# Trade liberalization and firm productivity: Evidence from Chinese manufacturing industries *

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**Abstract**

We examine the impact of tariff reduction following China's WTO entry on the productivity of Chinese manufacturing firms using a firm-level panel database that comprises all of China's manufacturing firms with an annual turnover above five million yuan and spans the period of 2000 to 2006. We separate the effect of trade liberalization into that of output tariff and input tariff reduction. Overall, our results indicate that China's trade liberalization in the five years after its WTO entry has led to a 2.25 percent annual increase in TFP for Chinese manufacturing firms. However, we find that output tariff reduction significantly depressed Chinese firms' productivity. This can be attributed to the production scale reducing effect of output tariff reduction, which makes foreign produced goods more price competitive in the Chinese market. That the Chinese firms' profit margin falls as a result of lower output tariffs affirms the competitive pressure created by output tariff liberalization. On the other hand, through the intermediate inputs' channel, the trade liberalization has significantly boosted the productivity of Chinese firms and increased their profit margin. Our results are robust to alternative productivity and tariff measures and allowing for firm heterogeneity.

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# 1 Introduction

China's entry to the World Trade Organization (WTO) in 2001 has been one of the most significant economic events in recent world history. The trade liberalization that it engendered has produced deep and far-reaching implications both within China and around the world. The Chinese economy has prospered in the decade that followed China's WTO entry despite concerns at the time that domestic Chinese firms may not be able to withstand the competition from foreign goods and services, which was expected to intensify as a result of the liberalization measures that China was to implement. Notwithstanding the obvious intellectual and policy interest, there has been little economic research to empirically substantiate the nexus between how China's WTO entry has affected the performance of Chinese industries.

Reducing import tariffs can raise the level of a country's welfare by making imports - both final goods and intermediate inputs - cheaper and by making the domestic product market more competitive with lower-priced foreign produced goods. Numerous studies have subjected this central tenet of international economics to rigorous empirical investigation (Schor, 2004; Trefler, 2004; Amiti and Konings, 2007; Fernandes, 2007; Topalova and Khandelwal, 2011).

The common approach of these authors has been to relate measures of the productivity of domestic firms or industries to reduction in tariffs as a result of trade liberalization or a major reform that liberalizes the country's international trade regime. These studies generally affirm the industrial productivity enhancing benefit of trade liberalization, which they attribute to either a more competitive market place due to the easy entry of foreign competitions, the availability of cheaper and greater variety of imported intermediate inputs, or both.

Our approach is similar to that of these earlier authors, but we place greater emphasis on the endogeneity of trade liberalization. Both economic theory and empirics have suggested that change in a country's international regime does not take place in isolation and is subject to the influence of various interest groups that are likely to be affected by the trade liberalization (Mayer, 1984; Goldberg and Pavcnik, 2005; Karacaovali, 2011). In particular, less productive industries and unions that represent comparatively less productive workers will lobby against policies that are to subject them to more foreign competition. Therefore, properly addressing the endogeneity of trade liberalization becomes imperative in any effort to assess whether trade liberalization leads to productivity improvement.

It is against this intellectual and institutional backdrop that we situate our study. We use a firm-level database that comes from China's industry census for 1999 to 2005 to investigate how the sharp tariff reductions in the aftermath of China's WTO entry have affected Chinese manufacturing firms' productivity. Our main strategy to deal with the endogeneity of trade liberalization is instrumental variable estimation. The instrument we adopt for China's import tariff reductions is Philippines' tariff reductions in the years following its entry to WTO from 1996 to 2002. We measure the performance of Chinese industry by both an estimated total factor productivity and other performance measures such as labor productivity. We also use a Chinese input-output table to construct input tariffs so that we can estimate and compare the effects of both output and input tariff reductions.

We find a positive overall effect of trade liberalization on Chinese firms' productivity: a one percent reduction in tariffs has led to a 2.25 percent annual increase in TFP for Chinese manufacturing firms. However, this is a result of two opposite effects of the trade liberalization taking place through the output and input tariff reduction channels separately. Our results indicate a negative impact of the output tariff reductions on Chinese firms' productivity, which is in contrast to what most other studies have found for other countries. This negative effect has to do with lower production scale and incomplete adjustment of capital service, an inflexible factor of production, as a result of the lower output tariffs. Moreover, the output tariff liberalization has also eroded the profit margin of the Chinese firms affirms. This finding corroborates the hypothesis that monopolistic domestic firms may experience a negative productivity shock when they are forced to reduce output as import competition intensifies (Graham, 1923; Markusen, 1981; Ethier, 1982; Grinols, 1991; Rodrik, 1988).

On the other hand, through the intermediate inputs' channel, lower input tariffs have significantly boosted the productivity of Chinese firms and increased their profit margin. That is, input tariff reductions help to raise the productivity of Chinese manufacturing firms, which may have been caused by access to greater varieties and higher quality of intermediate inputs (Markusen, 1989; Ethier, 1982; Grossman and Helpman, 1991).

We have subjected our results to a large number of robustness checks, including different productivity measures and tariff measures. The results carry through in all these alternative regressions. We have also explored the implication of firm heterogeneity for the impact of trade liberalization on Chinese firms' productivity. The state-owned enterprises appear to be mostly severely affected by the productivity depressing impact of output tariff reduction.

The rest of the paper follows the following structure: we review the related literature in the Section 2. In the following section, we describe China's efforts in liberalizing its foreign trade regime. In Section 4 we lay out the empirical strategy and discuss the various methodological issues. Section 5 provides a description the data. We then discuss the results in Section 6 before we conclude.

## 2 The literature

### 2.1 The theoretical foundation

With the introduction of the monopolistic competition theory of international trade, Krugman (1979)) shows that trade liberalization - gaining access for domestic firms to foreign markets - can lead to productivity gains for domestic firms as they increase sales, expand production scale and ride down the cost curve, or the scale effect (Feenstra, 2004). There is also the selection effect: some domestic firms will exit, releasing factors of production to be used in the expansion of the surviving domestic firms. But in Krugman's model, firms are symmetric so that selection takes place on a purely random basis.

Melitz (2003) takes the selection effect to a new level by introducing firm heterogeneity. Since firms are endowed with different productive capability, more productive firms will be more likely to take advantage of the access to foreign markets as a result of trade liberalization. The more productive firms will thus expand, drawing resources from unproductive firms by raising factor prices. Rising costs will then force the unproductive firms to exit. This reallocation of market shares then leads to rising industry productivity despite the fact that individual firms' productivity remains unchanged. [1]

These studies presume that positive turnover - exit of inefficient firms - is frictionless. If there are, for example, institutional barriers to such turnover so that inefficient firms do not exit in the aftermath of trade liberalization but are forced to reduce production scale, this can lead to productivity losses if there are economies of scale in these firms' production. Graham (1923) used this argument as a reason for protection. Other authors (Markusen, 1981; Ethier, 1982; Grinols, 1991; Rodrik, 1988) have also analyzed and affirmed this potential negative effect of trade liberalization on domestic firms' productivity.

Thirdly, there are what Tybout and Westbrook (1995) call "residual effects", such as learning-by-doing and technical innovation, although there has been growing interest in these so that residual is no longer an appropriate characterization. Both the learning-by-doing and technical innovation hypotheses build on a dynamic dimension to the impact on industrial productivity of trade liberalization. Krugman (1987)'s highly stylized model is premised on learning-by-doing at the industry level and external to individual firms. He shows that patterns of comparative advantage can be path-dependent: industries that are

[1] In Melitz and Ottaviano (2008) the selection effect works differently: increased competition from imports does not affect factor market given their CES specification of demand but raises overall demand elasticity. The downward shift of the distribution of markups then forces inefficient or low productivity firms to exit. Bernard et al. (2007) blend Melitz's mechanism into a two-good, two country Heckscher-Olin framework. They show that trade liberalization engenders a stronger selection or reallocation effect in the industry that enjoys an ex ante endowment-driven comparative advantage than in the other.

producing will see their productivity further increasing in their production experience, and thus entrenching their cost advantage. By implication, for those industries that expand as a result of trade liberalization, productivity will also increase.[2]

This path dependence feature of the learning by doing literature also characterizes the basic mechanism of how trade liberalization affects firm productivity in Aw et al. (2011). Their model is premised on the notion that the returns to exporting and R&D, two investments the firms in their structual model make, increase in the current productivity levels of the firms. Since the firms are heterogeneous in their productivity, they self-select into these two activities: more productive firms are more likely to export and conduct R&D. At the same time, exporting and R&D raise these firms' future productivity. Thus, when access to export market increases, in addition to the usual productivity gains from larger market size, the firms' productivity increases further because of the investments in exporting and R&D. They confirm this result when they simulate their model using Taiwanese plant level data for the Taiwanese electronics industry.

Finally, trade liberalization may induce restructuring of production within a firm that is exposed to international trade. Trefler (2004) suggests the possibility of plant rationalization - firms reorganize their plants in order to produce fewer product lines, each with a global mandate. Bernard et al. (2010)'s model generalizes Melitz (2003) to a multi-product setting. One implication of their model predicts that trade liberalization prompts affected firms to drop their least successful products. They suggest that reallocation may not just takes place between firms but also within firms, between products and export destinations.

[2]Young (1991)'s learning-by-doing model also examines how trade liberalization affects growth and technical progress. It incorporates two empirically relevant features of the process of learning by doing: there is inter-industry spillover, though not international spillover of knowledge generation and that the productivity gains from learning by doing are bounded. At any point in time, such productivity gains have been exhausted in some industries/goods, but not in others. Trade liberalization influences technical progress and thus economic growth by moving countries to different sets of goods that are distinct by whether the productivity gains from learning by doing have been exhausted. His results show that less developed country may experience lower rate of technical progress because freer trade leads them to specialize in goods/industries that have exhausted potential gains from learning by doing; whereas the opposite is true with developed countries. Nevertheless, less developed countries may still see their welfare improving with trade liberalization by benefiting from the higher rate of technical progress in developed countries through international trade.

## 2.2 The empirical evidence

Numerous studies have examined the trade liberalization and productivity nexus under the guidance of the above theoretical consideration. Head and Ries (1999) examine how the free trade agreement between Canada and U.S. affected plant scale of Canadian industries. They find that while the tariff reductions in the U.S. increased plant scale by 10 percent, the tariff reductions in Canada reduced plant scale by 8.5 percent. So the net positive effect is quite small. Trefler (2004) finds that Canada-U.S. free trade agreement had reduced plant scale in terms of employment and output and the number of plants were also reduced. But these short-term losses were compensated by a significant long-run labor productivity gain. He attributes the productivity gain to reallocation of market shares towards more efficient firms and increasing technical efficiency.[3]

Our study is closest to Trefler (2004), Amiti and Konings (2007), Fernandes (2007), and Topalova and Khandelwal (2011). All these authors use information on tariff reductions rather than a general event of trade liberalization to examine the impact of trade liberalization on industrial productivity. Trefler (2004) further examines the impact on Canadian industries of both tariff reductions in Canada and U.S. associated with the Canada-U.S. free trade agreement. The results affirm his earlier findings that trade liberalization comes with short-run adjustment costs in the form of displaced workers and contracting plants, which are likely outweighed by lower prices and more efficient plants in the long-run.

Amiti and Konings (2007) use Indonesian plant level data to investigate how (import) tariff reductions in Indonesia affected the productivity of Indonesian firms. A novel feature of their study is that they are able to separately identify the impact of output and input tariff reductions. The impact of the latter is distinct from that of the former in the mechanism through which the impact takes place. Lower input tariffs make available to domestic industries cheaper and greater varieties of inputs that enhance these industries'

[3]Pavcnik (2002) finds the reallocation effect of trade liberalization for Chilean manufacturing industries. The paper shows that more productive firms gain market shares and production resources when trade opens.

productivity. Their results indicate that trade liberalization through both types tariffs raises domestic Indonesian industries' productivity.

Fernandes (2007) and Topalova and Khandelwal (2011) confirm the positive impact of tariff reductions on industrial productivity for Columbia and India respectively. De Loecker (2011) shows that the elimination of non-trade barrier (import quotas) can also generate productivity gains. Controlling for firm-level demand and thus mark-up, his results indicate that elimination of all import quotas could increase firm's physical productivity by 2 percent.

# 3 China's WTO entry and tariff reductions

China started negotiations to join the then General Agreement on Trade and Tariffs in 1986. When it became a member of WTO in December 2001, China committed to a broad range of reforms to open up its economy. These reforms include extending the right to engage in international trade to a much broader range of domestic enterprises and significant tariffs reductions. In fact tariff reductions started well before China's entry into WTO. From 1992 to 1999, China reduced the average nominal tariff from 43 percent to 17 percent. China's promise in the agreement to join WTO to further lower average industrial tariffs to 9.4 percent by 2005 had already been achieved by 2004 (Naughton, 2007). Compared with other developing countries, China agreed to much more significant tariff reductions in negotiating its entry to WTO.

Table 1 tabulates the average import tariff rates for Chinese manufacturing industries by two-digit ISIC classification. Both output and input tariff rates are reported. Our tariff data are obtained from the World Integrated Trade Solution (WITS) database. We use the effective rates of tariff (denoted as AHS tariff in WITS) at four-digit level under ISIC Rev.3. The tariff rates at the two-digit ISIC level reported in Table 1 are averaged from the four-digit rates.

To impute the input tariff rate, we use the following formula: $\tau_i^{in} = \sum_j \theta_{ij} \tau_j^{out}$, where

$\tau_i^{in}$ is industry $i'$'s input tariff rate, $\theta_{ij}$ is the share of industry $i$'s input usage that is attributable to industry $j$, and $\tau_j^{out}$ is industry $j$'s tariff rate. In other words, the input tariff rate of an industry is computed as the weighted average of the output tariffs rates of its upstream industries. We obtain the weights from the Chinese Input-output table for 2002.

While tariff reductions started before China's entry to WTO, they clearly accelerated after the entry in 2001. From 2001 to 2002, the average output tariff rate dropped from 18.2 to 13.9 percent, and the average input tariff rate fell from 8.4 to 6.2 percent. The most protected industries in 1999 were food and beverage and vehicles with output tariff rates of 32.8 and 29.6 percent respectively. In 2005 the two rates fell to 18 to 14.5 percent respectively. Food and beverage remained the most protected industry in 2005, followed by apparel, 16.6 percent.

# 4 Empirical strategy

## 4.1 Econometric specification

To identify the effects of input and output tariff on Chinese firms' productivity, we specify the following equation to estimate:

$$tfp_{ijt} = \alpha + \gamma_1 \tau_{j,t-1}^{out} + \gamma_2 \tau_{j,t-1}^{in} + \mathbf{x}'_{ijt}\beta + \delta_j + \mu_t + \varepsilon_{ijt} \tag{1}$$

where $tfp_{ijt}$ is the logarithm of revenue-based productivity (TFP) of firm $i$ in industry $j$ at year $t$. $\tau_{jt}^{out}$ is the industry-level output tariff. $\tau_{jt}^{in}$ is the industry-level input tariff. Both tariff variables are entered with a lag to accommodate that it may take time for tariff reductions to affect firms' performance. $\mathbf{x}'_{ijt}$ is a vector of other firm characteristics such as ownership, export orientation and firm size. $\delta_j$ and $\mu_t$ are shorthand for industry and year fixed effects. Equation 1 is similar to what other authors have estimated.

Table 1: Chinese industry output and input tariffs: 1999-2005

| | Output tariffs | | | | | | | Input tariffs | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Industry | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
| Food and beverage (15) | 32.83 | 32.64 | 32.44 | 24.48 | 22.08 | 18.86 | 17.99 | 13.06 | 13.14 | 13.22 | 9.84 | 9.23 | 8.42 | 8.23 |
| Textile (17) | 24.61 | 23.24 | 21.88 | 17.87 | 15.12 | 12.52 | 10.83 | 12.37 | 11.94 | 11.52 | 9.11 | 8.01 | 6.99 | 6.53 |
| Apparel (18) | 24.88 | 23.44 | 22.00 | 20.13 | 18.80 | 17.33 | 16.63 | 12.40 | 11.98 | 11.57 | 9.56 | 8.58 | 7.65 | 7.30 |
| Leather (19) | 20.08 | 19.48 | 18.88 | 15.95 | 15.09 | 13.97 | 13.79 | 11.84 | 11.60 | 11.36 | 9.57 | 8.89 | 8.23 | 8.10 |
| Wood (20) | 12.63 | 11.91 | 11.18 | 8.11 | 6.75 | 5.37 | 5.10 | 6.93 | 6.70 | 6.47 | 4.97 | 4.42 | 3.98 | 3.83 |
| Paper (21) | 18.79 | 18.40 | 18.01 | 12.34 | 10.11 | 8.07 | 6.48 | 8.04 | 7.90 | 7.75 | 5.52 | 4.78 | 4.12 | 3.68 |
| Printing (22) | 15.84 | 15.07 | 14.30 | 10.88 | 8.65 | 7.68 | 6.72 | 7.63 | 7.47 | 7.30 | 5.16 | 4.38 | 3.70 | 3.22 |
| Petroleum (23) | 6.25 | 6.14 | 6.03 | 5.53 | 5.59 | 5.58 | 5.56 | 4.10 | 4.06 | 4.02 | 1.45 | 1.37 | 1.22 | 1.27 |
| Chemicals (24) | 12.81 | 12.52 | 12.23 | 9.99 | 9.11 | 8.45 | 8.09 | 6.73 | 6.61 | 6.48 | 4.87 | 4.49 | 4.16 | 4.04 |
| Rubber and Plastics (25) | 17.09 | 16.82 | 16.55 | 13.47 | 12.87 | 12.20 | 12.05 | 8.20 | 8.08 | 7.96 | 6.20 | 5.72 | 5.35 | 5.21 |
| Non metal (26) | 18.26 | 18.17 | 18.09 | 14.43 | 13.58 | 12.66 | 12.41 | 5.09 | 5.01 | 4.92 | 3.85 | 3.59 | 3.34 | 3.26 |
| Basic metal (27) | 8.48 | 8.29 | 8.11 | 6.05 | 5.68 | 5.52 | 5.55 | 3.81 | 3.73 | 3.66 | 2.84 | 2.68 | 2.59 | 2.58 |
| Fabricated metal (28) | 14.37 | 14.17 | 13.97 | 11.46 | 10.71 | 10.29 | 10.26 | 6.47 | 6.36 | 6.25 | 4.70 | 4.35 | 4.13 | 4.10 |
| Machinery (29) | 13.69 | 13.56 | 13.43 | 9.87 | 9.12 | 8.63 | 8.52 | 7.13 | 7.03 | 6.92 | 4.97 | 4.53 | 4.25 | 4.19 |
| Electrical (31) | 15.25 | 15.10 | 14.95 | 10.55 | 9.60 | 9.00 | 8.96 | 7.38 | 7.26 | 7.13 | 5.23 | 4.80 | 4.49 | 4.42 |
| Communication equipment (32) | 15.85 | 15.68 | 15.50 | 7.98 | 6.42 | 5.89 | 5.85 | 8.34 | 8.21 | 8.08 | 4.27 | 3.66 | 3.39 | 3.31 |
| Precision instrument (33) | 13.29 | 13.09 | 12.88 | 9.33 | 8.85 | 8.63 | 8.51 | 7.36 | 7.24 | 7.12 | 4.42 | 3.95 | 3.70 | 3.63 |
| Vehicles (34) | 29.58 | 29.32 | 29.05 | 20.52 | 17.90 | 15.93 | 14.53 | 12.57 | 12.32 | 12.07 | 9.03 | 8.10 | 7.31 | 6.78 |
| Other transport equipment (35) | 18.35 | 18.16 | 17.97 | 14.31 | 12.30 | 12.10 | 11.29 | 9.69 | 9.55 | 9.41 | 6.86 | 6.04 | 5.64 | 5.31 |
| All (average) | 18.86 | 18.53 | 18.21 | 13.92 | 12.54 | 11.33 | 10.84 | 8.68 | 8.56 | 8.44 | 6.22 | 5.67 | 5.20 | 5.03 |

The firm-level TFP is separately estimated using the Olley and Pakes (1996) approach. Since this has become a standard methodology in estimating TFP, we will not elaborate on the estimation procedure. More details can be found in the appendix.

We are primarily interested in the estimates of $\gamma_1$ and $\gamma_2$, the impact of output and input tariff on a firm's TFP. It should be noted that they capture the impact on the *average existing* firm. In other words, they represent the net impact of tariffs on firm TFP through all the channels discussed earlier: scale, within and between-firm reallocation, entry and exit, technical innovation, and learning by doing. Due to the short time dimension of our panel data, the effects we identify here are likely to be dominated by short-run forces.[4]

We expect lower input tariffs to have a clear, positive effect on Chinese firms' productivity. The impact of output tariffs is less clear cut. The pro-competition effect is likely to take time to materialize; China's complex institutional environment may impede the selection/reallocation process, whether within firms or between firms, from proceeding smoothly; the benefits from learning by doing and technical innovation also require time to realize. While the productivity and efficiency enhancing effect takes time to come to fruition, the short-run adjustment costs are likely to be immediate. Facing greater competition as a result of trade liberalization, inefficient firms may see their production scale contracting and productivity falling. Institutional barriers to exit prevents resources from being released by the inefficient firms to be absorbed by efficient ones. These negative consequences of trade liberalization are further exacerbated by the short panel nature of our firm-level data.

### 4.2 Endogeneity of Trade Policy

An obvious challenge of estimating $\gamma_1$ and $\gamma_2$ is the potential endogeneity of trade liberalization. Facing the prospect of reduced profits, the incumbent firms and their various

[4] Unlike Trefler (2004), but similar to Amiti and Konings (2007) and many others, we are only examining the impact of Chinese tariff reductions, not that of tariff reductions by China's trade partners.

stakeholders have every incentive to lobby against reducing tariffs on the products they sell. On the other hand, they have every incentive to lobby for reducing the tariffs on their intermediate inputs, which helps to increase their profits. While the process of policy making may be different in China than in a western democracy, the feedback loop between the firms and the government is every bit as strong.

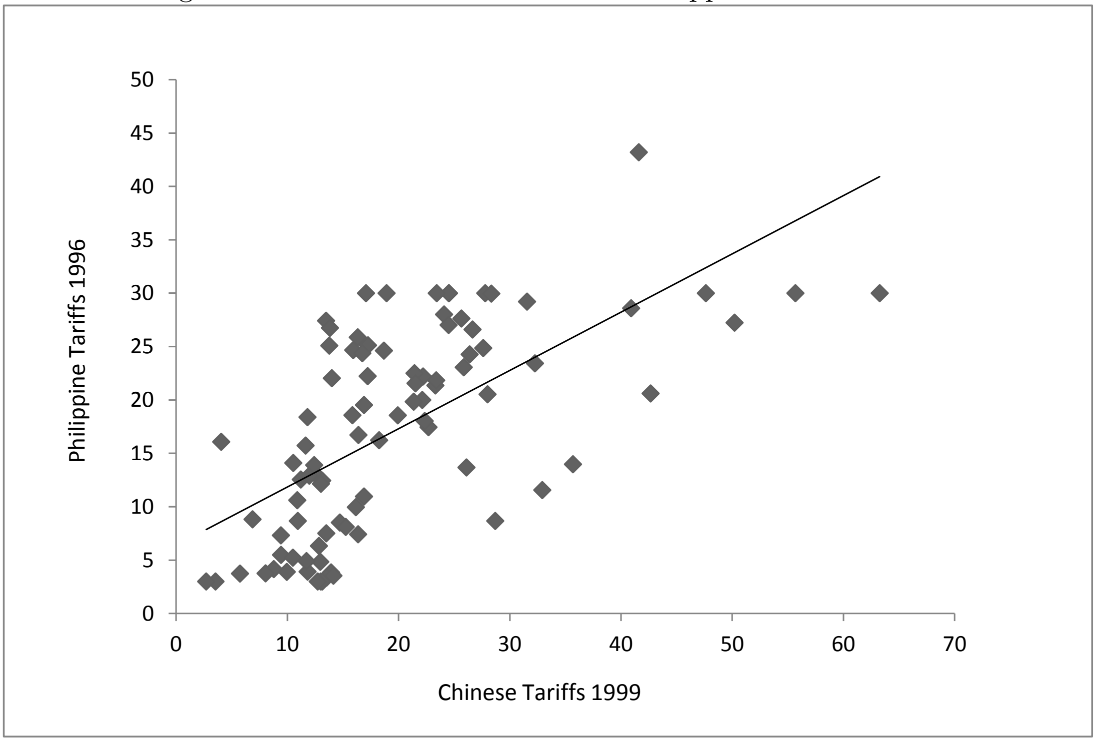
The feedback loop may take place at several different levels. On the eve of China's entry to WTO, the Chinese government had largely completed the de facto privatization that saw most small and medium size state-owned enterprises privatized, and what SOEs remained were mainly central government-controlled very large ones. These SOEs wielded tremendous influence in the process of policy making, including that of trade policy. Local Chinese government officials had their prospect of promotion tied to the performance of local enterprises, an important indicator of which is unemployment.[5] There was also inter-jurisdiction competition. All these prompt local government officials to lobby against tariff reductions that reduced the profitability and employment of those firms in their jurisdiction.

Our main approach to address the endogeneity problem is instrumental variable estimation. We propose that a good instrument for Chinese import tariff reductions is the tariff reductions adopted by another developing country that joined WTO earlier than China did. In our case this is the Philippines, which became a member of WTO in 1995. Thus we use for instrument for Chinese tariffs the WTO-mandated tariffs of the Philippines for 1996-2002. China in 2001 was at a similar stage of economic development as the Philippines was in 1996: China's GDP per capita in constant year 2000 prices was $1,106, and that of the Philippines in 1996 was $926. Their comparative advantage in international trade resides with labor-intensive industries. We thus expect the import tariff structure to be similar between the two countries.

In Figure (1) we plot the Chinese effective tariffs in 1999 against Philippines effective

[5] For example, Li and Zhou (2005) finds that the likelihood of promotion of provincial leaders increases with their economic performance, while the likelihood of termination decreases with their economic performance.

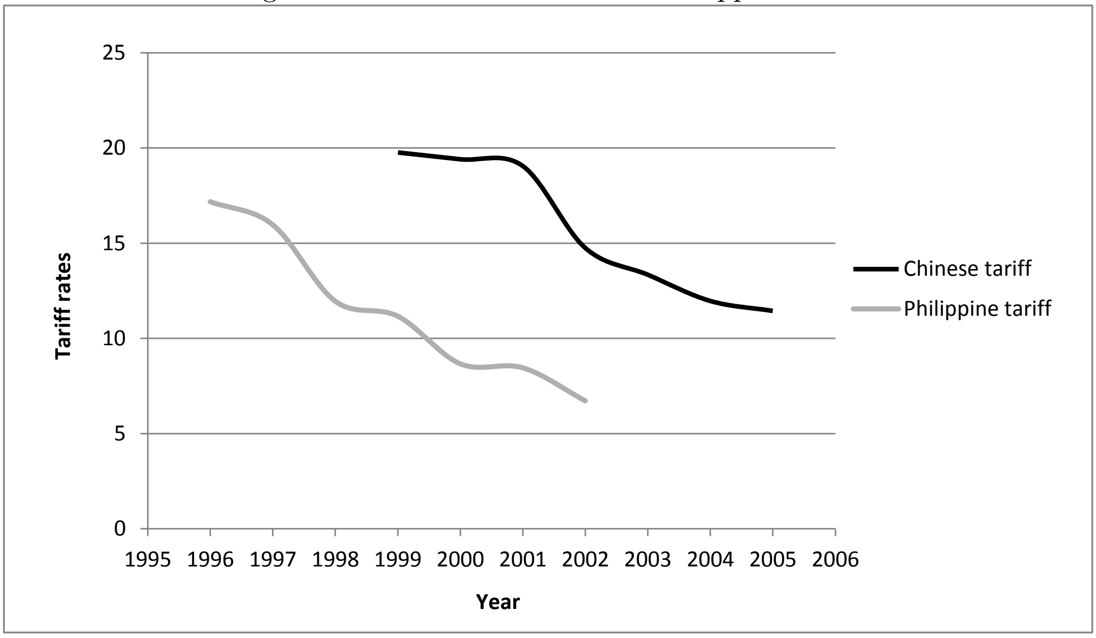
Figure 1: Chinese tariffs in 1999 and Philippine tariffs in 1996




tariffs in 1996. There is clearly a positive relationship between the two: industries that are highly protected in the Philippines are likely to be highly protected in China as well. Moreover, Figure (2) tracks the trends of aggregate level of tariffs - average tariffs of 90 four-digit industries - in China (for 1999-2005) and Philippines (for 1996-2002). It shows that tariff reductions in the two countries followed a similar path.

On the other hand, it is unlikely that the Philippine tariff reductions we choose as instrument are correlated with the productivity shocks that the Chinese firms faced in the process of trade liberalization. The Philippine tariff reductions occurred five years before the Chinese firms observed their productivity shocks. The unique institutional environment of China also suggests that the kind of productivity shocks that Chinese firms had to respond to following trade liberalization to are different from those that affected the Philippine firms. Finally, data shows that the trade link between the Philippines and China is rather weak. In 2007, the Philippines accounted for less than 2%

Figure 2: Trends of Chinese and Philippine tariffs




of China's imports.[6] Therefore, we expect the Philippine tariff reductions to be a good instrument for Chinese tariff reductions.

## 5 The Data

Our main firm-level data source is China's industrial census database compiled by the National Bureau of Statistics (NBS) of China. It contains annual balance sheet and income statement data for all Chinese industrial firms with an annual turnover of at least five million yuan. The data set we use for the current study spans the period 2000 to 2006 and only includes manufacturing firms. The original dataset consists of 361 four-digit manufacturing industries under Chinese Industrial Classification (CIC). Since the CIC classification was revised by NBS in 2002, we employ the concordance developed by Brandt et al. (2012) to make industry assignment consistent before and after 2002.

[6]We could not find data for the exact share of the Philippines in China's imports. But China's Statistical Yearbook indicates that the Philippines is not among the top ten origins of China's imports and the tenth largest source of imports to China is Saudi Arabia, whose share of China's total imports was 2% in 2007.

Furthermore, to make it compatible with our tariff data, which is by the International Standard Industrial Classification (ISIC), we use a concordance between CIC and ISIC Rev.3 to assign each firm an ISIC four-digit code.

To deflate monetary variables, we use several price deflators. Capital is deflated by country-level fixed capital investment price deflator and intermediate inputs are adjusted by price indices of raw material and power. Both of these are publicly available at the website of NBS. Total output of each firm is deflated by two-digit industry-level deflators constructed by Brandt et al. (2012). [7]

We also rid the sample of observations containing incomplete and inaccurate information (e.g., negative values for capital or labor). While the database is supposed to cover firms with an annual turnover over five million yuan, there is a sizable number of firms in the database that report turnover well below that threshold. We drop firms that report annual turnover below two million yuan. In addition, to mitigate the impact of extreme values on the regression results, we drop 0.1 percent of the extreme values at both end of the distribution of output, capital stock, materials and labor. We do this within each size class of large and medium and small firms. A small number of firms in the database have switched their industry affiliation at the two-digit ISIC level. We drop these firms from our analysis as well. The final data set is an unbalanced panel with about 600,000 observations for seven years.

Summary statistics of the variables used in our regressions are presented in Table 2.

# 6 The Results

## 6.1 Trade Liberalization and Firm's TFP: baseline results

We report the baseline results in Table (3). In column (1), we regress the logarithm of TFP on the two tariffs variables using a fixed effects estimator. The coefficients of output

[7] Ideally, when computing productivity, firm-level price deflators should be used to isolate physical efficiency from mark-ups (see Bartelsman and Doms (2000); Foster et al. (2008); De Loecker (2011)). However, we are not able to do so due to data availability.

Table 2: Descriptive Statistics

| Variable | Mean | Std. Dev. | N |
|---|---|---|---|
| log(output) | 10.494 | 1.226 | 586,641 |
| log(labor) | 5.231 | 1.026 | 586,641 |
| log(capital) | 9.193 | 1.236 | 586,641 |
| log(intermediate) | 10.055 | 1.248 | 586,641 |
| Profits/sales ratio | 0.024 | 0.107 | 586,641 |
| log(TFP) (OP) | 0.703 | 0.254 | 586,641 |
| log(TFP) (OLS) | 0.723 | 0.251 | 606708 |
| log(TFP) (OP w/o SOE) | 0.716 | 0.273 | 579,318 |
| log(output per worker) | 5.245 | 0.994 | 613,310 |
| Output tariff (AHS) | 0.133 | 0.081 | 586,641 |
| Input tariff (AHS, I/O Table 2002) | 0.063 | 0.029 | 586,641 |
| Input tariff (AHS, I/O Table 2007) | 0.075 | 0.034 | 591,128 |
| Output tariff (MFN) | 0.135 | 0.082 | 591,128 |
| Intput tariff (MFN, I/O Table 2002) | 0.063 | 0.029 | 591,128 |

The unit for all value variables is thousand yuan.

and input tariffs are -0.0372 and -1.647 respectively. These estimates imply that firm productivity will increase by 0.0372 and 1.647 percent respectively with a one percent reduction in output and input tariffs. The robust standard errors clustered by firm indicate both estimates are also statistically significant at the one percent level. Both the specification and the results of column (1) are similar to those of other recent papers (Amiti and Konings, 2007; Fernandes, 2007; Topalova and Khandelwal, 2011)..

We report results from IV estimation of equation (1) in column (2) of Table 3. The sign of the output tariffs coefficient has now been reversed. The estimate suggests that a one percent reduction in output tariffs will lead to a nearly 0.459 percent decline in Chinese firms' productivity. On the other hand, the estimate of the input tariffs coefficient remains negative and becomes much larger. The implied marginal effect of input tariff reduction is quite large: reducing input tariffs by one percent can lead to a 3.627 percent increase in total factor productivity. Both coefficient estimates are estimated with high degree of precision and the magnitudes of both effects have apparently been amplified with the IV estimation. These changes are what the endogeneity of tariff reductions would have predicted. Firms that have experienced (unobserved) negative productivity shocks are likely to lobby for greater protection or smaller output tariff reductions on one hand, and greater input tariff reductions on the other. These productivity shocks, left unaccounted for, create downward bias to the output tariffs coefficient and upward bias to the input tariffs coefficient.

The first-stage results of the IV estimation, which affirm that the Philippine tariffs are highly correlated with the Chinese tariffs, are included in the appendix. The instruments pass the Stock-Yogo test (Stock and Yogo, 2002) with ease. The Hausman test of endogeneity also confirms that we cannot reject the null of the Chinese tariffs being endogenous.

While there is no shortage of theoretical conjecture on it, to the best of our knowledge, ours is the first to find and report evidence for a productivity depressing effect of output tariffs reduction. When imported final goods become cheaper, domestic firms' market share can be reduced, pushing them to move back up their average cost curve. Our results suggest that this negative effect may dominate the "pro-competitive" effect that greater competition, as a result of tariffs-reduction, may engender. On the other hand, the large productivity boosting effect of lower input tariffs indicates that Chinese firms do benefit from cheaper and perhaps greater availability of foreign produced intermediate goods.

From 2001 to 2005, China's average output tariffs had been reduced from 18.21 to 10.84 percent, and the average input tariffs fell from 8.44 to 5.03 percent. Combining these tariffs reductions and our IV estimates of the marginal effects on Chinese firms' productivity, we obtain a net negative coefficient of -8.99, indicating an annual productivity increase of 2.25 percent due to trade liberalization following China's entry to WTO.

### 6.2 Robustness check

As a robustness check, we also estimate equation (1) using alternative ways to obtain the firm-level TFP measure, alternative productivity and tariff measures. These results

Table 3: Baseline results and robustness checks

| | (1) OLS | (2) IV | (3) Fixed-effects | (4) One-step | (5) OP w/o SOE | (6) Labour Productivity | (7) I/O table 2007 | (8) MFN tariff |
|---|---|---|---|---|---|---|---|---|
| Output tariff | -0.0372** | 0.459*** | 0.421*** | 0.521*** | 0.515*** | 0.528*** | 0.587*** | 0.244*** |
| | [0.0163] | [0.0435] | [0.0416] | [0.0497] | [0.0492] | [0.0497] | [0.0500] | [0.0496] |
| Input tariff | -1.647*** | -3.627*** | -3.323*** | -3.175*** | -3.745*** | -3.266*** | -3.517*** | -2.357*** |
| | [0.0655] | [0.146] | [0.145] | [0.174] | [0.165] | [0.174] | [0.133] | [0.121] |
| Observations | 586,641 | 586,641 | 606,721 | 613,211 | 579,318 | 613,310 | 591,128 | 591,128 |
| $R^2$ | 0.199 | | | | | | | |
| Weak identification F | | 3558 | 3858 | 3911 | 3248 | 3908 | 3266 | 4021 |

Dependent variable $log(TFP)$ except for column (6), for which the dependent variable is log(output per worker).
All regressions include firm and year fixed effects.
The weak identification F statistics are significantly higher than the critical values of Stock and Yogo.
Robust standard errors clustered by firm in brackets
*** p<0.01, ** p<0.05, * p<0.1

are reported in the rest of the columns of Table 3.

**Alternative TFP measures**

For column (3), we estimate firm-level TFP using a fixed effects estimator instead of using the Olley-Pakes approach. The results obtained using this alternative TFP measure are very similar to those in column (2).

A critique of the two-step approach we have been using so far to estimate TFP is the underlying assumption that tariffs are uncorrelated with input usage when estimating the production function in the first step.[8] So we adopt a one-step approach by including the tariff variables in the production function estimation so that we obtain both the production function parameters and the coefficients of the tariff variables at once. The results are reported in column (4). Again they do not deviate from the baseline results.

The Olley-Pakes approach is premised on firms maximizing their profits, which motivates the increasing, one-to-one mapping between productivity shocks and firm investment. This assumption may not characterize the investment decision of Chinese state-owned enterprises, whose management can be heavily influenced by the government officials for political purposes. To address this concern, we exclude state-owned enterprises from the Olley-Pakes estimation and use the resulted production function parameters to derive firm-level TFP estimates. The results are reported in column (5) and they are in line with those of the baseline case.

Some authors of this literature have used labor productivity as the productivity measure. To make our results more comparable to theirs, we use labor productivity, defined as total output divided by number of workers, as the productivity measure and dependent variable while controlling for capital per worker and material use per worker. The fixed effects estimates of this specification are reported in column (6) of Table 3. They are similar to those in the previous columns.

[8] See, for example, Fernandes (2007).

Table 4: The competitive pressure of import competition

| | (1) Production Scale | (2) Capital | (3) Profit Margin |
|---|---|---|---|
| Output tariff | 1.548*** | 0.819*** | 0.0534** |
| | [0.144] | [0.122] | [0.0216] |
| Input tariff | -0.227 | 0.0874 | -0.176*** |
| | [0.496] | [0.415] | [0.0664] |
| Observations | 586,641 | 586,641 | 586,641 |
| Weak identification F | 3558 | 3558 | 3558 |

The dependent variables for columns (1) to (3) are respectively log(output), log(capital) and profits over sales revenue.
All regressions include firm and year fixed effects.
The weak identification F statistics are significantly higher than the critical values of Stock and Yogo.
Robust standard errors clustered by firm in brackets
*** p<0.01, ** p<0.05, * p<0.1

**Alternative tariff measures**

We have used the Chinese input-output table for 2002 to construct the input tariffs. Since our firm-level data span the period from 2001 to 2006, and the input-output relations may have changed Chinese industries since 2002, we use the Chinese input-output table for 2007 to construct the input tariffs as a robustness check. The results, reported in column (7) of Table 3, are again similar to those of the baseline case.

Finally, we use most-favored-nation tariffs (MFN tariffs) instead of effective tariffs to measure tariff reductions. In reality, MFN tariffs are normally higher than their corresponding effective tariffs. But the results we report in the last column of Table 3, obtained using the MFN tariffs, show that the different tariff measures do not generate results that deviate from the baseline case.

## 6.3 The competitive effect of output tariffs reduction

The productivity depressing effect of output tariff reduction can be a result of increasing competition of imports that erodes domestic firms' market share and forces them to reduce their production scale. When production scale is curtailed, the firms will have lower volumes of output over which to spread their fixed costs of production. This in turn will force the firms to move back up their average cost curve. In column (1) of Table 4, we regress the logarithm of firm output on the output and input tariffs using the same IV estimator. The estimate of the coefficient of the output tariff suggests that a one percent decrease in output tariffs lead to a 1.548 percent decline in the production scale of the firms. The input tariff reduction, on the other hand, has no impact on the firms' output levels.

In the second column of Table 4, we report the results from regressing a firm's capital stock on the two tariff variables. Capital, being the relatively inflexible factor of production, may not swiftly respond to the demand shock generated by the tariff reduction, thus raising the cost of production for the firm. The coefficient estimate of the output tariff implies that a one percent reduction in output tariffs leads to a 0.819 percent reduction in capital. This is in sharp contrast with the 1.548 percent decrease in production scale that a similar output tariff reduction engenders.

For the last column of Table 4, we regress firm's profit margin on the two tariff variables. The profit margin is defined as profits over sales, $(p - ac)Q/pQ$, where p, ac and Q are unit price, unit cost and total quantity produced. The results exhibit a pattern that is similar to that of the productivity regression results: output tariff reduction reduces the firms' profitability, whereas input tariff reduction raises it; both effects are statistically significant, with the latter effect more than offsetting the former, yielding a net positive effect on profitability. Thus, the competitive effect of output tariff reduction also finds supportive evidence in how the firms' profitability is affected by it.

### 6.4 Trade Liberalization, productivity and firm heterogeneity

We have so far estimated the impact of tariffs reduction on the productivity of the "average firm", and thus implicitly treated the firms as homogenous units of production. The actual impact of trade liberalization is likely to be felt differently by the Chinese

Table 5: Trade liberalization and firm ownership

| | (1) TFP | (2) Production Scale | (3) Capital | (4) Profit Margin |
|---|---|---|---|---|
| Output tariff | 0.730*** | 2.091*** | 0.524*** | 0.139*** |
| | [0.0714] | [0.210] | [0.181] | [0.0411] |
| Output tariff*Private | -0.408*** | -1.456*** | -0.0145 | -0.0834** |
| | [0.0740] | [0.227] | [0.200] | [0.0400] |
| Output tariff*Other | -0.264*** | -0.718*** | 0.162 | -0.0778** |
| | [0.0679] | [0.199] | [0.180] | [0.0380] |
| Output tariff*Foreign | -0.462*** | 0.242 | 1.273*** | -0.179*** |
| | [0.111] | [0.343] | [0.295] | [0.0604] |
| Input tariff | -4.449*** | -0.322 | 2.571*** | -0.416*** |
| | [0.208] | [0.648] | [0.549] | [0.111] |
| Input tariff*Private | 1.020*** | 0.357 | -3.518*** | 0.237*** |
| | [0.166] | [0.513] | [0.459] | [0.0903] |
| Input tariff*Other | 0.744*** | 0.00585 | -3.035*** | 0.228*** |
| | [0.154] | [0.456] | [0.417] | [0.0863] |
| Input tariff*Foreign | 1.272*** | -0.855 | -3.396*** | 0.386*** |
| | [0.242] | [0.751] | [0.654] | [0.132] |
| Observations | 586,641 | 586,641 | 586,641 | 586,641 |
| Weak identification F | 728.2 | 728.2 | 728.2 | 728.2 |

The dependent variables for columns (1) to (4) are respectively log(TFP) log(output), log(capital) and profits over sales revenue.
All regressions include firm and year fixed effects.
The weak identification F statistics are significantly higher than the critical values of Stock and Yogo.
Robust standard errors clustered by firm in brackets
*** p<0.01, ** p<0.05, * p<0.1

firms that are differentiated along a multitude of dimensions. Some of these firms have gained from the tariff reductions, while others have been negatively affected by it. Thus we investigate whether and how the impact of trade liberalization on Chinese firms' productivity may vary along three such dimensions - ownership, export status and firm size.

**Ownership**

China's economic reform, enterprise restructuring in particular, has created a highly diverse ownership structure for Chinese industry. Firm ownership carries implications for market power, access to capital and other factor markets and the relationship between government and firms. These differences in turn bear upon the firms' performance and how they react to demand and supply shocks. At the risk of aggregating away some of the nuanced governance differences that different ownership structure creates, we group the firms in our sample into four broad ownership categories: state-owned and state-controlled, private, other domestic and foreign-invested.

To examine how the productivity impact of tariffs reductions vary by firm ownership, we modify our baseline model by allowing the coefficients of the tariff variables to vary by ownership. The results are reported in column (1) of Table 5. For both output and input tariffs, the reference ownership group is state firms. The productivity depressing effect of output tariff reduction is most acutely felt at state-owned firms; a one percent reduction in output tariff engenders a 0.73 percent decrease in these firms' productivity. The productivity of foreign and domestic private firms is least negatively affected by the tariff liberalization. The other group, which mostly consists of restructured former state-owned enterprises fall in between as far as the impact of output tariff liberalization is concerned.

In columns (2) to (4) we investigate how the firms' production scale, capital and profit margin react to output and input tariff liberalization depending on the firms' ownership structure. The large and negative productivity shock caused by output tariff reduction to the state-owned enterprises can be attributed to the sharp fall in their production scale as a result of the trade liberalization: a one percent decrease in output tariff causes the state-owned firms' output to contract by over two percent. On the other hand, there is minimal contraction of the production scale of private firms. For the other domestic firms, their output level falls by a bit over half of the fall of state-owned firms' output. Foreign-invested firms, on the other hand, see their production scale fall by the same amount as the state-owned firms.

The adjustment of the firms' capital service, as we have argued earlier, provides a clue as to how the fall in production scale translates into productivity change. The sharpest contrast is between state-owned and foreign-invested firms. Both groups have seen their production scale curtailed by import competition as a result of lower output tariffs; state-owned enterprises manage to reduce their capital service by about half a percent in response to a shock of two percent drop in output; facing a similar shock, foreign-invested firms are able to adjust downward their capital service by almost 1.3 percent. As a result, profit margin at state-owned firms falls by 0.14 percent, whereas profitability of foreign-invested firms actually rises a bit.

Turning to input tariff liberalization, the results in column (1) indicates that state-owned firms receive the largest productivity boost from input tariff liberalization. Foreign-invested firms' productivity rises by the least amount in response to input tariff liberalization. One potential explanation is that foreign-invested firms, particularly those engaged in processing trade, were already enjoying low or no tariffs on imported materials and other intermediate inputs. The production scale regression suggests that input tariff liberalization has no effect on the firms' output level.

Surprisingly the state-owned firms react to the positive productivity shock of input tariff liberalization by cutting back on their capital service, whereas all the other firms increase their capital service. The way the impact of input tariff liberalization on profit margin depends on ownership is similar to how the productivity impact varies by ownership. State-owned firms experience the most robust increase in profitability as a result of input tariff liberalization.

**Exporter status**

Much of the theoretical literature on trade liberalization and firm-level productivity performance focuses on the impact of gaining access to export market on exporting firms' productivity. The higher volume of production made possible by the overseas market

Table 6: Trade liberalization and firm export status

| | (1) TFP | (2) Production Scale | (3) Capital | (4) Profit Margin |
|---|---|---|---|---|
| Output tariff | 0.832*** | 2.333*** | 1.342*** | -0.00237 |
| | [0.0914] | [0.304] | [0.261] | [0.0435] |
| Output tariff*Non-exporter | -0.550*** | -1.142*** | -0.742** | 0.0838* |
| | [0.103] | [0.344] | [0.293] | [0.0496] |
| Input tariff | -4.345*** | -2.104*** | -1.639*** | -0.106 |
| | [0.207] | [0.689] | [0.597] | [0.0963] |
| Input tariff*Non-exporter | 1.165*** | 3.098*** | 2.909*** | -0.108 |
| | [0.226] | [0.756] | [0.647] | [0.109] |
| Observations | 586,641 | 586,641 | 586,641 | 586,641 |
| Weak identification F | 541.9 | 541.9 | 541.9 | 541.9 |

The dependent variables for columns (1) to (4) are respectively log(TFP) log(output), log(capital) and profits over sales revenue.
All regressions include firm and year fixed effects.
The weak identification F statistics are significantly higher than the critical values of Stock and Yogo.
Robust standard errors clustered by firm in brackets
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

and the fixed/sunk costs involved in accessing the overseas market have two implications: 1) serving the export market helps to raise the exporting firms' productivity due to the scale effect, and 2) only the more productive firms get to serve the export market as they can afford the fixed/sunk costs of penetrating into the market. However, what we are investigating here, as did other authors, is the impact of import tariff liberalization on domestic firms' productivity. So the theoretical literature does not provide much guidance as to the impact of such trade liberalization on exporting firms' productivity. Nevertheless, both conceptually and empirically, exporting firms and non-exporting firms tend to be different. Thus, we allow the impact of import tariff reduction to depend on a firm's exporter status.

We classify the firms into two categories: the non-exporters are firms that never exported during the sample period; the remaining firms are exporters. About 62 percent (96,893) of the firms in our sample are non-exporters. We interact the non-exporter dummy variable with both tariff variables in four regressions: TFP, production scale, capital and profit margin. The results are reported in Table 6.

The TFP regression results in column (1) indicate that the exporters benefit more from lower input tariffs than non-exporters, but also see their productivity depressed more by lower output tariffs than the non-exporters. Again the channel of the productivity depressing effect is reduced production scale and the incomplete adjustment of the inflexible production factor of capital. However, there is little difference between the exporters and non-exporters when it comes to the impact of output tariff liberalization on their profit margins, neither of which are affected by lower output tariffs. In response to lower input tariffs, the exporters increase their production scale and capital service.

Taking into account both the impact of output and input tariffs, we can see that China's trade liberalization has generated a net benefit for both Chinese exporters and non-exporters, with the benefits coming exclusively from lower input tariffs. In other words, the production scale reducing effect of more import competition is offset by the benefits from having access to cheaper imported intermediate inputs. In the end the

Table 7: Trade liberalization and firm size

| | (1) TFP | (2) Production Scale | (3) Capital | (4) Profit Margin |
|---|---|---|---|---|
| Output tariff | 0.622*** | 2.140*** | 0.691*** | 0.100*** |
| | [0.0522] | [0.167] | [0.140] | [0.0288] |
| Output tariff*Small | -0.215*** | -0.515*** | 0.403*** | -0.0516** |
| | [0.0378] | [0.124] | [0.111] | [0.0212] |
| Input tariff | -4.006*** | 1.637*** | 3.309*** | -0.162** |
| | [0.164] | [0.535] | [0.447] | [0.0822] |
| Input tariff*Small | 0.441*** | -3.134*** | -4.622*** | -0.0531 |
| | [0.0818] | [0.269] | [0.245] | [0.0461] |
| Observations | 586,641 | 586,641 | 586,641 | 586,641 |
| Weak identification F | 1774 | 1774 | 1774 | 1774 |

The dependent variables for columns (1) to (4) are respectively log(TFP) log(output), log(capital) and profits over sales revenue.
All regressions include firm and year fixed effects.
The weak identification F statistics are significantly higher than the critical values of Stock and Yogo.
Robust standard errors clustered by firm in brackets
*** p<0.01, ** p<0.05, * p<0.1

profit margin of neither group of firms is affected by the trade liberalization.

#### 6.4.1 Firm size

The impact of tariff reductions can also depend on firm size: larger firms with greater market power have more to lose from trade liberalization. Also the Chinese small firms are overwhelmingly privately owned, and thus more likely to gain from trade liberalization as the ownership results show. The results reported in Table 7 confirm these conjectures.

We adopt the size classification used by China's National Bureau of Statistics and categorize the firms in our sample into two groups: the large and medium size firms and the small firms. Results in column (1) shows that the productivity depressing effect of output tariff liberalization is more prominent in the larger firms than in the small firms. The production scale and the capital service regression results in columns (2) and

(3) indicate that the differential impact of output tariff liberalization derives from how production scale and adjustment of capital service react to the negative shock in the two groups of firms. The large and medium size Chinese firms have had their production scale curtained by a bigger share than the small firms and a smaller adjustment of their capital service relative to the fall in output level. As column (4) shows, all these translate into a significant erosion of the larger firms' profit margin, but a boost to the profitability of small firms.

The impact of the input tariff liberalization paints a different picture. The larger firms receive a huge boost in productivity from input tariff liberalization. They seem to have achieved this through cutting back on capital service as well as the level of production. The small firms, on the other hand, respond to the lower input tariffs by increasing both capital service and production scale, in other words, scaling up in the process of trade liberalization.

When we evaluate the net effect of trade liberalization, the lowering of both input and output tariffs, we can see that both groups of firms derive a net benefit from it, in terms of both TFP and profitability.

# 7 Conclusion

China's entry to WTO has been considered a watershed event in the recent history of both Chinese and world economic history. Despite its far reaching ramifications, there has been little empirical evidence on how the trade liberalization that China has committed to has affected the performance of Chinese industrial firms. This is essential to the case for free trade both from the policy and academic perspectives.

A challenge facing such investigations is the need to account for the endogeneity of trade liberalization. Trade policy is not made in vacuum, but instead reflects the complex interaction between various stakeholders and the government. There is no reason to believe that China is an exception in this regard. Chinese firms, through their influence over local and central governments, have incentives to shape the making of trade policy in their favor. That export has been an important driver of China's economic growth and employment creation over the last decade only accentuates the relevance of this concern for the potential distorting effect of the endogeneity on the econometric evidence obtained without properly accounting for it. We deal with this issue with an instrumental variable approach.

A novel feature of our study is the use of a new instrument for trade liberalization. We use the tariffs of the Philippines in the years following its entry to WTO in 1995 as an instrument for China's import tariffs. The two countries had a similar level of economic development at the time of their entry to WTO; both were populous countries relative to their other endowments. The process of tariff reduction is thus similar in the two countries. Yet firms in the two countries are likely to have been subject to different idiosyncratic shocks that may prompt them to lobby for favorable tariff reform given the time lag between the two trade reforms and the different institutional structures.

We examine the productivity-trade liberalization nexus using a firm-level panel database that comprises all of China's manufacturing firms with an annual turnover above five million yuan and spans the period of 2000 to 2006. We separate the effect of trade liberalization into that of output tariff reduction and input tariff reduction. The input tariffs are imputed using China's input-output table. Overall, our results indicate that trade liberalization has led to a 2.25 percent annual increase in TFP for Chinese manufacturing firms. However, this is a result of the trade liberalization working differently through two different channels. By increasing product market competition, output tariff reduction significantly depressed Chinese firms' productivity. We find that this largely has to do with lower production scale and incomplete adjustment of capital service, an inflexible factor of production. That the output tariff reduction has significantly eroded the profit margin of the Chinese firms affirms the competitive pressure created by import competition. On the other hand, through the intermediate inputs' channel, the trade liberalization has significantly boosted the productivity of Chinese firms and increased their profit margin. There is no effect of the input tariff reduction on production scale or capital service. We have subjected our results to a large number of robustness checks, including different productivity measures and tariff measures. The results carry through in all these alternative regressions.

We also explore the implications of firm heterogeneity for how the trade liberalization affects Chinese firms' productivity. Along the ownership dimension, state-owned enterprises appear to have received the most negative impact of output tariff reduction, with their production scale significantly curtailed and profit margin diminished. Foreign-invested and private Chinese firms hold up best in the face of greater import competition; both groups have responded to lower output tariffs by either adjusting production scale swiftly or not losing sales. On the input tariff reduction side, the picture is somewhat different, with the state-owned enterprises gaining more from lower input tariffs than the other firms.

Depending on whether the firms have ever exported, the impact of tariff liberalization works through different channels. The exporters have experienced a negative shock from the output tariff reduction, but a large positive one through the lower input tariffs; the non-exporters have not been hit hard by the lower output tariff, nor have they gained as much as the exporters through the input tariff liberalization. Finally, the large firms have experienced a bigger negative shock from the output tariff liberalization than the small firms, but also gained more from the lower input tariffs.

While we have found some robust evidence to show that the overall impact of China's trade liberalization in the first decade following China's WTO entry has been a positive on, our results also show that the trade liberalization - productivity nexus is quite complex. In particular, the dislocation that greater competition the trade liberalization engenders and how the Chinese firms respond and adapt to such shocks certainly warrant more research.

# A Appendix

## A.1 Production function estimation

To measure firm-level TFP, we follow the methodology of Olley and Pakes (1996) which uses firm's investment as proxy variable for unobservable productivity shocks and hence corrects for simultaneity in the estimation of production function parameters. Consider a Cobb-Douglas production function, by taking natural logarithm we have the estimation equation as:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + e_t \tag{A-1}$$

where the small letters denote logarithm of the corresponding variables. As well-addressed in the literature, there is simultaneity problem for the estimation of equation (1). Specifically, the error term, $e_{it}$, consists of two components: a white noise $\eta_{it}$ and a time-varying productivity shock $w_{it}$. The latter, which is unobservable by econometricians, is often positively correlated to input choices such as labour and material since more productive firms are likely to hire more workers and use more materials. An OLS estimation, in this case, would lead to upward biased coefficients of labour and material. The idea of Olley-Pakes methodology is that, one can use firms' investment as proxy variable for the productivity shock. A key assumption is that firm's investment must be a monotonically increasing with respect to its capital and productivity. Moreover, a firm's productivity is assumed to follow a Markov process. Under mild condition, firm's investment can be written as a monotonically increasing function of capital and productivity. By taking inversion, the unobservable productivity can be written as $w_{it} = w_t(I_{it}, k_{it})$. The estimation of Olley-Pakes methodology consists of two steps. In the first step, the coefficients of labour and intermedia inputs can be identified using semiparametric estimation. In the second stage, the coefficient of capital is recovered. The estimates of production parameters using OLS estimation and Olley-Pakes methodology are presented

Table A-1: Estimates of input coefficients

| Industry | Labour | Capital | Materials | Observations |
|---|---|---|---|---|
| Food and beverage (15) | 0.044 | 0.021 | 0.939 | 62,614 |
| Textile (17) | 0.051 | 0.007 | 0.927 | 56,301 |
| Apparel (18) | 0.090 | 0.035 | 0.876 | 23,679 |
| Leather (19) | 0.067 | 0.021 | 0.913 | 12,682 |
| Wood (20) | 0.052 | 0.017 | 0.935 | 9,410 |
| Paper (21) | 0.045 | 0.017 | 0.940 | 20,090 |
| Printing (22) | 0.058 | 0.051 | 0.890 | 11,943 |
| Petroleum (23) | 0.022 | 0.016 | 0.944 | 5,119 |
| Chemicals (24) | 0.033 | 0.031 | 0.931 | 62,875 |
| Rubber and Plastics (25) | 0.042 | 0.024 | 0.930 | 28,473 |
| Non metal (26) | 0.042 | 0.014 | 0.939 | 61,362 |
| Basic metal (27) | 0.062 | 0.021 | 0.920 | 26,915 |
| Fabricated metal (28) | 0.040 | 0.043 | 0.922 | 28,237 |
| Machinery (29) | 0.029 | 0.030 | 0.929 | 54,478 |
| Electrical (31) | 0.029 | 0.031 | 0.948 | 24,763 |
| Communication equipment (32) | 0.063 | 0.032 | 0.907 | 17,379 |
| Precision instrument (33) | 0.036 | 0.016 | 0.932 | 7,159 |
| Vechicles (34) | 0.033 | 0.038 | 0.933 | 14,283 |
| Other transport equipment (35) | 0.045 | 0.025 | 0.924 | 9,119 |

All coefficient estimates are statistically significant at the one percent level, with the standard errors clustered by firm.
Three industries, Tobacco (16), Computing Machinery (30) and Furniture (36), are dropped from the table as their production function estimates are either statistically insignificant or unreasonable. They account for 1281, 718 and and 16109 observations respectively.

in Table (A-1).

## A.2 First stage regression results

As baseline model, we estimate equation (1) using our proposed instrumental variables and compare the results with those obtained from previous studies in the literature. Table (A-2) presents the first stage regression results. Column (1) and (2) show the results under pooled regression setting in which industry fixed effect is controlled. As shown, the coefficients for output and input tariff are 0.309 and 0.865, respectively, and both are significant at 1% level. This shows strong positive relationship between Chinese and Philippine tariffs. In addition, the R-squared are high (0.921 and 9.48),

Table A-2: First stage results of IV estimation

| | (1) | (2) |
|---|---|---|
| | FS | FS |
| VARIABLES | output_tariff | input_tariff |
| phlahso | 0.253*** | -0.0410*** |
| | [0.00481] | [0.000667] |
| phlahsi | 0.495*** | 0.450*** |
| | [0.0145] | [0.00298] |
| Observations | 586,641 | 586,641 1 |
| R-squared | 0.621 | 0.861 |

Robust standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

meaning Chinese output tariffs can be well-predicted by Philippine tariffs. The results confirm our conjecture that the reduction processes of Chinese and Philippine tariffs are significantly correlated. Column (3) and (4) present the first stage results under panel regression setting where firm fixed effect is controlled. The coefficients of output and input tariffs drop to 0.263 and 0.61, respectively, but both still remain highly significant. Furthermore, since part of firm-level variation has been absorbed by firm fixed effect, the R-squared drops to 0.644. Overall, the first stage regression shows that Philippine tariffs are strong instruments for Chinese tariffs.

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