to study how competition and openness influence firms’ innovation in emerging transition economies.

The research examining the impact of competition or openness on firm’s innovation in China is limited, with only a few exceptions. Nie et al. (2008) find that firms’ R&D intensity has an inverted-U relationship with firms’ market power in China over the 2001-2005 period. Liu and Qiu (2016) show that input-tariff reductions in China have had negative effects on firms’ patent applications because high-quality imports have substituted for internal innovation. Hu and Jefferson (2009) and Li et al. (2010) show that foreign investments have positive effects on China’s domestic firms’ innovation, while Fu and Gong (2011) find that FDI exerted negative pressure on technical change in domestic firms in China, due to crowding out effects on product
and factor (especially talent) markets, and limited technology spillovers due to concerns about IPR protection.

The paper contributes to the literature in the following ways. Firstly, this paper integrates domestic competition and openness in one framework and applies the methods of Amiti and Konings (2007) to innovation study, which uses output tariff and input tariff to distinguish between foreign competition effect and productivity spillover effect induced by openness. Secondly, this paper studies the role of ownership in firm’s innovation in the context of transition economies. Different from the existing literature that argues private ownership enhances innovation, it finds that increasing the share of state-owned capital is associated with more innovation in the privately-owned firms, while it hampers innovation in state-owned firms. Hence, reforms of SOEs towards mixed ownership instead of privatization is more favorable for innovation. Thirdly, the paper extends the analyses of Aghion et al. (2004) and Iacovone (2012) and applies them to innovation study to explore the effect of openness and competition on innovation at different technology levels and in firms of different ownership. It finds that the level of technology and the type of ownership of a firm can affect a firm’s innovation behavior as its responses to competition pressure. There is an inverted-U relationship between domestic competition and innovation in all types of firms, regardless of technology levels and ownership types. Nevertheless, the effects of import-induced competition on innovation vary by a firm’s technology level and ownership type.

This paper is structured as follows. Section 2 introduces the theoretical model of firms’ innovation and Section 3 presents the empirical model. Section 4 outlines the data sources and descriptions. Statistical and empirical results are presented and discussed in Sections 5 and 6, respectively. Section 7 concludes.

2. Theoretical Model

Following Aghion et al. (2004) and Iacovone (2012), we assume that there is a priced product $Y$ in a competitive market, which can be produced by continuously inputting intermediates $v$, $v \in (0, 1)$. Accordingly, let the production function be:
\[ Y_t = \frac{1}{\alpha} \int_0^1 A_t^{1-\alpha} [x_t(v)]^{\alpha-1} dv \]  

(1)  

in which, \( Y_t \) is the number of priced products at time \( t \), \( \alpha \in (0, 1) \), \( A_t \) is the technology level of firms at time \( t \), and \( x_t(v) \) is the number of intermediate input \( v \) at time \( t \).

In addition, the price of intermediates \( v \) is determined by an oligopolistic group. Following Iacovone (2012, p. 477), the oligopolistic group can produce at constant marginal cost. Given the market environment of the oligopolistic group, \( v \) is priced according to the following equation:

\[ P_t(v) = 1 + \sigma S_t \]  

(2)  

where \( \sigma > 0 \) is a constant, \( S_t \) is the rate of market concentration at time \( t \), \( \sigma S_t \) is the price mark up of monopolistic competition, the level of \( S_t \) reflects the market power of a monopolistic group that increases with market concentration and, it is expected, will increase the price mark up.

Since \( Y \) is in a perfectly competitive market, the marginal product of intermediate input \( v \) should equal its price. Combining equations (1) and (2), we get:

\[ \frac{\partial Y_t}{\partial x_t} = A_t^{1-\alpha} [x_t(v)]^{\alpha-1} = 1 + \sigma S_t \]  

(3)  

Re-arrange equation (3):

\[ x_t(v) = (1 + \sigma S_t) \frac{1}{\alpha-1} A_t. \]

Therefore, the profit of monopolistic group \( (\pi_t(v)) \) is:

\[ \pi_t(v) = [P_t(v) - 1]x_t(v) = \sigma S_t (1 + \sigma S_t) \frac{1}{\alpha-1} A_t = \delta_t A_t \]  

(4)  

in which, \( \delta_t = \sigma S_t (1 + \sigma S_t) \frac{1}{\alpha-1} \). Since \( \sigma S_t > 0 \), we also have \( \delta_t > 0 \).

First order differentiation of equation (4) is:

\[ \frac{\partial \pi_t(v)}{\partial S_t} = A_t \sigma (1 + \sigma S_t) \frac{1}{\alpha-1} \left( \frac{1-\alpha}{1-\alpha} \right) \]

The optimization conditions are:

\[
\begin{align*}
\frac{\partial \pi_t(v)}{\partial S_t} &= A_t \frac{\partial \delta_t}{\partial S_t} \geq 0, & \sigma S_t &\in (0, \frac{1}{\alpha} - 1] \\
\frac{\partial \pi_t(v)}{\partial S_t} &= A_t \frac{\partial \delta_t}{\partial S_t} < 0, & \sigma S_t &\in (\frac{1}{\alpha} - 1, +\infty)
\end{align*}
\]  

(5)  

when \( 0 < \sigma S_t \leq \frac{1}{\alpha} - 1, \frac{\partial \delta_t}{\partial S_t} \geq 0 \), and \( \frac{\partial \pi_t(v)}{\partial S_t} = A_t \frac{\partial \delta_t}{\partial S_t} \geq 0 \). Therefore, \( \pi_t(v) \) and \( S_t \) are positively correlated, i.e. increases in market concentration will increase the profits of a firm.
When $\sigma S_t > \frac{1}{a} - 1, \frac{\partial \delta_t}{\partial S_t} < 0$, and $\frac{\partial \pi_t(v)}{\partial S_t} = A_t \frac{\partial \delta_t}{\partial S_t} < 0$. $\pi_t(v)$ and $S_t$ are negatively correlated, this indicates that higher market concentration will decrease a firm’s profit. According to equation (5), we propose Hypothesis I: there is an optimal level of sectoral market concentration for a firm to innovate. Below the optimal level, the rise in sectoral market concentration will increase the innovation share in a firm’s profit. On the other hand, if sectoral market concentration exceeds the optimal level, excessive concentration in market power will lead to a decrease in the innovation share in a firm’s profit.

In an open economy, capital and products move internationally. At time $t$, intermediate input $v$ is facing threats from foreign competition (i.e. FDI and imports). Assuming that foreign competitors are at the technological frontier of production $\bar{A}_t$, which grows at a constant rate $\gamma > 0$, we have:

$$\bar{A}_t = (1 + \gamma)\bar{A}_{t-1}$$

(6)

where $\gamma = \frac{\bar{A}_t - \bar{A}_{t-1}}{\bar{A}_{t-1}}$. The domestic monopolistic group will need to protect itself from threats and, therefore, will have an incentive to innovate. It can be predicted that, having been confronted by foreign firms and imports, different firms will possess different incentives to innovate. Such heterogeneity is introduced through two channels: 1) firms’ internal technology levels are different; 2) firms’ external environments and associated conditions are different. Based on the observations above, we further develop the behavioral analysis of heterogeneous firms under competitive pressure.

Compared to Aghion et al. (2004), Iacovone (2012) and others, our model contributes to the existing literature in the following ways: in addition to Aghion et al. (2004) and Iacovone (2012), who considered heterogeneity of firms’ internal technology levels, we include heterogeneity of firms’ external environments. With both indicators, we can explain the differences in innovation activities more comprehensively. On the other hand, we also include sectoral market concentration in the analysis, so we can examine the impact of the domestic market structure on firms’ innovation behavior.

(1) **Heterogeneity of Technological Levels and Innovation**

We classify firms into two types according to their technological differences: low-
technology firms \( l \), and high-technology firms \( h \). At time \( t-1 \), \( l \) firms produce at technology level \( \bar{A}_{t-2} \), and \( h \) firms at \( \bar{A}_{t-1} \). At time \( t \), both types of firms improve their productivity through innovation. The application of productivity, however, is incomplete. \( l \) firms produce \( R_{lt} \) share of new product sales at productivity \( \bar{A}_{t-1} \), and \( 1-R_{lt} \) share of the old product at productivity \( \bar{A}_{t-2} \). \( h \) firms produce \( R_{ht} \) share of new product sales at productivity \( \bar{A}_{t} \), and \( 1-R_{ht} \) share of the old product at productivity \( \bar{A}_{t-1} \). There are costs for producing new products attributable to innovation, which is positively correlated with the ratio of new product sales (\( R_{lt} \) and \( R_{ht} \)), as well as firms’ previous technology levels. Therefore, firms’ cost of producing a new product due to innovation is:

\[
C_{lt} = c \left( \frac{R_{lt}^2}{2} \right) \bar{A}_{t-2} \tag{7}
\]

\[
C_{ht} = c \left( \frac{R_{ht}^2}{2} \right) \bar{A}_{t-1} \tag{8}
\]

in which, \( c>0 \) is a constant, \( C_{lt} \) is the cost of innovation for \( l \) firm at time \( t \), and \( C_{ht} \) is the cost of innovation for \( h \) firm at time \( t \).

We also assume that the foreign competitors’ productivity is \( \bar{A}_t \), and that they participate in the domestic market via FDI and imports. The probability of entering is \( Pr_t \). The competition model after entering is Bertrand.

**A. Low-technology firm \( l \)'s ratio of new product sales**

According to equations (4) and (7), we can calculate the expected profit \( \pi_{lt} \) for firm \( l \) at time \( t \):

\[
\pi_{lt} = (1-Pr_t)R_{lt}\delta_t\bar{A}_{t-1} + (1-Pr_t)(1-R_{lt})\delta_t\bar{A}_{t-2} - c \left( \frac{R_{lt}^2}{2} \right) \bar{A}_{t-2} \tag{9}
\]

Solving for the first order condition to optimize equation (9), we get:

\[
\frac{\partial \pi_{lt}}{\partial R_{lt}} = (1-Pr_t)\delta_t\bar{A}_{t-1} - (1-Pr_t)\delta_t\bar{A}_{t-2} - cR_{lt}\bar{A}_{t-2} = 0 \tag{10}
\]

Substitute \( \delta_t = \sigma S_t \ (1 + \sigma S_t)^{\frac{1}{\alpha-1}} \) into equation (10) and rearrange:

\[
R_{lt} = \frac{1-Pr_t}{c} \delta_t \gamma = \frac{1-Pr_t}{c} \sigma S_t \ (1 + \sigma S_t)^{\frac{1}{\alpha-1}} \gamma
\]

Furthermore, differentiating \( R_{lt} \) with respect to market concentration (\( S_t \)) and outsider entry probability (\( Pr_t \)), we get the reaction function of \( R_{lt} \)
\[
\frac{\partial R_{lt}}{\partial S_t} = \frac{1 - Pr_t}{c} \delta_t (1 - \alpha - \alpha \sigma S_t) / S_t (1 - \alpha) (1 + \sigma S_t)
\]

(11)

\[
\frac{\partial R_{lt}}{\partial Pr_t} = -\frac{\delta_t \gamma}{c}
\]

(12)

From equation (11), we know that, when \(0 < S_t < \frac{1 - \alpha}{\alpha \sigma}\), then \(\frac{\partial R_{lt}}{\partial S_t} > 0\), which indicates that the rise in sectoral market concentration \((S_t)\) will increase the ratio of new product sales through innovation. However, when \(S_t > \frac{1 - \alpha}{\alpha \sigma}\), then \(\frac{\partial R_{lt}}{\partial S_t} < 0\), i.e. the increase in \(S_t\) will hamper innovation. Therefore, for low-technology firms, the market concentration of a firm is its market power and has an optimal level \(S_t = \frac{1 - \alpha}{\alpha \sigma}\) for innovation. Since \(\delta_t > 0, \gamma > 0, c > 0\) and \(1 - Pr_t \geq 0\), it is always the case that \(\frac{\partial R_{lt}}{\partial Pr_t} < 0\). Therefore, according to equation (12), as FDI and imports grow, low-technology firms’ ratio of new product sales \((R_{lt})\) will decrease.

Outsider threats can encourage innovation through competition, however, external competition may lower firms’ profits as well as their incentives to innovate. For low-technology firms, the reduction in incentive to innovate exceeds the former, thus limiting their tendency to adopt new productivity and reducing the ratio of new product sales through innovation.

B. High-technology firm h’s ratio of new product sales

According to equations (4) and (8), expected profit \(\pi_{ht}\) of high-technology firm \(h\) at time \(t\) is:

\[
\pi_{ht} = R_{ht} \delta_t \bar{A}_t + (1 - Pr_t)(1 - R_{ht}) \delta_t \bar{A}_{t-1} - c \left( \frac{R_{ht}^2}{2} \right) \bar{A}_{t-1}
\]

(13)

First order condition to optimize equation (13) is:

\[
\frac{\partial \pi_{ht}}{\partial R_{ht}} = \delta_t \bar{A}_t - (1 - Pr_t) \delta_t \bar{A}_{t-1} - c R_{ht} \bar{A}_{t-1} = 0
\]

(14)

Substitute \(\delta_t = \sigma S_t \left(1 + \sigma S_t\right)^{\frac{1}{\alpha - 1}}\) into equation (14), we get:

\[
R_{ht} = \frac{\gamma + Pr_t}{c} \delta_t = \frac{\gamma + Pr_t}{c} \sigma S_t \left(1 + \sigma S_t\right)^{\frac{1}{\alpha - 1}}
\]

Therefore, by differentiating \(R_{ht}\) with respect to market concentration \((S_t)\) and outsider entry probability \((Pr_t)\), we get the reaction function:

\[
\frac{\partial R_{ht}}{\partial S_t} = \frac{\gamma + Pr_t}{c} \delta_t \frac{1 - \alpha - \alpha \sigma S_t}{S_t (1 - \alpha) (1 + \sigma S_t)}
\]

(15)
\[
\frac{\partial R_{ht}}{\partial P_{rt}} = \frac{\delta_t}{c}
\]  

(16)

According to equation (15), when \( 0 < S_t < \frac{1-\alpha}{\alpha \sigma} \), there will be \( \frac{\partial R_{ht}}{\partial S_t} > 0 \), which indicates that the increase in \( S_t \) will increase the ratio of new product sales through innovation. On the other hand, when \( S_t > \frac{1-\alpha}{\alpha \sigma} \), then \( \frac{\partial R_{ht}}{\partial S_t} < 0 \), i.e. the increase in \( S_t \) leads to too much market power to increase the share of innovation products. Therefore, for high-technology firms \( h \), there is also an optimal level of sectoral market concentration for innovation. Since \( \delta_t > 0 \) and \( c > 0 \), we have \( \frac{\partial R_{ht}}{\partial P_{rt}} = \frac{\delta_t}{c} > 0 \). According to equation (16), with the rise of FDI and imports (i.e. foreign competitors), domestic high-technology firms \( h \) will increase the share of innovative products.

For instance, equations (11) and (15) suggest that Hypothesis I applies to both high- and low-technology firms. From equations (12) and (16), we arrive at Hypothesis II: with the increase in FDI and imports, the share of products under innovation will decrease in low-technology firms, while increasing in high-technology firms.

(2) Heterogeneity of Ownership and Innovation

For Chinese enterprises, not only is innovation influenced by their technology levels, but also by their ownership types. There exist both state-owned enterprises and private firms. Compared to private firms, state-owned enterprises can more easily acquire support from government and banks. On the other hand, state-owned enterprises also suffer from the principal-agent problem, which can lead to lower efficiency in production. These two aspects introduce differences in the incentive to innovate for the two types of firms when they are confronted with foreign competition.

Assuming that, at time \( t-1 \), domestic firms are at technology level \( \bar{A}_{t-2} \), and that there are both private firms \( f \) and state-owned firms \( g \). Through innovation, both \( f \) and \( g \) realize some level of technological improvement at time \( t \). With the introduction of foreign competition, i.e. FDI and imports, firm \( f \) at time \( t \) can leapfrog growth owing to their higher efficiency; the firm produces new product at a ratio of \( R_{ft} \) under technology level \( \bar{A}_t \), and other products at a ratio of \( 1 - R_{ft} \) under its original technology level \( \bar{A}_{t-2} \). To invest in R&D to be able to
leapfrog, firms need to apply for loans. The interest rate for \( f \) firms is \( r \) times higher than that for \( g \) firms. Under open economy conditions, \( g \) firm does not adopt new technologies completely at time \( t \); it produces new products at technology level \( \bar{A}_{t-1} \) and \( \bar{A}_t \) with share \( R_{gt} \) and \( r_{gt} \) respectively. The rest of the products are produced under technology level \( \bar{A}_{t-2} \). For simplification, we assume the relationship of \( R_{gt} \) and \( r_{gt} \) satisfy:
\[
r_{gt} = \eta_g R_{gt}
\] (17)
where, \( \eta > 0 \) is a constant. Since \( R_{gt} \) and \( r_{gt} \) are the share of products of \( g \) firm at technology level \( \bar{A}_{t-1} \) and \( \bar{A}_t \) at time \( t \) respectively, we have \( R_{gt} + r_{gt} \leq 1 \).

Combining equations (7) and (8), we can calculate the cost of innovation for firm \( f \) and \( g \) as:
\[
C_{ft} = c \left( \frac{R_{ft}^2}{2} \right) \bar{A}_{t-2} (1 + r)
\] (18)
\[
C_{gt} = c \left( \frac{R_{gt}^2}{2} \right) \bar{A}_{t-2} + c \left( \frac{r_{gt}^2}{2} \right) \bar{A}_{t-2}
\] (19)

Similarly, we assume that, at time \( t \), foreign competitors are at technology level \( \bar{A}_t \); they enter the domestic market through FDI and through imports with probability \( Pr_t \). Once foreign competitors have entered, domestic firms and their foreign counterparts engage in Bertrand competition.

**A. Share of innovative goods in private firm \( f \)**

According to equations (4) and (18), we can obtain the expected profit \( \pi_{ft} \) of firm \( f \) at time \( t \):
\[
\pi_{ft} = R_{ft} \delta_t \bar{A}_t + (1 - Pr_t) (1 - R_{ft}) \delta_t \bar{A}_{t-2} - c \left( \frac{R_{ft}^2}{2} \right) \bar{A}_{t-2} (1 + r)
\] (20)
the first order condition of which is:
\[
\frac{\partial \pi_{ft}}{\partial R_{ft}} = \delta_t \bar{A}_t - (1 - Pr_t) \delta_t \bar{A}_{t-2} - c R_{ft} \bar{A}_{t-2} (1 + r) = 0
\] (21)
Substituting \( \delta_t = \sigma S_t (1 + \sigma S_t)^{-\frac{1}{\alpha-1}} \), we get:
\[
R_{ft} = \frac{Pr_t + 2\gamma + \gamma^2}{c(1+r)} \delta_t \gamma = \frac{1 - Pr_t}{c(1+r)} \gamma \sigma S_t (1 + \sigma S_t) \frac{1}{\alpha - 1}
\]

Therefore, the reaction functions of the share of innovative products in firm \( f \) with respect to sectoral market concentration and entry probability of foreign competitors are:

\[
\frac{\partial R_{ft}}{\partial S_t} = \frac{Pr_t + 2\gamma + \gamma^2}{c(1+r)} \delta_t \gamma \frac{1 - \alpha - \alpha \sigma S_t}{S_t(1 - \alpha)(1 + \sigma S_t)} \quad (22)
\]

\[
\frac{\partial R_{ft}}{\partial Pr_t} = \frac{\delta_t \gamma}{c(1+r)} \quad (23)
\]

According to equation (22), when \( 0 < S_t < \frac{1 - \alpha}{\alpha \sigma} \), the rise in the market concentration of firms, i.e. the rise in the market power, can lead to the increase in the share of innovative goods. Nevertheless, when \( S_t > \frac{1 - \alpha}{\alpha \sigma} \), the opposite occurs. Therefore, for \( f \) firms, which did not gain benefits as state-owned firms did, there is also an optimal level of sectoral market concentration for innovation. According to equation (23), given that \( \delta_t > 0, \gamma > 0, c > 0 \) and \( r > 0 \), we have \( \frac{\partial R_{ft}}{\partial Pr_t} > 0 \). That is to say, FDI and imports will increase the share of innovative products in firm \( f \), and this declines as the interest rate \( r \) increases.

**B. Share of innovative goods in state-owned firm \( g \)**

According to equations (4) and (19), we can obtain the expected profit \( \pi_{gt} \) of firm \( g \) at time \( t \):

\[
\pi_{gt} = r_{gt} \delta_t \bar{A}_t + (1 - Pr_t)R_{gt} \delta_t \bar{A}_{t-1} + (1 - Pr_t)(1 - r_{gt} - R_{gt}) \delta_t \bar{A}_{t-2}
\]

\[
- c \left( \frac{R_{gt}^2}{2} \right) \bar{A}_{t-2} - c \left( \frac{r_{gt}^2}{2} \right) \bar{A}_{t-2} \quad (24)
\]

Substitute equation (17) in (24), and calculate for the first order condition:

\[
\frac{\partial \pi_{gt}}{\partial R_{gt}} = \eta \delta_t \bar{A}_t + (1 - Pr_t) \delta_t \bar{A}_{t-1} - (1 - Pr_t)(1 + \eta) \delta_t \bar{A}_{t-2} - cR_{gt} \bar{A}_{t-2} - c\eta^2 R_{gt} \bar{A}_{t-2}
\]

\[
= 0 \quad (25)
\]

We can, therefore, solve for the reaction functions of share of innovative goods with respect to sectoral market concentration and entry probability of foreign competitors, which are:
\[
\frac{\partial R_{gt}}{\partial S_t} = \frac{2\eta \gamma + \eta \gamma^2 + (1 - Pr_t)\gamma + \eta Pr_t}{c(1 + \eta^2)} \frac{(1 - \alpha - \alpha \sigma S_t)}{S_t(1 - \alpha)(1 + \sigma S_t)}
\]

\[
\frac{\partial R_{gt}}{\partial Pr_t} = \frac{\delta_t(\eta - \gamma)}{c(1 + \eta^2)}
\]

According to equation (26), since \(\eta > 0, \gamma > 0, c > 0, 0 < Pr_t < 1, \alpha \in (0, 1), \sigma > 0,\) and \(S_t > 0,\) \(\frac{\partial R_{gt}}{\partial S_t}\) depends on the sign of \((1 - \alpha - \alpha \sigma S_t)\). When \(0 < S_t < \frac{1-\alpha}{\alpha \sigma}\), the increase in sectoral market concentration of firms, i.e. the increase in their market power, can lead to the rise in the share of innovative goods in state-owned firms \(g\). Nevertheless, when \(S_t > \frac{1-\alpha}{\alpha \sigma}\), the opposite occurs. Therefore, for \(g\) firms, which benefit from less rigid regulations, there is an optimal level of sectoral market concentration for innovation.

According to equation (27), given that \(\delta_t > 0, \gamma > 0, c > 0\) and \(r > 0\), the effects of FDI and imports on share of innovative products in firm \(g\) depend on the relationship between \(\eta\) and \(\gamma\). When \(\eta > \gamma\), the entry of foreign competitors will increase the share of innovative goods. When \(\eta < \gamma\), the opposite situation occurs. When \(\eta = \gamma\), the entrance of foreign competitors does not affect the innovation of firm \(g\).

In summary, equations (22) and (26) suggest that Hypothesis I exists for both private firms and state-owned enterprises. According to equations (23) and (27), we propose Hypothesis III: under the same technology level, as FDI and imports increase, the share of innovative products in private firms will increase, while that of state-owned firms is uncertain.

3. Empirical Models

(1) Empirical Models

A. Heterogeneity of technology and innovation

According to our model of heterogeneity in technology levels and innovation, from equations (11), (15), (12) and (16), we see the effects of foreign competitors and market concentration on firms’ innovation at two different technology levels. Based on our theoretical model and variables, we construct empirical model I (equation (28)) to test Hypotheses I and II.
\[
\begin{align*}
R_{ljt} &= \zeta_1 S_{jt} + \zeta_2 S_{jt}^2 + \zeta_3 FAR_{jt} + \zeta_4 IMR_{jt} + \zeta_5 RD_{lt} + \zeta_6 D\text{P}_{lt} + \zeta_7 TFP_{lt} + \zeta_8 STATE_{lt} + \theta_l + \theta_{lj} + \theta_{lt} + \varepsilon_{ljt} \\
R_{htj} &= \beta_1 S_{jt} + \beta_2 S_{jt}^2 + \beta_3 FAR_{jt} + \beta_4 IMR_{jt} + \beta_5 RD_{ht} + \beta_6 D\text{P}_{ht} + \beta_7 TFP_{ht} + \beta_8 STATE_{ht} + b_h + b_{hj} + \lambda_{ht} + \varepsilon_{htj}
\end{align*}
\]

where, \(R_{ljt}\) is the sales share of innovative products of low-technology firms \(l\) (i.e. firms with lower than sector \(j\) average TFP) at time \(t\), and \(R_{htj}\) is that of high-technology firms \(h\) (i.e. firms with higher than sector \(j\) average TFP) at time \(t\). \(S_{jt}\) is the Herfindahl index of sector \(j\) at time \(t\), which is used to identify sectoral market concentration level. \(S_{jt}^2\) is the quadratic form of the Herfindahl index of sector \(j\) at time \(t\). \(FAR_{jt}\) is the share of foreign firms’ capital in sector \(j\) at time \(t\). \(IMR_{jt}\) is the import tariff of sector \(j\) at time \(t\). \(RD_{lt}\) and \(RD_{ht}\) are shares of R&D of low-technology firms \(l\) and high-technology firms \(h\) at time \(t\) respectively. \(D\text{P}_{lt}\) and \(D\text{P}_{ht}\) are the ages of low-technology firms \(l\) and high-technology firms \(h\) at time \(t\) respectively. \(TFP_{lt}\) and \(TFP_{ht}\) are TFPs of low-technology firms \(l\) and high-technology firms \(h\) at time \(t\) respectively. \(STATE_{lt}\) and \(STATE_{ht}\) are state-owned capital shares of low-technology firms \(l\) and high-technology firms \(h\) at time \(t\) respectively. \(\theta_l\) and \(b_h\) are firm-level dummies. \(\theta_{lj}\) and \(b_{hj}\) are sector dummies of low-technology firms \(l\) and high-technology firms \(h\) respectively. \(\theta_{lt}\) and \(\lambda_{ht}\) are time dummies of low-technology firms \(l\) and high-technology firms \(h\) respectively. \(\varepsilon_{ljt}\) and \(\varepsilon_{htj}\) are random disturbances.

Therefore, based on equations (11) and (15) and Hypothesis I, we expect that: \(\zeta_1 > 0, \zeta_2 < 0; \beta_1 > 0, \beta_2 < 0\).

Similarly, based on equations (12) and (16) and Hypothesis II, we expect that: \(\zeta_3 < 0, \zeta_4 > 0; \beta_3 > 0, \beta_4 < 0\).

**B. Heterogeneity of ownership and innovation**

According to our model of heterogeneity of ownership and innovation, from equations (22), (26), (23) and (27), we see the effects of entry probability of foreign competitors and sectoral market concentration on firms’ innovation under different ownership types. Based on our theoretical model and variables, we construct empirical model II (equation (29)) to test Hypotheses I and III.
\( R_{ft} = \varphi_1 S_{jt} + \varphi_2 S_{jt}^2 + \varphi_3 FAR_{jt} + \varphi_4 IMR_{jt} + \varphi_5 RD_{ft} + \varphi_6 DP_{ft} + \varphi_7 TFP_{ft} + \varphi_8 STATE_{ft} + \varphi_f + \varphi_f + \mu_{ft} + \varepsilon_{ft} \)

\( R_{gt} = \phi_1 S_{jt} + \phi_2 S_{jt}^2 + \phi_3 FAR_{jt} + \phi_4 IMR_{jt} + \phi_5 RD_{gt} + \phi_6 DP_{gt} + \phi_7 TFP_{gt} + \phi_8 STATE_{gt} + \phi_g + \phi_g + \xi_{gt} + \tau_{gt} \)

where, \( R_{ft} \) is the sales share of innovative products of private firms \( f \) at time \( t \), and \( R_{gt} \) is that of state-owned firms \( g \) at time \( t \). \( S_{jt} \) is the Herfindahl index of sector \( j \) at time \( t \), which is used to identify the sectoral market concentration level. \( S_{jt}^2 \) is the quadratic form of the Herfindahl index of sector \( j \) at time \( t \). \( FAR_{jt} \) is the share of foreign firms’ capital in sector \( j \) at time \( t \). \( IMR_{jt} \) is the import tariff of sector \( j \) at time \( t \). \( RD_{ft} \) and \( RD_{gt} \) are shares of R&D of private firms \( f \) and state-owned firms \( g \) at time \( t \) respectively. \( DP_{ft} \) and \( DP_{gt} \) are the ages of private firms \( f \) and state-owned firms \( g \) at time \( t \) respectively. \( TFP_{ft} \) and \( TFP_{gt} \) are TFPs of private firms \( f \) and state-owned firms \( g \) at time \( t \) respectively. \( STATE_{ft} \) and \( STATE_{gt} \) are state-owned capital shares of private firms \( f \) and state-owned firms \( g \) at time \( t \) respectively. \( \varphi_f \) and \( \phi_g \) are firm-level dummies. \( \varphi_{fj} \) and \( \phi_{gj} \) are sector dummies of private firms \( f \) and state-owned firms \( g \). \( \mu_{ft} \) and \( \xi_{gt} \) are time dummies of private firms \( f \) and state-owned firms \( g \) respectively. \( \varepsilon_{ft} \) and \( \tau_{gt} \) are random disturbances.

Therefore, based on equations (22) and (26) and Hypothesis I, we expect that:

\[ \varphi_1 > 0, \varphi_2 < 0_1; \varphi_1 > 0, \varphi_2 < 0 \]

Similarly, based on equations (23) and (27) and Hypothesis III, we expect that:

\[ \varphi_3 > 0, \varphi_4 < 0; \varphi_3 \text{ and } \varphi_4 \text{ are uncertain.} \]

### 4. Data and Measurement

In this paper, we use micro firm-level data to study the relationship between competition and innovation, which come from firm-level production data and tariff data.

#### 4.1 Firm-level production data and tariff data

##### 4.1.1 Firm-level production data

Firm-level production data come from Chinese Industrial Enterprises Database that is provided by China’s National Bureau of Statistics (NBS), covering all state-owned (SOE) firms and non-SOE firms with sales exceeding RMB 5 million ($0.7 million). The data set contains
information about firms’ accounting statements and other production information we need, such as new product sales and R&D.

After deleting duplications, the data set covers 3,336,315 observations between 1998 and 2010. We match them across years and obtain 835,030 firms. Following the literature (Jefferson et al., 2008; Cai and Liu, 2009; Nie et al., 2012; Yang, 2015), we eliminate observations that have missing, zero or negative paid-up capital, total output, assets or fixed assets; as also we eliminate observations that have fewer than eight employees, less-than-five-million RMB sales, total assets less than current assets or fixed assets, or profit margins more than one. For the purposes of this paper, we also drop observations that have negative R&D. After further cleaning data for missing values, the final dataset has 2,876,947 observations for 727,257 firms.

4.1.2 Tariff data

Tariff data between 1998 and 2000 come from World Integrated Trade Solution (WITS), which belongs to the World Bank (WB). Tariff data between 2001 and 2010, after China’s accession to the World Trade Organization (WTO), can be acquired from the WTO database. China adopted the 1996 version, the 2002 version and the 2007 version of the Harmonized System (HS) at the six-digit disaggregated level to measure tariff in the years 1998-2001, 2002-2006 and 2007-2010 respectively. Since import tariff is attached to product rather than sector, we need to match them to sectoral level. In this paper, we use the World Integrated Trade Solution (WITS) HS-ISIC Rev.3 Correspondence Table, which offers 2001-2010 Chinese import tariffs by HS code, with the corresponding International Standard of Industrial Classification (ISIC). Then, we match SIC Rev.3 with the Chinese national classification GB/T 4754-2002 and get the HS product code of imports by two-digit sectors. Thus we use Most Favored Nations (MFN) applied duty rates at the two-digit level of Chinese sectors to measure trade openness.

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According to Brandt et al. (2012) and Yang (2015), we match our sample to panel data in the following manner: matching firms by code of legal representative, “name of legal representative + registration region”, “region code + telephone number + funding year”. Firms that cannot be matched in this manner are treated as different firms.
4.2 Measurement

A. Dependent variable

Following Deng et al. (2014) and Guan and Yam (2015), we use the sales of the new product of firm $i$ in sector $j$ at time $t$ divided by firm $i$’s sales as the share of innovation ($R_{ijt}$). Deng et al. (2014) believe that new products are the outcome of innovation, the sales of which represent the efficiency of innovation. There are only 184,556 positive observations in the whole sample, and 2,037,743 observations with value 0 in the Chinese Industrial Enterprises Database. In addition, in 2004 and 2008, the Chinese Industrial Enterprises Database did not record new product sales and hence these are not included in our estimation.

B. Key explanatory variables

First, according to Hypothosis I, there is an optimal level of sectoral market concentration for innovation for a firm. Within that optimal level, the rise in sectoral market concentration can lead to the increase in the share of innovative goods (Zhou, 2014). Beyond that optimal level, the opposite relationship holds. We, therefore, use the Herfindahl index ($S_{jt}$) of four-digit sector $j$ at time $t$ to identify sectoral market concentration in the domestic market. Because that information uses the national industrial classification GB/T 4754-1994 from 1998 to 2002, and the national industrial classification GB/T 4754-2002 from 2003 to 2010, we need to match the two sets of values. The previous studies (Yang, 2015) have matched industries at the three-digit level of GB/T 4754-2002. However, sectoral competition is the core of this paper, which will be affected by the level of sectoral aggregation. We, therefore, matched GB/T 4754-1994 to GB/T 4754-2002 at the four-digit level, and adjusted the mismatching issue by reassigning firms’ sectors before 2003 by their sectors in and after 2003.\footnote{Matched observations take up 98.79\% of the sample, so the likely mismatch in sector is only 1.21\% of the sample.}

The four-digit Herfindahl index is calculated as follows:

$$S_{jt} = \sum_{i}^{N} \left(\frac{X_{ijt}}{X_{jt}}\right)^2$$

where $S_{jt}$ is the Herfindahl index of sector $j$ at time $t$, $X_{ijt}$ is the sales of firm $i$ in sector $j$ at time $t$, and $X_{jt}$ is the total sales of sector $j$ at time $t$. The Herfindahl index evaluates the sectoral
market concentration. The smaller the value of the Herfindahl index, the more competitive the sectoral market becomes; when its value is infinitely close to 0, the sectoral market is perfect competition. On the other hand, the higher its value, the more monopolistic the sectoral market is; the Herfindahl index takes a value 1 in the case of a monopoly. In some years, there are few above-the-scale firms in some sectors. We, therefore, calculated two versions of the Herfindahl index – with the top 50 sales firms and with all firms of each sector.

Second, according to Hypotheses II and III, FDI and imports will affect the share of innovation goods of different firms. We, therefore, use the share of foreign capital $FAR_{jt}$, and import tariff $IMR_{jt}$ to represent the openness of sector $j$. Brambilla et al. (2009) show that the larger the share of FDI, the more frequently domestic firms produce new goods. Bloom et al. (2016), and Lu and Ng (2012) prove that import induced market competition can encourage innovation in domestic firms. Meanwhile, Pamukcu (2003), Fracasso and Marzetti (2015), and Li et al. (2010) suggest that trade and FDI can have spillover effects. According to our model and literature review, expected sectoral openness can influence domestic innovation, but the sign varies by type of firm. $FAR_{jt}$, and $IMR_{jt}$ are measured as follows:

Sectoral foreign capital share ($FAR_{jt}$) uses the ratio of the capital of foreign firms in sector $j$ at time $t$ and the total capital of sector $j$. The Chinese Industrial Enterprises Database holds information on the types of firms. We define firms from Hong Kong, Macaw, and Taiwan (type code 200, 210, 220, 230 and 240), and foreign invested firms (type code 300, 310, 320, 330 and 340) as foreign firms.

$IMR_{jt}$ is the import tariff of sector $j$ at time $t$. Following Amiti and Konings (2007), we distinguish sectoral output tariff ($Output\_tariff_{jt}$) and sectoral input tariff ($Input\_tariff_{jt}$). Following Amiti and Konings (2007) and Yu (2015), we use the simple average of HS products import tariffs by sector to represent the sectoral output tariff ($Output\_tariff_{jt}$) to avoid endogeneity. While Yu (2015) only used the input/output table (IO tables) in 2002, we use IO tables in 1997, 2002 and 2007 to calculate the sectoral output tariff for periods 1998-2000, 2001-2005 and 2006-2010 respectively:

$$Input\_tariff_{jt} = \sum_{i} \frac{Input_{ij}}{Total\_input_{j}} \times Output\_tariff_{jt}$$
C. Control variables

First, we consider firms’ R&D. Liu and Zou (2008) show that increases in R&D will significantly accelerate the ratio of new product sales of firms. Therefore, we introduce share of R&D ($RD_{ijt}$) to control for that effect, which is calculated by firm $i$’s R&D divided by firm $i$’s output. Second, age of firms, calculated as year of observation minus funding year plus one. Some of the firms were funded very early. We reassign the funding year of those who were funded before 1949 to 1949. Age of firms, to an extent, reflects firms’ ability to take risks. Following Guan and Yam (2015), therefore, we use age of firms as a control variable, the expected effect should be positive. Third, we introduce sector, firm and time dummies; we use those dummies to control for sectoral, firm-level and time effects that influence the share of innovative goods. The signs of their effects are uncertain.

In addition, according to Hypotheses II and III, with the occurrence of foreign competitors, the technology levels and types of ownership of firms can affect the innovation share. Therefore, we develop an empirical model that distinguishes the effects of technology levels and types of ownerships of firms on the shares of innovation.

As with Bloom et al. (2016) and Liu and Qiu (2016), we use firms’ productivity to measure technology level. Firms’ productivity $TFP_{ijt}$ is calculated by means of Olley-Pakes methodology (OP) and Levinsohn-Petrin methodology (LP) using Yang (2015)’s specification of fixed assets, investment, investment deflator and output deflator, and Lu and Lian (2012)’s specification of productivity at the two-digit sector level.\(^1\) The fixed capital deflator index from 1986 to 1990 is calculated following Zhang et al. (2004), and for 1991-2008 is obtained from the China Statistical Yearbook. The output deflator index comes from the 2011 China Urban Life and Price Yearbook. The input deflator index is calculated from the output deflator index and IO tables. Since we focus on how firms with different technology levels respond to competition within the industry, we define firms’ technological position as their relative position in the industry in terms of productivity. Therefore, we define the firms with above industry average TFPs as high-technology firms, and those below industry average as low-

\(^1\) Here, we further eliminate observations with zero or missing intermediate inputs, and only calculate TFP for manufacturing firms.
technology firms.

We use registered firms’ types and state-owned capital shares to identify the types of ownerships of firms. Firms with type code 110, 141, 143 and 151 are defined as state-owned firms. Additionally, we use state-owned paid-up capital share to identify ownership of firms \( \text{STATE}_{ijt} \) and classify those who have equal to or more than 50% state-owned shares as state-owned firms. The ownership of firms is thus identified.

Table 1 presents the summary statistics of key variables. The ratio of new product sales falls within the range \([0, 1]\), which should be considered in the regression equations. The sample average for the ratio of new product sales is 2.68% and only 184,556 observations, 8.30% of the sample\(^{\dagger}\) sells new products, indicating that Chinese industrial firms, on average, still have low sales of new products.

\[\text{Table 1 here}\]

5. Statistical Analyses

The model presented in this paper explores the effect of different technology levels and ownership types on firms’ innovation. Our model shows that the relationship between competition and innovation has an inverted-U relationship under different technology levels and ownership types. Openness can encourage innovation of high-technology firms, but it discourages that of low-technology firms. Trade and FDI are beneficial for private firms in conducting innovation but have an ambiguous effect on state-owned enterprises. What are the differences in innovation between firms with heterogeneous technology levels and ownership types under similar sectoral competition and openness? We present statistical analysis of firms by technology level and ownership type.

(1) Comparative analysis of firms’ innovation by technological level

Figure 1 shows the share of total sales and the average ratio of new product sales of high-technology firms and low-technology firms. The ratio of new product sales measures

\(^{\dagger}\) Only observations with non-missing new product sales are included.
firms’ innovation at different technology levels. We find that high-technology firms had a dominant market share between 1998 and 2007, the share of total sales by high-technology firms reached 71% and maintained a moderately positive trend, from 66.6% in 1998 to 72.3% in 2007. On the other hand, low-technology firms only make up 15.8% of total sales over the same period and saw a decline from 20.4% in 1998 to 13.0% in 2007. Moreover, there is a significant difference between the ratios of new product sales in high- and low-technology firms. Overall, the average ratios of new product sales in both firm types are low and diverging from a 0.08% difference in 1998, rising to 0.77% in 2001, reaching 0.87% in 2007. In particular, the ratio of new product sales of high-technology firms increased moderately over the period between 1998 and 2001, decreased between 2001 and 2003, and accelerated again between 2005 and 2007 to reach 3.72%. The ratio of new product sales of low-technology firms was decreasing between 1998 and 2003, and then began to increase between 2005 and 2007. Evidence from the figure suggests that Chinese firms’ innovation has a positive trend, indicating they increasingly value innovation. Therefore, it is very important to study the factors influencing innovation of high-technology firms. In 2001, China joined the WTO. In the same year, differences in the sales’ shares of new products for firms with different technology levels increased. Whether openness has heterogeneous impacts on firms with different technology levels remains to be resolved.

(2) Comparative analysis of firms’ innovation by ownership type

In studying Chinese firms, ownership type is an important factor. Differences in firm ownership type reveal significant differences in market power and productivity. Therefore, it is important to distinguish in our discussion between state-owned enterprises, domestic private firms, and foreign firms. Figure 2 presents the share of total sales by ownership, and average market share of firms by ownership. There has been a decline in the share of total sales by state-owned enterprises, and a rise in the share of total sales by private enterprises. The share of total sales by state-owned enterprises decreased from 37.7% in 1998 to 12.7% in 2008, then increased to 15.7% in 2010. Chinese private firms contributed 37.2% of total sales in 1998, slightly less than state-owned firms, increasing to 58.9% of total sales in 2009, and declined to
49.8% in 2010. Foreign firms’ share of total sales remained stable around 30%.

Average market share of state-owned firms is at its highest and remains stable until 2008, and it accelerated significantly after the subprime crisis. On the one hand, this implies that state-owned firms have advantages in dealing with a crisis because they get privileges from banks and government. On the other hand, it may be because state-owned firms are the main beneficiaries in the 2008-2009 Chinese economic stimulus plan. The government’s effort in consolidating the state-owned sector through mergers and acquisitions and alliances may also be a factor which results in the increase of average market share of the SOEs after 2008. The average market share of foreign firms is the next highest and that of domestic private firms is the lowest, both of these showed a declining trend initially but this increased slowly after 2008. We think that this phenomenon is due to the exit of small firms caused by the financial crisis, which resulted in the increase in the average market share of the remaining firms. In summary, though state-owned firms have a smaller share of market, each of them is more powerful in the market. In addition, domestic private firms are mostly medium and small firms. The market structure may have different effects on firms with different ownership types.

6. Empirical Results

(1) Benchmark regression

As shown in Table 1, the dependent variable, the ratio of new product sales, falls between 0 and 1. The OLS estimation is inconsistent, and mis-specifies the model. To avoid bias due to mis-specification we use a panel Tobit estimation. The benchmark regression does not distinguish between differences in technology levels and ownership types.

As shown in Table 2, since sectoral market structure is strongly influenced by large firms, in regressions (1), (2) and (3), we used the top 50 firms’ total sales in four-digit level sectors to
calculate the core independent variable, the Herfindahl index. In regressions (4), (5) and (6), we used all firms to calculate the Herfindahl index as a robustness check for sectoral market concentration. In addition, regressions (2) and (5) include productivity (TFP) estimated from the OP model, whereas, in regressions (3) and (6), we add state-owned capital share of firms ($STATE_{ijt}$) to control for the effects of heterogeneous productivity and ownership.

First, *ceteris paribus*, the Herfindahl index ($S_{jt}$) has a positive effect on innovation in all regressions at the 1% significance level, while the quadratic form of the Herfindahl index ($S_{jt}^2$) has a negative effect on innovation in all regressions at the 1% significance level. In other words, the relationship between market competitiveness and firms' innovation appears to be an inverted-U shape. When the value of the Herfindahl index is low, i.e. sectoral market concentration is low and its competition is intense, a modest decrease in sectoral market competition can encourage firms' innovation. When the value of the Herfindahl index is high, i.e. there exists high sectoral market concentration and a lack of competition, leading firms show similarities to monopolistic firms and become reluctant to innovate, in which case a moderate increase in market competition can encourage innovation. Focusing on regression (3), with first order differentiation of the ratio of new product sales with respect to the Herfindahl index, we can derive the optimal value of the Herfindahl index. If the Herfindahl index converges to 0, the market converges to a perfectly competitive market, firms become price takers, and the incentive to innovate is low. When the Herfindahl index is greater than 0.23, sectoral market concentration increases, the ratio of new product sales at firm-level decreases. Therefore, 0.23 is the turning point of the Herfindahl index. Similarly, we can calculate the turning point for other regressions. These empirical results can prove Hypothesis I that “there is an optimal level of sectoral market concentration for firm’s innovation.”

Secondly, the increase in sectoral foreign capital share ($FAR_{jt}$) has a significant and

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Regression used all firms in the sample, while HHI calculation uses only the top 50 firms in total sales. Researchers, such as Nie et al. (2008), use CR4 (top 4 firms in core revenue) to calculate market concentration. We, thus, think that using the top 50 firms in total sales is sufficiently representative.
positive effect on firms’ innovation. Specifically, 1% increase in sectoral foreign capital share is associated with 0.06%-0.10% increase in ratio of new product sales at the firm-level. The increase in foreign capital has accelerated domestic market competition, which may result in more efficient resource use or innovation investment, thus having a positive effect on firms’ innovation. Meanwhile, competition may cause reductions in sectoral market concentration, which, in turn, affects profits and the ability to innovate, and may have a negative effect on firms’ innovation (Brambilla et al., 2009; Fu and Gong, 2011). On the other hand, there may be spillovers from foreign firms through productivity transfer, productivity sales, human capital flows, and domestic firms’ imitation (Spulber, 2008), which can positively impact domestic firms’ innovation. Therefore, the net effect of FDI on domestic innovation depends on the value of three aforementioned effects. From the benchmark regression, the positive effect of FDI dominates.

Thirdly, the decrease in import tariff has a promoting effect on innovation. Falling sectoral output tariff introduces a competitive effect, while a fall in input tariff leads to learning and spillover effects, all of which encourage innovation. Given regression (1), the coefficient of output tariff is -6.11, while that of input tariff is -1.85, which indicates that a decrease in output tariff has a significantly larger effect on innovation than a decrease in input tariff. After accounting for missing factor productivity and the state-owned capital share in regressions (2) and (3), the tariff coefficients change considerably from regression (1). The coefficient of output tariff increases, but the coefficient of input tariff decreases, which is consistent with the existing literature which holds that productivity is affected by both output and input tariffs (Amiti and Konings, 2007; Yu, 2015). More specifically, in regression (3), the coefficient of output tariff is -4.39, and coefficient of input tariff is -3.66. The effect of decreasing output tariff is slightly larger than that of input tariff.

Fourthly, firms’ R&D shares ($RD_{ijt}$) have a significant and positive effect on their sales’ shares of new products, i.e. the more R&D, the higher the probability of producing new products. Age of firms ($DP_{ijt}$) also has a significant and positive effect on innovation. If firms exist for one year longer, their sales’ shares of new products increase by 1%. Therefore, mature
firms have a relatively higher ratio of new product sales. On the one hand, start-up firms need to accumulate capital, technology and human capital. On the other hand, it takes time for new technologies to become new products. As firms operate for longer, they accumulate market experience and their new product sales rise.

Last but not least, in regressions (3) and (6), we use firm productivity ($TP_{ijt}$) and the state-owned capital share ($STATE_{ijt}$). The results show that the increase in productivity has a significant and positive effect on the ratio of new product sales through a greater ability to adapt new technologies and conduct innovation. After controlling for productivity, the higher the state-owned capital share, the larger the ratio of new product sales becomes. This finding is mostly due to the scale of the economy and the privileges enjoyed by state-owned firms in financial markets. In reality, we find that state-owned firms’ ratio of new product sales is the highest, followed by that of foreign firms, and is the lowest for domestic private firms. Before the financial crisis in 2007, the average ratio of new product sales of state-owned firms is 0.040, and that of foreign firms and domestic private firms is 0.036 and 0.029 respectively. The fact also supports our regression results.

(2) Robustness check

Considering the lag-effects of sectoral FDI, import of output and input goods, and firm-level R&D on firms’ innovation, Table 3 uses lag terms of independent variables in the regressions as a robustness check.

[Insert Table 3 here]

Spillovers between foreign and domestic firms take place due to labor movements, product transactions and geographical clustering, which are limited by time and location. Therefore, in regression (1) of Table 3, we first use a one period lag of sectoral FDI, the coefficient of which has the same sign and similar magnitude as those in regression (3) of Table 2. In regression (2) of Table 3, we use a one period lag of sectoral FDI, output tariff, and input tariff. The coefficient of output tariff greatly increased and becomes insignificant, which indicates that the effect of
output tariff occurs in the current period. In addition, the coefficient of input tariff increases and remains significantly negative; the spillover effect of current imported intermediate goods is larger than for the lag terms. Further, we add one period lag terms for R&D and productivity in regression (3) of Table 3. The coefficients of lag R&D and lag productivity are similar to those in regression (3) of Table 2 as well. These facts suggest our benchmark regression is robust. The competition effect is mostly current, while technology spillovers have both current and lagged effects on innovation.

(3) Regressions by technology levels

Table 4 reports the estimated results of empirical test model I (equation (28)) which tests Hypotheses I and II of innovation under heterogeneous technology levels. The OP and LP estimations of productivity are used for the estimation of TFP and firms are classified by their productivity relative to the average productivity of the industry. Those firms’ whose productivity levels are lower than the industry average are grouped as low-technology firms and those with above average productivity are termed high-technology firms. Regressions (1) and (2) are based on the OP estimation of productivity, while regressions (3) and (4) are based on the LP estimation as a robustness check. In addition, to avoid bias caused by outliers, we define high-technology firms as those with above median productivity and low-technology firms as below it, using the OP productivity measure, the results of which are presented in regressions (5) and (6). Comparing the results of regressions (1) with (3) and (2) with (4), we can see significant changes between coefficients, while their signs remain the same. This indicates that while we use different productivity estimation methods, firms’ reactions to innovate with respect to our independent variables maintain the same relationship. Given that results in (1) and (2) are similar to those in (5) and (6), respectively, classifications of technology levels using mean and median productivity offer consistent results.

[Insert Table 4 here]

As shown in Table 4, the coefficients on the Herfindahl index ($S_{jt}$) and the quadratic form
of the Herfindahl index ($S_{jt}^2$) are similar to those in Table 2. In regressions (1) and (2), the magnitudes of the coefficients on the Herfindahl index ($S_{jt}$) and the quadratic form on the Herfindahl index ($S_{jt}^2$) of high-technology firms are lower than those in the benchmark regression. When the Herfindahl index falls in the range $(0, 0.25]$, the increase in the Herfindahl index, i.e. lowering sectoral competition, is beneficial for innovation; while if the Herfindahl index falls in the range $[0.25, 1]$, sectoral market power decreases firms’ incentive to innovate, and thus sectoral market competition must be raised to encourage innovation. In regression (2) for low-technology firms, the coefficient of the Herfindahl index ($S_{jt}$) and the quadratic form of the Herfindahl index ($S_{jt}^2$) are both larger than those in the benchmark regression. The turning point of the Herfindahl index is 0.22 for low-technology firms. Similarly, under the LP estimation of productivity, the coefficients of the Herfindahl index ($S_{jt}$) and the quadratic form of the Herfindahl index ($S_{jt}^2$) are both less than those in the benchmark regression for high-technology firms. The turning point of the Herfindahl index is 0.23 for high- and low-technology firms. All regressions grouped by heterogeneous technology levels show that the effect of sectoral market competition is significant and positive, and that the quadratic form is significant and negative. Nevertheless, high-technology firms can be adapted to a wider range of sectoral market structures. Hypothesis I, there is an optimal level of sectoral market concentration for firm’s innovation, is thus proved. When sectoral market concentration lies within the optimal threshold, the rise in sectoral market concentration can increase firms’ innovation with different technologies. However, when sectoral market concentration is above the optimal level, monopolistic power hampers firms’ innovation.

Sectoral share of FDI ($FAR_{jt}$) continues to have a significant positive effect on innovation in low-technology firms, but this effect becomes insignificant on innovation in high-technology firms. This is consistent with findings from Fu (2011) which finds limited technology spillovers from FDI, which are heavily engaged with processing trade and assembly activities, on the technological capabilities’ development in the domestic firms in high-technology industries in China (e.g. Fu, 2011). In the low-technology firms, the effect of FDI on innovation appears to
be higher than that in the benchmark regression, suggesting that FDI may have greater spillover effects on innovation in low-technology firms.

The decrease in sectoral input tariff has significant and promoting effects on innovation in both high- and low-technology firms. The magnitude of the sectoral input tariff coefficients for low-technology firms is minutely higher than that of high-technology firms. Both FDI and various imports have influenced Chinese firms’ innovation through technological spillovers and have larger effects on low-technology firms. For high-technology firms, the decrease in sectoral output tariff ($Output\_tariff_{jt}$) has strong promoting effects on firms’ innovation through competition. The decrease in sectoral input tariff ($Input\_tariff_{jt}$) also has promoting effects on high-technology firms’ innovation through learning and cost reduction. For low-technology firms, on the other hand, more competition results in less profit due to lower productivity, thus limiting capital for R&D. Therefore, the decrease in sectoral output tariff has an adverse effect on low-technology firms’ innovation; this is supported by its significant and positive coefficient in regression (4). There are significant differences in the effects of a decrease in sectoral output tariff on low- and high-technology firms’ innovation through trade-induced competition. The decrease in sectoral output tariff encourages innovation in high-technology firms, while it discourages innovation in low-technology firms, which proves Hypothesis II.

Consistent with the benchmark regression, R&D ($RD_{ijt}$) of both high- and low-technology firms has a significant and positive effect on innovation, the coefficient being stronger for high-technology firms. High-technology firms have a higher R&D transformation rate. Similarly, age ($DP_{ijt}$) of firms has a significant effect on innovation of both high- and low-technology firms. These effects are very similar amongst technological groups. In addition, productivity ($TFP_{ijt}$) and the share of state-owned capital ($STATE_{ijt}$) have significant and positive effects on high- and low-technology firms.

**4) Regressions by ownership types**

Based on our model and the literature, we derived empirical model II (equation (29)) of
innovation under heterogeneous ownership types. Therefore, we test Hypotheses I and III.

[Insert Table 5 here]

In Table 5, regressions (1) and (2) are based on registered ownership type. Samples in regressions (3) to (6) are grouped by the share of state-owned capital, those who have at least 50% state-owned shares are categorized as state-owned firms. The variable share of state-owned capital is included in regressions (5) and (6).①

From the results in regression (1) in Table 5, the coefficient of the Herfindahl index ($S_{jt}$) is positive and its quadratic form ($S_{jt}^2$) is negative, neither of which are significant. Other results are consistent with the benchmark regression in Table 2; the coefficient of the linear term is significant and positive, and the quadratic term is significant and negative. From regressions (3) and (4), we find that when the Herfindahl index falls in the range (0, 0.19], the moderate increase in the Herfindahl index can have significantly positive effects on innovation by state-owned firm. When the Herfindahl index falls in the range of (0, 0.24], it is significantly promoting innovation by private firms. Thus, compared to state-owned enterprises, private firms can be adapted to a larger range of market structures. When the Herfindahl index is too high, it hampers innovation in both state-owned firms and private firms. The above has proved Hypothesis I: there is an optimal level of sectoral market concentration for firm’s innovation. Below the optimal level, the rise in sectoral market concentration will increase the innovation share of firms’ profit. On the other hand, if sectoral market concentration rises above this optimal level, greater market power will lead to a decrease in firms’ innovation share of profit.

Similar to the results in our benchmark regression, the increase in the sectoral share of FDI ($FAR_{jt}$) can significantly raise innovation in state-owned and private firms. In reality, the

① In regression (1), all firms are state-owned firms. In regression (2), none of the firms is state-owned. Ownership type is a binary variable and thus invariant within groups. On the other hand, in regressions (3) to (6), ownership type is classified by the share of state-owned capital, which varies within group ownership type and thus can be included in regressions (5) and (6).
increase in FDI has already had a positive effect on Chinese firms through both the competition and the technological spillover effects. The decrease in sectoral input tariff \((Input\_tariff_{jt})\) significantly encouraged innovation in state-owned and private firms. Nevertheless, contrary to the results in the benchmark regression, the decrease in output tariff \((Output\_tariff_{jt})\) improved innovation only in private firms. Comparing regression (1) to regression (3), the effects of sectoral FDI, sectoral output tariff, and sectoral input tariff on innovation in state-owned firms differ in magnitude and significance levels depending on their ownership classification. Whereas, in regressions (2) and (4), the effects of sectoral FDI, sectoral output tariff, and sectoral input tariff on innovation in private firms are similar in magnitude and level of significance. This shows that the effects of trade openness on private firms’ innovation are robust, but those of innovation in state-owned firms are not significant. The above results prove Hypothesis III: as the openness increases, the share of innovative products in private firms will increase, while that of state-owned firms is uncertain. A possible explanation of these results is that state-owned enterprises are protected by local governments, and thus remain insensitive to foreign competition. However, private firms have to win market share by innovating themselves and, therefore, react to the increase in openness. Openness in both investment and trade is beneficial for innovation by private firms, while trade openness does not significantly influence innovation in state-owned firms.

Similar to the benchmark regression, the share of R&D in state-owned and private firms \((RD_{ijt})\) has a significant and positive effect on innovation, especially for private firms. In other words, it indicates that private firms have higher R&D transformation rates. Age of firms \((DP_{ijt})\) has a significant and positive effect on firms’ innovation; this relationship is very similar for both state-owned and private firms. In addition, the increase of productivity \((TFP_{ijt})\) has significant and positive effects on firms’ innovation irrespective of ownership type. Comparing results in regression (5) and in regression (6), the share of state-owned capital \((STATE_{ijt})\) has different effects on state-owned and private firms. In private firms, the increase in share of state-owned capital has a significant and positive effect on innovation; whereas in state-owned firms, such an increase has a significant and negative effect on innovation. This indicates that forging connections with government is beneficial for firms in accumulating resources, in turn,
promoting innovation. However, as a state-owned firm, the increase in state-owned capital reduces firms’ efficiency and hampers innovation.

As shown in Figure 3, there are differences in the levels and trends of the ratio of new product sales between domestic private firms and foreign firms. Table 6 further distinguishes domestic private firms from foreign firms and estimates the effects of competition and openness on those two types of firms. Samples in regressions (1) and (2) are grouped by registered ownership types, while those in regressions (3) and (6) are based on shareholding structure, in which foreign firms are defined as firms with at least 50% share of foreign capital. Similar to Table 5, the linear sectoral market concentration term has a significant and positive effect on innovation, and its quadratic term has a significant and negative effect, which is consistent with Hypothesis I. The turning point of the Herfindahl index is comparably higher for foreign firms, indicating foreign firms adapt more easily to sectoral market structure than do domestic private firms. In contrast to the results in Table 5, the effect of the sectoral share of FDI is significant and negative for innovation by foreign firms, while its effect on innovation in domestic private firms is positive in Table 6. From Figure 3, we know that foreign firms are more productive than domestic private firms. FDI encourages innovation in domestic private firms via technological spillover effects but impairs innovation in foreign firms through the competition amongst them. In addition, we find that sectoral output tariff has an insignificant effect on foreign firms’ innovation in regressions (4) and (6), which is likely due to the substitution effect between trade and FDI. Similar to the results in Table 5, the decrease in sectoral output tariff has a significant and promoting effect on innovation in domestic private firms. Moreover, the decrease in sectoral input tariff has a significant and promoting effect on innovation of domestic private and foreign firms through either a cost reduction or technology spillover effect. The impact of R&D, age of firms, and productivity are similar for both firms, as shown in Table 5. Moreover, a higher share of state-owned capital in a firm’s total capital appears to encourage innovation in both domestic private and foreign firms.

[Insert Table 6 here]
7. Conclusions

This paper attempts to examine how domestic market competition and openness-induced foreign competition affect innovation in an emerging transition economy, and how ownership and technology affect firms’ responses to these pressure. This is of particular importance after the financial crisis in 2008 when countries looked for stronger new drivers of economic growth. The main findings of the research can be summarized as follows:

Firstly, consistent with Aghion et al. (2005), we find that the relationship between innovation and competition also follows an inverted-U shape at firm-level in China. Competition levels for the turning point are different, varying in the range of [0.18, 0.30], under heterogeneous productivity and ownership. When sectoral market concentration is low, reducing market competition moderately can be beneficial for innovation in the Chinese firms. When sectoral market concentration is high, however, the lack of competition and excessively concentrated market power can result in a low level of innovation. In such a case, sectoral market competition needs to be promoted to stimulate innovation. The inverted-U shaped relationship between competition and innovation is robust across technology levels or ownership types, although the turning points differ from each other. Nevertheless, compared to low-technology firms, high-technology productive firms are adaptive to a wider range of competitive environments. Similarly, the market structure whose degree of market concentration is favorable to firms’ innovation is broader for private than that for state-owned firms.

Secondly, the openness to foreign investment promotes innovation in Chinese firms. The competition induced by decrease in output tariff and the technology spillovers induced by input tariff reduction also have a promoting effect on firm’s innovation. The effect of decreasing output tariff is slightly larger than that of input tariff reduction. The competition effect of trade openness is mostly current, while technological spillovers have both a current effect and a lagged effect on innovation.
Thirdly, state-owned and private firms behave differently in innovation when responding to the competition pressure. The openness of foreign investment can significantly stimulate innovation in both state-owned and privately-owned firms through the competition and the technology spillovers effects. With regard to openness to foreign trade, as sectoral input tariff decreases, innovation in both state-owned and private firms rises. As sectoral output tariff decreases, innovation in private firms increases due to the competition effect of foreign imports. However, the effects are insignificant for innovation in state-owned firms. Moreover, the share of state-owned capital has a significant and positive effect on innovation, but only for private firms. In state-owned firms, increase in the share of state-owned capital hampers innovation.

Finally, relationships between openness and innovation vary between high- and low-technology firms. FDI only has a significant positive effect on innovation in low-technology firms. The decrease in sectoral input tariff has a significantly promoting effect on innovation in high-and low-technology firms via the mechanisms of cost reduction and technological spillovers. However, its effect is also stronger for low-technology firms. In contrary, the decrease in sectoral output tariff leads to greater innovation in high-technology firms, while hampers innovation in low-technology firms.

Findings from this research have important policy implications. Firstly, since innovation has an inverted-U relationship with competition at the firm-level in China, neither over-competitive nor under-competitive is beneficial for innovation in Chinese firms. Therefore, on the one hand, the government should provide a market environment with sufficient competition and transparent information for firms to decide whether to enter a market, rather than design industrial policies which introduce firms to a new market forcefully. On the other hand, competition should be promoted through the introduction of Anti-Trust Law and opening up market entry so as to encourage innovation in Chinese firm.

Secondly, as openness to foreign investment and trade (decreases in output and input tariffs) have significant positive effects on firm innovation, policy makers should continue to promote high-level openness in investment and in trade especially with the revival of trade
protectionism on the part of the US and other countries. Thirdly, our results show that import-induced competition stimulates innovation in private firms, but not in state-owned firms. Therefore, protection of SOEs should be abandoned. With the competition pressure induced by openness and no bail-out option, SOEs will have greater incentives to innovate. Finally, mixed ownership is beneficial for firm’s innovation as the share of state-owned capital has a positive effect on private firms’ innovation, but has a negative effect on state-owned firms’ innovation. Hence, governance reforms of the SOEs towards a mixed ownership structure and developing public-private partnership are useful avenues to incentivize more innovation in the Chinese economy.
References


Song, M., H. Ai, and X. Li (2015), “Political Connections, Financing Constraints, and the


Figure 1: Trend of share of total sales and ratio of new product sales under heterogeneous technology levels

Notes: The left y-axis refers to the share of total sales(bars), and the right y-axis corresponds the ratio of new product sales(lines). The share of total sales of high-technology firms is the ratio of sum of sales of all high-technology firms by the sum of total sales of all firms in the Chinese Industrial Enterprises Database. Low-technology firms’ share of total sales is calculated in the same was as that of high-technology firms. As some firms are missing productivity data, the sum of the total sales’ share of high- and low-technology firms is less than one. The ratio of new product sales is calculated as stated in section 4 Data and Measurement and the averages by the technology level of firms are shown in the figure. As there are no new product sales data for 2004, there is a break in the time-series plot for the ratio of new product sales.

Source: Authors’ calculation from the Chinese Industrial Enterprises Database.
Figure 2: Distribution of total sales and unit sales’ shares by ownership

Notes: The left y-axis represents the share of total sales (bars), and the right y-axis refers to the average market share of firm (lines). Share of total sales of state-owned firms is the ratio of total sales of state-owned firms to total sales of all firms in the sample. The average market share of state-owned firms is the sum of market share of state-owned firms divided by the number of state-owned firms. The average market shares of domestic private and foreign firms are estimated using a similar method.

Source: Authors’ calculation from Chinese Industrial Enterprises Database.
<table>
<thead>
<tr>
<th>Table 1</th>
<th>Summary statistics of key variables</th>
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</tr>
<tr>
<td>Sample size</td>
<td>Mean value</td>
</tr>
<tr>
<td>Ratio of new product sales ($R_{ijt}$)</td>
<td>2,222,299</td>
</tr>
<tr>
<td>Share of R&amp;D ($RD_{ijt}$)</td>
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</tr>
<tr>
<td>Age of firm ($DP_{ijt}$)</td>
<td>2,876,526</td>
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<tr>
<td>Productivity ($TFP_{ijt}$)</td>
<td>1,740,815</td>
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<tr>
<td>Four-digit sectoral competition and openness – annual statistics</td>
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</tr>
<tr>
<td>Sample size</td>
<td>Mean value</td>
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<tr>
<td>HHI (Top 50 firms) ($S_{jt-50}$)</td>
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<tr>
<td>HHI (All firms) ($S_{jt-all}$)</td>
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</tr>
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<td>Sectoral foreign capital share ($FAR_{jt}$)</td>
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<td>Two-digit sectoral openness – annual statistics</td>
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<td>Mean value</td>
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<td>Sectoral output tariff ($Output_\text{tariff}_{jt}$)</td>
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<tr>
<td>Sectoral input tariff ($Input_\text{tariff}_{jt}$)</td>
<td>2,875,898</td>
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Table 2  
**Benchmark regressions of innovation model: panel Tobit estimation**

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<th>(4)</th>
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<td></td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>$S_{jt}$</td>
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<td>0.97***</td>
<td>0.96***</td>
<td>1.27***</td>
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<td>1.28***</td>
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<td>-2.08***</td>
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<td>-2.27***</td>
<td>-2.24***</td>
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<td>$FA_{jt}$</td>
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<td>0.09***</td>
<td>0.08***</td>
<td>0.06***</td>
<td>0.07***</td>
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<td>Output_tariff$_{jt}$</td>
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<td>-4.39***</td>
<td>-6.24***</td>
<td>-4.49***</td>
<td>-4.45***</td>
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<tr>
<td>Input_tariff$_{jt}$</td>
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<td>-3.65***</td>
<td>-3.66***</td>
<td>-1.87***</td>
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<td>-3.62***</td>
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<tr>
<td>$RD_{ijt}$</td>
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<td>2.42***</td>
<td>2.42***</td>
<td>1.45***</td>
<td>2.40***</td>
<td>2.40***</td>
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<td>0.01***</td>
<td>0.01***</td>
<td>0.01***</td>
<td>0.01***</td>
<td>0.01***</td>
</tr>
<tr>
<td>$TFP_{ijt}$</td>
<td>—</td>
<td>0.05***</td>
<td>0.05***</td>
<td>—</td>
<td>0.05***</td>
<td>0.05***</td>
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<tr>
<td>STATE$_{ijt}$</td>
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<td>—</td>
<td>0.09***</td>
<td>—</td>
<td>—</td>
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</tr>
<tr>
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<td>-0.81***</td>
<td>-1.35***</td>
<td>-0.77***</td>
<td>-0.78***</td>
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|                  |         |         |         |         |         |         |
| No. Obs.         | 1,063,812 | 774,161 | 774,161 | 1,071,078 | 778,439 | 778,439 |
| No. Firms        | 432,521 | 335,992 | 335,992 | 435,127 | 337,521 | 337,521 |
| Time Effect      | Yes     | Yes     | Yes     | Yes     | Yes     | Yes     |
| Sector Effect    | Yes     | Yes     | Yes     | Yes     | Yes     | Yes     |

Note: (i) This is a panel Tobit estimation; (ii) the time effect is controlled by time dummies; (iii) the sector effect is controlled by sector dummies; (iv) *** , ** and * indicate significance levels 1%, 5% and 10% respectively; (v) HHI stands for the Herfindahl index, and STATE$_{ijt}$ is the state-owned capital share of firms.  
**Source:** please refer to Data and Measurement in section 4.
### Table 3  The lagged effects of openness on firms’ innovation: Tobit model estimation

<table>
<thead>
<tr>
<th>$R_{ijt}$</th>
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<tbody>
<tr>
<td>$S_{jt}$</td>
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<td>$S_{jt}$</td>
<td>0.84***</td>
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<tr>
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<td>$L.FAR_{jt}$</td>
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</tr>
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<td>$RD_{ijt}$</td>
<td>2.35***</td>
</tr>
<tr>
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<td>$TFP_{ijt}$</td>
<td>0.04***</td>
</tr>
<tr>
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<td>$DP_{ijt}$</td>
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</tr>
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<td>$STATE_{ijt}$</td>
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<tr>
<td>_cons</td>
<td>-0.56***</td>
<td>_cons</td>
<td>-1.82***</td>
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No. Obs. 632,398 632,417 442,153
No. Firms 271,942 271,976 254,445
Time Effect Yes Yes Yes
Sector Effect Yes Yes Yes

Note: This is a panel Tobit estimation; ***, ** and * indicate significance levels 1%, 5% and 10% respectively; HHI50 stands for the Herfindahl index, and $STATE_{ijt}$ is the state-owned capital share of firms; (vi) $L.FAR_{jt}$, L.Output tariff, $L.Input_{ijt}$, $L.RD_{ijt}$ and $L.TFP_{ijt}$ represent one period lag terms of sectoral FDI, output tariff, input tariff, R&D and productivity, respectively.
Table 4 Results of empirical model I: heterogeneity of technology levels and innovation

<table>
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<th>(1)</th>
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<th>(3)</th>
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<tr>
<td>$R_{ijt}$</td>
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<td>Low-</td>
<td>High-</td>
<td>Low-</td>
<td>High-</td>
<td>Low-</td>
</tr>
<tr>
<td></td>
<td>technology (Above mean TFP_OP)</td>
<td>technology (Below mean TFP_OP)</td>
<td>technology (Above mean TFP_LP)</td>
<td>technology (Below mean TFP_LP)</td>
<td>technology (Above median TFP_OP)</td>
<td>technology (Below median TFP_OP)</td>
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<tr>
<td>$S_{jt}$</td>
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<td>1.15***</td>
<td>0.76***</td>
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<td>0.07***</td>
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<tr>
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<td>-0.25</td>
<td>-1.58***</td>
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</table>

No. Obs.: 374,323 399,838 420,573 353,588 387,139 387,022
No. Firms: 195,360 222,842 208,286 204,944 200,964 217,868
Time Effect: Yes Yes Yes Yes Yes Yes
Sector Effect: Yes Yes Yes Yes Yes Yes

Note: (i) This is a panel Tobit estimation; (ii) the time effect is controlled by time dummies; (iii) the sector effect is controlled by sector dummies; (iv) *** and * indicate significance levels 1%, 5% and 10% respectively; (v) HHI50 stands for the Herfindahl index, and $STATE_{ijt}$ is the state-owned capital share of firms.
<table>
<thead>
<tr>
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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_{ijt} )</td>
<td>State-Owned (By registration)</td>
<td>Private (By registration)</td>
<td>State-Owned (By share of state-owned capital)</td>
<td>Private (By share of state-owned capital)</td>
<td>State-Owned (By share of state-owned capital)</td>
<td>Private (By share of state-owned capital)</td>
</tr>
<tr>
<td>( S_{jt} )</td>
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<td>0.99***</td>
<td>1.14***</td>
<td>0.96***</td>
<td>1.13***</td>
<td>0.95***</td>
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<tr>
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<td>-4.57***</td>
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<tr>
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<td>-3.79***</td>
<td>-3.13*</td>
<td>-4.02***</td>
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<td>20,998</td>
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Note: (i) This is a mixed-effect Tobit estimation; (ii) the time effect is controlled by time dummies; (iii) the sector effect is controlled by sector dummies; (iv) *** , ** and * indicate significance levels 1%, 5% and 10% respectively; (v) HHI50 stands for the Herfindahl index, and TFP_{ijt} is productivity by OP estimation.
Table 6    Results of empirical model II: domestic private versus foreign firms

<table>
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<td></td>
<td>(by registration)</td>
<td>(by registration)</td>
<td>(by shareholding)</td>
<td>(by shareholding)</td>
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<td>0.89***</td>
<td>1.26***</td>
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<td>-0.14***</td>
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<tr>
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<td>-4.10***</td>
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<td>$DP_{ijt}$</td>
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<td>0.01***</td>
<td>0.01***</td>
<td>0.01***</td>
<td>0.01***</td>
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<td>0.05***</td>
<td>0.06***</td>
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<td>125,555</td>
<td>627,608</td>
<td>125,555</td>
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<td>57,618</td>
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<td>Time Effect</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</tr>
<tr>
<td>Sector Effect</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Note: (i) This is a mixed-effect Tobit estimation; (ii) the time effect is controlled by time dummies; (iii) the sector effect is controlled by sector dummies; (iv) ***, ** and * indicate significance levels 1%, 5% and 10% respectively; (v) HHI50 stands for the Herfindahl index, and $TFP_{ijt}$ is productivity by OP estimation.