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Competition, Openness and Innovation in China – an integrated firm-level model

Abstract

This paper contributes to the literature by examining the innovation effects of domestic and foreign competition in an integrated model, with a special emphasis on the moderating effects of ownership and productivity. Using a firm-level production and trade tariff linked panel dataset from 387,725 Chinese firms over the 1998-2007 period and China's WTO entry as an exogenous paradigm change in openness, the paper finds that the innovation effect of competition is stronger in a more open economic system. The innovation responses of these firms to openness-induced competition differ between the pre- and post-WTO entry periods. The innovation effect of a decrease in sectoral input tariffs became positive and significant post-WTO entry. The paper also finds that market concentration has an inverted U-shaped impact on innovation with an optimal Herfindahl level of 15-25%. Ownership and productivity level of the firms also played a significant moderating role, with high-productivity and private firms post-WTO entry both appearing to have a higher level of optimal competition, and both respond positively to higher levels of foreign competitions induced by input tariff reduction in comparison to their counterparts.

Key words: Innovation, competition, openness, ownership, productivity

***JEL classification codes*:** O31; F13; L22

1. Introduction

Competition is considered a key factor affecting firms' innovation behaviour (Schumpeter, 1942; Geroski, 1990; Aghion *et al.*, 2005; Xia and Liu, 2017; Genin et al, 2021). Competition invokes rivalry, and consequently the associated objectives and instruments of rivalry (Vickers, 1995). The pressure of competition forces firms and individuals to improve productivity and work efforts and to allocate resources to more productive activities and firms (Nickell, 1996). Although monopoly power may ensure higher post-innovation rents which may incentivize firms to invest in costly and risky research and development (R&D) activities (Schumpeter, 1942; Kraft, 1989; Hashmi, 2013), competition in the industry and product markets are found to promote innovation in the UK and the European Union (Geroski, 1990; Blundell *et al.,* 1999; Griffith *et al.*, 2010; and Aghion *et al.*, 2015). As a result, the effect of competition on innovation is mixed. Recent studies find an inverted U-shaped relationship between competition and innovation (Aghion *et al.,* 2005; Im *et al.,* 2015).

Innovation behaviour in domestic firms may also be influenced by foreign competition induced by imports. Trade liberalization raises the number of firms in a market, intensifies domestic competition, thus reducing profits and R&D investment (Long *et al.*, 2011; Xia and Liu, 2017). As evidence of this, import competition is found to reduce innovation of enterprises in the US (Liu and Rosell, 2013). Conversely, imports from China are found to explain 13.9% of the increase in patents in 12 European countries during 2000-2007 (Bloom *et al.,* 2016). Moreover, when the intermediation of inputs through wholesalers is a strong feature of input supply within an industry, there are productivity gains for firms not directly importing (Defever et al., 2020). Importing intermediate inputs also allows both importers and non-importers they supply inputs to, to upgrade their technology (Eslava et al., 2015). Furthermore, there is a sizeable body of literature demonstrating learning effects from trade (e.g., Keller, 2010) and FDI (e.g., Görg & Greenaway, 2004). To note, however, the effect of competition on firms' innovation is influenced by how far a firm's productivity is from the productivity frontier (Aghion *et al.,* 2005). Evidence from Mexico corroborates the theory that the effect of trade liberalization on a firm's productivity growth depends on its distance from the frontier (Iacovone, 2012).

In the context of China, firms' behaviour is likely very different to that of Western counterparts where the majority of this literature has thus far focussed on [Buckley, 2007; Xia and Liu, 2017], reflecting data inadequacy, different state-firm relations and second-mover advantage [Ramamurti and Hillemann, 2018]. Greater government control over business and regulation, as is the case in China, has been shown to affect innovation in different ways [Genin et al, 2021]. As such, the competition-innovation nexus may be different in the context of China. Investigating this claim, Nie *et al.* (2008) find that firms' R&D intensity and firms' market power in China exhibit an inverted-U relationship. Hu and Jefferson (2009) show that foreign investment has a positive effect on the innovation of China's domestic firms, while Fu and Gong (2011) find that FDI exerts negative pressure on technical change in domestic firms. Xia and Liu (2017) demonstrate that this picture is more nuanced upon disaggregating firms into private and state-owned enterprises (SOEs), with the former exhibiting a U-shaped relationship and the latter a purely positive relationship. Girma et al. (2015) show that FDI in a regional cluster leads to local spillover effects and TFP growth among domestic firms. Olabisis (2017) does so for innovation and Gong and Henley (2021) demonstrate that learning within local clusters from exporting experience of other firms have a positive impact on both new product introduction and R&D. Finally, Liu and Qiu (2016) show that input tariff reductions in China have had a negative effect on firms' patent applications, while Lu and Ng (2012) find that import-induced market competition can encourage innovation in domestic firms.

Although the existing literature has explored the innovation effect of domestic competition and openness separately, it does not integrate domestic and foreign competition into the same framework. In fact, foreign and domestic competition not only co-exist in a market, but they interact with each other. The entry of foreign products and large MNEs may force inefficient domestic firms to exit and lead to greater concentration in the domestic industry. At the same time, the level of domestic competition will influence the amount and type of imports and foreign firms' entry into the domestic market. Therefore, it is important to model both domestic and foreign competition in an integrated framework.

This paper contributes to the literature in several ways. Firstly, it integrates domestic and foreign competition into the same framework to distinguish between the impact of different types of competition on the innovation of Chinese enterprises. In this paper, we extend the models of Aghion *et al.* (2004) and Iacovone (2012) and apply them to the study of innovation to explore the effect of foreign and domestic competition on innovation in an integrated model, and across enterprises of different productivity levels and ownership types.

Secondly, using China's WTO entry as a quasi-natural experiment, this paper examines and compares the impact of competition on innovation in a closed and an open economy. We find that the innovation response of Chinese domestic firms to openness-induced competition differs pre- and post-WTO entry. The innovation effect of a sectoral input tariffs reduction became positive and significant post-WTO entry. On the other hand, Chinese firms' innovation response to domestic competition remains consistent and follows an inverted U-shaped relationship, although the turning points in the post-WTO open economy became larger suggesting greater resilience of Chinese firms to competition.

Finally, it is also one of the rare studies that distinguish how firms with different productivity levels and ownership types (state versus private ownership in particular), may respond differently to domestic and foreign competition through innovation. Whilst the existing literature primarily focuses on developed countries in which most firms in the market are private, we consider the effect of competition and openness on innovation in emerging transition economies. State-owned enterprises (SOEs) are pervasive in transition economies like China (Berkowitz et al., 2017) and differ from non-SOEs with respect to efficiency, financial constraints, and governance structure (Jiang et al., 2013; Song et al., 2015; Berkowitz et al., 2017). Moreover, firm productivity in developing economies is lower than those in developed countries (Bloom et al., 2010), thus openness may not always enhance innovation through increased competition, incurring productivity spillovers via trade and investment which are an important source of innovation in developing countries (Pamukcu, 2003; Crescenzi and Rodríguez-Pose, 2012). We also find that high-productivity and private firms demonstrate greater innovation resilience to market structure as the optimal levels of sectoral market concentration for these firms are higher. Moreover, the effect of import-induced competition on firms' innovation varies with their productivity level and ownership type.

This paper is structured as follows. Section 2 introduces the theoretical model of competition and enterprises' innovation. Section 3 presents the empirical model. Section 4 shows the data and measurement of variables and descriptive statistics. Empirical results are presented and discussed in Section 5. Section 6 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:

$$Y_t = \frac{1}{\alpha}\int_0^1 A_t^{1-\alpha}[x_t(v)]^{\alpha}dv \quad (1)$$

in which, Y_t is the number of priced products at time t, α is a parameter varying between 0 and 1, A_t is the productivity level of the firm at time t, and $x_t\ (v)$ is the quantity used of the intermediate input v at time t (Iacovone, 2012). Since Y is in a perfectly competitive market, the marginal product of the intermediate input v should equal its price. Then, the profit of the monopolistic group ($\pi_t\ (v)$) is:

$$\pi_t\ (v)\ = [P_t(v) - 1]x_t(v) = \sigma S_t\ (1 + \sigma S_t)^{\frac{1}{\alpha-1}}A_t = \delta_t A_t \quad (2)$$

in which, $\delta_t = \sigma S_t\ (1 + \sigma S_t)^{\frac{1}{\alpha-1}}$. where $\sigma > 0$ is a constant and S_t is the degree of market concentration at time t. Since $\sigma S_t > 0$, we also have $\delta_t > 0$.

In an open economy, assuming foreign competitors are at the technological frontier of production $\overline{A}_t$, which grows at a constant rate $\gamma > 0$, we have:

$$\overline{A}_t = (1 + \gamma)\overline{A}_{t-1} \quad (3)$$

where $\gamma = \frac{\overline{A}_t - \overline{A}_{t-1}}{\overline{A}_{t-1}}$, represents the rate of technological progress. It can be theorized that, faced with diverse foreign firms and imports, different firms will face different incentives to innovate. In our model, we not only incorporate heterogeneity into the productivity levels of domestic enterprises as per Aghion *et al.* (2004) and Iacovone (2012), we also include heterogeneity in the ownership types of enterprises. Moreover, we also include sectoral market concentration as to examine the impact of domestic market structures on firms' innovative behaviour.

2.1 Heterogeneity of Productivity Level and Innovation

We classify firms into two types according to their technological differences: low-productivity firms *l,* and high-productivity firms *h*. At time *t*-1, *l* firms produce at productivity level $\overline{A}_{t-2}$, and *h* firms at $\overline{A}_{t-1}$. At time *t*, both types of firms improve their productivity through innovation. R_{lt} and R_{ht} denote the share of new product sales in firms' total sales of low- and high-productivity firms respectively. *l* firms produce R_{lt} at productivity level $\overline{A}_{t-1}$, and $1 - R_{lt}$ of the old product at productivity level $\overline{A}_{t-2}$. h firms produce R_{ht} at productivity level $\overline{A}_t$, and $1 - R_{ht}$ of the old product at productivity level $\overline{A}_{t-1}$.

The cost of innovation to firms producing a new product is C_{lt}, C_{ht} for low- and high-productivity firms at time *t* respectively. Here, following Iacovone (2012), we assume that the cost of innovating is quadratic in the innovation effort and linear in the current technological level, and that low productivity firms need to take extra effort, and hence longer time. So $C_{lt} = c\left(\frac{R_{lt}^2}{2}\right)\overline{A}_{t-2}, C_{ht} = c\left(\frac{R_{ht}^2}{2}\right)\overline{A}_{t-1}$, with $c > 0$ a constant.

We also assume that the foreign competitors' productivities are $\overline{A}_t$, and that they participate in the domestic market through FDI and imports. The probability of a foreign firm entering is Pr_t. Firms engage in Bertrand competition upon entering.

A. Low-productivity firms' ratio of new product sales

Referring to equation (2), we can calculate the expected profit, π_{lt}, for firm *l* at time *t*. And then, we can derive the following reaction functions:

$$\frac{\partial R_{lt}}{\partial S_t} = \frac{1-Pr_t}{c}\delta_t\gamma\frac{1-\alpha-\alpha\sigma S_t}{S_t(1-\alpha)(1+\sigma S_t)} \tag{4}$$

$$\frac{\partial R_{lt}}{\partial Pr_t} = \frac{-\delta_t\gamma}{c} \tag{5}$$

Therefore, for low-productivity firms, the optimal level of market concentration for innovation is $S_t = \frac{1-\alpha}{\alpha\sigma}$. Since $\delta_t > 0, \gamma > 0, c > 0$, and $1 - Pr_t \geq 0$, it is always the case that $\frac{\partial R_{lt}}{\partial Pr_t} < 0$. As FDI and imports grow, the share of new product sales among low-productivity firms' total sales (R_{lt}) decreases.

B. High-productivity firms' ratio of new product sales

Similarly, we can calculate the expected profit, π_{ht}, of high-productivity firms *h* at time *t*. And then, we derive the following reaction function:

$$\frac{\partial R_{ht}}{\partial S_t} = \frac{\gamma+Pr_t}{c}\delta_t\frac{1-\alpha-\alpha\sigma S_t}{S_t(1-\alpha)(1+\sigma S_t)} \tag{6}$$

$$\frac{\partial R_{ht}}{\partial Pr_t} = \frac{\delta_t}{c} \tag{7}$$

Therefore, for high-productivity firms h, there is also an optimal level of sectoral market concentration which maximizes innovation within firms. Since $\delta_t > 0$ and $c > 0$, we have $\frac{\partial R_{ht}}{\partial Pr_t} = \frac{\delta_t}{c} > 0$. Thus, in response to an increase in FDI and imports (i.e. foreign competitors), domestic high-productivity firms h increase their shares of new product sales.

Based on the above, we propose propositions I and II below**:**

Proposition I: There is an optimal level of sectoral market concentration which maximizes innovation within firms. Beyond the optimal turning point, an excessive concentration in market power will lead to a decrease in firms' innovation**.**

Proposition II: As foreign competition increases, e.g., through imports and FDI, the share of new product sales of low-productivity enterprises decreases, while that of high-productivity enterprises increases.

The intuition behind Proposition II is that higher productivity firms enjoy lower costs and higher profits. They are also likely to have greater technological capabilities. Therefore, in the face of foreign competition, they have greater capabilities and more resources to innovate as a response to foreign competition. They might also benefit more from the foreign knowledge spillovers because their absorptive capacity should be higher than that of lower productivity firms.

2.2 Heterogeneity of Ownership and Innovation

Innovation is also influenced by ownership type. State-Owned Enterprises (SOEs) have the advantage of being able to obtain support more easily from government and banks. However, SOEs suffer from the principal-agent problem which can lead to lower efficiency in production; indeed, the productivity of most SOEs was found to be lower than that of private and foreign firms in China (Berkowitz *et al.*, 2017). Differences in terms of access to credit and efficiency in production may affect the incentives to innovate when faced by foreign competition.

We assume a two-stage model; in detail, there is private firm *f* and state-owned firm *g* in the economy and continue to use the productivity level of the domestic firm at time *t*-1 as $\overline{A}_{t-2}$.

With the introduction of foreign competitors through FDI and imports at time *t*, firm *f* can leapfrog growth owing to its higher efficiency; the firm produces new products at a ratio of R_{ft} under productivity level $\overline{A}_t$, and other products at a ratio of $1 - R_{ft}$ under its original productivity level $\overline{A}_{t-2}$. Firms need to apply for loans to invest in R&D and be able to leapfrog growth. We assume that the interest rate for firm *f* is *r* times greater than for firm *g*. We assume that under open economy conditions, firm *g* does not completely adopt new technologies at time *t*. Instead, it dedicates a fixed share of its production to new products, R_{gt}, at productivity level $\overline{A}_{t-1}$ and a further share of its production to new products, r_{gt}, at productivity level $\overline{A}_t$. Other non-innovative products are produced at productivity level $\overline{A}_{t-2}$ and their share of total production is $1 - R_{gt} - r_{gt}$ where $R_{gt} + r_{gt} \leq 1$. For simplification, we assume the relationship between R_{gt} and r_{gt} satisfies the following equation:

$$r_{gt} = \eta_g R_{gt} \tag{8}$$

where, $\eta > 0$ is a constant, representing the ratio of the share of new products with higher productivity to that of new products with lower productivity.

Through innovation, both *f* and *g* realise some level of technological improvement at time *t*, but at a cost. Combining C_{lt} and C_{ht}, we calculate the cost of innovation to firms *f* and *g* as:

$$C_{ft} = c\left(\frac{R_{ft}^2}{2}\right)\overline{A}_{t-2}\,(1 + r) \tag{9}$$

$$C_{gt} = c\left(\frac{R_{gt}^2}{2}\right)\overline{A}_{t-2} + c\left(\frac{r_{gt}^2}{2}\right)\overline{A}_{t-2} \tag{10}$$

As before, we assume that at time *t* foreign competitors produce at a productivity level of $\overline{A}_t$ and enter the domestic market through FDI and imports with probability Pr_t. Once foreign competitors have entered, domestic and foreign firms engage in Bertrand competition, i.e. they produce a homogenous good and compete in prices.

A. Share of innovative products in private firm *f*

Using equations (2) and (9), we obtain the expected profit π_{ft} of firm *f* at time *t*:

$$\pi_{ft} = R_{ft}\delta_t\overline{A}_t + (1 - Pr_t)\big(1 - R_{ft}\big)\delta_t\overline{A}_{t-2} - c\left(\frac{R_{ft}^2}{2}\right)\overline{A}_{t-2}\,(1 + r) \tag{11}$$

We can then deduce that the reaction functions of the share of innovative products produced by firm *f* with respect to sectoral market concentration and outsider entry probability are:

$$\frac{\partial R_{ft}}{\partial S_t} = \frac{Pr_t + 2\gamma + \gamma^2}{c\,(1+r)} \delta_t \gamma \frac{1-\alpha-\alpha\sigma S_t}{S_t(1-\alpha)(1+\sigma S_t)} \tag{12}$$

$$\frac{\partial R_{ft}}{\partial Pr_t} = \frac{\delta_t \gamma}{c\,(1+r)} \tag{13}$$

When $0 < S_t < \frac{1-\alpha}{\alpha\sigma}$, an increase in market concentration and market power of a firm, leads to an increase in the share of innovative products. When $S_t > \frac{1-\alpha}{\alpha\sigma}$, the converse is true. Therefore, for firm *f*, there is a level of sectoral market concentration which optimizes innovation. Given that $\delta_t > 0, \gamma > 0, c > 0$ and $r > 0$, it follows that $\frac{\partial R_{ft}}{\partial Pr_t} > 0$. That is to say, the share of innovative products in firm *f* is increasing in FDI and imports. This share decreases as the interest rate *r* increases.

B. Share of innovative products in state-owned firm *g*

Using equations (2) and (10), we obtain the expected profit π_{gt} of firm *g* at time *t*:

$$\pi_{gt} = r_{gt}\delta_t \overline{\mathrm{A}}_t + (1-Pr_t)R_{gt}\delta_t\overline{\mathrm{A}}_{t-1} + (1-Pr_t)\big(1-r_{gt}-R_{gt}\big)\delta_t\overline{\mathrm{A}}_{t-2}$$
$$-c\left(\frac{R_{gt}^2}{2}\right)\overline{\mathrm{A}}_{t-2} - c\left(\frac{r_{gt}^2}{2}\right)\overline{\mathrm{A}}_{t-2} \tag{14}$$

Solving for the reaction functions of the share of innovative products with respect to sectoral market concentration and outsider entry probability gives:

$$\frac{\partial R_{gt}}{\partial S_t} = \frac{2\eta\gamma + \eta\gamma^2 + (1-Pr_t)\gamma + \eta Pr_t}{c(1+\eta^2)} \frac{(1-\alpha-\alpha\sigma S_t)}{S_t(1-\alpha)(1+\sigma S_t)} \tag{15}$$

$$\frac{\partial R_{gt}}{\partial Pr_t} = \frac{\delta_t(\eta-\gamma)}{c(1+\eta^2)} \tag{16}$$

Here, $\eta > 0, \gamma > 0, c > 0, 0 < Pr_t < 1, \alpha \in (0,1), \sigma > 0$ and $S_t > 0$, so $\frac{\partial R_{gt}}{\partial S_t}$ is dependent on the sign of $(1-\alpha-\alpha\sigma S_t)$. When $0 < S_t < \frac{1-\alpha}{\alpha\sigma}$, an increase in the sectoral market concentration of firms, i.e. an increase in their market power, leads to an increase in the share of innovative products produced by state-owned firm *g*. When $S_t > \frac{1-\alpha}{\alpha\sigma}$, the converse is true. Therefore, for *g* firms, there is a level of sectoral market concentration which optimizes innovation. Given that $\delta_t > 0, \gamma > 0, c > 0$ and $r > 0$, the effect of FDI and imports on the share of innovative products in firm *g* depends on the relationship between η and γ. When $\eta > \gamma$, the entry of foreign competitors increases the share of innovative products. When $\eta < \gamma$, the converse is true. When $\eta = \gamma$, the entry of foreign competitors has no effect on innovation within firm g.

Equations (12) and (15) indicate that the inverted U-shaped relationship between the share of innovative products and market concentration holds for both private firms and SOEs. Based on equations (13) and (16), we have the following:

Proposition IIIa: The share of innovative products of private enterprises will rise as FDI and imports increase.

For SOEs, the impact of foreign competition on the share of innovative products becomes uncertain, as the response of SOEs to foreign competition will depend on the relationship between the ratio of the share of new products with higher productivity to that of new products with lower productivity (η) and the rate of technological progress (γ). This is consistent with SOEs being more sheltered from foreign competition. Therefore, we conjecture:

Proposition IIIb: The impact of foreign competition on the share of innovative products is uncertain among SOEs.

The intuition behind Proposition IIIa and IIIb is that private enterprises need to find a way to effectively compete against foreign firms, which they see in innovating, whereas this need is lower for SOEs, which benefit from various preferential policies.

In sum, our analysis of the theoretical model suggests that, firstly, the relationship between market concentration and innovation in Chinese firms will also follow an inverted U-shaped relationship. Secondly, high-productivity Chinese firms will respond positively to foreign competition, while innovation activities of low-productivity Chinese firms will decrease. Finally, the share of innovative products of private enterprises will rise as FDI and imports increase, while the impact of foreign competition on the share of innovative products in SOEs remains uncertain.

3. Modelling and estimation strategy

To determine the effect of both domestic and foreign competition on firms' innovation behaviour, two main econometric strategies are employed: Probit models to analyse the probability of new product innovation occurring, and Tobit models to estimate the determinants of the share of new products sales, as a proportion of total sales.

3.1 Estimation Strategy

Before turning to our main regression analysis to investigate the impact of competition on the share of new product sales, we start with Probit models to examine the impact of competition on the firm's probability to innovate. We create a dummy variable for firms introducing new products and use Probit and heteroskedastic Probit models with lagged and non-lagged specifications to estimate the impact of competition on innovation decisions.[1] As independent variables, we include the Hefindahl index and its squared term, sectoral foreign capital share, as well as sectoral output and input tariffs. A full set of industry and time dummies are also included in the model. The choice of these covariates is guided by theoretical considerations discussed in section 2, as well as existing empirical evidence (e.g., Amiti and Konings, 2007, Girma et.al, 2006; and Gong and Hanley, 2021).

The purpose of running lagged models is two-fold, firstly to see for how long the independent variables, and especially the competition variables, impact innovation. Is it the same year, or is there a time lag? Secondly, we cannot ignore heteroskedasticity when we consider a latent variable model, like the Tobit model, as heteroskedasticity would otherwise bias the estimators. When testing for heteroskedasticity in latent variable models, it is advisable to use the heteroskedastic Probit model (Moussa, 2019). The heteroskedastic robust Wald test then suggests whether we indeed need to consider the heteroskedasticity issue or not.

When we consider a limited dependent variable, we understand that careful attention must be paid to methodological selection when dependent variables are expressed in percentage or proportional terms. Many econometrics textbooks argue that, conventional linear models, namely ordinary least squares (OLS) and fixed effects (FE) specifications, fail to address dependent variables with bounded responses, such as percentages or proportions (e.g., Wooldridge, 2010), because they could lead to systematic overestimation at each end of the

1 We use R&D expenditure as a robustness check Results are consistent and available upon request.

distribution (Papke & Wooldridge, 1996). However, Angrist & Pischke (2008) test and conclude that OLS estimations show, in the face of a non-linear estimator, very similar results compared to Probit and Tobit models. We include the OLS estimation and fixed effect model in our baseline regressions[2].

The literature suggests alternative methods when using dependent variables expressed in percentage or proportional terms, namely fractional logit (FLOGIT), panel Tobit, and zero-inflated multiple regression (ZIMR). As 90% of the observed firms had zero new product innovation and none of the sample groups in our data always have zero new product innovation, we discard the use of FLOGIT and ZIMR (Baum, 2008; Cook et al., 2008). Panel Tobit models differ from FLOGIT models by treating boundary values as systematically different from intermediate values, which is especially important amid a large number of boundary values. While panel Tobit is more restrictive than FLOGIT, it can paint a much richer picture of marginal effects across bounded variables, although in extreme cases, it can introduce sample selection bias (Baum, 2008). We use heteroskedastic Probit models to test whether we need worry about such an issue in the model. Once confirmed, we will then employ a Tobit multiplicative heteroskedasticity regression with robust standard errors to estimate the regression. All Tobit models are estimated with lagged explanatory variables in response to endogeneity concerns (Bellemare et al., 2017).

3.2 Heterogeneity

Equations (4) - (7) from our theoretical model of heterogeneity in productivity and innovation show the effect of market concentration and foreign competitors on the innovation of enterprises with differing productivity levels. In our Tobit model we divide firms into two groups based on their productivity level (high or low) to test Propositions I and II. When a firm's productivity is higher than the mean value of the sector's productivity level, the firm is classified as a high-productivity firm. To avoid bias caused by outliers, we use five different

2 OLS model results are very similar to the results based on fractional logit and tobit models, as Angrist and Prischke (2008) observed, however fixed effect models' results are mostly insignificant. As explained, it is not a suitable model for this case. Hence, we don't report the fixed effect model in the paper, but the results are available upon request.

productivity measurements for creating different strata: Olley and Pakes (OP) estimates of productivity, Levinsohn and Petrin (LP) estimates of productivity, initial TFP above mean OP estimates, average TFP above mean OP estimates, and firms whose productivity groups have not changed across the period[3]. This detailed alternative measurement of productivity groups provides insight into firms' innovation in the context of heterogenous productivity levels and serve as an empirical test for Propositions I and II.

Equations (12), (13) (15) and (16) show the effect of sectoral market concentration and foreign competitors on the innovation of enterprises of different ownership types. In our Tobit model, to test Propositions I and III, we divide the data sample into two groups: SOEs and Private firms.

In addition to considering heterogeneity in productivity and ownership, there is one more important heterogeneity group. Though not presented in our theoretical model, there could be heterogeneity in the technological sophistication of a firm. Firms in the data sample are divided into four categories: high-tech, middle-high tech, middle-low tech, and low tech. Previous research has demonstrated that among domestic Chinese firms, different technological sophistication categories have differing impacts of foreign capital shares on innovation (Fu and Gong, 2011).

4. Data and variable construction

4.1. Data description

In order to investigate the impact of both domestic and foreign competition on innovation empirically, we draw on two granular datasets: a Chinese firm-level panel dataset and a tariff dataset.

4.1.1 Firm-level panel dataset

3 When we define high- and low-productivity firms as those with LP-measured productivity above and below the median respectively, the results are similar to the results based on OP-measured productivity. Therefore, the results are not sensitive to outliers and the use of initial or average to classify firms' productivity levels does not affect the regression results. Full results are not presented here but are available upon request.

The first dataset is a comprehensive Chinese firm-level panel dataset from the manufacturing sector which is based on the Annual Reports of Industrial Enterprise Statistics, compiled by the China National Bureau of Statistics. The dataset covers all firms with an annual turnover of more than 5 million RMB (approximately 770K USD). These companies account for an estimated 85-90 percent of total output in most industries and include detailed accounting information of the firm and sector including new product sales and R&D expenditure.

For analysis purposes, we only keep domestic firms, as we are interested in understanding the competition impact on Chinese domestic firms. However, we use all firms in the dataset to construct sectoral variables, including the sectoral foreign capital share and the Herfindahl indices. Given that the dataset only includes private firms with more than 5 million Chinese Yuan turnover, we dropped state-owned enterprises (SOEs) where the turnover is less than 5 million Chinese Yuan, in order to compare these two types of ownership forms.

As a result of China entering the WTO in 2001, China enjoys lowered import tariffs and higher degrees of economic openness. Moreover, in 2003, the reforms of China's SOEs entered a new and deeper stage. This led to a reduction of the market share of the SOEs (Hsieh and Song, 2015) and stiffened market competition for all firms. Therefore, we divide the full sample into two periods: 1998-2001 (Period I) pre-WTO membership, and 2005-2007 (Period II) after China's WTO entry and SOE reform[4]. This enables us to study the effect of competition and openness on the innovation of Chinese firms. We exclude the data sample between 2002 and 2004 from our empirical analysis due to three reasons: 1) The change of legal regulations and tariffs due to WTO only have impact after a period of time; 2) The shock of the SOE reform did not occur until 2003; 3) One of our variables of interest, new product sales, does not have information in the year 2004.

After dropping some outliers, like zero or negative capital, employment and assets, the data contains 1,392,158 observations from 387,725 firms between 1998 and 2007, with 351,969 observations from 143,232 firms in Period I (1998-2001) and 801,483 observations from 342,210 firms in Period II (2005-2007).

4 We also run our benchmark models using the full sample data including 2002 and 2003. Results are similar and available upon request.

4.1.2 Import tariff data

The second dataset used is the import tariff data, which is drawn from two data sources. The tariff data between 1998 and 2000 is taken from the World Bank's World Integrated Trade Solution (WITS), also used by Kamal et. al. (2019) and Hu (2014). The tariff data between 2001 and 2007, after China's entry into WTO, is drawn from the WTO database following Yu (2015). China adopted the 1996, 2002 and 2007 versions of the Harmonized Commodity and Description and Coding System (HS) of tariff respectively during the years 1998-2001, 2002-2006 and 2007. We also employ Chinese input-output tables (IO tables) published in 1997, 2002 and 2007 for constructing output and input tariffs variables for the periods 1998-2000, 2001-2005, and 2006-2007 respectively. We use Most Favored Nations (MFN) applied duty rates at the two-digit level of Chinese sectors to measure trade openness[5].

4.2 Variable construction

4.2.1 Dependent variable: Measurement of innovation

Innovation is measured in the literature in different ways, such as R&D expenditure, number of patents, and ratio of new product sales to total sales. In this paper, we measure innovation using the share of new product sales (new product sales/total sales) following Guan and Yam (2015). We also use R&D intensity, measured as the R&D expenditure to sales ratio, as a robustness check. New product innovation in this dataset is defined as products that either adopt completely new technological principles, new design concepts, or are significantly improved in terms of performance or function (NBS, 2020). This definition picks up most of the quantitative and qualitative aspects of organisations' innovation performance (Fu, 2012). In the full sample dataset, there are about 100,000 (9%) observations with new product sales in the given year. Number of patents is not considered as an innovation measurement here due to the limitation that patents are widely used to register and protect intellectual property in some industries but not in others, and as the number of patents does not reflect the quality of innovation (Hagedoorn and Cloodt, 2003).

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5 We understand that the 2-digits level tariff is aggregated but matching the code at more disaggregated levels of the classification is not practical here, given that there are no corresponding tables to link the WITS HS-ISIC, CIC and IO sector codes. Manually linking these codes at a more disaggregated level could lead to bias and inaccuracies. Hence we follow Yu (2015)'s work to construct the tariff variable at 2-digit level.

4.2.2 Independent variables: Measurement of competition

There are two types of competition: competition existing in the domestic market and competition from foreign markets.

Following Zhou (2014), we use the Herfindahl index at 4-digit industrial sector level to identify sectoral market concentration in the domestic market. A perfectly competitive market boasts a HHI of zero, while the index takes a value 1 in the case of a monopoly. In the empirical analysis, we use HHI50, calculating the sum of sales based on the total 50 firms, as Nie et. al (2008) suggests that market structure is mainly shaped by the top firms in the sector.[6]

To measure competition from foreign markets, we use the share of foreign capital in the sector and sectoral import tariffs to represent capital and trade openness of a sector respectively. The share of foreign capital in a sector is defined as the ratio of foreign firms' capital to total capital in a given 4-digit sector and is also a measurement of FDI spillovers. The sectoral FDI spillover (horizontal FDI spillover) effects could be measured in different ways, for example Girma and Gong (2008) construct this variable as the proportion of output accounted for by multinational companies. In this paper, we are more interested in the impact of foreign capital, but not the impact of multinational companies that may also contain domestic capital if not wholly foreign-owned.

Following Amiti and Konings (2007) we distinguish between sectoral output and sector input tariffs. We construct output and input tariffs in China using Input-Output (IO) two-digit sector categories. The simple average of HS product import tariffs by sector is used to represent the sectoral output tariff to avoid endogeneity. The input tariff for each IO sector is measured by using input-cost shares as the weight to aggregate those IO sector output tariffs in sector j at time t. The measurement is as follow:

6 We use HHIall, calculating the sum of all firms in the sector at the time, as well as CR4 (top four firms in revenue in the sector), as a robustness check, but do not include the results in the paper as they are very similar.

$$Input\_tariff_{jt} = \sum_i \frac{Input_{ij}}{Total\ input_j} \times Output\_tariff_{it} \quad (18)$$

Rather than using input-output shares from China's 2002 IO table as the weights (Yu, 2015), we include three IO tables published in the years 1997, 2002 and 2007 respectively. Although this could introduce the problem that the weights might reflect tariff-induced changes in input choices, we think that this improves the accuracy of the weight as the Chinese IO sector, which we used to link to the data[7], has changed over the years.

All sectoral variables constructed here (HHI, share of foreign capital, import tariffs) are based on all firms, including foreign firms.

4.2.3 Control variables

We introduce control variables at firm level including firm size, age, exports and share of state-owned firms. Time and sector dummies are included to control for sectoral and time effects.

In this paper, we use state-owned paid-up capital shares to identify ownership types of firms, although we also adopt the registered firm type information from the dataset as a robustness check[8]. We divide all Chinese domestic firms into two categories: state-owned firms and private firms. Firms with more than 50% state-owned capital are regarded as state-owned firms, all other firms are treated as private firms.

Table 1 summarises our variables of interest. On average, Chinese domestic firms only have a relatively low share of new products sales (2.9%) and R&D intensity (0.2%). Apart from firms in the top quartile, most firms have no innovative activities at all.

[Insert Table 1 here]

7 We also run models using the input tariff structured based on the 2002 IO table alone. Results are similar and available upon request.

8 The results based on the registered firm type are consistent, but for brevity not presented here. They are available upon request.

Table 2 presents the summary statistics of key variables by productivity (high/low) and ownership (SOE/private). The data shows that firms with high productivity are associated with higher sales of new products, are younger, export more, and have a lower share of state-owned capital. Sectoral level competition variables do not show significant differences between high- and low-productivity firms. In terms of firm ownership, SOEs are not only more likely to have a higher share of new product sales and R&D intensity, but they also tend to be older, bigger, less productive and more likely in sectors with higher import tariff rates and less foreign capital.

[Insert Table 2 here]

5. Empirical Results

5.1 Benchmark regression

Before getting to our main baseline regression to investigate the competition impact on the share of new product sales, we create a dummy variable for firms introducing new products and use Probit and Heteroskedastic Probit models with lagged and non-lagged specifications to estimate the impact of competition on innovation decisions (see Table 3). There are three main results. Firstly, we find an inverted U-shaped relationship between competition and innovation. Secondly, we find that the impact of competition upon innovation is more significant and of larger magnitude with a year time lag, i.e. competition effects are stronger over time. Therefore, for all subsequent models, we will only present the results based on lagged values. Thirdly, heteroskedastic robust Wald tests suggest that we do indeed need to consider heterogeneity issues. Therefore, when investigating the relationship between competition and share of new product sales, we will reflect this result in our choice of heteroskedastic Tobit as the preferred model.

[Insert Table 3 here]

Table 4 reports our main baseline results using OLS (columns 1 and 5), panel Tobit (columns 2 and 5) and Tobit multiplicative heteroskedasticity regression with robust standard errors (columns 3 and 6), named as Heteroskedasticity Tobit in the tables. Results are very consistent with each other, but the Tobit multiplicative heteroskedasticity model shows the best fit as we discussed in section 3.2, which is why we describe the heteroskedastic Tobit results in the following unless there are meaningful differences between the models.

[Insert Table 4 here]

As expected, the coefficient on market competition, the Herfindahl index, is positively associated with innovation, and the quadratic form of the Herfindahl index is negatively related to innovation in all regressions. Both are significant at the 1% level in Period I and Period II. This indicates that the relationship between market competition and firm innovation exhibits an inverted U-shape. When the value of the Herfindahl index is low, a small increase in the Herfindahl index is associated with an increase in the innovation of firms. When the value of the Herfindahl index is high, i.e. when there is high sectoral market concentration and a lack of competition, leading firms are comparable with monopolistic firms and become reluctant to innovate. Proposition I is supported by the data, suggesting that there is an optimal level of sectoral market concentration for firm innovation. The relationship between the Herfindahl index and firm innovation in Period I and II based on heteroskedastic Tobit regressions are plotted in Figure 1. From the estimated coefficients, we derive the optimal level of the Herfindahl index, as 0.166 in Period I and 0.188 in Period II.

[Insert Figure 1 here]

Sectoral foreign capital share has a significant and positive effect on firm innovation in Period I and Period II. Since foreign firms are more productive than domestic firms (Griffith *et al.*, 2004; Berkowitz *et al.*, 2017), especially in the closed economy of Period I, there may be spillovers as a result of the entry of foreign firms through productivity transfer, productivity sales, human capital flows, and domestic firms' imitation of foreign firms (Spulber, 2008). However, upon controlling for heterogeneity in the heteroskedastic Tobit model, the coefficient turns significantly negative in the more open economy of Period II. One explanation could be that foreign capital leads to different responses by low- and high-productivity domestic firms respectively, namely that highly productive domestic firms produce less new products in the presence of more foreign capital (Aghion *et.al.*, 2004), which we are further exploring below.

The effect of tariffs differs between Period I and Period II. In Period I, an increase in output tariffs is associated with increasing innovation. High output tariffs are often advocated as a method to protect domestic infant industries (List, 1841). Therefore, lower competition induced by the increase in tariffs especially for weaker competitors may explain the corresponding increase in firms' innovation. In Period I, higher input tariffs have a significant but positive impact on innovation since high input tariffs hamper firms' ability to import intermediate inputs. In Period II, the coefficients of sectoral output tariffs are insignificant, while interestingly input tariffs are now negative. A fall in input tariffs leads to learning and spillover effects, which encourage firms' innovation (Goldberg, et al., 2010). In the post-WTO period, Chinese firms have learned from imports and exports through knowledge spillovers and learning by exporting (Fu, 2015), and gradually adapt to global markets and competition. Thus, a decrease in input tariffs has a promoting effect on firms' innovation. Defever et al. (2021) also show that this learning effect is present to the extent that wholesalers are a feature of input supply within an industry.

The higher the state-owned capital share, the larger the ratio of new product sales to total sales. This finding may be best explained by economies of scale and privileges enjoyed by SOEs in financial markets. Usually, SOEs have easier access to bank credit to do research and investment supporting their innovations. Finally, firm age and size are also positively associated with innovation. As firms operate for longer and are bigger, they accumulate more market experience and new product sales rise more.

5.3 Regressions by productivity levels

In Table 5, we differentiate between high- and low productivity firms. The Herfindahl index demonstrates the same impact as discussed in the baseline regressions, with all models suggesting an inverted U-shape relationship. The optimal level for high and low productivity firms in the 1998-2001 period are 0.16 and 0.15 respectively, and 0.25 and 0.21 for high and low productivity in the 2005-2008 period respectively. Upon comparison, this suggests that firms with higher-than-average productivity levels are more resilient and have a higher turning point at which innovation is reduced by increasing concentration.

[Insert Table 5 here]

All coefficients pertaining to sectoral foreign capital share are positive and significant. Higher levels of foreign capital in the sector translate to more innovation. Both output and input tariffs show interesting results. In a closed economy, lower output tariffs mean more final products are imported to China leading to stronger products' competition in the market, thereby crowding out similar products produced by Chinese firms. Our results are consistent with the findings of Konings and Vandenbussche (2008) who find that relatively low-productivity firms may experience productivity gains under trade protection and frontier firms may suffer. These crowding out effects become insignificant when the market is more accessible in period II. For firms with higher-than-average productivity, the lower output tariff shows a positive sign, which means that these firms are promoting innovation, although this effect is not significant. Think about the case of Apple and Nokia, whose entry to China with lower prices stimulated innovation and ultimately heads-on competition by Huawei and Xiaomi.

Input tariffs always have had a significant impact on firms' innovation activity, although the direction of the impact significantly changes before and after China joining the WTO. In a more closed economy before WTO entry, higher sectoral intermediate input tariffs limited imports of foreign intermediate products. Import substitution was often adopted as a strategy for development at national level (Fu, 2003). As a result, Chinese domestic firms had to innovate more to solve problems in the production process and substitute foreign materials or intermediary inputs. In an open economy, lower intermediate input tariffs mean cheaper, better and more varied intermediate goods; firms are able to produce new, cheaper and higher quality products. Therefore, the estimated coefficients of the input tariff variable change indicating the change in direction and impact mechanisms of input tariffs under different trade regimes and development strategies.

5.4 Regressions by ownership types

Table 6 reports the estimated coefficients of empirical model for periods I and II respectively, differentiated by ownership type. The results provide insight into the innovation efforts of SOEs and private domestic firms to test Propositions IIIa and IIIb. In columns 1 to 4, we estimate the model without an interaction term of sectoral foreign capital share and state-owned capital, which we include in columns 5 to 8, in order to examine the impact of varying degrees of state-owned capital in a firm.

[Insert Table 6 here]

As with the previous regression results, the Herfindahl and Herfindahl square are significant and display an inverted U-shape relationship between market competition and a firm's innovation. The optimal values for state-owned and private firms are 0.19 and 0.17 between 1998-2001 and 0.16 and 0.25 between 2005-2007 respectively, indicating that private firms' new product sales are significantly more adaptable to high market concentration in a more open economy. Interestingly, the optimal level becomes higher for private firms in an open economy compared to state-owned firms. This suggests that competition is fiercer among private firms and promotes innovation more.

Turning to output and input tariffs, as predicted in proposition III, private firms responded positively to foreign competition. For private firms, the impact of input tariffs has been significant both before and after the WTO entry, and across different model specifications. The impact of output tariffs on innovation are significantly negative, as expected, in a closed economy. In other words, the higher output tariffs, the lower foreign competition in the sector, and hence the less incentive to innovate in domestic Chinese firms. However, this effect of output tariff becomes insignificant in a more open economy in Period II. This is likely because of the overall low tariff level in an open economy as well as other sources of foreign competition such as higher presence of foreign competition through FDI in the domestic market in an open economy.

For SOEs, both such import tariffs have little impact on innovation in a closed economy. Before China joined the WTO, state-owned firms had the privilege of holding trading licenses which allowed them to trade with foreign firms. These trade licenses were very difficult for private firms to obtain. SOEs also benefit from soft budget constraints which protect them from bankruptcy even if they lose money (Lin and Tan, 1999; Fu and Balasubramanyam, 2003). All these special statuses rendered SOEs less sensitive to competition pressure, and hence likely to respond to competition pressure through innovation. Therefore, Propositions IIIa and IIIb are supported for FDI, but partially supported with respect to imports, as the impact of intermediate and end products differs for private firms.

Now, recall that private firms in this case could have up to 50% other capital shares, including state-owned capital. Moreover, the results pertaining to the share of state-capital and the interaction term suggest that for state-owned firms, a higher percentage of state-owned capital makes innovation less likely. In other words, state-owned firms with other capital (private, foreign) are more likely to innovate. For private firms, if there is state-owned capital in the company, then the higher the percentage of state-owned capital, the more likely the firm is to be innovating. When we consider the interaction term of sectoral foreign capital and state-owned capital, it suggests state-owned firms are more likely to innovate, only if the firms are in sectors with higher foreign capital. To illustrate, take the automotive industry, which is dominated by SOEs, but where innovation is driven by foreign investment into the sector.

5.5 Regression by technological sophistication category

Table 7 reports the impact of different levels of technological sophistication of firms on innovation using the Tobit multiplicative heteroskedasticity model. Interestingly, the share of sectoral foreign capital has a different, i.e. significant and negative, impact on innovation for high-tech firms, whereas the impact is positively significant for all other levels of technological sophistication. In other words, for these firms, the crowding out effect of FDI outweighs the benefits from knowledge spillovers, which is consistent with the findings of Fu and Gong (2011). Moreover, among high-tech firms, exporting also does not lead to more innovation, as it does for other categories. For the variable input-tariff, consistent with estimated results earlier, the higher the input tariff, the more innovation of Chinese domestic firms in the pre-WTO import substitution regime; while the impact changed significantly in the post-WTO regime with the lower the tariff more innovation from domestic firms. The estimated coefficients of the output tariff variable vary across sectors. In the sectors where they are statistically significant, the high- and low-tech sectors pre-WTO and the middle-low tech sector in the post-WTO period, the higher the output import tariff, the lower the innovation in Chinese firms.

[Insert Table 7 here]

6. Conclusions

In this paper, we examine how domestic competition and openness-induced foreign competition affect the innovation of domestic enterprises in China using a linked dataset of firm-level panel data of 387,725 firms and trade tariff data over the 1998 to 2007 period. Our main findings can be summarized as follows:

First, evidence from the study suggests that the relationship between firms' innovation and competition follows an inverted U-shape in China, both before and after entry into the WTO. The relationship between competition and innovation is robust across different productivity levels, ownership types and the technological sophistication category, although the optimal level of sectoral market concentration (the turning point of the Herfindahl index) differs across time and different type of firms. For example, high-productivity firms have a higher turning point, indicating that they are adaptable to a wider range of sectoral market competition . Similarly, the degree of sectoral market concentration favouring firms' innovation is broader for private domestic firms than for SOEs.

Second, the impact of openness to foreign trade on firms' innovation varies before and after China's entry into the WTO. Pre-WTO entry, a decrease in sectoral output tariffs hampers firms' innovation, while an increase in sectoral input tariffs has a significant and positive effect on innovation. Post-WTO entry, while output tariffs are insignificant, input tariffs introduce a competitive effect leading to an increase in firms' innovation. In other words, in the more open post-WTO entry period, firms responded positively to the competition pressure from increased imports through innovation.

Third, the relationship between openness and firms' innovation varies across high- and low-productivity firms. Pre-WTO entry, FDI promotes innovation in both high- and low-productivity firms, whilst post-WTO entry, the promoting effect of FDI on innovation exists only for low-productivity firms. The increasing entry threat of foreign competitors, caused from a decrease in sectoral output tariffs, pressured high-productivity firms to innovate. On the other hand, this reduces the expected profits of low-productivity firms because productivity is too low to compete with foreign entrants, and further hampers innovation of low-productivity firms. In comparison, a decrease in sectoral input tariffs promotes innovation in both high- and low-productivity firms post-WTO entry. This is likely because high-quality and high-technology import intermediate goods became cheaper and more firms were able to use imported intermediate inputs and benefited from technological spillovers from these imported inputs.

Finally, the effect of competition on innovation varies by ownership type. The openness to foreign investment and the decrease in sectoral input tariffs post-WTO entry significantly stimulated innovation in both state-owned and private firms through technological spillover and cost reduction. Meanwhile, the promoting effect of decreased sectoral output tariffs on firms' innovation, which can be attributed to the competition effect of imports, exists only for private firms, but this is not the case for SOEs. Interestingly, an increase in the share of state-owned capital has a significant and positive association with innovation of private firms but is detrimental to the innovation of SOEs, suggesting that a mixed ownership may be beneficial to the innovation in Chinese firms.

There are important policy implications pertinent to the findings of this research. Firstly, since innovation at the firm-level has an inverted U-shaped relationship with competition, neither an over-competitive nor under-competitive market is beneficial to innovation for Chinese firms. Therefore, the government should further develop a market-oriented economy and improve business environment with a sufficient level of competition and transparent information. Firms can themselves decide new market entry, resource allocation and innovation strategy instead of being directed by government policy. Secondly, openness to foreign investment and trade proves to have a significant and encouraging effect on innovation in Chinese firm after China's entry into the WTO. Policymakers should continue to promote a high level of openness to investment and trade, especially in the face of increasing trade protectionism in the global economy.

Finally, protectionist measures for SOEs should be abandoned. With the competition pressure induced by openness and no bail-out options, SOEs have a greater incentive to innovate. They have the potential to respond positively to competition through innovation as domestic private firms have done. Finally, evidence from our research suggests that a mixed-ownership may be beneficial to firms' innovation in China. The governance reforms of SOEs towards a mixed ownership structure, introducing external strategic investors, and the development of public-private partnership are useful avenues through which innovation may be enhanced in the Chinese economy.

References

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P., 2005. Competition and Innovation: An inverted-U Relationship. Quarterly Journal of Economics 120, 701–28.

Aghion, P., Blundell, R., Griffith, R., Howitt, P., Prantl, S., 2004. Entry and Productivity Growth: Evidence from Microlevel Panel Data. Journal of the European Economic Association 2, 265-76.

Aghion, P., Howitt, P., Prantl, S., 2015. Patent Rights, Product Market Reforms, and Innovation. Journal of Economic Growth 20, 223–62.

Aghion, P., Jaravel, X., 2015. Knowledge Spillovers, Innovation and Growth. The Economic Journal 125, 533-73.

Amiti, M., Davis, D. R., 2012. Trade, firms, and wages: Theory and evidence. Review of Economic Studies 79, 1-36

Amiti, M., Konings, J., 2007. Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia. American Economic Review 97, 1611–38.

Angrist, J. D., Pischke, J. S., 2008. Mostly harmless econometrics: An empiricist's companion. Princeton University Press.

Baum, C. F., 2008. Stata tip 63: Modeling proportions. The Stata Journal 8, 299–303.

Bellemare, M. F., Masaki, T., Pepinsky, T. B., 2017. Lagged Explanatory Variables and the Estimation of Causal Effects. The Journal of Politics 79, 964-78.

Berkowitz, D., Ma, H., Nishioka, S., 2017. Recasting the Iron Rice Bowl: The Reform of China's State-Owned Enterprises. Review of Economics and Statistics 99, 735-47.

Bloom, N., Draca, M., Reenen, J, 2016. Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity. Review of Economic Studies 83, 87–117.

Bloom, N., Mahajan, A., McKenzie. D., Roberts, J., 2010. Why Do Firms in Developing Countries Have Low Productivity? The American Economic Review, Papers and Proceedings of the One Hundred Twenty Second Annual Meeting of the American Economic Association 100, 619-23.

Blundell, R., Griffith, R., Van Reenen, J, 1999. Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms. Review of Economic Studies 66, 529-54.

Cook, D. O., Kieschnick, R., McCullough, B. D., 2008. Regression analysis of proportions in finance with self selection. Journal of Empirical Finance 15, 860–867.

Crescenzi, R., Rodríguez-Pose, A., 2012. An 'Integrated' Framework for the Comparative Analysis of the Territorial Innovation Dynamics of Developed and Emerging Countries. Journal of Economic Surveys 26, 517–33.

Defever, F., Imbruno, M., Kneller, R., 2020. Trade liberalization, input intermediaries and firm productivity: Evidence from China. Journal of International Economics 126, 103329.

Eslava, M., Fieler, A.C., Xu, D.Y., 2015. (Indirect) input linkages. American Economic Review 105, 662–666.

Fu, X., 2011. Processing-trade, FDI and Exports of Indigenous Firms: Firm-level Evidence from Technology-Intensive Industries in China. Oxford Bulletin of Economics and Statistics 73, 792-817.

Fu, X., 2012. How does openness affect the importance of incentives for innovation? Research Policy 41, 512-523.

Fu, X., Balasubramanyam, V.N., 2011. Township and Village Enterprises in China. The Journal of Development Studies 39, 27-46.

Fu, X., Gong, Y., 2011. Indigenous and Foreign Innovation Efforts and Drivers of Technological Upgrading. World Development 39, 1213-25.

Geroski, P.A., 1990. Innovation, Technological Opportunity, and Market Structure. Oxford Economic Papers 42, 586-602.

Girma. S., Gong, Y., Goerg, H., 2006. Product innovation as a source of FDI spillover? The case of Chinese state-owned enterprises in Multinationals, Clusters and Innovation: Does Public Policy Matter? Palgrave Publishers, Basingstoke, 48-62.

Girma, S., Gong, Y., Görg, H., Lancheros, S., 2015. Estimating direct and indirect effects of foreign direct investment on firm productivity in the presence of interactions between firms. Journal of International Economics 95, 157–169.

Görg, H., Greenaway, D., 2004. Much Ado about Nothing? Do Domestic Firms Really Benefit from Foreign Direct Investment? World Bank Research Observer 19, 171-198.

Gong, Y., Hanley, A., 2021. Exports and New Products in China – A Generalized Propensity Score Approach with Firm-to-Firm Spillovers, Journal of Development Studies, forthcoming.

Girma, S., Gong, Y., 2008. FDI, linkage and the efficiency of state-owned enterprises in China. Journal of Development Studies 44, 728 -749

Goldberg P.K., Khandelwal, A.K., Pavcnik, N., Topalova, P., 2010. Imported Intermediate Inputs and Domestic Product Growth: Evidence from India. Quarterly Journal of Economics 125, 1727-1767.

Griffith, R., Harrison, R., Simpson, H., 2010. Product Market Reform and Innovation in the EU. The Scandinavian Journal of Economics 112, 389-415.

Guan, J., Yam, R.M., 2015. Effects of Government Financial Incentives on Firms Innovation Performance in China: Evidences from Beijing in the 1990s. Research Policy 44, 273-82.

Hagedoorn, J., Cloodt, M., 2003. Measuring innovation performance: Is there an advantage in using multiple indicators? Research Policy 32, 1365-1379.

Hashmi, A. R., 2013. Competition and Innovation: The Inverted-U Relationship Revisited. The Review of Economics and Statistics 95, 1653-68.

Hsieh, C., Song, Z, 2015. Grasp the Large, Let Go of the Small: The Transformation of the State Sector in China. Brookings Papers on Economic Activity 1, 295-366.

Hu, A.G., Liu, Z., 2014. Trade Liberalization and Firm Productivity: Evidence from Chinese Manufacturing Industries. Review of International Economics 22, 448-512.

Hu, A., Jefferson, G.H., 2009. A Great Wall of Patents: What is Behind Chinas Recent Patent Explosion? Journal of Development Economics 90, 57-68.

Iacovone, L., 2012. The Better You Are the Stronger It Makes You: Evidence on the Asymmetric Impact of Liberalization. Journal of Development Economics 99, 474–85.

Im, H.J., Park, Y.J., Shon, J., 2015. Product Market Competition and the Value of Innovation: Evidence from US Patent Data. Economics Letters 137, 78–82.

Jiang, L, Waller, D.S., Cai, S., 2013. Does Ownership Type Matter for Innovation? Evidence from China, Journal of Business Research 66, 2473-78.

Kamal, F., Lovely, M. E., Mitra, D., 2019. Trade liberalization and labour shares in China. The World Economy 42, 3588-3618.

Keller, W., 2010. International Trade, Foreign Direct Investment, and Technology Spillovers, in: Hall, B. H., & Rosenberg, N. (Eds). Handbook of the Economics of Innovation (Vol. 2). Elsevier, 793-829.

Konings, J., Vandenbussche, H., 2008. Heterogeneous Responses of Firms to Trade Protection. Journal of International Economics 76, 371-83.

Kraft, K., 1989. Market Structure, Firm Characteristics and Innovative Activity. Journal of Industrial Economics 37, 329-36.

Levinsohn, J., Petrin, A., 2003. Estimating production functions using inputs to control for unobservables. Review of Economic Studies 70, 317-342

List, F., 1841. The National System of Political Economy. The Commercial Press.

Lin, J. Y., Guofu, T., 1999. Policy Burdens, Accountability, and the Soft Budget Constraint. American Economic Review 89, 426-431.

Liu, Q., Qiu, L.D., 2016. Intermediate Input Imports and Innovations: Evidence from Chinese Firms' Patent Filings. Journal of International Economics 103, 166-83.

Liu, R.J., Rosell, C., 2013. Import Competition, Multi-Product Firms, and Basic Innovation. Journal of International Economics 91, 220-34.

Long, J. S., 1997. Regression models for categorical and limited dependent variables (Vol. 7). Sage.
Long, N.V., Raff, H., Stähler, F., 2011. Innovation and Trade with Heterogeneous Firms. Journal of International Economics 84, 149-59.
Lu, Y., Ng, T., 2012. Do Imports Spur Incremental Innovation in the South?. China Economic Review 23, 819-32.
Moussa, R. K., 2019. Heteroskedasticity in One-Way Error Component Probit Models. Econometrics 7, 1-22.
National Statistics Bureau (NBS), 2020. China Statistical Yearbook. Available at www.stats.gov.cn.
Nickell, S. J., 1996. Competition and Corporate Performance. Journal of Political Economy 104, 724-46.
Nie, H., Tan, S., Wang, Y., 2008. Innovation, Firm Size and Market Competition: From the Evidence of Firm-level Panel Data in China. The Journal of World Economy (Chinese) 31, 57-66.
Olabisi, M., 2017. The impact of exporting and foreign direct investment on product innovation: evidence from Chinese manufacturers. Contemporary Economic Policy 35, 735–750.
Olley, G. S., Pakes, A., 1996. The dynamics of productivity in the telecommunications equipment industry. Econometrica 64, 1263-1297.
Pamukcu, T., 2003. Trade Liberalization and Innovation Decisions of Firms: Lessons from Post-1980 Turkey. World Development 3, 1443-58.
Papke, L. E., Wooldridge, J. M., 1996. Econometric methods for fractional response variables with an application to 401 (k) plan participation rates. Journal of Applied Econometrics 11, 619–632.
Schumpeter, J., 1942. Capitalism, Socialism and Democracy. New York: Harper Perennial.
Song, M., Ai, H., Li, X., 2015. Political Connections, Financing Constraints, and the Optimization of Innovation Efficiency among China's Private Enterprises. Technological Forecasting and Social Change 92, 290-99.
Spulber, D. F., 2008. Innovation and International Trade in Technology. Journal of Economic Theory 138, 1-20.
Vickers, J., 1995. Concepts of Competition. Oxford Economic Papers 47, 1-23.
Wooldridge, J. M., 2010. Econometric analysis of cross section and panel data. Cambridge, MA. MIT press
Yu, M., 2015. Processing Trade, Tariff Reductions and Firm Productivity: Evidence from Chinese Firms. Economic Journal 125, 943–88.
Zhou, Y., 2014. Role of Institutional Quality in Determining the R&D Investment of Chinese Firms. China & World Economy 22, 60–82.

Table 1: Summary Statistics of Key Variables

Variable	Definition	Obs	Mean	Std. Dev.	Min	Lower quartile	Median	Upper quartile	Max
Variables at sector level									
Herfindahl index (4 digit)	Ratio of sum of top 50 firms' sales to total sector sales	1,375,523	0.047	0.032	0.022	0.03	0.036	0.05	0.594
Sectoral foreign capital share (4 digit)	Ratio of foreign firms' capital to total sector capital	1,392,158	0.312	0.164	0	0.17	0.296	0.431	0.935
Sectoral output tariff (2-digit)	Average of HS product import tariffs by sector	1,390,589	0.133	0.062	0.024	0.086	0.128	0.165	0.65
Sectoral input tariff (2-digit)	Weighted average of output tariffs	1,391,495	0.067	0.025	0.004	0.049	0.061	0.079	0.151
Variables at firm level									
Share of new products	Ratio of new product to total sales	1,208,181	0.029	0.128	0	0	0	0	1
R&D Intensity	Ratio of R&D expenditure to total sales	625,359	0.002	0.014	0	0	0	0	1
Age	Firm age	1,391,925	11.948	11.93	1	4	8	14	59
Firm size	Log of number of employees	1,392,158	4.753	1.109	2.079	3.989	4.644	5.394	12.053
Log Export	Log of firm's exports	1,392,158	1.792	3.702	0	0	0	0	17.871
Log Productivity	Log of TFP (OP-measured productivity)	1,357,972	4.234	1.095	-6.885	3.557	4.232	4.933	10.815
Share of state-owned capital	Ratio of state capital to total capital	1,392,158	0.088	0.271	0	0	0	0	1

Table 2: Summary Statistics by Productivity and Ownership

	Productivity				Ownership			
	High		Low		SOE		Private	
Variable	Obs	Mean (s.d.)	Obs	Mean (s.d.)	Obs	Mean (s.d.)	Obs	Mean (s.d.)
Variables at sector level								
Herfindahl index (4-digit)	640,867	0.047 (0.033)	700,952	0.046 (0.031)	119,438	0.046 (0.029)	1,249,242	0.047 (0.032)
Sectoral foreign capital share (4-digit)	648,424	0.310 (0.161)	709,548	0.314 (0.167)	123,005	0.246 (0.163)	1,262,222	0.318 (0.162)
Sectoral output tariff (2-digit)	647,655	0.134 (0.062)	708,791	0.133 (0.061)	122,974	0.167 (0.088)	1,260,692	0.130 (0.057)
				(				
Sectoral input tariff (2-digit)	648,092	0.067 (0.025)	709,234	0.067 (0.025)	122,988	0.080 (0.030)	1,261,580	0.066 (0.024)
Variables at firm level								
Share of new products	562,743	0.032 (0.136)	615,579	0.026 (0.120)	113,229	0.051 (0.153)	1,088,494	0.027 (0.125)
R&D Intensity	289,675	0.002 (0.012)	320,353	0.002 (0.014)	20,581	0.004 (0.022)	602,689	0.002 (0.013)
Age	648,388	10.559 (10.425)	709,530	13.154 (12.991)	122,967	26.421 (16.744)	1,262,028	10.549 (10.332)
Firm size	648,424	4.741 (1.193)	709,548	4.760 (1.023)	123,005	5.770 (1.302)	1,262,222	4.651 (1.035)
Log Export	648,424	1.937 (3.932)	709,548	1.674 (3.490)	123,005	1.786 (3.717)	1,262,222	1.777 (3.685)
Log Productivity	648,424	4.963 (0.818)	709,548	3.568 (0.869)	117,462	3.576 (1.247)	1,233,789	4.296 (1.058)
Share of state-owned capital	648,424	0.061 (0.226)	709,548	0.108 (0.300)	123,005	0.939 (0.133)	1,262,222	0.005 (0.040)

Note: In brackets are standard error.

Table 3: Baseline regression – probability of new product sales

	Period I: 1997-2001				Period II: 2004-2007			
	simultaneous year		lagged year		simultaneous year		lagged year	
	probit	Heteroskedastic Probit robust model	probit	Heteroskedastic Probit robust model	probit	Heteroskedastic Probit robust model	Probit	Heteroskedastic Probit robust model
Herfindahl index	2.944***	2.097***	3.419***	2.280***	1.900***	1.614***	1.544***	1.646***
	(0.312)	(0.265)	(0.436)	(0.467)	(0.148)	(0.212)	(0.161)	(0.47)
Herfindahl index squared	-8.113***	-5.627***	-10.366***	-5.782***	-4.047***	-4.286***	-3.064***	-5.668**
	(1.332)	(1.012)	(1.904)	(1.977)	(0.51)	(0.632)	(0.546)	(2.526)
Sectoral foreign capital share	0.441***	0.357***	0.476***	0.382***	-0.064***	-0.735***	0.013	-0.102***
	(0.028)	(0.029)	(0.036)	(0.039)	(0.02)	(0.092)	(0.021)	(0.028)
Sectoral output tariff	0.722*	0.042	-1.141**	-0.827**	-7.096**	-4.021	0.098	-1.778***
	(0.395)	(0.301)	(0.469)	(0.358)	(3.443)	(3.39)	(-0.398)	(-0.352)
Sectoral input tariff	-1.046	0.188	3.055**	1.975*	-5.963***	-8.625***	-6.559***	-2.210**
	(0.963)	(0.748)	(1.35)	(1.034)	(1.44)	(1.791)	(1.066)	(0.928)
Age	0.012***	0.008***	0.012***	0.008***	0.008***	0.006***	0.007***	0.004***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Firm size	0.331***	0.268***	0.339***	0.273***	0.131***	0.213***	0.173***	0.183***
	(0.004)	(0.009)	(0.005)	(0.013)	(0.003)	(0.006)	(0.003)	(0.005)
Log Export	0.048***	0.029***	0.046***	0.029***	0.091***	0.060***	0.056***	0.026***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.005)	(0.001)	(0.002)
Log Productivity	0.080***	0.051***	0.089***	0.062***	0.070***	0.096***	0.063***	0.057***
	(0.004)	(0.005)	(0.005)	(0.006)	(0.003)	(0.007)	(0.003)	(0.004)
Share of state-owned capital	0.205***	0.178***	0.199***	0.190***	0.170***	0.184***	0.130***	0.122***
	(0.01)	(0.014)	(0.012)	(0.019)	(0.013)	(0.021)	(0.013)	(0.014)
Constant	-4.705***	-3.481***	-4.821***	-3.591***	-1.925***	-2.204***	-3.061***	-2.328***
	(0.093)	(0.123)	(0.1)	(0.169)	(0.381)	(0.377)	(0.429)	(0.26)
Observations	335,308	335,308	193,782	193,782	605,528	605,528	489,110	489,110
Wald test		413.47		266.01		3520.28		1863.89
		(p=0.000)		(p=0.000)		(p=0.000)		(p=0.000)

Note: Robust standard errors in brackets. *p < 0.1, **p < 0.05, ***p<0.01. All covariates measured in 1-year lag. Time and sector dummies included in all models.

Table 4: Benchmark regression on share of new product sales

	Period I: 1997-2001			Period II: 2005-2007		
	OLS (marginal effect)	Panel tobit	Heteroskedastic tobit	OLS (marginal effect)	Panel tobit	Heteroskedastic tobit
	(1)	(2)	(3)	(4)	(5)	(6)
Herfindahl index	0.209***	1.319***	3.246***	0.068***	0.680***	1.614***
	(0.03)	(0.214)	(0.244)	(0.013)	(0.106)	(0.212)
Herfindahl index squared	-0.594***	-3.933***	-9.756***	-0.142***	-1.419***	-4.286***
	(0.138)	(0.893)	(1.027)	(0.039)	(0.356)	(0.632)
Sectoral foreign capital share	0.015***	0.208***	0.367***	0.015***	0.115***	-0.735***
	(0.003)	(0.022)	(0.023)	(0.002)	(0.015)	(0.092)
Sectoral output tariff	-0.092***	-1.005***	-3.163***	-0.102***	-0.127	-4.021
	(0.015)	(0.179)	(0.254)	(0.023)	(0.172)	(3.39)
Sectoral input tariff	0.203***	2.521***	4.422***	-0.027	-3.160***	-8.625***
	(0.054)	(0.526)	(0.439)	(0.052)	(0.458)	(1.791)
Age	0.001***	0.005***	0.006***	0.000***	0.004***	0.006***
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Firm size	0.011***	0.140***	0.182***	0.009***	0.100***	0.213***
	(0.001)	(0.003)	(0.003)	(0.000)	(0.002)	(0.006)
Log Export	0.002***	0.015***	0.018***	0.002***	0.013***	0.060***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.005)
Log Productivity	0.004***	0.036***	(0.002)	0.003***	0.020***	0.096***
	(0.001)	(0.003)	(0.003)	(0.000)	(0.002)	(0.007)
Share of state-owned capital	0.009***	0.065***	0.137***	0.008***	0.035***	0.184***
	(0.001)	(0.007)	(0.009)	(0.001)	(0.009)	(0.021)
Constant	-0.076***	-2.198***	-2.057***	-0.044***	-1.827***	-2.204***
	(0.009)	(0.049)	(0.033)	(0.004)	(0.286)	(0.377)
Observations	193,782	193,782	189,918	489,110	489,110	605,528

Note: Robust standard errors in brackets. *p < 0.1, **p < 0.05, ***p<0.01. All covariates measured in 1-year lag. Time and sector dummies included in all models.

Table 5: Competition and innovation in firms with different levels of productivity

	No interaction term			
	Period I: 1998-2001		Period II: 2005-2007	
	high	low	high	low
	(1)	(2)	(3)	(4)
Herfindahl index	1.455***	1.363***	0.626***	0.816***
	(0.327)	(0.281)	(0.134)	(0.175)
Herfindahl index squared	-4.548***	-4.395***	-1.278***	-1.966***
	(1.35)	(1.208)	(0.438)	(0.641)
Sectoral foreign capital share	0.175***	0.249***	0.053***	0.176***
	(0.033)	(0.028)	(0.02)	(0.023)
Sectoral output tariff	-1.222***	-0.780***	0.067	-0.184
	(0.266)	(0.262)	(0.218)	(0.313)
Sectoral input tariff	3.135***	2.152***	-3.968***	-1.638**
	(0.78)	(0.764)	(0.593)	(0.796)
Age	0.005***	0.006***	0.004***	0.004***
	(0.000)	(0.000)	(0.000)	(0.000)
Firm size	0.152***	0.130***	0.107***	0.084***
	(0.004)	(0.004)	(0.002)	(0.003)
log Export	0.016***	0.014***	0.012***	0.022***
	(0.001)	(0.001)	(0.001)	(0.001)
log Productivity	0.033***	0.024***	0.012***	0.020***
	(0.005)	(0.004)	(0.002)	(0.003)
Share of state-owned capital	0.098***	0.056***	0.064***	0.041***
	(0.011)	(0.008)	(0.012)	(0.013)
Constant	-2.277***	-2.096***	-1.680***	-4.015
	(0.073)	(0.068)	(0.283)	(135.25)
Observations	93169	97332	243494	237137

Note: Robust standard errors in brackets. *p < 0.1, **p < 0.05, ***p<0.01. All covariates measured in 1-year lag. Time and sector dummies included in all models.

Table 6: Competition and innovation in firms with different type of firms

	No interaction term				With interaction term			
	Period I: 1998-2001		Period II: 2005-2007		Period I: 1998-2001		Period II: 2005-2007	
	SOE	private	SOE	private	SOE	private	SOE	private
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Herfindahl index	1.029***	1.560***	1.113***	0.710***	1.030***	1.562***	1.116***	0.710***
	(0.301)	(0.281)	(0.344)	(0.108)	(0.301)	(0.281)	(0.344)	(0.108)
Herfindahl index squared	-2.743**	-4.523***	-3.586***	-1.402***	-2.773**	-4.536***	-3.594***	-1.401***
	(1.321)	(1.162)	(1.312)	(0.36)	(1.321)	(1.163)	(1.312)	(0.36)
Sectoral foreign capital share	0.245***	0.189***	0.171***	0.099***	0.074	0.174***	0.212***	0.097***
	(0.031)	(0.029)	(0.046)	(0.016)	(0.059)	(0.029)	(0.064)	(0.016)
Sectoral output tariff	-0.337	-1.418***	-0.980*	-0.09	-0.336	-1.410***	-0.969*	-0.087
	(0.238)	(0.257)	(0.564)	(0.178)	(0.238)	(0.257)	(0.563)	(0.178)
Sectoral input tariff	0.658	3.573***	1.866	-3.308***	0.689	3.582***	1.839	-3.314***
	(0.804)	(0.702)	(1.389)	(0.471)	(0.804)	(0.702)	(1.389)	(0.471)
Age	0.003***	0.007***	0.001***	0.004***	0.003***	0.007***	0.001***	0.004***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
Firm size	0.111***	0.157***	0.110***	0.098***	0.111***	0.157***	0.110***	0.098***
	(0.004)	(0.004)	(0.006)	(0.002)	(0.004)	(0.004)	(0.006)	(0.002)
log Export	0.014***	0.016***	0.014***	0.013***	0.015***	0.016***	0.014***	0.013***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
log Productivity	0.036***	0.040***	0.035***	0.020***	0.036***	0.040***	0.035***	0.020***
	(0.003)	(0.004)	(0.005)	(0.002)	(0.003)	(0.004)	(0.005)	(0.002)
sectoral foreign capital share * state-owned capital share					0.210***	0.145**	-0.061	0.133*
					(0.062)	(0.066)	(0.065)	(0.072)
Share of state-owned capital	0.002	0.088***	-0.048***	0.084***	-0.061***	0.047**	-0.031	0.048**
	(0.011)	(0.012)	(0.012)	(0.013)	(0.021)	(0.022)	(0.022)	(0.023)
Constant	-1.728***	-2.501***	-3.225	-1.857***	-1.676***	-2.499***	-3.241	-1.857***
	(0.094)	(0.061)	(68.249)	(0.291)	(0.095)	(0.061)	(68.227)	(0.291)
Observations	41322	171383	18873	507938	41322	171383	18873	507938

Note: Robust standard errors in brackets. *p < 0.1, **p < 0.05, ***p<0.01. All covariates measured in 1-year lag. Time and sector dummies included in all models.

Table 7: Competition and innovation in firms with different level of technological sophistication

	Period I: 1998-2001				Period II: 2005-2007			
	High-tech	Middle-High tech	Middle-low tech	Low tech	High-tech	Middle-High tech	Middle-low tech	Low tech
Herfindahl index	1.028**	0.994***	1.660***	1.576**	1.734***	0.496***	0.823***	0.301
	(0.487)	(0.351)	(0.292)	(0.716)	(0.359)	(0.166)	(0.187)	(0.203)
Herfindahl index squared	-2.337	-3.165**	-4.687***	-8.518*	-4.146***	-0.940*	-2.172***	-0.146
	(1.76)	(1.428)	(1.567)	(4.481)	(1.21)	(0.489)	(0.645)	(0.728)
Sectoral foreign capital share	-0.315***	0.193***	0.151***	0.164***	-0.397***	0.074***	0.139***	-0.064**
	(0.062)	(0.032)	(0.029)	(0.048)	(0.042)	(0.024)	(0.027)	(0.032)
Sectoral output tariff	-2.619***	-0.425	-0.478	-0.434*	0.884	-0.418	-0.926***	0.017
	(0.71)	(0.554)	(0.361)	(0.243)	(0.552)	(0.482)	(0.304)	(0.318)
Sectoral input tariff	6.242**	1.127	1.711**	0.939	-4.734***	0.094	-2.056***	-5.047***
	(2.446)	(1.299)	(0.775)	(0.936)	(1.422)	(1.269)	(0.702)	(0.909)
Age	0.009***	0.005***	0.005***	0.006***	0.010***	0.006***	0.004***	0.003***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Firm size	0.147***	0.153***	0.090***	0.135***	0.058***	0.121***	0.089***	0.067***
	(0.008)	(0.005)	(0.003)	(0.006)	(0.006)	(0.004)	(0.003)	(0.004)
log Export	-0.002	0.011***	0.012***	0.012***	0.001	0.009***	0.012***	0.008***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
log Productivity	0.055***	0.033***	0.029***	0.046***	0.048***	0.027***	0.019***	0.015***
	(0.007)	(0.004)	(0.003)	(0.006)	(0.005)	(0.003)	(0.003)	(0.003)
Share of state-owned capital	0.072***	0.065***	0.107***	0.056***	0.117***	0.048***	0.072***	-0.031
	(0.019)	(0.011)	(0.009)	(0.016)	(0.026)	(0.014)	(0.015)	(0.02)
Constant	-1.809***	-1.844***	-1.643***	-2.417***	-1.035***	-1.629***	-1.465***	-1.745***
	(0.169)	(0.075)	(0.052)	(0.1)	(0.082)	(0.06)	(0.049)	(0.296)
Observations	16307	56919	90649	87383	42915	142658	231889	216279

Note: Robust standard errors in brackets. *p < 0.1, **p < 0.05, ***p<0.01. All covariates measured in 1-year lag. Time and sector dummies included in all models.

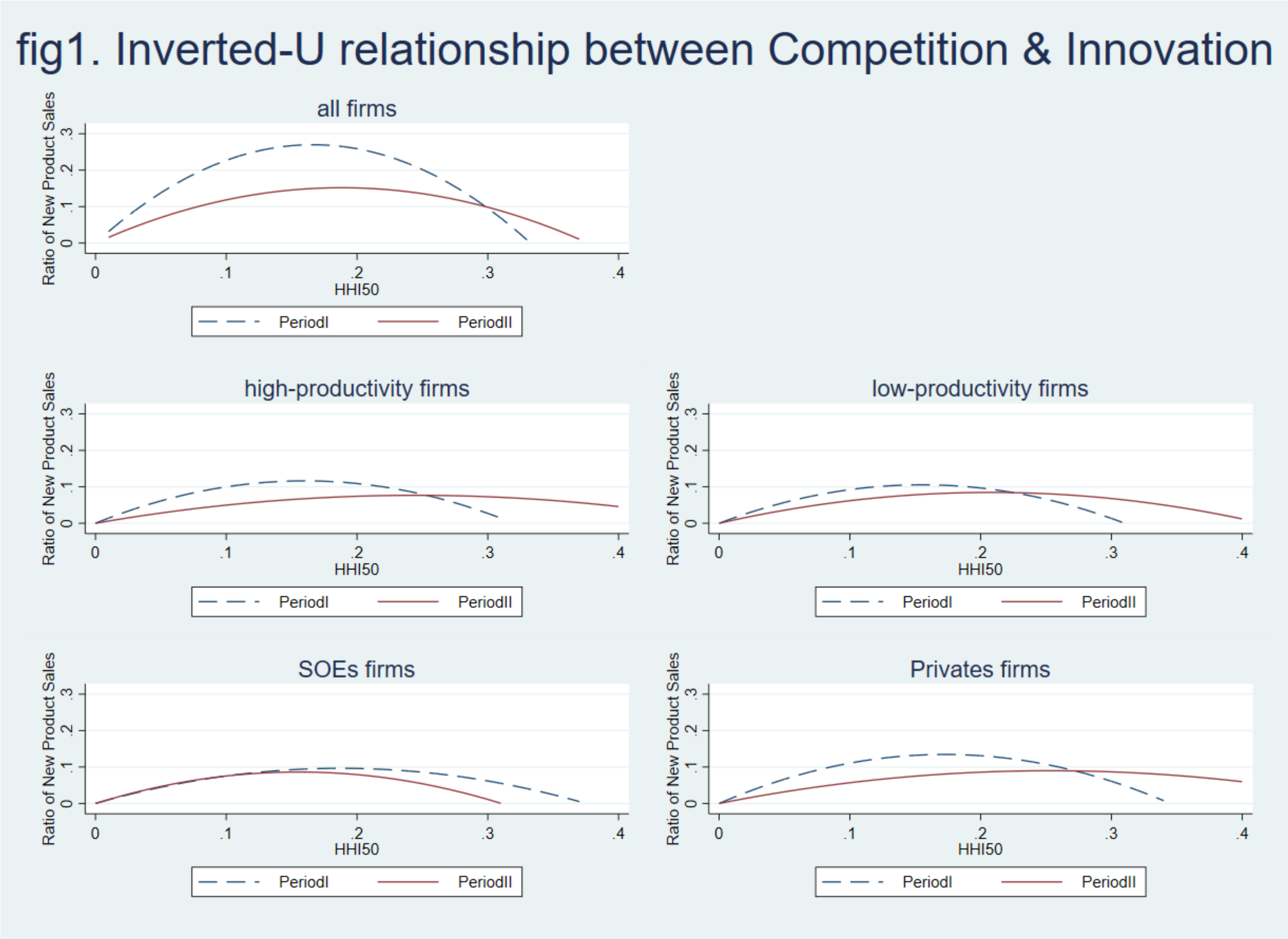

Figure 1: The inverted-U relationship between Competition & Innovation

Note: The solid line is based on regression (1) of table 2, while the dash line is based on regression (4) of table 2.