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Trade Liberalisation, Product Complexity and Productivity Improvement: Evidence from Chinese Firms

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1. INTRODUCTION

THIS paper investigates the effect of trade liberalisation on Chinese firms' productivity. In the past three decades, China has experienced dramatic trade liberalisation as well as productivity gains. The average unweighted tariffs decreased from around 55 per cent in the early 1980s to about 13 per cent in 2002. At the same time, China's average annual increase in total factor productivity (TFP) in the first two decades since economic reform in 1978 was around 4 per cent, although this pace seems to have slowed down after that (Zheng et al., 2009). It is interesting to see whether or not China's trade liberalisation has boosted its productivity. Although economists have paid some attention to this issue, the research is far from conclusive and deserves further exploration.

First, in much of the existing work on TFP, TFP is usually measured as the Solow residual, defined as the difference between the observed output and its fitted value calculated via ordinary least squares (OLS) regressions. However, this method suffers from a number of econometric problems, including simultaneity bias and selection bias. The first bias comes from the fact that a profit-maximising firm would respond to productivity shocks by adjusting its output, which, in turn, requires reallocating its inputs. Since such a productivity shock is observed by firms and not by econometricians, this creates an endogeneity issue. Moreover, firms covered in the samples are usually those that have relatively high productivity and

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survived during the period of investigation. Those firms that have exited the market due to low productivity were not observed and thus excluded from the samples. Ignoring the firms' entry and exit from the market means that the samples are not randomly selected, and hence, the estimation results may suffer from selection bias.

Second, previous studies ignored the heterogeneity of goods in their estimations. Complex products are differentiated and have many characteristics, including size, design, material and other specifications (Berkowitz et al., 2006). In contrast, simple goods are more homogeneous, and they are either traded on organised exchanges or are reference-priced. When facing trade liberalisation, firms that produce complex goods may react differently with those that produce simple goods. However, there has been no empirical evidence on whether trade liberalisation affects the productivity of producers of complex goods and simple goods differently.

Third, much of the literature has used output tariffs as an indicator of trade liberalisation. Recently, Amiti and Konings (2007) took a step forward to take input tariffs into account. However, a tariff is just one of the many instruments in trade policies, which has already been reduced to a very low level after the Uruguay Round of the WTO in 1994. Other trade policy instruments, including various non-tariff barriers (NTBs), also play important roles in protecting domestic import-competing industries. Restricting the scope to tariffs only is insufficient in understanding the impact of trade liberalisation on productivity.

Last but not least, the existing literature has faced an empirical challenge in using China's data. Holz (2004) emphasised the bias of using China's aggregated data since there is a mismatch between disaggregated and aggregated statistical data. This is consistent with Krugman's (1994) complaint that it is a challenging job to explain China's economic growth due to its low-quality data. Young (2003) argued that China's TFP growth rate was quite modest and perhaps negative in the post-Mao era. However, his work is based on aggregated industrial data, which would be subject to some bias as well.

In this paper, to mitigate the above-mentioned estimation issues, the effect of China's trade liberalisation on its productivity was estimated by precisely measuring TFP, by taking into account the difference in complex goods and simple goods, by choosing an appropriate indicator of trade liberalisation and by using the most disaggregated firm-level data.

First, to address the two empirical challenges (i.e. simultaneity bias and selection bias) caused by OLS, we adopt the Olley–Pakes (1996) approach. This approach was also revised by imbedding a survival probability model to control for the problem of selection bias. Second, we estimate the effect of trade liberalisation on firm productivity for complex and simple goods separately using a classification system in line with Rauch (1999). Third, as stated above, trade liberalisation includes the removal of various NTBs in addition to tariff cuts. However, data on NTBs are very difficult to obtain, especially for developing countries like China. The import penetration ratio, which is defined as industrial imports over its outputs, is the economic consequence of both tariffs and NTBs. Compared to tariffs, the import penetration ratio is a better instrument for measuring trade liberalisation (Levinsohn, 1993). In this paper, the import penetration ratio is used to measure trade liberalisation. Finally, the sample in this paper is a rich firm-level panel, covering more than 150,000 manufacturing firms per year from 1998 to 2002. For each firm, the coverage is more than 100 financial variables listed in the main accounting sheets of all state-owned enterprises (SOEs) and those non-SOEs firms, whose sales are more than five million yuan RMB per year.

The estimation results suggest that trade liberalisation significantly increases productivity for firms that produce complex goods. In contrast, we find that trade liberalisation has the opposite effect on the productivity of producers of simple goods. These findings are robust after controlling for potential endogeneity. We further find that the effect of trade liberalisation on firm productivity to exporting firms is smaller than non-exporting firms.

This paper joins the growing literature on the nexus between trade liberalisation and productivity. To measure productivity, papers such as Trefler (2004) emphasised labour productivity, although most studies have concentrated on TFP. In the early stage, researchers usually rely on industrial-level data to measure TFP. These include, among others, Tybout et al. (1991), Levinsohn (1993), Harrison (1994) and Head and Ries (1999). Most recent studies, such as Pavcnik (2002) and Amiti and Konings (2007), consider firm productivity by using plant data. However, most of these above-mentioned works only use tariffs to measure trade liberalisation. Only a few exceptions, like Harrison (1994), include the import penetration ratio as a robustness check.

Our study also contributes to the recent development in the literature that emphasises on the difference in trade patterns of complex goods and simple goods (Berkowitz et al., 2006; Berkowitz and Moenius, 2011; Ma et al., 2011). We find empirical evidence showing that the effect of China's trade liberalisation on firm productivity depends on the product complexity. We argue that since complex goods are highly differentiated products, the increased degree of trade liberalisation creates learning opportunities and encourages firms to engage in more innovative activities to develop more differentiated products. However, for firms that produce simple goods, a high level of import penetration means that these firms face severe competition from abroad and their operating performance may decline. As a result, these firms have less resources to invest in technology improvement.

The remainder of the paper is organised as follows: Section 2 reviews China's trade liberalisation in the last three decades. Section 3 introduces the estimation methodology. Section 4 describes data. Section 5 discusses estimation results and robustness checks, and Section 6 concludes the paper.

2. CHINA'S TRADE LIBERALISATION

In the past three decades, China has experienced dramatic trade liberalisation. As a result, China changed from an almost fully isolated economy to the second largest open economy today. China's openness ratio (i.e. the sum of exports and imports relative to GDP) increased from around 10 per cent in the early 1970s to 64 per cent in 2007. The 'open-door' policy has become one of the two most fundamental doctrines of the Chinese government after 1978.[1] During the last three decades, China has proceeded with its trade liberalisation by setting up export-processing zones (EPZs) to absorb foreign direct investments (FDIs), by acceding to the WTO and by significantly cutting tariffs.

Before 1978, China's foreign trade was completely monopolised by 12 national foreign trade companies (FTCs). They imported products at world prices and sold them domestically at projected prices. As a result, China was insulated from the world economy (Naughton, 2006). Like many other East Asian countries, the Chinese government set up EPZs in 1978 to launch trade liberalisation. The first wave of the EPZs formation saw the setting up of four special economic zones (SEZs) in the early 1980s, which allowed export-processing duty-free imports. The second wave mainly opened up two eastern coastal provinces (i.e. Guangdong and Fujian) by allowing foreign firms to sign 'export-processing' contracts with domestic firms. In the early 1990s, China experienced its third wave of dramatic proliferation of SEZs

[1] The other fundamental doctrine is the 'deepen economic reform' policy.

by generalising the open-door policy to many other eastern coastal provinces. China then set up 18 economic and technical development zones (ETDZs), in which foreign investors are encouraged to set up joint ventures with rural collectives and various subsidiaries. By the end of 2003, China had already more than 100 investment zones that enjoy various special foreign trade policies.

Before the economic reform, tariffs did not play an important role since FTCs had already served as an 'air-lock' to insulate China from the world. In the 1980s, China began to set up a whole system of tariff rates. In 1992, China's unweighted average tariffs were 42.9 per cent, which was similar to the level of other developing countries. Shortly after the Uruguay Round of the WTO, China experienced huge tariff reductions due, in large part, to the WTO accession application. China cut its tariffs from 35 per cent in 1994 to around 17 per cent in 1997. After that, from 1998 to 2002, China's average tariffs did not decrease much. The largest adjustment was in 2001, in which the average tariff rates decreased from 16.4 to 15.3 per cent.

Besides tariffs, China also used various NTBs to protect its import-competing industries. According to UNCTAD's classification, the NTBs include many types of measures, such as price control measures, quantity control measures, customs charges and taxes, financial measures, technical measures, monopolistic measures and miscellaneous measures. According to Fujii and Ando's (2000) calculation, China maintained a large number of NTBs in various products. For example, the core non-tariff measures was 51.9 per cent for wood products, whereas it was 55.1 per cent for chemicals in 1996.

Moreover, to fully integrate into the world trade system, China applied to rejoin the GATT in 1986. It took China 15 years to accede to the WTO in 2001, as its 143rd member. Although such a long march was not expected, China's trade policies were changed many times to fit this largest international trading organisation. China's inward FDI increases dramatically after Deng Xiaoping's southern China tour in 1992. In 2007, China's FDI reached $74.7 billion, which was 17 times higher than that in 1991. According to *The Economist*,[2] it is predicted that China's inward FDI will become the third largest, followed by the US and the UK, in 2011.[3]

Following trade liberalisation, China also maintains a huge volume of processing exports (i.e. China imports the parts or raw materials from abroad and exports the finished products to other countries). According to *China's Statistical Yearbook*, the value of China's processing exports is much higher than that of its ordinary exports since the 1990s. Although the level of processing trade has been decreasing over the recent years, in 2006, China's processing export still accounted for around 52 per cent out of its total exports.

3. THE METHODOLOGY

a. Measuring Total Factor Productivity

The literature on TFP usually suggests a Cobb–Douglas production function to introduce technology improvement.[4] Following Amiti and Konings (2007), we consider a form as follows:

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[2] Source: The *Economist* (5 September 2007), via http://www.economist.com.

[3] However, since China also has a remarkable growth rate of its economy scale, the ratio of FDI over GDP is only 2.1 per cent, which is lower than many OECD countries (World Bank, 2007).

[4] An alternative specification is to use a trans-log production function, which also leads to very similar estimation results.

$$Y_{it} = \pi_{it}(\tau_{jt}) M_{it}^{\beta_m} K_{it}^{\beta_k} L_{it}^{\beta_l}, \tag{1}$$

where Y_{it}, M_{it}, K_{it}, L_{it} are firm i's output, materials, capital and labour at year t, respectively. Firm i's productivity, π_{it}, is affected by trade policy, τ_{jt}, in its industry level j in year t. To measure firm's TFP, one needs to estimate equation (1) by taking a log-function first:

$$\ln Y_{it} = \beta_0 + \beta_m \ln M_{it} + \beta_k \ln K_{it} + \beta_l \ln L_{it} + \varepsilon_{it}, \tag{2}$$

Traditionally, the TFP is measured by the estimated Solow residual between the true data on output and its fitted value, $\ln \hat{Y}_{it}$. That is:

$$TFP_{it} = \ln Y_{it} - \ln \hat{Y}_{it}. \tag{3}$$

However, this approach suffers from two problems: simultaneity bias and selection bias. As first suggested by Marschak and Andrews (1944), at least some parts of TFP changes could be observed by the firm early enough so that the firm could change its input decision to maximise profit. From another perspective, the firm's TFP could have reverse endogeneity in its input factors. The lack of such a consideration would make the firm's maximising choice biased. In addition, the firms' dynamic behaviour also introduces selection bias. In a panel data set, the firms observed are those that have already survived. On the other hand, firms with low productivity that collapsed and exited from the market are not included in the data set. This means that the samples covered in the regression actually are not randomly selected, which in turn causes estimation bias.

Econometricians tried hard to address these empirical challenges, but were not successful until the pioneering work by Olley and Pakes (1996). In the beginning, researchers used two-way (i.e. firm-specific and year-specific) fixed effects to mitigate simultaneity bias. Although the fixed-effect approach controls for some unobserved productivity shocks, it does not offer much help in dealing with reverse endogeneity. So this approach still seems unsatisfactory. Similarly, to mitigate selection bias, one may estimate a balanced panel by dropping those observations that disappeared during the period of investigation. The problem is that a substantial part of information contained in the data set is wasted, and the firm's dynamic behaviour is completely unknown.

The Olley–Pakes (1996) methodology makes a significant contribution in addressing these two empirical challenges. By assuming that the expectation of future realisation of the unobserved productivity shock, υ_{it}, relies on its contemporaneous value, firm i's investment is modelled as an increasing function of both unobserved productivity and log-capital, $k_{it} \equiv \ln K_{it}$. Following previous work (Van Biesebroeck, 2005; Amiti and Konings, 2007), the Olley–Pakes approach is revised (equation 4 below) by adding the firm's export decision as an extra argument of the investment function, since most of the firms' export decisions are determined in the previous period (Tybout, 2003).

$$I_{it} = \tilde{I}(\ln K_{it}, \upsilon_{it}, EF_{it}), \tag{4}$$

where EF_{it} is a dummy to measure whether firm i exports in year t. Therefore, the inverse function of (equation 4) is $\upsilon_{it} = \tilde{I}^{-1}(\ln K_{it}, I_{it}, EF_{it})$.[5] The unobserved productivity also

[5] Olley and Pakes (1996) show that the investment demand function is monotonically increasing in the productivity shock υ_{it}, by making some mild assumptions about the firm's production technology.

depends on log-capital and the firm's export decision. Accordingly, the estimation specification (equation 2) can now be written as:

$$\ln Y_{it} = \beta_0 + \beta_m \ln M_{it} + \beta_l \ln L_{it} + g(\ln K_{it},\ I_{it},\ EF_{it}) + \varepsilon_{it}, \tag{5}$$

where $g(\ln K_{it},\ I_{it},\ EF_{it})$ is defined as $\beta_k \ln K_{it} + \tilde{I}^{-1}(\ln K_{it},\ I_{it},\ EF_{it})$. Following Olley–Pakes (1996) and Amiti–Konings (2007), fourth-order polynomials are used in log-capital, log-investment and the firm's export dummy to approximate $g(\cdot)$.[6] In addition, since our firm data set is from 1998 to 2002, we include a WTO dummy (i.e. one for year after 2001 and zero for before) to characterise the function $g(\cdot)$ as follows:

$$g(K_{it}, I_{it}, EF_{it}, WTO_t) = (1 + \theta_{WTO} WTO_t + \theta_{EF} EF_{it}) \sum_{h=0}^{4} \sum_{q=0}^{4} \delta_{hq} k_{it}^h I_{it}^q. \tag{6}$$

After estimating the coefficients $\hat{\beta}_m$ and $\hat{\beta}_l$, we calculate the residual R_{it}, which is defined as $R_{it} \equiv \ln Y_{it} - \hat{\beta}_m \ln M_{it} - \hat{\beta}_l \ln L_{it}$.

The next step is to obtain an unbiased estimated coefficient of β_k. To correct the selection bias as mentioned above, Amiti–Konings (2007) suggested estimating a probability of a survival indicator on a high-order polynomial in log-capital and log-investment. Precisely, one can estimate the following specification:

$$R_{it} = \beta_k \ln K_{it} + \tilde{I}^{-1}(g_{i,t-1} - \beta_k \ln K_{i,t-1},\ \hat{pr}_{i,t-1}) + \varepsilon_{it}, \tag{7}$$

where $\hat{pr}_i$ denotes the fitted value for the probability of the firm's exit in the next year. Since the specific 'true' functional form of the inverse function $\tilde{I}^{-1}(\cdot)$ is unknown, it is appropriate to use fourth-order polynomials in $g_{i,t-1}$ and $\ln K_{i,t-1}$ to approximate that. In addition, equation (7) also requires the estimated coefficients of the log-capital in the first and second term to be identical. Therefore, non-linear least squares seem to be the most desirable econometric technique (Pavcnik, 2002; Arnold, 2005). Finally, the Olley–Pakes (OP) type of TFP for each industry j is obtained once the estimated coefficient β_k is obtained:

$$TFP_{ijt}^{OP} = \ln Y_{it} - \hat{\beta}_m \ln M_{it} - \hat{\beta}_k \ln K_{it} - \hat{\beta}_l \ln L_{it}. \tag{8}$$

b. Econometric Model

We estimate the equation as follows:

$$\ln TFP_{ijt}^{OP} = \alpha_0 + \alpha_1 \ln imp_{jt} + \alpha_2 EF_{it} + \alpha_3 (\ln imp_{jt} \times EF_{it}) + \alpha_4 exit_{it} + \theta X_{it} + \varpi_i + \eta_t + \mu_{ijt,}, \tag{9}$$

where $\ln TFP_{ijt}^{OP}$ is the logarithm of firm i's OP-type TFP in industry j in year t, whereas $\ln imp_{jt}$ denotes the logarithm of import penetration ratio for industry j in year t. EF_{it} is a dummy for exporting firm i. in year t, whereas $exit_{it}$ denotes a dummy for firm i's exit in year t.[7] X_{it} denotes other control variables for firm i in year t. such as FDI dummy and SOE dummy, and if so, whether it is controlled by the central government. The error term is

[6] Using a higher-order polynomials to approximate $g(\cdot)$ does not change the estimation results.
[7] The reason that we do not include a dummy for importing firm here is that our data set does not include information on importing firms.

decomposed into three components: (i) firm-specific fixed effects ϖ_i to control for time-invariant factors; (ii) year-specific fixed effects η_t to control for firm-invariant factors like Chinese *yuan* real appreciation; and (iii) an idiosyncratic effect μ_{ijt} with normal distribution $\mu_{ijt}\tilde{N}(0, \sigma_{ij}^2)$ to control for other unspecified factors.[8]

From equation (9), the import penetration ratio in industry j has two following effects on productivity of firm i. within industry j:

$$\partial \ln TFP_{ijt}^{OP} / \partial \ln imp_{jt} = \alpha_1 + \alpha_3 EF_{it}, \tag{10}$$

where parameter α_1 measures the impact of trade liberalisation, which is measured by industry j 's import penetration, on non-exporting firm i in that industry. In contrast, the effect of trade on an exporting firm's productivity is $\alpha_1 + \alpha_3$. Previous works, such as Levinsohn (1993) and Harrison (1994), emphasised that the high import penetration ratio, an indicator of trade liberalisation, made domestic firms face more intense competition from foreign firms. Therefore, it is reasonable to hypothesise that both α_1 and $\alpha_1 + \alpha_3$ are positive since tougher import competition would force both non-exporting and exporting firms to exert every effort to improve their efficiency for survival.

Moreover, the productivity of exporting firms is expected to increase less than those of non-exporting firms. Put another way, the coefficient α_3 is expected to be negative. This is possibly because more than half of exporting firms in China also import raw materials and parts from overseas, as was discussed in the previous section.[9] With trade liberalisation, processing exporting firms are now able to acquire raw materials and parts from foreign producers at relatively lower costs. They would still enjoy a large price-cost markup by their access to low-priced imports. Therefore, the processing exporting firms have less incentive to adopt up-to-date technology to improve their efficiency, given the fact that they do not face strong competition.

c. *Classification of Complex and Simple Goods*

We classify goods into complex and simple goods in line with Rauch (1999), and this classification method has also been used by previous research (Berkowitz et al., 2006; Ma et al., 2011). Our data set reports firm's industry according to the Harmonised System (HS) 10-digit industry codes. Based on a concordance table provided by the Statistical Office of the European Communities, we are able to link the HS code identified in the enterprise survey to the four-digit SITC code in the classification table provided by Rauch (1999). Rauch (1999) has two classification methods: liberal and conservative. We adopt the conservative method. Rauch (1999) classifies four-digit SITC industries into three categories: (i) goods that are traded on organised exchanges; (ii) goods that are reference-priced; and (iii) goods that are not traded on organised exchanges and do not have reference prices. We regard category (i) and (ii) as simple goods and category (iii) as complex goods.

[8] In this paper, we only include firm-level fixed effects and year-specific fixed effects. The province-level fixed effect is not included here since data on industry-level import penetrations and firm-level TFP do not uniquely match.

[9] Of course, some firms also import parts and raw materials from abroad but only sell their products in the domestic market. Such importing firms still face tough import competition for their final outputs in China and hence only enjoy reasonable markup from lower cost on raw materials. Put another way, such non-exporting firms still bear relatively large price pressure, compared to exporting firms.

4. DATA

The sample used in this paper comes from two large data sets. The first is a rich firm-level panel that covers more than 150,000 manufacturing firms per year for the years 1998–2002.[10] Such data were collected from China's National Bureau of Statistics (2007) as an annual survey for manufacturing enterprises. It covers more than 100 financial variables listed in the main accounting sheets of all SOEs, and those non-SOEs firms, whose sales are more than five million yuan per year.[11]

Table 1 provides some basic statistical information about the Chinese plant data. Although this data set contains rich information, a few samples in the data set are noisy and misleading due, in large part, to the misreporting by some firms (Holz, 2004). For example, data information for some family-based firms, which usually did not set up a formal accounting system, is based on a unit of 1,000, whereas the official requirement is a unit of 10,000. Following Jefferson et al. (2008), the observations were dropped if (i) the number of employees hired for a firm is less than eight people[12] and (ii) the ratio of value-added relative to the sales is less than zero or higher than one. As seen in Table 1, FDI-type firms[13] account for more than two-thirds of all plants in each year. In contrast, SOE-type firms account for around one-third.

The previous TFP literature suggests that output should also be measured in physical terms. Recent papers, such as Felipe et al. (2004), have emphasised the estimation bias of using monetary terms to measure output when estimating the production function. In that way, what one actually did is to estimate an accounting identity. To get a precise measure of TFP, one should work on physical data or, at least, deal with deflated terms of output. However, like the problems that many previous studies have encountered, the data on physical output are unavailable. We therefore deflate each firm's output following Amiti and Konings (2007). The statistical information is reported in Table 2.

Column (2) of Table 3 reports the estimated firm's survival probability in the next year by industry.[14] They varied from 0.97 to 0.99 with the mean of 0.978, which suggests that the firm exits are not so severe during this period. The rest of Table 3 presents the difference in the estimated coefficients for labour, materials and capital by using both the OP methodology and the usual OLS approach. A total of 39 manufacturing industries were covered and coded from 6 to 46 according to China's industrial classifications (GB/T4754-2002). Compared to OLS estimates, as seen from the bottom line of Table 3, the inputs' coefficients for all manufacturing industries estimated by the OP approach seem much lower. This suggests that, without controlling for simultaneity bias and selection bias, the estimated industrial TFP using the OLS approach has a downward bias, which could partially explain why some previous researchers did not find large productivity growth in China (Young, 2003).

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[10] Following Levinsohn and Petrin (2003), plants were treated as firms. In the present paper, I do not capture scope economics due to their multi-plant nature. This remains a topic for future research.

[11] Indeed, aggregated data of the industrial sector in the annual *China's Statistical Yearbook* by the Natural Bureau of Statistics is compiled from such a data set.

[12] Levinsohn and Petrin (2003) suggest covering all Chilean plants with at least 10 workers instead.

[13] Here a firm is classified as a FDI-type, one if it, by nature, belongs to one of the followings: (i) equity joint venture; (ii) wholly foreign-owned venture; (iii) contractual joint venture; or (iv) foreign-owned limited liability corporation.

[14] Noted that here 'firm's exit' means a firm either died and exited from the market or simply had an annual sale, which is lower than the 'large scale' (i.e. 5 million sales per year) and dropped from the data set. Due to the restriction of the data set, we are not able to distinguish the difference between the two.

TABLE 1
Basic Chinese Plants Data

Year	*1998*	*1999*	*2000*	*2001*	*2002*
Raw observations	154,882	154,882	162,883	169,031	140,741
Filtered observations	146,490	149,557	156,400	164,037	137,060
FDI firms	10,718	10,718	11,956	13,116	10,063
SOE firms	49,098	49,098	51,363	35,327	27,304

TABLE 2
Summary Statistics (1998–2002)

Variables	*Mean*	*Standard Deviation*	*Minimum*	*Maximum*
Year	2000	1.14	1999	2002
Log-Import Penetration Ratio	1.576	2.27	−8.41	11.62
Dummy of SOE	0.250	0.433	0	1
Dummy of central-control SOE	0.014	0.117	0	1
Dummy of Foreign-invested Enterprises	0.074	0.261	0	1
Log of Labour Productivity	2.21	3.08	−11.69	13.15
Log of total factor productivity (Olley–Pakes)	1.84	1.29	−8.51	8.14

Notes:
(i) Observations of output, materials and value-added are dropped from the data set if negative.
(ii) We obtain different real investment by allowing different depreciation rates (depre.), respectively.

As introduced above, we use import penetration ratio as an index to measure trade liberalisation since it captures the effects from both tariffs and NTBs.[15] Our import data are at the HS 10-digit level, which are from the General Administration of China's Customs. Although highly aggregated HS 2-digit import data are publicly available in various publications, such as *China Statistical Yearbook*, their disaggregated data are not. In this paper, we access HS 10-digit import data up to 2002.[16] To calculate industry j's import penetration ratio, the HS 10-digit imports (IM_h) up to HS 4-digit industrial level, $\sum_h IM_h^j$, were first aggregated. The firm's output, y_i, was simultaneously aggregated up to China's 2-digit sector classifications, $\sum_i y_i^j$. Finally, we obtained the industry j's import penetration ratio imp^j as $\sum_h IM_h^j / \sum_i y_i^j$ according to the concordance between HS 4-digit level and China's sector classifications two-digit level. For the readers' convenience, we report the industrial concordance in Table 4, in which only HS 2-digit level of the customs code is reported to save space.

Figure 1 shows the average magnitudes of both the import penetration ratio and the industrial-augmented OP-type TFP over 1998 to 2002. Although there are firm data for all industries, products for some industries are non-tradable, and hence, there are no matching data on imports. If the industrial data on either TFP or import penetration ratio are unavailable, such an industry is dropped from the sample since there is no way to investigate the effect of its

[15] Ideally, it would be a plus to use both tariffs and NTBs as alternative measures of trade liberalisation. Unfortunately, we are currently not able to access the data sets, although China's disaggregated tariff data in 2001 are accessible.
[16] An alternative source for such disaggregated data is the Center for International Data maintained by Robert Feenstra at the University of California-Davis.

TABLE 3
Total Factor Productivity of Chinese Plants

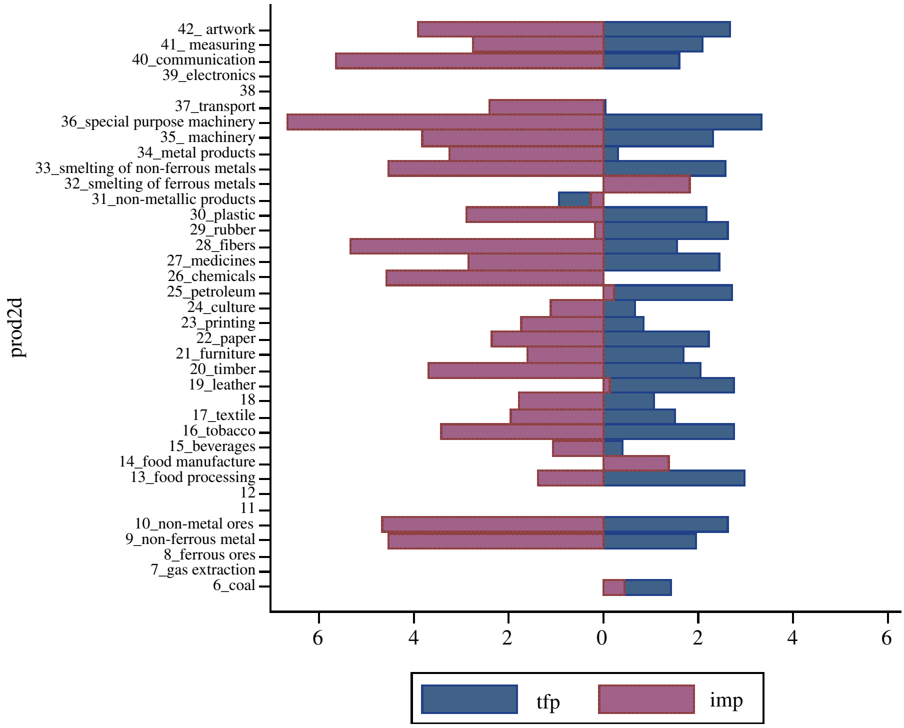
Industry (Code)	*Estimated Probability*	*Labour*		*Materials*		*Capital*	
		OLS	*OP*	*OLS*	*OP*	*OLS*	*OP*
Mining & washing of coal (6)	0.983	0.092	0.062	0.431	0.468	0.382	0.237
Extraction of petroleum & natural gas (7)	0.989	0.099	0.048	0.239	0.210	0.646	0.592
Mining & processing of ferrous metal ores (8)	0.984	0.125	0.087	0.466	0.442	0.299	0.184
Mining & processing of non-ferrous metal (9)	0.971	0.112	0.126	0.474	0.484	0.303	0.154
Mining & processing of non-metal ores (10)	0.982	0.131	0.106	0.473	0.494	0.213	0.109
Processing of food (13)	0.972	0.170	0.147	0.508	0.521	0.304	0.202
Manufacture of foods (14)	0.974	0.155	0.141	0.569	0.535	0.359	0.283
Manufacture of beverages (15)	0.975	0.150	0.124	0.463	0.476	0.410	0.264
Manufacture of tobacco (16)	0.970	0.076	0.078	0.214	0.224	0.777	0.510
Manufacture of textile (17)	0.983	0.137	0.120	0.341	0.345	0.296	0.228
Manufacture of apparel, footwear & caps (18)	0.988	0.132	0.104	0.294	0.287	0.296	0.276
Manufacture of leather, fur & feather (19)	0.982	0.139	0.107	0.371	0.385	0.265	0.212
Processing of timber, manufacture of wood, bamboo, rattan, palm & straw products (20)	0.983	0.148	0.109	0.457	0.453	0.238	0.141
Manufacture of furniture (21)	0.988	0.142	0.102	0.427	0.434	0.294	0.222
Manufacture of paper & paper products (22)	0.981	0.114	0.086	0.366	0.378	0.346	0.226
Printing, reproduction of recording media (23)	0.983	0.128	0.098	0.502	0.514	0.381	0.265
Manufacture of articles for culture, education & sport activities (24)	0.990	0.141	0.111	0.291	0.286	0.343	0.348
Processing of petroleum, coking & fuel (25)	0.979	0.109	0.084	0.343	0.295	0.469	0.350
Manufacture of raw chemical materials (26)	0.980	0.140	0.114	0.366	0.378	0.352	0.253
Manufacture of medicines (27)	0.986	0.119	0.090	0.359	0.342	0.404	0.285
Manufacture of chemical fibres (28)	0.975	0.155	0.099	0.301	0.279	0.371	0.309
Manufacture of rubber (29)	0.980	0.135	0.115	0.315	0.336	0.367	0.267
Manufacture of plastics (30)	0.985	0.120	0.106	0.360	0.352	0.350	0.268
Manufacture of non-metallic mineral goods (31)	0.981	0.111	0.095	0.389	0.395	0.334	0.207
Smelting & pressing of ferrous metals (32)	0.975	0.148	0.108	0.419	0.383	0.339	0.249
Smelting & pressing of non-ferrous metals (33)	0.981	0.133	0.099	0.369	0.332	0.319	0.246
Manufacture of metal products (34)	0.986	0.140	0.117	0.358	0.354	0.316	0.252
Manufacture of general purpose machinery (35)	0.985	0.159	0.109	0.423	0.401	0.203	0.190
Manufacture of special purpose machinery (36)	0.982	0.174	0.116	0.502	0.472	0.271	0.226
Manufacture of transport equipment (37)	0.985	0.133	0.102	0.414	0.415	0.377	0.309
Electrical machinery & equipment (39)	0.989	0.211	0.126	0.715	0.761	0.045	0.152
Manufacture of communication equipment, computers & other electronic equipment (40)	0.990	0.118	0.094	0.341	0.345	0.350	0.328
Manufacture of measuring instruments & machinery for cultural activity & office (41)	0.986	0.175	0.100	0.370	0.338	0.329	0.361
Manufacture of artwork (42)	0.987	0.202	0.111	0.708	0.466	0.185	0.208
Recycling & disposal of waste (43)	0.987	0.201	0.187	0.335	0.354	0.272	0.268
Electric power & heat power (44)	0.994	0.190	0.082	0.384	0.316	0.403	0.379
Production & supply of gas (45)	0.990	0.079	0.039	0.366	0.330	0.432	0.382
Production & supply of water (46)	0.998	0.069	0.049	0.324	0.299	0.523	0.221
All industries	0.978	0.150	0.097	0.439	0.406	0.307	0.214

Note:
(i) We do not report standard errors for each coefficient to save space, which are available upon request.

TABLE 4
Concordance of Products

Industry (Code)	*Harmonised System 2-Digit Customs Code*
Mining & washing of coal (6)	27
Extraction of petroleum & natural gas (7)	27
Mining & processing of ferrous metal ores (8)	26
Mining & processing of non-ferrous metal (9)	25, 26
Mining & processing of non-metal ores (10)	25, 71
Processing of food (13)	02, 03, 04, 07, 11, 15, 17, 20, 23
Manufacture of foods (14)	04, 17, 19, 21, 22, 23, 25, 76
Manufacture of beverages (15)	09, 20, 22
Manufacture of tobacco (16)	24
Manufacture of textile (17)	50, 51, 52, 53, 54, 56, 60
Manufacture of leather, fur & feather (19)	41, 42, 43, 64, 67
Processing of timber, manufacture of wood, bamboo, rattan, palm & straw products (20)	44, 45, 46
Manufacture of furniture (21)	94
Manufacture of paper & paper products (22)	48
Printing, reproduction of recording media (23)	49
Manufacture of articles for culture, education & sport activities (24)	32, 92, 95, 96
Processing of petroleum, coking, processing of nuclear fuel (25)	27
Manufacture of raw chemical materials & chemical products (26)	28, 29, 31, 32, 33, 34, 38, 39, 40, 54, 55
Manufacture of medicines (27)	30
Manufacture of chemical fibres (28)	47, 54, 55
Manufacture of rubber (29)	40, 64
Manufacture of plastics (30)	30, 39, 64
Manufacture of non-metallic mineral products (31)	13, 25, 68, 69, 70
Smelting & pressing of ferrous metals (32)	72
Smelting & pressing of non-ferrous metals (33)	28, 74, 75, 76, 78, 80, 81
Manufacture of metal products (34)	72, 76, 82, 83, 86
Manufacture of general purpose machinery (35)	84
Manufacture of special purpose machinery (36)	84
Manufacture of transport equipment (37)	86, 87, 88, 89
Electrical machinery & equipment (39)	85, 94
Manufacture of communication equipment, computers & other electronic equipment (40)	85
Manufacture of measuring instruments & machinery for cultural activity & office work (41)	90, 91
Manufacture of artwork (42)	96, 97
Recycling & disposal of waste (43)	
Electric power & heat power (44)	
Production & supply of gas (45)	27
Production & supply of water (46)	

FIGURE 1
Total factor productivity (TFP) and Import Penetration Ratio by Industry



Notes:
(i) This figure plots the average number of log-import penetration ratio and TFP by industry over 1998–2002. (ii) An industry with blank bar means that import penetration ratio or (and) TFP is (are) unavailable for such an industry in the data set. (iii) As seen from the figure above, for some industries such as the manufacture of foods (14) and smelting and pressing of ferrous metals (32), their magnitudes of TFP are much smaller than those of log-import impetration ratio.

trade liberalisation on its productivity. As a result, eight industries are dropped, and only 32 industries were covered in the data set.[17] Although most industries have both positive TFP and log of import penetration ratios, a few exceptions occur: industries like coal, foods, leather, petroleum and smelting and pressing of furious metals have negative log of import penetration ratios, which suggest that imports from these industries are less than sales. On the other hand, the manufacture of smelting and pressing of furious metals also suffers from a negative TFP. Yet, overall, Figure 1 suggests that an industrial import penetration ratio is positively associated with its TFP.

[17] The eight industries dropped include extraction of petroleum and natural gas, mining and processing of ferrous metal ores, mining of other ores, recycling and disposal of waste, electrical power and heat power, production and supply of electric power and heat power, production and supply of gas, and production and supply of water.

TABLE 5
Benchmark Estimation Results

Dependent Variable ($\ln TFP^{OP}_{ijt}$)	*(1)*	*(2)*	*(3)*
Import penetration ($\ln imp_{jt}$)	0.006**	0.006**	0.006**
	(2.23)	(2.19)	(211)
Exporting firm (EF_{it})	0.045**	0.044**	0.043**
	(6.03)	(5.98)	(5.88)
$\ln imp_{jt} \times EF_{it}$	−0.005**	−0.005**	−0.005**
	(−2.47)	(−2.46)	(−2.46)
Firm exit in next year		−0.209**	−0.209**
		(−2.83)	(−2.83)
SOE_{it}		−0.028	−0.038
		(−1.52)	(−1.43)
$(\text{SOE} \times \text{central-control})_{it}$			−0.099**
			(−4.09)
FDI_{it}		−0.007	−0.008
		(−0.62)	(−0.60)
(SOE $\times$ $\ln imp_{jt}$)			0.005
			(0.66)
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
R-squared	0.860	0.860	0.860

Notes:
(i) Following Amiti–Konings (2007), the depreciation rate is taken as 15 per cent to measure investment by using the perpetual inventory method. (ii) Dependent variables are logarithm of total factor productivity (TFP_{OP}). (iii) Robust *t*-values corrected for clustering at the firm level in parentheses. (iv) There are 175,764 observations for each estimate. (v) ** means significant at the 15 per cent level.

5. EMPIRICAL RESULTS

a. Main Estimation Results

Table 5 reports the estimation results for equation (9).[18] To consider the effect of the import penetration ratios on TFP, we first run a regression on TFP of import penetration ratio, a dummy for export firms, and their interaction term as a benchmark. The estimated coefficient of α_1 in equation (9) is 0.006, which is significant at the conventional statistical level. This suggests that strong trade liberalisation tends to result in high productivity gains. As discussed above, some firms could collapse and drop out next period due to bad operations or other reasons. Ignoring such behaviour would cause a selection bias problem. Therefore, the firms' dynamic behaviours were taken into account for the estimations in columns (2) and (3) by adding a variable to measure a firm's exit from the market in the next period. As shown in Table 5, firms that dropped out from the market have low productivity compared to those that did not.

After controlling for firm exits, column (2) shows that the effect of trade liberalisation on firm TFP is still positive and significant. In addition, the effect of trade liberalisation on

[18] In our estimation, we allow for different coefficients for *WTO* and *EF* dummy in equation (6), that is, the effect from accession to WTO is different with that of a firm being in the export market. We thank one anonymous referee for pointing this out.

a firm's productivity in exporting firms is smaller than in non-exporting firms, since the interaction term, $\ln imp_{jt} \times EF_{it}$, is significantly negative. Given that the mean of the variable of exporting firms is 0.49, the net elasticity of firm's TFP with respect to trade liberalisation for exporting firm is still positive (0.006 − 0.005 × 0.49 = 0.004). These results suggest that compared to non-exporting firms, exporting firms seem to enjoy few benefits from trade liberalisation than do non-exporting firms. One possible reason is that most of the exporting firms also import products from abroad. Instead of introducing tougher competition, trade liberalisation allows exporting firms to access raw materials at lower costs. Such exporting firms can still enjoy some profit margin without increasing their productivity. Put another way, trade liberalisation, to some extent, hampers their incentive to adopt up-to-date technology. An alternative explanation is that since exporting firms achieved TFP improvement at very early stage when they started to export and to face foreign competition, the exporting firms have relatively high TFP and there is not much room for the trade liberalisation to make further productivity improvement. On the other hand, non-exporting firms, ones with low TFP, have much room to improve their efficiency. They learn and benefit more from trade liberalisation. This would result in more significant effect for non-exporting firms.

In the absence of trade liberalisation, other channels, such as preferential taxation reduction, might affect an exporting firm's productivity. The parameter α_2 in equation (9) investigates the effects on the exporting firm's productivity from such channels.[19] It turns out that $\hat{\alpha}_2$ is significantly positive, which suggests that exporting firms are associated with higher productivity even in the absence of strong import penetration.

Previous work also suggests that SOEs have relative low productivity compared to non-SOEs due to their low efficiency and impotent incentive systems (Jefferson et al., 2000; Wu, 2005). Therefore, a dummy of SOEs as a controllable variable in column (2) is included. It turns out that the coefficient is negative but not significant. By definition, the SOEs are controlled by the government. However, the central government and the local government have different economic interests. For the purpose of self-promotion, the main objective of local government officials is to maximise gross local output (Wu, 2005). To do so, they are more likely to give incentives to SOEs, which, in turn, would lead to greater productivity and profits. As predicted, the interaction term between SOEs and the central-controlled dummy of column (3) is shown to be significantly negative. In addition, SOEs may have more connection with the government than non-SOE firms and thus have more channels to bypass trade restrictions before trade liberalisation. Hence, the differential effect of trade liberalisation may be different for these various types of firms. A similar argument is stated in Chan et al. (2012) for financial liberalisation. To examine this potential effect, an interaction term of import penetration ratio and SOE is added to the regression (column 3 of Table 5). There is no significant effect identified, and adding this term does not change the benchmark results.[20]

Finally, foreign-owned enterprises are expected to have high productivity due to their quick learning, better technology adoption or higher quality inputs (Amiti and Konings,

[19] Mathematically, the parameter α_2 equals the partial derivative of log TFP with respect to the *EF* variable: $\partial \ln TFP_{ijt} / \partial EF_{it}$.

[20] We include the interaction term of import penetration ratio and SOE in other regressions (as reported in Tables 6–11). The coefficient on this term is generally insignificant, and the main estimation results are robust. We thank one anonymous referee for making this suggestion.

2007). The FDI is included in columns (2) and (3). However, the coefficient estimates are insignificant.

b. Complex Goods Versus Simple Goods

In this subsection, we re-estimate equation (9) for complex and simple goods separately. The results are reported in Tables 6 and 7, respectively. Similar to the regression results reported in Table 5, in the regressions with complex goods (Table 6), the coefficients of the import penetration are all positive and statistically significant (at the 5 per cent level). The coefficient estimates of other variables are also quite similar to those of the full sample regressions reported in Table 5.

Turning to simple goods estimation, the coefficient of import penetration turns negative and is statistically significant, while the coefficients of the other variables are insignificant (Table 7). This is probably because a higher degree of import penetration has two opposite effects on firm productivity. First, a high level of import penetration means that these firms face great competition from abroad and their operating performance may decline. As a result, these firms have less resources to invest in technology improvement. Second, more trade may bring in newer and more differentiated products with more advanced technology. This may create learning opportunities for domestic firms and induce them to enhance their productivity to meet the foreign competition. Since complex goods are highly differentiated products, the

TABLE 6
Benchmark Estimation Results (Complex Goods)

Dependent Variable ($\ln TFP^{OP}_{ijt}$)	*(1)*	*(2)*	*(3)*
Import penetration ($\ln imp_{jt}$)	0.007**	0.007**	0.006**
	(2.36)	(2.33)	(2.20)
Exporting firm (EF_{it})	0.045**	0.045**	0.044**
	(6.15)	(6.10)	(6.00)
$\ln imp_{jt} \times EF_{it}$	−0.006**	−0.006**	−0.005**
	(−2.66)	(−2.65)	(−2.66)
Firm exit in next year		−0.210**	−0.210**
		(−2.81)	(−2.81)
SOE_{it}		−0.026	−0.039
		(−1.39)	(−1.47)
$(\mathrm{SOE} \times \text{central-control})_{it}$			−0.100**
			(−4.13)
FDI_{it}		−0.008	−0.008
		(−0.62)	(−0.60)
$(\mathrm{SOE} \times \ln imp_{jt})$			0.0066
			(0.85)
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
R-squared	0.860	0.860	0.860

Notes:
(i) Following Amiti–Konings (2007), the depreciation rate is taken as 15 per cent to measure investment by using the perpetual inventory method. (ii) Dependent variables are logarithm of total factor productivity (TFP_{OP}). (iii) Robust *t*-values corrected for clustering at the firm level in parentheses. (iv) There are 175,141 observations for each estimate.
(v) ** means significant at the 5 per cent level.

TABLE 7
Benchmark Estimation Results (Simple Goods)

Dependent Variable ($\ln TFP_{ijt}^{OP}$)	*(1)*	*(2)*	*(3)*
Import penetration ($\ln imp_{jt}$)	−12.400**	−12.272**	−11.872**
	(−4.30)	(−4.22)	(−4.00)
Exporting firm (EF_{it})	4.502	5.806	6.293
	(0.65)	(0.82)	(0.86)
$\ln imp_{jt} \times EF_{it}$	−0.824	−1.076	−1.167
	(−0.64)	(−0.81)	(−0.86)
Firm exit in next year		−0.429	−0.403
		(−0.90)	(−0.81)
SOE_{it}		−0.535	2.81
		(−1.18)	(0.73)
FDI_{it}		−0.051	−0.099
		(−0.41)	(−0.76)
Time	1.670**	1.665**	1.649**
	(5.99)	(5.92)	(5.71)
(SOE $\times \ln imp_{jt}$)			−0.64
			(−0.88)
Firm fixed effects	Yes	Yes	Yes
R-squared	0.780	0.784	0.786

Notes:
(i) Following Amiti–Konings (2007), the depreciation rate is taken as 15 per cent to measure investment by using the perpetual inventory method. (ii) Dependent variables are logarithm of total factor productivity (TFP_{OP}). (iii) Robust t-values corrected for clustering at the firm level in parentheses. (iv) (SOE $\times$ central-control)$_{it}$ is dropped because there are no centrally controlled SOEs in this sample. (v) The time fixed effects are replaced with time variable due to multi-collinearity. (vi) There are 623 observations for each estimate.
(vii) ** means significant at the 5 per cent level.

increased degree of trade liberalisation encourages firms to engage in more innovative activities to develop more differentiated products. The higher degree of product differentiation also shields the domestic firms from the first (negative) effect of important penetration to some degree. However, for firms that produce simple goods, the first effect on productivity is stronger and it is relatively difficult to develop differentiated products due to the high degree of product homogeneity. Therefore, the effect of import penetration on firm productivity (the coefficient of $\ln imp_{jt}$) is different in the sample of complex goods with that of the simple goods.

Since our empirical findings suggest that the improvement in firm productivity induced by trade liberalisation is primarily driven by firms that produce complex goods, in the further econometric work that follows, we only include firms that produce complex goods in the sample, which is actually the majority of the full sample.

c. *Choices of Depreciation Rates*

An essential component in the calculation of the Olley–Pakes's TFP variable is to obtain data on investment, which is usually calculated by adopting the perpetual inventory method as follows:

$$I_{it} = K_{it} - (1 - \delta)K_{it-1}, \tag{11}$$

where I_{it}, K_{it} denotes investment and fixed capital in year t for firm i, respectively.[21] The parameter δ denotes a common depreciation rate across firms and years given that China did not change its depreciation rate over 1998–2002.[22]

The only problem left to calculate investment is the appropriate value for the depreciation rate. As recommended by Perkins (1988) and Wang and Yao (2003), a 5 per cent depreciation rate is a good choice, since this number is adopted to calculate SOEs' depreciation in *China's Statistical Yearbook*. However, some other researchers have different views on this number. Liang (2006) suspected that the number should be 4 per cent instead. Amiti and Konings (2007) adopted 15 per cent for Indonesia, another large developing country. China, indeed, may adopt a number up to 16 per cent as its depreciation rate in some years in the 1990s (Wang and Yao, 2003). Therefore, the depreciation rate is allowed to show its flexibility to form the firm's investment level. Following Amiti and Konings (2007), 15 per cent is adopted as a default number, but performed the robustness check by using 10, 5 and 4 per cent as alternative depreciation rates. As seen in Table 8, the estimation results are robust to using different depreciation rates.

d. Specifications of Periodic Differences

To reduce estimation bias caused by unobserved firm heterogeneity, estimations in Tables 5–8 control for the firm-specific and year-specific fixed effects by adopting the firm annual level data. However, some unobserved factors would change according to firms and the relevant year. One possible example is that taxation reduction policies in SEZs vary by year, affecting the productivity of firms based in these zones. The regular two-way fixed effects seem not be able to fully control for this omitted-variable problem.

To address this empirical challenge, alternative econometric specifications with data on periodic differences were considered and are reported in Table 9. Since the samples cover 1999–2002, several specifications from one to three periodic difference(s) were considered.[23] The periodic differences in import penetration ratio and the exporting firm's dummy have expected positive signs, which are consistent with the findings in Tables 5–8. However, the coefficients of the interaction term of the import penetration ratio and the dummy for exporting firms become insignificant and those of the SOE dummies are significantly positive in one (two) periodic difference(s) estimates, which seems inconsistent with the estimates of the three periodic differences, as well as the previous findings in Table 5. Since most measurement errors and possible serial correlations are controlled by the fixed-effect econometric

[21] Another way to form investment data is to use information on net physical capital by adopting the formula $I_{it} = K_{it} - NK_{it-1}$ where NK_{it-1} is firm i's net fixed assets in year $t-1$. Since only data on net physical capital for years 2000–02 were accessed, the main estimations on raw physical capital data use such expression (depreciation).

[22] Another assumption of Olley–Pakes approach is that a productivity shock should be increasing monotonically with investment conditional predetermined capital. The investment proxy is only valid for firms reporting non-zero investment. To avoid this possible challenge, the Levinsohn–Petrin (2003) approach is a useful alternative to calculate TFP. However, the Levinsohn–Petrin type TFP is found to be similar to the OP type TFP in my data set, which are not reported here to save space, although available upon request.

[23] Although the data covers the years 1998–2002, to calculate the investment, one needs to use one-year lag data. Accordingly, only the data for the years 1999–2002 are covered in the estimations.

TABLE 8
Alternative Investment Measures

Dependant Variable $\ln(TFP_{ijt}OP)$	*(1)* *Depreciation Rate (15%)*	*(2)* *Depreciation Rate (10%)*	*(3)* *Depreciation Rate (5%)*	*(4)* *Depreciation Rate (4%)*
Import penetration ($\ln imp_{jt}$)	0.006**	0.007**	0.007**	0.005**
	(2.21)	(2.19)	(2.19)	(1.94)
Exporting firm (EF_{it})	0.043**	0.046**	0.046**	0.049**
	(5.86)	(6.21)	(6.21)	(7.22)
$\ln imp_{jt} \times EF_{it}$	−0.005**	−0.005**	−0.005**	−0.004**
	(−2.45)	(−2.23)	(−2.23)	(−2.07)
Firm exit in next year	−0.209**	−0.226**	−0.226**	−0.169**
	(−2.83)	(−2.93)	(−2.93)	(−2.50)
SOE_{it}	−0.026	−0.038	−0.038	−0.049*
	(−1.38)	(−1.45)	(−1.45)	(−1.77)
$(\text{SOE} \times \text{central-control})_{it}$	−0.099**	−0.089**	−0.089**	−0.088**
	(−4.07)	(−3.59)	(−3.59)	(−3.49)
FDI_{it}	−0.008	−0.019	−0.019	−0.014
	(−0.60)	(−1.16)	(−1.17)	(−1.13)
($\text{SOE} \times \ln imp_{jt}$)		0.008	0.008	0.083
		(0.98)	(0.98)	(0.95)
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	175,764	175,046	175,047	175,764
R-squared	0.860	0.857	0.858	0.864

Notes:
(i) Depreciation rate *n* per cent means taking a *n* per cent depreciation rate to measure investment by using perpetual inventory method (*n* takes 15, 10, 4 and 5, respectively). (ii) Robust *t*-values corrected for clustering at the firm level in parentheses.
(iii) *(**) Means significant at the 10(5) per cent level.

method, there is suspicion that such inconsistency mainly comes from reverse causality, which will be addressed shortly.

e. Endogeneity

Trade liberalisation is not exogenously given, but affected by firm productivity. With better performance, some firms have stronger incentive to expand their economic scale, which, in turn, requires more inputs from the international market. The strong demand from firms leads to a greater import penetration ratio for each industry. One needs to control for the endogeneity of trade liberalisation in order to obtain accurate estimated effects of trade liberalisation on TFP. The instrumental variable (IV) estimation is a powerful econometric method that can address this problem (Wooldridge, 2002).

In the paper, provincial government savings is chosen as the instrument for import penetration. The economic rationale is as follows. As many economists like Krugman (1998) emphasised, trade deficit means, in essence, government deficit. To reduce the sizable government deficit, the government usually appreciates its currency to generate more trade deficit. With a greater trade deficit, the government can finance government deficits from

TABLE 9
Alternative Econometric Specifications

Dependant Variable $\ln(TFP_{ijt}^{OP})$	*1-Period Difference*		*2-Period Difference*		*3-Period Difference*	
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
$\Delta \ln imp_{jt}$	0.004	0.004	0.001	0.001	0.007**	0.007**
	(1.39)	(1.57)	(1.35)	(0.51)	(2.17)	(2.20)
ΔEF_{it}	0.039**	0.039**	0.022**	0.024**	0.009	0.011*
	(7.64)	(7.86)	(4.66)	(4.89)	(1.37)	(1.66)
$\Delta(\ln imp_{jt} \times EF_{it})$	0.001	0.001	0.001	0.001	−0.001	−0.000
	0.14	(0.27)	(0.12)	(0.25)	(−0.17)	(−0.05)
Firm exit in next year	−0.151**	−0.153**	−0.274**	−0.312**	−0.305**	−0.299**
	(−3.12)	(−3.16)	(−2.91)	(−3.33)	(−3.82)	(−3.74)
$\triangle \text{SOE}_{it}$	0.135**	0.135**	0.123**	0.100**	−0.181**	−0.187**
	(3.44)	(3.46)	(2.87)	(2.32)	(−2.04)	(−2.12)
$\triangle$(SOE	0.085**	0.082**	0.150**	0.123**	−0.149*	−0.156*
$\times$ central-control)$_{it}$	(4.05)	(3.95)	(3.97)	(3.30)	(−1.66)	(−1.75)
$\triangle \text{FDI}_{it}$	−0.006	−0.005	−0.003	−0.002	−0.023*	−0.023*
	(−0.49)	(−0.43)	(−0.34)	(−0.25)	(−1.70)	(−1.68)
(SOE $\times \ln imp_{jt}$)	0.03	−0.028	−0.036*	−0.038**	−0.018	−0.017
	(1.17)	(1.1)	(−1.92)	(−2.02)	(−1.06)	(−1.01)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	No	Yes	No	Yes	No
Province $\times$ year fixed effects	No	Yes	No	Yes	No	Yes
Observations	87,336	87,336	44,116	44,116	17,007	17,007
R-squared	0.700	0.705	0.604	0.613	0.006	0.009

Notes:
(i) ΔImp_{it} denotes *n*-period difference for import penetration (n = 1–3). Similarly, ΔFX_{it}, ($\Delta(\ln imp_{ijt} \times EF_{it})\Delta$ SOE$_{it}$, $\triangle$(SOE $\times$ Central-Control)$_{it}$, $\triangle$FDI$_{it}$) denotes *n*-period difference for dummy of exporting firm (interaction term of import penetration and exporting firm's dummy, dummy of state-owned enterprises (SOE), whether the SOE is directly controlled by the central government and foreign direct investment, respectively). (ii) Robust *t*-values corrected for clustering at the firm level in parentheses.
(iii) *(**) Means significant at the 10(5) per cent level.

foreigners. Put another way, more government savings tends to lower trade deficits. Given that other factors remain constant, an incremental amount of government savings is correlated with lower import penetration.

Several tests were performed to verify the quality of the instrument. First, Anderson's canonical correlation likelihood-ratio test is conducted to check whether or not the excluded instrument (i.e. government savings) is correlated with the endogenous regressors (i.e. import penetration ratio). The null hypothesis that the model is under-identified is rejected at the 1 per cent level. Second, we also take another step to see whether or not government savings is weakly correlated with import penetration. If so, then the estimates will perform poorly in this IV estimate. Luckily enough, the Cragg and Donald *F*-statistics provide strong evidence to reject the null hypothesis that the first stage is weakly identified at a highly significant level. Third, the Anderson and Rubin χ^2 statistics reject the null hypothesis that the coefficient of the endogenous regressor is equal to zero. In short, such statistical tests give sufficient evidence that the instrument is well performed, and therefore, the specification is well justified.

Estimates in Table 10 show that, after controlling for endogeneity, trade liberalisation still has a positive effect on a firm's productivity. In all estimations, the coefficients $\hat{\alpha}_1^{IV}$ are quite stable

TABLE 10
Estimates with Controlling for Endogeneity

Dependant Variable ln(TFP^{OP}_{ijt})	*(1)*	*(2)*	*(3)*	*(4)*
$\ln imp_{jt}$	0.433**	0.231**	0.199**	0.226**
	(4.07)	(2.97)	(2.77)	(2.89)
EF_{it}	0.714**	0.399**	0.355**	0.371**
	(4.48)	(3.43)	(3.29)	(3.42)
$\ln imp_{jt} \times EF_{it}$	−0.268**	−0.142**	−0.123**	−0.130**
	(−4.11)	(−2.98)	(−2.78)	(−2.93)
Firm exit in next year	−0.140**	−0.158**	−0.166**	−0.166**
	(−3.15)	(−4.69)	(−5.15)	(−5.14)
SOE_{it}		−0.445**	−0.450**	−0.201**
		(−45.20)	(−46.08)	(−2.22)
(SOE × central-control)$_{it}$			0.098**	0.108**
			(5.18)	(5.15)
FDI_{it}	0.132**	0.061**		0.062**
	(7.59)	(4.86)		(4.80)
(SOE × $\ln imp_{jt}$)				−0.101**
				(−2.56)
Firm-specific fixed effects	Yes	Yes	Yes	Yes
year-specific fixed effects	Yes	Yes	Yes	Yes
F-statistic	2,637.36	4,410.60	4,738.37	3,620.934
Anderson likelihood-ratio χ^2 statistic	30.27	32.70	35.62	33.67
Cragg–Donald χ^2 statistic	30.28	32.72	35.64	33.69
Anderson–Rubin χ^2 statistic	36.49	12.01	9.70	11.12
Probability > *F* or probability > χ^2	0.000	0.000	0.000	0.000
R-squared	0.384	0.200	0.255	0.219

Notes:
(i) The logarithm of import penetration ratio ($\ln imp_{jt}$) is taken as an endogenous variable whose instrument is government saving at province *j* in year *t*. (ii) There are 137,312 observations in each estimation. (iii) Robust *t*-values corrected for clustering at the firm level in parentheses. (iv) All the test statistics are significant at 1 per cent level. (v) The Hansen over-identification test is included but not reported here since the estimation is exactly identified.
(vi) ** means significance at the 5 per cent level.

and much higher than its counterparts $\hat{\alpha}_1$ without controlling for the endogeneity shown in Table 5. The interaction term of the import penetration ratio and the exporting firm dummy, $\hat{\alpha}_3^{IV}$, is still significantly negative, which is consistent with previous findings. This implies that the implicit negative reverse causality undercuts the effect of trade liberalisation on firm productivity.

f. Alternative Measure of Firm Productivity

As discussed above, the augmented Olley–Pakes approach to calculate the TFP is able to deal with both the simultaneity bias and selection bias. The approach is based on an assumption that capital is more aggressively responsive to the unobserved productivity shock compared with labour. Put another way, labour input here is assumed to be exogenous to the productivity shock. However, China is a labour-abundant country, and hence, labour costs are relatively low. When facing a productivity shock, China's firms are more likely to adjust their labour input to reoptimise their production behaviour. This is consistent with the idea suggested by papers such as Blomström and Kokko (1996) that labour would embody more productivity improvements than capital.

TABLE 11
More Estimation Results Using Labour Productivity

Dependent Variable ($\ln TFP_{ijt}^{BB}$)	*(1)*	*(2)*	*(3)*	*(4)*
Import penetration ($\ln imp_{jt}$)	0.025**	0.025**	0.025**	0.022**
	(2.72)	(2.72)	(2.71)	(2.37)
Exporting firm (EF_{it})	0.437**	0.437**	0.442**	0.443**
	(24.81)	(24.87)	(25.20)	(25.23)
$\ln imp_{jt} \times EF_{it}$	−0.002	−0.002	−0.002	−0.002
	−0.37	(−0.33)	(0.36)	(0.39)
Firm exit in next year	−1.303**	−1.301**	−1.299**	−1.301**
	(−13.98)	(−13.95)	(−13.93)	(−13.94)
SOE_{it}		−0.302**	−0.315**	−0.372**
		(−6.64)	(−6.92)	(−5.70)
$(\text{SOE} \times \text{central-control})_{it}$			0.532**	0.530**
			(7.45)	(7.43)
FDI_{it}				0.038
				(0.88)
(SOE $\times \ln imp_{jt}$				0.024
				(1.28)
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
R-squared	0.959	0.959	0.959	0.959

Notes:
(i) Dependent variable $\ln TFP_{ijt}^{BB}$ is a logarithm of TFP, which is calculated by using the Blundell and Bond (1998) approach. (ii) Robust *t*-values corrected for clustering at the firm level in parentheses.
(iii) ** means significant at the 5 per cent level.

Table 11 reports the estimated effects of trade liberalisation on labour productivity. The key coefficients $\hat{\alpha}_1$, $\hat{\alpha}_2$, and $\hat{\alpha}_3$ are highly close to those estimated by the augmented Olley–Pakes approach as shown in Table 5. Both exporting and non-exporting firms benefit from trade liberalisation, although exporting benefit less. The negative significant coefficient of $\hat{\alpha}_4$ also suggests that firms that exit from the market are those with low productivity. SOEs firms have lower productivity than those non-SOEs. The only striking finding of Table 11 is that those SOEs controlled by the central government seem to have higher productivity than those controlled by the local governments. Generally speaking, the estimation results are robust to different ways of calculating a firm's productivity.

6. CONCLUDING REMARKS

In this paper, we estimate the effect of trade liberalisation on firm productivity by using Chinese plant-level data. After controlling for firms' exits and the endogeneity of trade liberalisation, the effect of trade liberalisation on firm productivity is significantly positive. More interestingly, we find that the improvement in firm productivity induced by trade liberalisation is primarily driven by firms that produce complex goods, and the effect on simple goods producers is the opposite. One implication of these empirical findings is that gradually resources will move out of simple goods production and into complex goods production as a result of higher degree of trade liberalisation in China.

Furthermore, we find that the effect on exporting firms is smaller than on non-exporting firms. Such a finding is consistent with the stylised fact that the processing export is still dominant in China's trade pattern today. It is worthwhile pointing out that although exporting firms benefit less from trade liberalisation in terms of productivity improvement compared to non-exporting firms, exporting firms show a positive increase in productivity. In this sense, the finding of this paper is in line with previous studies, like those of Bernard and Jensen (1999), who showed that good firms export in the US because they have high productivity. However, this result is not necessarily applicable for China since China's economic reform, to some extent, is unique. In any case, whether or not good firms lead to exports in China is a possible future research topic.

REFERENCES

Amiti, M. and J. Konings (2007), 'Trade Liberalisation, Intermediate Inputs, and Productivity: Evidence from Indonesia', *American Economic Review*, **97**, 5, 1611–38.

Arnold, J. M. (2005), 'Productivity Estimation at the Plant Level: A Practical Guide', mimeo (Milan: Bocconi University).

Berkowitz, D. and J. Moenius (2011), 'Law, Trade, and Development', *Journal of Development Economics*, **96**, 2, 451–60.

Berkowitz, D., J. Moenius and K. Pistor (2006), 'Trade, Law, and Product Complexity', *Review of Economics and Statistics*, **88**, 2, 363–73.

Bernard, A. and B. Jensen (1999), 'Exceptional Exporter Performance: Cause, Effect, or Both?', *Journal of International Economics*, **47**, 1, 1–25.

Blomström, M. and A. Kokko (1996), 'The Impact of Foreign Investment on Host Countries: A Review of the Empirical Evidence', Policy Research Working Paper, No. 1745 (Washington, DC: World Bank).

Blundell, R. and S. Bond (1998), 'Initial Conditions and Moment Restrictions in Dynamic Panel Data Models', *Journal of Econometrics*, **87**, 1, 11–143.

Chan, K. S., V. Q. T. Dang and I. K. M. Yan (2012), 'Financial Liberalisation and Financing Constraints: Some Evidence from Panel Data of Listed Chinese Firms', *China Economic Review*, **23**, 2, 482–97.

China's National Bureau of Statistics (2007), *China Statistical Yearbook* (Beijing: China Statistics Press).

Felipe, J., R. Hasan and J. S. L. McCombie (2004), 'Correcting for Biases When Estimating Production Functions: An Illusion of the Laws of Algebra?', CAMA Working Paper Series, No. 14 (Canberra: Australia National University).

Fujii, T. and M. Ando (2000), 'Quantifying the Economic Impact of Removing Non-Tariff Measures: Tariff Equivalent Approach', mimeo (GTAP at Purdue University, West Lafayette.).

Harrison, A. (1994), 'Productivity, Imperfect Competition and Trade Reform', *Journal of International Economics*, **36**, 1–2, 53–73.

Head, K. and J. Ries (1999), 'Rationalisation Effects of Tariff Reduction', *Journal of International Economics*, **47**, 2, 295–320.

Holz, C. (2004), 'China's Statistical System in Transition: Challenges, Data Problems, and Institutional Innovations', *Review of Income and Wealth*, **50**, 3, 381–409.

Jefferson, G., T. Rawski, W. Li and Y. Zheng (2000), 'Ownership, Productivity Change, and Financial Performance in Chinese Industry', *Journal of Comparative Economics*, **28**, 4, 786–813.

Jefferson, G., T. Rawski and Y. Zhang (2008), 'Productivity Growth and Convergence across China's Industrial Economy', *China Economic Quarterly*, **7**, 3, 809–26 (in Chinese).

Krugman, P. (1994), 'The Myth of Asia's Miracle', *Foreign Affairs*, **73**, 6, 62–78.

Krugman, P. (1998), *The Age of Diminished Expectations* (Cambridge, MA: The MIT Press).

Levinsohn, J. (1993), 'Testing the Imports-as-Market-Discipline Hypothesis', *Journal of International Economics*, **35**, 1, 1–22.

Levinsohn, J. and A. Petrin (2003), 'Estimating Production Functions Using Inputs to Control for Unobservable', *Review of Economic Studies*, **70**, 2, 317–41.
Liang, H. (2006), China's Investment Strength is Sustainable, Global Economic Paper, No. 146 (Beijing: Goldman Sachs).
Ma, Y., B. Qu and Y. Zhang (2011), 'Complex Goods Exports and Institutions: Empirics at the Firm Level', *Review of International Economics*, **20**, 4, 841–53.
Marschak, J. and W. Andrews (1944), 'Random Simultaneous Equations and the Theory of Production', *Econometrica*, **12**, 4, 143–205.
Naughton, B. (2006), *The Chinese Economy: Transition and Growth* (Cambridge, MA: MIT press).
Olley, S. and A. Pakes (1996), 'The Dynamics of Productivity in the Telecommunications Equipment Industry', *Econometrica*, **64**, 6, 1263–97.
Pavcnik, N. (2002), 'Trade Liberalisation, Exit, and Productivity Improvements: Evidence from Chilean Plants', *Review of Economic Studies*, **69**, 1, 245–76.
Perkins, D. (1988), 'Reforming China's Economic System', *Journal of Economic Literature*, **26**, 2, 601–45.
Rauch, J. (1999), 'Networks versus Market in International Trade', *Journal of International Economics*, **48**, 1, 7–35.
Trefler, D. (2004), 'The Long and Short of the Canada–US Free Trade Agreement', *American Economic Review*, **94**, 3, 870–95.
Tybout, J. (2003), 'Plant and Firm-Level Evidence on "New" Trade Theories', in J. Harrigan and K. Choi (eds.), *Handbook of International Trade* (New York: Blackwell Publishing Ltd), 388–415.
Tybout, J., J. de Melo and V. Corbo (1991), 'The Effects of Trade Reforms on Scale and Technical Efficiency: New Evidence from Chile', *Journal of International Economics*, **31**, 3, 231–50.
Van Biesebroeck, J. (2005), 'Exporting Raises Productivity in Sub-Saharan African Manufacturing Firms', *Journal of International Economics*, **67**, 2, 373–91.
Wang, Y. and Y. Yao (2003), 'Sources of China's Economic Growth 1952–1999: Incorporating Human Capital Accumulation', *China Economic Review*, **14**, 1, 32–52.
Wooldridge, J. M. (2002), *Econometric Analysis of Cross Section and Panel Data* (Cambridge, MA: MIT Press).
World Bank (2007), *The World Development Indicator (WDI) CD-ROM* (Washington, DC: World Bank).
Wu, J. (2005), *Understanding and Interpreting Chinese Economic Reform* (Mason, OH: Thomson).
Young, A. (2003), 'Gold into Base Metals: Productivity Growth in the People's Republic of China during the Reform Period', *Journal of Political Economy*, **111**, 6, 1220–61.
Zheng, J., A. Bigsten and A. Hu (2009), 'Can China's Growth be Sustained? A Productivity Perspective', *World Development*, **37**, 4, 874–88.