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† National School of Development, Peking University, No.5 YiHeYuan Road, Haidian District, Beijing 100871, China. Email: jcao2019@nsd.pku.edu.cn

‡ School of Economics, Peking University, No.5 YiHeYuan Road, Haidian District, Beijing 100871, China. Tel: 010-62750331. Email: weitianpku@163.com

§ Corresponding author. China Center for Economic Research (CCER), National School of Development, Peking University, No.5 YiHeYuan Road, Haidian District, Beijing 100871, China. Tel: 010-62753109. Email: mjyu@nsd.pku.edu.cn

1. Introduction

Productivity reflects a firm's production technology and efficiency and plays an important role in the firm's product quality. The existing theoretical literature generally finds that high-productivity firms produce high-quality products (Hallak & Sivadasan, 2009; Johnson, 2012), and this is widely supported empirically (Kugler & Verhoogen, 2012; Manova & Zhang, 2012).

However, this wisdom does not necessarily hold in China. Take Foxconn (an exclusive iPhone assembler in China) as an example. Its main business is to import iPhone components from the United States, Japan, and South Korea, then process and assemble them in China, and finally export all the finished products back to the United States and other markets. It is well known that the quality of the iPhone is very high. However, Foxconn's value added is small, accounting for less than 4% of iPhone profits, which implies that the productivity of Foxconn is relatively low.[1] Therefore, low-productivity firms can also produce high-quality products. This anomaly challenges the traditional theory.

This observation can be illustrated explicitly in Figure 1. Taking unit value of a product as a simple index to reflect its intrinsic quality (Hallak, 2006; Kugler & Verhoogen, 2012; Manova & Zhang, 2012), Figure 1 shows the average unit value of all Chinese exports from 2000 to 2007, as well as those of processing exports and ordinary exports. The average unit value of Chinese exports declined for three consecutive years after 2000, because a large number of new entrants in the export market after China's WTO accession in 2001. Compared with incumbent firms, new entrants have lower productivity, export lower quality products, and adopt the low-price strategy to compete in the international market, thus lowering the overall quality and price of Chinese exports. Since 2003, the average unit value of Chinese exports has risen steadily, reflecting the upgrading of Chinese export quality. The average unit value of processing exports is always higher than that of ordinary exports, implying that the average export quality of processing firms may be very different from that of ordinary firms, which inspires our following study.

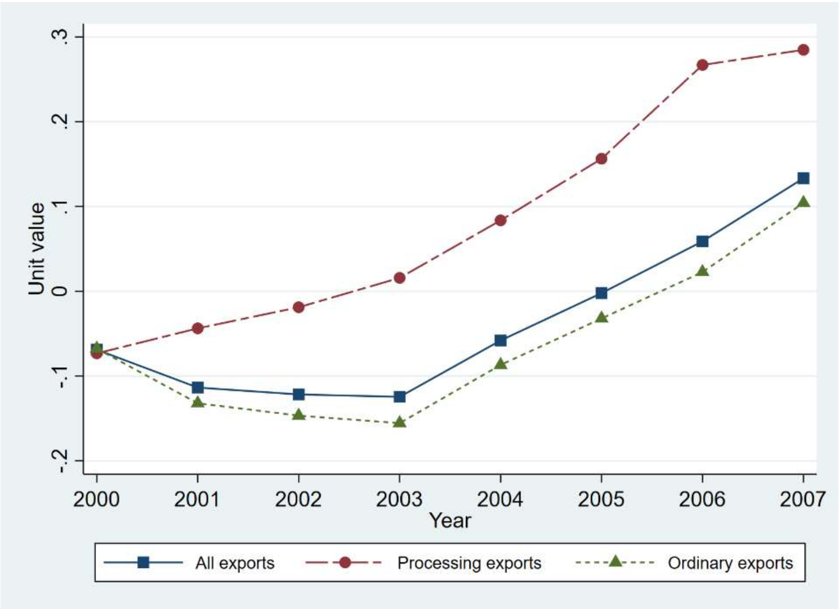

Figure 1 Average Unit Value of Chinese Exports from 2000 to 2007

Note: Unit values are in logarithm. We first regress unit values on HS6-country fixed effects, and then average the residuals for each year.

1 According to China's Ministry of Commerce, China accounts for less than 4% of iPhone profits (https://www.chinanews.com.cn/gn/2013/07-17/5052692.shtml, 2013-07-17).

Using the matched data of Chinese manufacturing firms and highly disaggregated product-level trade transaction data from 2000 to 2007, this paper investigates the relationship between firm productivity and firm quality. It finds no significant positive correlation between firm productivity and export quality, particularly in Chinese capital-intensive sectors. This finding is robust even when the analysis addresses possible endogeneity issues, by excluding outliers and adopting different specifications. Why is the traditional wisdom inconsistent with our findings? What causes the mismatch between product quality and firm productivity?

We conjecture the reason is that the traditional theory is mainly used to explain the phenomenon of ordinary trade in developed countries, but it does not consider the existence of processing trade. Processing trade is an important part of China's foreign trade, accounting for more than 50% of the country's total trade (Feenstra and Hanson, 2005). The business model of processing firms is called "two ends are outside, with large-scale imports and exports,"[2] which is very different from ordinary firms. Accordingly, we start with comparisons between processing firms and ordinary firms. The empirical results reveal that it is the differences in firm productivity and export quality between different types of trade that causes the mismatch paradox. The productivity of processing firms is lower than that of ordinary firms, but the export quality is higher. If we do not distinguish the type of trade, the so-called mismatch paradox will arise. Given the type of trade, whether it is processing trade or ordinary trade, the conclusion that more productive firms export higher quality products still holds.

To explain the findings of our paper, we develop a novel trade model with heterogeneous firms, building on Melitz (2003), Fan et al. (2015), and Rodriguez-Lopez & Yu (2017), allowing firms to choose their type of trade and product quality endogenously. Specifically, we characterize the differences between processing firms and ordinary firms from the aspects of production and sales. On the one hand, processing firms import large-scale foreign intermediate inputs and enjoy the privileged policy of exemption from import duties. As a result, the marginal cost of a processing firm is lower than that of an ordinary firm when producing a final product of the same quality. Considering that consumer demand is greater for high-quality products, the product quality of processing firms is higher than that of ordinary firms in equilibrium. One the other hand, the cost of this privileged import policy for processing firms is that they must export all their products abroad, thereby losing the entire domestic market. However, ordinary firms can sell their products to both domestic and foreign markets. Therefore, the sales revenue of ordinary firms is greater than that of processing firms. In addition, the fixed cost of sales faced by ordinary firms is greater than that of processing firms, so only high-productivity firms choose ordinary trade, while low-productivity firms choose processing trade.

This paper makes two contributions. First, the paper finds that there is a *mismatch paradox of quality and productivity* in Chinese capital-intensive sectors, and explains it from the perspective of processing trade, which complements the literature on processing trade. Second, the paper develops a heterogeneous firm trade model that is a better fit to China's reality, providing a consistent and tractable framework for subsequent research on the relationship between firm productivity and product quality.

This paper is related to three strands of literature. The first is on the measurement of product quality. Hallak (2006), Kugler & Verhoogen (2012), and Manova & Zhang (2012) use unit price as a proxy for product quality, that is, more expensive products are of higher quality. However, unit price not only reflects product quality, but also is affected by firm productivity. High-productivity firms have low marginal costs and thus low unit prices. Therefore, unit price is an imprecise indicator of product quality. Khandelwal et al. (2013) measure

2 Processing firms import large-scale raw materials and intermediate inputs from abroad, process and assemble them at home, and finally export final outputs abroad. However, the upstream stage (such as research and development and design) and the downstream stage (such as marketing) remain outside the home country. Therefore, their business model is called "two ends are outside, with large-scale imports and exports."

product quality based on consumer demand, which is widely used in most of the trade literature (Bas & Strauss-Kahn 2015, Manova & Yu 2017, Fan et al. 2015, 2018). Their main idea is that consumers are more willing to buy higher quality products when the prices are the same. Feenstra & Romalis (2014) consider both consumer demand and firm supply and endogenize product quality as the optimal choice for firms to maximize profits. They measure product quality across countries at the macro level, while this paper aims to study firm behavior at the micro level. Therefore, in the empirical part, we measure product quality following Khandelwal et al. (2013) and Fan et al. (2015).

The second related literature studies the relationship between firm productivity and product quality. Verhoogen (2008), Hallak & Sivadasan (2009), and Johnson (2012) introduce product quality into the theoretical heterogeneous firm framework of Melitz (2003) and conclude that high-productivity firms produce high-quality products. Using data on manufacturing firms in Colombia, Kugler & Verhoogen (2012) find that larger firms pay workers higher wages, use more expensive intermediate inputs, and produce more expensive final outputs. Since the firm's size corresponds to its productivity level, this finding supports a positive correlation between firm productivity and product quality. Manova & Zhang (2012) find similar results using Chinese firm-product-level data. However, the existing literature mainly focuses on ordinary firms; it does not pay much attention to processing firms. Our contribution is that we study firms of different types of trade theoretically and empirically, which complements this literature.

Third, the paper is related to the literature that studies the behavior of processing firms. Compared with ordinary firms, processing firms have lower productivity, profitability, and fixed costs (Dai et al., 2016). Credit constraints prevent processing firms from being ordinary firms (Manova & Yu, 2016). The intermediate input tariff and domestic market size are important external factors for firms' choice of processing trade or ordinary trade. The decline in the intermediate input tariff and the expansion of the domestic market both decrease policy advantages for processing trade, prompting more firms to choose ordinary trade (Brandt & Morrow, 2017). A contribution of this paper is to build a tractable and flexible model to prove that there are large differences between processing firms and ordinary firms in productivity and product quality.

The remainder of the paper is organized as follows. Section 2 develops a novel heterogeneous firm trade model. Section 3 introduces the empirical strategy, including the specification of the model, the data, and the measurement of key variables. Section 4 describes the main results and robustness checks. Section 5 concludes.

2. Model

In this section, we develop a simple trade model with heterogeneous firms by allowing firms to choose their types of trade and product quality endogenously a la Melitz (2003), Fan et al. (2015), and Rodriguez-Lopez & Yu (2017).

Assume there are two countries in the world, Home and Foreign. The Home country has a population of L and each person provides one unit of labor inelastically with wage w, while the Foreign country's size is L^* and the wage is w^*. As in Melitz (2003), we assume that each firm produces one differentiated good and sells in monopolistic competitive markets.

2.1 Demand

The utility function of the representative Home household is

$$U=\left(\int_{\omega\in\Omega} z(\omega)^{\frac{\sigma-1}{\sigma}} x(\omega)^{\frac{\sigma-1}{\sigma}} d\omega\right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where $z(\omega)$ is the quality of variety ω and $x(\omega)$ is the quantity of variety ω. Ω is the set of differentiated goods available for purchase, and $\sigma > 1$ is the constant elasticity of substitution across varieties. The Home country's demand for variety ω is then given by

$$x(\omega) = \frac{p(\omega)^{-\sigma}}{P^{1-\sigma}} z(\omega)^{\sigma-1} wL \tag{2}$$

where $p(\omega)$ is the Home price of variety ω and P denotes the aggregate price index of the Home country. Similarly, the Foreign country's demand for variety ω is

$$x^*(\omega) = \frac{p^*(\omega)^{-\sigma}}{P^{*1-\sigma}} z^*(\omega)^{\sigma-1} w^* L^* \tag{3}$$

where $p^*(\omega)$ is the Foreign price of variety ω and P^* denotes the aggregate price index of the Foreign country.

2.2 Production

As in Melitz (2003), entrants firstly draw the productivity randomly. The least efficient firms cannot earn positive profits, so they will exit the market. The remaining firms that survive in the market will endogenously choose their types of trade, namely, processing type (P) or ordinary type (O). Since processing firms enjoy the privileged policy of exempting import duties on intermediate inputs, all their final outputs must be exported to Foreign; while ordinary firms need to pay import duties on intermediate inputs, and their final outputs can be freely sold at Home and Foreign. Firms choose optimal product quality and price in each market to maximize their profits. The timeline of a firm's actions is shown in Figure 2.

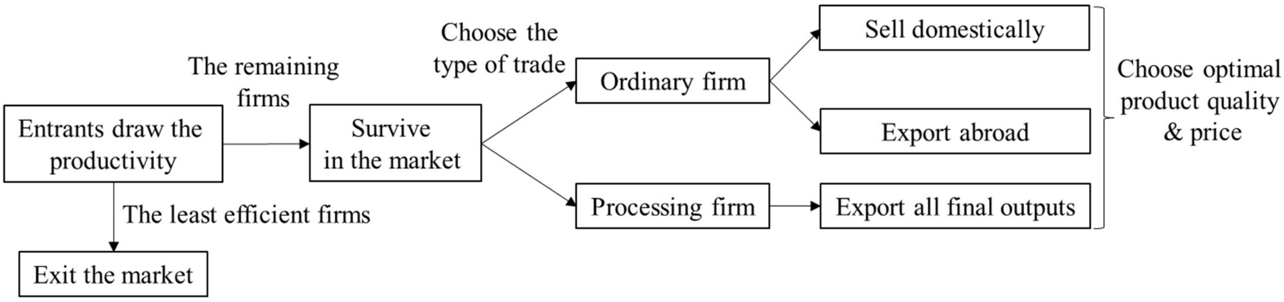

Figure 2 The Timeline of a firm's Actions

There are two factors of production, labor and intermediate inputs. Given firm productivity φ, the production function of the final output follows the Cobb-Douglas function:

$$x_s(\varphi) = \frac{\varphi}{z_s(\varphi)^{\alpha}} L_s(\varphi)^{1-\theta} M_s(\varphi)^{\theta} \tag{4}$$

where $s \in \{P, O\}$ is the firm's type, x_s is the quantity of the final output, and z_s is the quality of the final output. L_s is the amount of labor, M_s is the amount of intermediate inputs, and $0 < \theta < 1$ denotes the cost share of intermediate inputs. We assume $\alpha > 0$, implying that producing a high-quality final output requires using more factors (Fan et al., 2015).

The intermediate inputs are purchased outside the firm from domestic and foreign intermediate input suppliers. The amount of intermediate inputs for a firm of type $s \in \{P, O\}$ is:

$$M_s(\varphi) = m_s(\varphi) + m_s^*(\varphi) \tag{5}$$

where m is the amount of domestic intermediate inputs, and m^* is the amount of foreign intermediate inputs. Since they are complete substitutes, the firm will choose the lower cost one for production.

We denote the domestic and foreign prices of intermediate inputs as P_M and P_M^*, respectively, and assume $P_M^* < P_M$, implying the Foreign country has an absolute advantage in producing intermediate inputs.

Processing firms are exempted from import duties on intermediate inputs, so they use the intermediate inputs at the cost of $P_{MP} = min\{P_M,\ P_M^*\} = P_M^*$. While ordinary firms bear the import duty $\lambda > 1$, so $P_{MO} =$

$min\{P_M, \lambda P_M^*\}$. When $1 < \lambda < \frac{P_M}{P_M^*}$, ordinary firms will import intermediate inputs from Foreign, so that $P_{MO} = \lambda P_M^*$. When $\lambda > \frac{P_M}{P_M^*}$, ordinary firms will purchase intermediate inputs from Home, so that $P_{MO} = P_M$. In either case, the cost of intermediate inputs for processing firms is lower than that of ordinary firms, that is $P_{MP} < P_{MO}$.

For a firm with productivity φ of type $s \in \{P, O\}$, its marginal cost of the final output with quality z is:

$$C_s(z, \varphi) = \frac{z^\alpha}{\varphi} c_s \tag{6}$$

$$c_s = \left(\frac{w}{1-\theta}\right)^{1-\theta} \left(\frac{P_{Ms}}{\theta}\right)^\theta \tag{7}$$

where c_s is the variable cost, and $\frac{c_O}{c_P} = \left(\frac{P_{MO}}{P_{MP}}\right)^\theta > 1$. Thus, we have:

$$c_P < c_O \tag{8}$$

Therefore, the marginal cost of processing firms is lower than that of ordinary firms, provided that their productivity and product quality are equal.

2.3 Profit Maximization

Although processing firms can import low-cost intermediate inputs from abroad due to zero import tariffs, their disadvantage is that such firms cannot sell in the domestic market, that is, they must export all their products to Foreign. Conditional on productivity φ, a processing firm chooses the optimal price and quality to maximize its export profits in Foreign, which are given by

$$\pi_P^*(\varphi) = \max_{\{p_P^*, z_P^*\}} \left(p_P^* - \tau C_P(z_P^*, \varphi)\right) x^*(p_P^*, z_P^*) - {z_P^*}^\beta \tag{9}$$

By contrast, the products of ordinary firms can be freely sold in both Home and Foreign country. So an ordinary firm will choose the optimal price and quality in each market to maximize its total profits:

$$\pi_O(\varphi) = \max_{\{p_O, z_O\}} \left(p_O - C_O(z_O, \varphi)\right) x(p_O, z_O) - {z_O}^\beta \tag{10}$$

$$\pi_O^*(\varphi) = \max_{\{p_O^*, z_O^*\}} \left(p_O^* - \tau C_O(z_O^*, \varphi)\right) x^*(p_O^*, z_O^*) - {z_O^*}^\beta \tag{11}$$

where $x(p, z)$ and $x^*(p^*, z^*)$ denote the Home demand and Foreign demand, respectively. $\tau > 1$ is the iceberg trade cost, such as the output tariff imposed by Foreign. z^β and ${z^*}^\beta$ denote the fixed cost of production.[3] We assume $\beta > 0$, implying that the higher the quality of the final output, the higher the fixed cost of production. It should be noted that equations (9) - (11) have not yet introduced firms' fixed cost of sales at home and abroad.

By solving the first-order conditions, we get the optimal export quality of the processing firm:

$$z_P^*(c_P, \varphi) = A^{*\frac{1}{\beta-(1-\alpha)(\sigma-1)}} \left(\frac{\varphi}{\tau c_P}\right)^{\frac{\sigma-1}{\beta-(1-\alpha)(\sigma-1)}} \tag{12}$$

Similarly, the optimal domestic product quality and export quality of the ordinary firm are[4]:

3 Due to the different quality of domestic and export products of ordinary firms, they need to establish two different production lines, so such firms pay two fixed costs of production, ${z_O}^\beta$ and ${z_O^*}^\beta$.

4 See the Appendix A for the optimal product prices and maximum profits that a firm will obtain in each market.

$$z_O(c_O,\varphi) = A^{\frac{1}{\beta-(1-\alpha)(\sigma-1)}}\left(\frac{\varphi}{c_O}\right)^{\frac{\sigma-1}{\beta-(1-\alpha)(\sigma-1)}} \tag{13}$$

$$z_O^*(c_O,\varphi) = A^{*\frac{1}{\beta-(1-\alpha)(\sigma-1)}}\left(\frac{\varphi}{\tau c_O}\right)^{\frac{\sigma-1}{\beta-(1-\alpha)(\sigma-1)}} \tag{14}$$

where A and A^* are constants.[5] Following Fan et al. (2015), we assume $\beta > (1-\alpha)(\sigma-1) > 0$ to guarantee an interior solution.

According to equation (12) and equation (14), we have $\frac{z_P^*(c_P,\varphi)}{z_O^*(c_O,\varphi)} = \left(\frac{c_O}{c_P}\right)^{\frac{\sigma-1}{\beta-(1-\alpha)(\sigma-1)}}$, when the productivity of the processing firm is equal to that of the ordinary firm. Since $c_P < c_O$ from equation (8), we have $z_P^*(c_P,\varphi) > z_O^*(c_O,\varphi)$. Therefore, we have the following proposition:

Proposition 1: Other conditions being equal, the export quality of processing firms is higher than that of ordinary firms.

Taking the partial derivative of equation (12) and equation (14), we have $\frac{\partial z_P^*(c_P,\varphi)}{\partial \varphi} > 0$ and $\frac{\partial z_O^*(c_O,\varphi)}{\partial \varphi} > 0$. Thus, given the type of trade, as a firm's productivity increases, its export quality will increase too. Then we have the following proposition:

Proposition 2: Contingent on trade type, more productive firms export higher quality products.

2.4 Cutoff Productivity Levels

Let f_P be the fixed cost of selling in Foreig for processing firms, and f_D and f_X be the fixed costs of selling at Home and Foreign, respectively, for ordinary firms. There are three cutoff productivity levels between firms with different types of trade, which satisfy the following indifference conditions:

$$\pi_P^*(\widehat{\varphi_P}) = f_P \tag{15}$$

$$\pi_P^*(\widehat{\varphi_D}) - f_P = \pi_O(\widehat{\varphi_D}) - f_D \tag{16}$$

$$\pi_O^*(\widehat{\varphi_X}) = f_X \tag{17}$$

To simplify the analysis, we assume that the Home and Foreign country are symmetrical, that is they have the same wage, population, and aggregate price indices (Melitz, 2003). When $0 \approx f_P < f_D < f_X$ and $\lambda < \frac{1}{2}\tau$, we will have $\widehat{\varphi_P} < \widehat{\varphi_D} < \widehat{\varphi_X}$ (See the Appendix B for the detailed proof).[6]

As shown in Figure 3, a firm will choose the type of trade endogenously based on its productivity level. If $0 < \varphi < \widehat{\varphi_P}$, the firm cannot earn positive profits and will exit the market. If $\widehat{\varphi_P} < \varphi < \widehat{\varphi_D}$, the firm will choose to be a processing firm. If $\widehat{\varphi_D} < \varphi < \widehat{\varphi_X}$, the firm will become a non-exporting firm, which sells only in the domestic market. If $\varphi > \widehat{\varphi_X}$, the firm will become an ordinary firm that sells in both the domestic and foreign markets. Then we have the following proposition:

Proposition 3: Processing firms are less productive than non-exporting firms, while non-exporting firms are less productive than ordinary firms.

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5 $A = \frac{(1-\alpha)(\sigma-1)}{\beta\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} wLP^{\sigma-1}$, and $A^* = \frac{(1-\alpha)(\sigma-1)}{\beta\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} w^*L^*P^{*\sigma-1}$.

6 There are two main types of processing trade, namely, processing with assembly and processing with inputs. For processing with assembly, a Chinese firm obtains raw materials and intermediate inputs from its foreign trading partners. After local processing, the firm must sell its products back to the same foreign trading partner, so the fixed cost of sales is almost zero. For processing with inputs, a firm pays for intermediate inputs from a foreign seller, but can sell its final goods to any other foreign trading partners. In fact, its fixed cost of sales is also low. Additionally, it is generally believed that $f_D < f_X$ in the existing trade literature, so $0 \approx f_P < f_D < f_X$ holds. Furthermore, China's average industry-level input tariff from 2000 to 2006 was only 0.69% (Yu, 2015), while the US average output tariff was larger than 3% during the same period according to World Bank database (source: https://data.worldbank.org/indicator/TM.TAX.MRCH.SM.AR.ZS?end=2020&start=2000), so $\lambda < \frac{1}{2}\tau$ also holds.

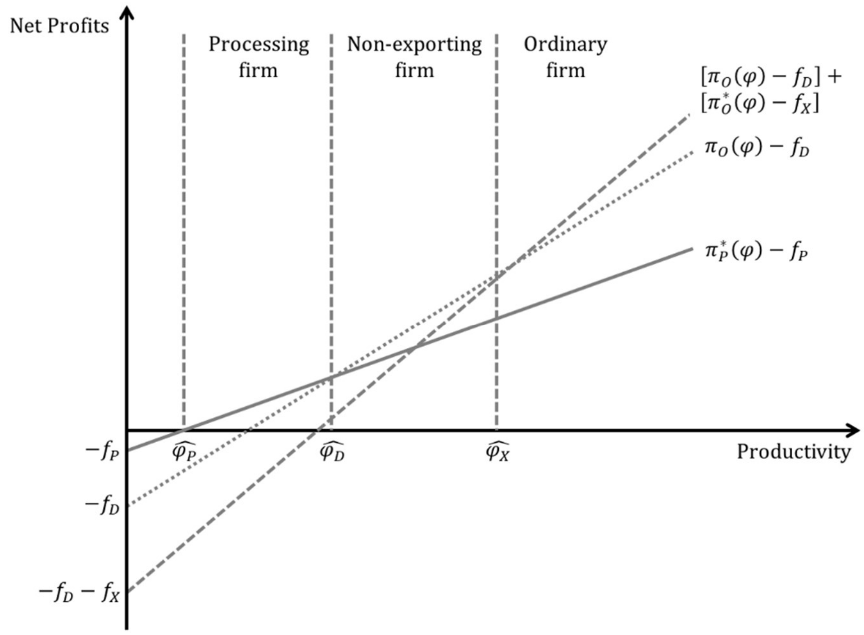

Figure 3: Cutoff Productivity Levels and the Partition of Firms

Finally, it is worthwhile to note the feature of hybrid firms that engage in both processing trade and ordinary trade. [7] From Proposition 1, we know that the export quality of processing firms is higher than that of ordinary firms, suggesting that a high degree of engagement in processing trade will improve the export quality of a firm. Proposition 3 shows that the productivity of processing firms is lower than that of ordinary firms, suggesting that a high degree of engagement in processing trade will reduce a firm's productivity. [8] Thus, the export quality is expected to be negatively correlated with firm productivity as the degree of engagement in processing trade of hybrid firms grows.

To sum up, the productivity of processing firms is lower than that of ordinary firms, but the export quality is diametrically opposite. Therefore, if we do not distinguish the type of trade across different firms, export quality may not be positively correlated with firm productivity.

3. Empirics, Data, and Measurement

3.1 Empirical Specification

To study the relationship between firm productivity and export quality, we estimate the following econometric model:

$$\ln z_{fhct} = \gamma_0 + \gamma_1 \ln TFP_{ft} + \gamma_2 X_{ft} + \varphi_{hc} + \varphi_i + \varphi_t + \varepsilon_{fhct} \quad (18)$$

where z_{fhct} denotes the quality of product h exported to destination country c by firm f in year t, and TFP_{ft} is firm f's measured total factor productivity in year t. X_{ft} denotes a vector of firm-level controls that have potential impacts on export quality, including firm size (measured by total employment), capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). We also include several fixed effects, such as product-country fixed effects φ_{hc}, two-digit Chinese Industrial Classification (CIC) industry fixed effects φ_i, and year fixed effects φ_t.

7 Once hbrid firms are introduced into the theoretical model, the mathematical derivation of the model becomes very complicated. Since hybrid firms are placed between processing firms and ordinary firms, we believe that the conclusions of the current theoretical framework are sufficient to shed light on such firms. Therefore, to ensure the tractability of the model, the theoretical part does not specifically study the hybrid firms.

8 Yu (2015) and Dai et al. (2016) empirically find that firm productivity is negatively correlated with the firm's degree of engagement in processing trade.

3.2 Data

Our empirical analysis mainly relies on two data sets. The first is the Chinese Industrial Enterprises Database collected by the National Bureau of Statistics of China. The data are used to obtain and construct firm-level variables. We cleaned the database following Cai & Liu (2009) and Brandt et al. (2012). First, we dropped observations whose key variables were missing or less than 0, such as gross output, value added, sales, employment, intermediate inputs, and net value of fixed assets. Second, we excluded firms with fewer than eight workers. Next, firms with financial indicators that violate accounting standards were deleted. Then, we excluded trading companies that specialize in import and export business and are significantly different from the manufacturing companies we wanted to study. Finally, we focused on capital-intensive sectors since the mismatch phenomenon is more prevalent in capital-intensive industries, inspired by the iPhone example. We calculate the capital intensity of 2-digit CIC industries (defined as the average capital-labor ratio of firms in the industry), and select industries with capital intensity above the median as capital-intensive sectors.

The second data set is disaggregated product-level trade transaction data obtained from China's General Administration of Customs. It records the detailed transaction information of all trading firms, including 8-digit Harmonized System (HS) product codes, trading amount, trading quantity, types of trade, and import or export country. Based on this, we can not only categorize our samples into different types of trade, but also measure firms' product quality.

We then match firm-product-level trade transaction data with firm-level production data following Yu (2015). Because the firm-level data after 2007 miss information on key variables such as intermediate inputs and value added, it is impossible to estimate the TFP of industrial firms (Chen et al., 2019); therefore, we use the matched samples from 2000 to 2007 for the empirical analysis. Table D1 shows the proportion of different types of firms by year.

3.3 Measurement of Key Variables

i. Export Quality

We measure export quality following Khandelwal et al. (2013) and Fan et al. (2015). From equation (3), the foreign demand for domestic product h is given by

$$x_{fhct} = z_{fhct}^{\sigma-1} \frac{p_{fhct}^{-\sigma}}{P_{ct}^{1-\sigma}} Y_{ct} \tag{19}$$

where x_{fhct} denotes the demand for product h (at the HS 6-digit level) exported by firm f in destination country c in year t. z_{fhct} denotes the quality and p_{fhct} denotes the price of the product. P_{ct} is the destination price index and Y_{ct} is the total income. We take the logarithm of equation (19) and use the following ordinary least squares (OLS) regression to infer product quality:

$$\ln x_{fhct} + \sigma \ln p_{fhct} = \alpha_h + \alpha_{ct} + \epsilon_{fhct} \tag{20}$$

where α_h is product fixed effects at the HS 6-digit level, which capture differences in prices and demands across products, and α_{ct} is country-year fixed effects which absorb destination price index P_{ct} and income Y_{ct}. The estimated export quality is $\widehat{\ln z_{fhct}} = \frac{\hat{\epsilon}_{fhct}}{\sigma-1}$,where $\hat{\epsilon}_{fhct}$ is the estimated residual. σ is the elasticity of substitution and we use the estimates from Broda & Weinstein (2006). Since the products of different 2-digit HS categories are not comparable, we infer the export quality for each 2-digit HS category separately.

ii. Productivity Measure

Firm productivity is typically measured by TFP. We follow Feenstra et al. (2014) to estimate the firms' TFP. The estimation equation is as follows:

$$\ln VA_{ft} = \alpha \ln K_{ft} + \beta \ln L_{ft} + \epsilon_{ft} \tag{21}$$

where VA_{ft}, K_{ft}, and L_{ft} denote firm f's value added (measured by the difference between the gross output and intermediate input), capital stock, and labor input in year t, respectively, and the residual $\hat{\epsilon}_{ft}$ is firm f's logarithm of measured TFP in year t. Given that the gross output, capital stock, and intermediate input are nominal variables recorded at current prices, we deflated them to obtain the real variables, according to Brandt et al. (2012). The production technology of different industries varies greatly, so we measure firms' TFP for each 2-digit CIC industry separately.

We adopt the augmented Olley & Pakes (1996) approach with some extensions to estimate firm TFP following Yu (2015). First, processing firms may use different technologies than non-processing firms. To control for the effect of the processing exports on the firm productivity and investment activity, we add a processing dummy in the control function in the first-step Olley–Pakes estimates. [9] Second, since exporting firms may use more factors and invest more in fixed assets, we also include an export dummy in the control function to allow different TFP between exporting firms and non-exporting firms. Third, China's WTO accession in 2001 is a positive demand shock, which would stimulate Chinese firms to expand their economic scales, so we also include a WTO dummy in the estimation.[10] Finally, we take the SOEs into account, as SOEs in China enjoy privileged policies for financing and market access during the time period examined. Thus, we add a SOE indicator it the control function. See Appendix C for the detailed estimation of Olley-Pakes TFP.

We also use other approaches to measure firm productivity, such as value-added labor productivity (henceforth VA_L), OLS approach, fiexed-effect approach, Levinsohn & Petrin (2003), and Ackerberg et al. (2015) for robustness checks.[11] Table 1 presents the summary statistics for product quality and various measures of firm productivity.

Table 1 Summary Statistics of Key Variables

Variable	Number	Mean	S.D.	25th percentile	75th percentile
Panel A: Export quality					
$\ln z$	1,392,467	1.238	5.875	-0.761	2.917
Panel B: Firm productivity					
$\ln VA_L$	1,392,467	4.390	1.190	3.607	5.124
$\ln TFP_{OLS}$	1,392,467	4.182	1.076	3.519	4.818
$\ln TFP_{FE}$	1,338,391	4.378	1.070	3.679	5.063
$\ln TFP_{OP}$	1,037,763	4.168	1.039	3.520	4.783
$\ln TFP_{LP}$	1,392,467	6.602	1.334	5.718	7.388
$\ln TFP_{ACF}$	1,392,467	5.547	1.181	4.772	6.256

4. Main Results and Analysis

4.1 Baseline Results

Table 2 reports the baseline results for the relationship between firm productivity and export quality, using full-sample data including all types of firms. Columns (1) use TFP_{OLS} as the firm productivity indicator, and columns (2) use TFP_{OP}. Both columns include controls, such as firm size, capital intensity, average wage per worker, dummy variables for state-owned enterprises and foreign invested enterprises, and fixed effects, such as product-country fixed effects, industry fixed effects and year fixed effects. The results show that the

9 The processing dummy takes the value one if a firm has any processing exports and zero otherwise.

10 The WTO dummy equals to one after 2001 and zero otherwise.

11 Each indicator is constructed as follows. Labor productivity is measured as the ratio of a firm's value added to labor input. The OLS approach means simple OLS estimation of equation (21). The FE approach includes firm fixed effects in the OLS regression. Levinsohn & Petrin (2003) controls for the simultaneous bias by inferring unobserved firm productivity through the intermediate inputs. Ackerberg et al. (2015) stress that examining a firm's dynamic optimal problem can better identify the coefficient of labor provided that a firm's labor inputs are fully determined in a static model.

coefficients of TFP_{OLS} and TFP_{OP} are only 0.056 and 0.057, respectively, and neither is significant.

Thus, there is no significant positive correlation between firm productivity and export quality in Chinese capital-intensive sectors, that is, high-productivity firms do not export high-quality products. This finding contradicts those of related studies (Hallak & Sivadasan, 2009; Johnson, 2012; Kugler & Verhoogen, 2012; Manova & Zhang, 2012), and we call it *the mismatch paradox of quality and productivity.* In the following subsections, we explore the economic rationale for the mismatch between export quality and firm productivity.

Table 2 Relationship between Firm Productivity and Export Quality (Baseline Results)

Dependent variable	$\ln z$	
Productivity indicator	TFP_{OLS}	TFP_{OP}
	(1)	(2)
$\ln TFP$	0.056	0.057
	(0.054)	(0.071)
Controls	Yes	Yes
FEs	Yes	Yes
Observations	1349190	996896
R-squared	0.27	0.28

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the firm level are in parentheses. Columns (1) use TFP_{OLS} as the firm productivity indicator, and columns (2) use TFP_{OP}. The controls are firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). The fixed effects include product-country fixed effects, industry fixed effects and year fixed effects.

4.2 Comparisons between Processing Firms and Ordinary Firms

We start with comparisons between processing firms and ordinary firms, then explore their differences in productivity and export quality, and then explain the mismatch paradox. The results are presented in Table 3. Panel A compares the means of the two groups using the simple t-test. Column (1) is export quality, and it shows that the average export quality of processing firms is significantly higher than that of ordinary firms, which is consistent with Proposition 1 of our theoretical model. Columns (2) to (7) list six other productivity indicators, respectively. The results show that regardless of the measure of productivity, the average productivity of processing firms is significantly lower than that of ordinary firms. This finding is consistent with the predictions of Proposition 3.

To validate the findings, we calculate the average treatment effects on the treated using the method of propensity score matching in Panel B in Table 3. Processing firms are the treatment group, and we match them with their nearest-neighbor ordinary firms, which are the control group. The covariates used for matching are the same as the controls in the previous regression, which are firm size, capital intensity, average wage per worker, and type of ownership. The results of the propensity score matching also provide empirical support for Propositions 1 and 3.

Therefore, the productivity of processing firms is lower than that of ordinary firms, but the export quality is higher. If we do not distinguish the type of trade across different firms, we can see a mismatch between export product quality and firm productivity, making our previous baseline results inconsistent with traditional conclusions.

Table 3 Comparisons between Processing Firms and Ordinary Firms

Variable	$\ln z$ (1)	$\ln VA_L$ (2)	$\ln TFP_{OLS}$ (3)	$\ln TFP_{FE}$ (4)	$\ln TFP_{OP}$ (5)	$\ln TFP_{LP}$ (6)	$\ln TFP_{ACF}$ (7)
Panel A: T-test							
Processing firms	1.847	4.029	3.745	3.739	3.722	5.904	4.951
Ordinary firms	0.970	4.274	3.901	4.279	3.908	6.096	5.182
Mean difference	0.877***	-0.245***	-0.156***	-0.540***	-0.186***	-0.192***	-0.231***
Panel B: Propensity score matching							
Processing firms	1.825	4.030	3.744	3.737	3.718	5.898	4.947
Ordinary firms	1.356	4.284	3.944	4.323	3.932	6.299	5.339
ATT	0.469***	-0.255***	-0.200***	-0.586***	-0.214***	-0.401***	-0.392***

Note: Significant at *10%, **5% and ***1%. ATT = average treatment effects on the treated.

4.3 Regression Results by Firm Type

Next, we study the relationship between productivity and export quality for each firm type separately. Table 4 reports the results for processing firms and ordinary firms. Columns (1) and (2) are processing firms. Their coefficients of productivity are significantly positive at the 1% level, ranging from 0.305 to 0.335. suggesting that if the productivity of processing firms increases by 10%, their average export quality will increase by 3.05%-3.35%. Columns (3) and (4) are ordinary firms, whose coefficients of productivity are also significantly positive at the 1% level, ranging from 0.108 to 0.126, suggesting that a 10% increase in the productivity of ordinary firms will increase their average export quality by 1.08%-1.26%. Therefore, Table 4 provides evidence for Proposition 2 of our model.[12]

Table 4 Relationship between Firm Productivity and Export Quality (Processing & Ordinary Firms)

Dependent variable	$\ln z$			
	Processing firms		Ordinary firms	
Productivity indicator	TFP_{OLS} (1)	TFP_{OP} (2)	TFP_{OLS} (3)	TFP_{OP} (4)
$\ln TFP$	0.305***	0.335***	0.108***	0.126***
	(0.109)	(0.120)	(0.022)	(0.025)
Controls	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes
Observations	159469	120415	593463	425002
R-squared	0.38	0.38	0.34	0.36

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the firm level are in parentheses. All columns include controls and fixed effects. The controls are firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). The fixed effects include product-country fixed effects, industry fixed effects and year fixed effects.

To study hybrid firms and how their extent of processing engagement ($Pext$)[13] affects the relationship between productivity and export quality, we estimate the following equation:

$$\ln z_{fhct} = \beta_0 + \beta_1 \ln TFP_{ft} + \beta_2 \ln TFP_{ft} \times Pext_{ft} + \beta_3 Pext_{ft} + \beta_4 X_{ft} + \varphi_{hc} + \varphi_s + \varphi_t + \varphi_p + \varepsilon_{fhct} \quad (22)$$

where β_2 and β_3 are the coefficients of the variable $Pext_{ft}$ and its interaction term with $\ln TFP_{ft}$. From

12 According to our calculations, the estimated $\ln TFP_{OLS}$ ($\ln TFP_{OP}$) of processing firms increases by 0.86 (0.83) log points overall from 2000 to 2007. The estimated $\ln TFP_{OLS}$ ($\ln TFP_{OP}$) of ordinary firms increases by 0.72 (0.66) log points. So the average export quality of processing firms increases by 26%-28% during the sample period, while the average export quality of ordinary firms increases by about 8%.

13 A firm's $Pext$ is measured by the proportion of its processing exports to total exports.

equation (22), $\partial \ln z / \partial \ln TFP = \beta_1 + \beta_2 Pext$.

As shown in columns (1) and (3) in Table 5, by abstracting away the variable $Pext_{ft}$ and its interaction term, the coefficients of productivity are negative but insignificant. The results show a nonpositive correlation between productivity and export quality for hybrid firms. After including the variable $Pext_{ft}$ and its interaction term in columns (2) and (4), the coefficients of productivity β_1 become significantly positive at the 1% level, and the coefficients of the interaction term β_2 are significantly negative at the 1% level.

A simple calculation shows that when the extent of processing engagement of hybrid firms is less (higher) than about half, export quality is positively (negatively) correlated with firm productivity.[14] Thus, there is a mismatch between export quality and productivity when the degree of engagement in processing trade of hybrid firms is high.

Table 5 Relationship between Firm Productivity and Export Quality (Hybrid Firms)

Dependent variable	$\ln z$			
	Hybrid firms			
Productivity indicator	TFP_{OLS}	TFP_{OLS}	TFP_{OP}	TFP_{OP}
	(1)	(2)	(3)	(4)
$\ln TFP$	-0.122	0.270***	-0.139	0.245***
	(0.097)	(0.056)	(0.126)	(0.062)
$\ln TFP \times Pext$		-0.572***		-0.558***
		(0.154)		(0.200)
$Pext$		2.171***		2.104***
		(0.601)		(0.778)
Controls	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes
Observations	559860	559860	418038	418038
R-squared	0.30	0.30	0.31	0.31

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the firm level are in parentheses. All columns include controls and fixed effects. The controls are firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). The fixed effects include product-country fixed effects, industry fixed effects and year fixed effects.

To illustrate the results, we study the role that a firm's extent of processing engagement plays in the relationship between firm productivity and export quality. We divide firms into 30 groups according to their extent of processing engagement, from low to high, and then calculate the average export quality and average productivity of each group separately. Since the quality of different products exported to different destinations is not comparable, we first regress export quality on the product-country fixed effect and use the residuals to calculate the average export quality. Similarly, we calculate the average productivity. In Figure 4, the horizontal axis is the grouping of the extent of processing engagement, while the vertical axes in panels A and B are average export quality and average productivity, respectively. The figure shows that the higher is the degree of engagement in processing trade, the higher is the average export quality but the lower is the average firm productivity. Therefore, export quality is negatively correlated with firm productivity when the degree of engagement in processing trade is high. Table D2 reports the OLS regression results, which are consistent with the conclusions of Figure 4.

14 The results of different productivity indicators are slightly different: TFP_{OLS} is 47% and TFP_{OP} is 44%.

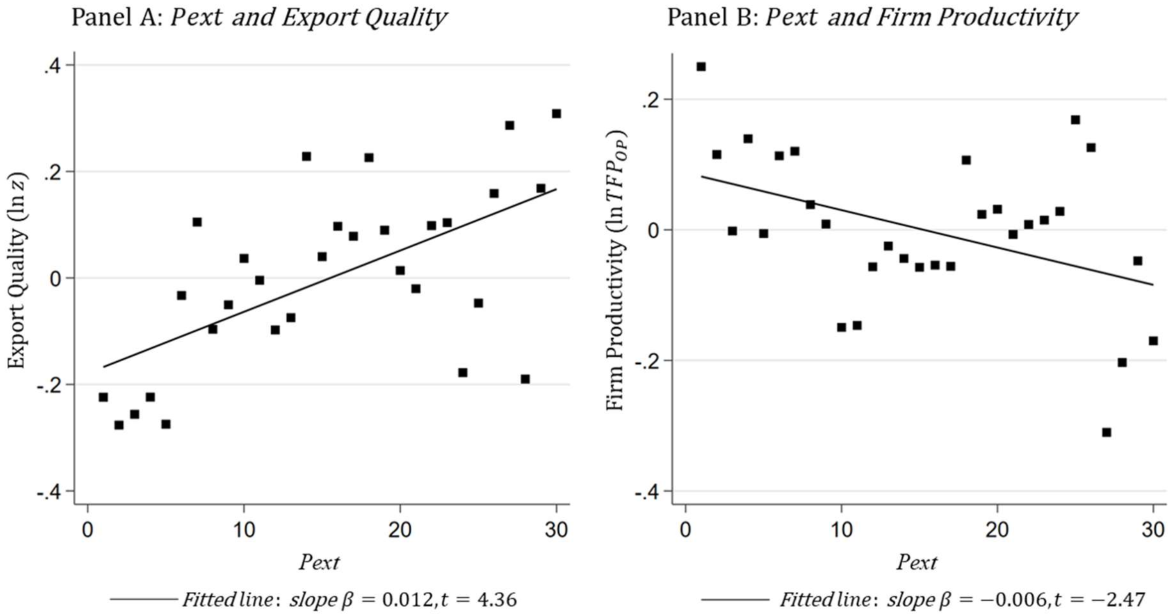

Figure 4 Role of the Extent of Processing Engagement

4.4 Endogeneity Issues

Similar to other studies, our empirical estimations may suffer from possible endogeneity issues, such as measurement errors, reverse causality, and omitted variables. We address these separately.

i. Measurement Errors

In section 3, we estimated six firm productivity indicators, VA_L (labor productivity), TFP_{OLS}, TFP_{FE}, TFP_{OP}, TFP_{LP}, and TFP_{ACF}. As is well known, each TFP measure has its own merits and disadvantages. We adopt all types of TFP to address possible measurement errors associated with the productivity measures. The results are shown in Table 6. Columns (1) to (4) are the full-sample data including all types of firms. We see that all four productivity indicators are insignificant, which is consistent with the benchmark results, strongly suggesting the existence of the mismatch paradox. Columns (5) to (8) are processing firms, columns (9) to (12) are ordinary firms, and columns (13) to (16) are hybrid firms. These results are also consistent with the previous ones.

Table 6 Robustness Check I: Different Productivity Indicators

Dependent variable	$\ln z$							
	All firms				Processing firms			
Productivity indicator	VA_L	TFP_{FE}	TFP_{LP}	TFP_{ACF}	VA_L	TFP_{FE}	TFP_{LP}	TFP_{ACF}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln TFP$	0.057	0.038	0.060	0.064	0.318***	0.326***	0.323***	0.340***
	(0.054)	(0.056)	(0.054)	(0.054)	(0.109)	(0.113)	(0.109)	(0.109)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1349190	1296714	1349190	1349190	159469	153617	159469	159469
R-squared	0.27	0.28	0.27	0.27	0.38	0.38	0.38	0.38
	Ordinary firms				Hybrid firms			
Productivity indicator	VA_L	TFP_{FE}	TFP_{LP}	TFP_{ACF}	VA_L	TFP_{FE}	TFP_{LP}	TFP_{ACF}
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
$\ln TFP$	0.100***	0.098***	0.103***	0.101***	0.143**	0.146***	0.166**	0.202***
	(0.023)	(0.021)	(0.022)	(0.022)	(0.060)	(0.051)	(0.067)	(0.062)
$\ln TFP \times Pext$					-0.386***	-0.441***	-0.400***	-0.455***
					(0.121)	(0.152)	(0.131)	(0.144)
$Pext$					1.459***	1.638***	2.420***	2.293***
					(0.485)	(0.622)	(0.812)	(0.745)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	593463	567021	593463	593463	559860	541112	559860	559860
R-squared	0.34	0.35	0.34	0.34	0.30	0.30	0.30	0.30

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the firm level are in parentheses. All columns include controls and fixed effects. The controls are firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). The fixed effects include product-country fixed effects, industry fixed effects and year fixed effects.

ii. Reverse Causality

A firm's extent of processing engagement is endogenous as firms with higher export quality may be more likely to receive foreign processing orders. Thus, there may be reverse causality between a firm's export quality and its extent of processing engagement in equation (22). In this case, following Feenstra et al. (2014) and Yu (2015), we replace the endogenous variable with its predicted fitted value by adopting the Heckman two-step estimation method as follows.

The first step is to determine the probability of firms engaging in processing trade using a probit model:

$$Pr(Processing_{ft} = 1) = \phi(\alpha_0 + \alpha_1 \ln TFP_{ft-1} + \alpha_2 X_{ft-1} + \alpha_3 Age_{ft-1} + \varphi_s + \varphi_t + \vartheta_{ft}) \qquad (23)$$

where $Processing_{ft} = 1$ is a dummy variable indicating whether firm f engages in processing trade in year t. According to the definition, if a firm's $Pext > 0$, its processing indicator variable takes the value 1; otherwise, it takes the value 0. TFP_{ft-1} and X_{ft-1} denote firm productivity and controls with a one-period lag, respectively. The predicted variable thus is only related to the one-period lagged variables, so it is not affected by current-period export quality. The Heckman two-step estimation requires an excluded variable that affects the firm's processing decision but is not related to the firm's extent of engagement in processing trade. Here, the firm's age (Age_{ft-1}) satisfies this requirement, as existing studies find that a firm's export probability is higher for older firms (Amiti and Davis, 2012). There is no correlation between a firm's extent of processing trade and its age (Yu, 2015). We also include 2-digit CIC industry fixed effects and year fixed effects.

The second step is to predict the firm's extent of processing engagement using the following OLS regression:

$$Pext_{ft} = \delta_0 + \delta_1 \ln TFP_{ft-1} + \alpha_2 X_{ft-1} + \alpha_3 IMR_{ft} + \varphi_s + \varphi_t + \omega_{ft} \tag{24}$$

where IMR_{ft} is the inverse Mills ratio obtained from the first-step probit estimates.

In Table 7, columns (1) and (2) are the results of the first-step probit estimations, which show that low-productivity firms are more likely to engage in processing trade. Columns (3) and (4) are the results of the second-step OLS estimations. Similarly, the coefficients of firm productivity are significantly negative at the 1% level, indicating that the lower is the productivity of a firm, the higher is its extent of processing engagement. Finally, we obtain the predicted value of the firm's extent of processing engagement ($\widehat{Pext}$), and use it to replace the actual value ($Pext$) in columns (5) and (6). The results are consistent with the previous ones.

iii. Omitted Variables

Our estimates may suffer from omitted variables, such as unobserved macroeconomic policy shocks, which would cause a bias. First, as shown in equation (19), the income and price index of the destination country change over time, and the demand for firm exports has a specific time trend. Therefore, we use more stringent product-country-year fixed effects to absorb the potential effects of these unobservable factors.

Second, trade liberalization has a significant impact on firms' production. On the one hand, the reduction of import tariffs on intermediate inputs enables firms to obtain foreign high-quality intermediate inputs at a lower cost, thereby promoting firm productivity and export quality. On the other hand, lower import tariffs on final outputs trigger more competition in the market, thereby eliminating low-productivity firms (Pavcnik, 2002; Amiti & Konings, 2007; Topalova and Khandelwal, 2011; Bas & Strauss-Kahn, 2015). Therefore, to control the effects of changes in industry tariffs over time, we include industry-year fixed effects in the robustness check.

Finally, industrial policies in different regions have different time trends. For example, Wang (2013) finds that the timing of the establishment of special economic zones in different provinces in China varies widely. Special economic zones can promote exports, generate agglomeration economies, and increase firm productivity. Therefore, we hope to exclude regional policy effects by including province-year fixed effects. As shown in Table 8, considering all the above cases, the results are still consistent with the previous ones.

iv. Additional Robustness Checks

In addition to addressing endogeneity issues, we examine the robustness of our results in other ways. First, to avoid that our estimated results are driven by extreme values or outliers, we winsorize the data at the 1% level. As shown in Table D3, the results are consistent with the previous ones. Second, note that capital-intensive sectors are defined as industries with capital intensity that is higher than the median level in all 2-digit CIC industries. Now, we tighten the criteria to define capital-intensive industries using a cutoff of the top one-third industries. As shown in Table D4, all the conclusions still hold. Third, we correct for standard errors clustered at the CIC 4-digit level instead of the firm level. As shown in Table D5, the results are not substantially different from the previous ones.

Table 7 Robustness Check II: Dealing with Reverse Causality

Dependent variable	*Processing indicator*		*Pext*		$\ln z$	
	Heckman 1st step		Heckman 2nd step		Hybrid firms	
Productivity indicator	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln TFP_{t-1}$	-0.010	-0.027***	-0.007**	-0.009***		
	(0.006)	(0.007)	(0.003)	(0.003)		
IMR			0.280***	0.233***		
			(0.063)	(0.066)		
$\ln TFP$					0.504**	0.545**
					(0.205)	(0.270)
$\ln TFP \times \widehat{Pext}$					-0.914**	-0.981*
					(0.392)	(0.527)
$\widehat{Pext}$					5.110**	4.999*
					(2.259)	(2.945)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	63667	46855	29276	22362	449865	288284
R-squared	0.20	0.20	0.23	0.23	0.32	0.34

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the firm level are in parentheses. All columns include controls for firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). The controls in columns (1) to (4) are lagged one period; the controls in columns (5) and (6) are for the current period. Columns (1) to (4) include industry fixed effects and year fixed effects, and columns (5) and (6) include product-country fixed effects, industry fixed effects and year fixed effects.

Table 8 Robustness Check III: Controlling for Omitted Variables

Dependent variable	$\ln z$							
	All firms		Processing firms		Ordinary firms		Hybrid firms	
Productivity indicator	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln TFP$	0.063	0.065	0.384***	0.442***	0.121***	0.145***	0.286***	0.250***
	(0.059)	(0.078)	(0.113)	(0.133)	(0.024)	(0.026)	(0.062)	(0.071)
$\ln TFP \times Pext$							-0.601***	-0.552***
							(0.148)	(0.180)
$Pext$							2.331***	2.101***
							(0.567)	(0.681)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1162421	831068	122989	89139	468152	318608	435033	309798
R-squared	0.33	0.34	0.43	0.44	0.41	0.43	0.35	0.37

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the firm level are in parentheses. All columns include controls and fixed effects. The controls are firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). The fixed effects include product-country-year fixed effects, industry-year fixed effects, and province-year fixed effects.

4.5 Heterogeneous Effects

We now classify firms into two groups from two dimensions, namely FIEs and non-FIEs, and coastal areas and inland areas. Table 9 reports the regression results for each group. It shows that the mismatch paradox only exists in FIEs and coastal areas, but does not exist in non-FIEs and inland areas.

On the one hand, processing firms are deeply integrated into global vertical specialization. By investing and building factories overseas, multinational firms transfer the low-end stages of the industrial chain to developing countries. They take advantage of the abundant local labor resources to save production costs. Therefore, the proportion of processing exports of FIEs is much higher than that of non-FIEs. On the other hand, inland areas are far from ports and transportation costs are high. Since the added value of the assembly process is very low, the firms engaged in processing trade are mainly concentrated in the coastal areas.[15] Therefore, the high proportion of processing exports is the main reason for the mismatch paradox in FIEs and coastal areas.

Table 9 Heterogeneous Effects

Dependent variable	$\ln z$							
	FIEs		Non-FIEs		Coastal areas		Inland areas	
Productivity indicator	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln TFP$	0.017	0.012	0.114***	0.135***	0.057	0.068	0.129**	0.113**
	(0.078)	(0.100)	(0.031)	(0.036)	(0.059)	(0.078)	(0.050)	(0.053)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	818536	606702	506083	367412	1224800	909042	111034	76218
R-squared	0.28	0.29	0.37	0.39	0.27	0.28	0.50	0.53

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the firm level are in parentheses. Columns (1) to (4) control for firm size, capital intensity, and average wage per worker. Columns (5) to (8) control firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). All columns include fixed effects, which are product-country fixed effects, industry fixed effects and year fixed effects.

5. Concluding Remarks

The paper finds that there is no significant positive correlation between firm productivity and export quality in Chinese capital-intensive sectors. Our intensive empirical research reveals that such a mismatch paradox is mainly driven by the prevalence of processing trade, caused by differences in firm productivity and export quality between different types of trade. The productivity of processing firms is lower than that of ordinary firms, but the export quality is higher than that of ordinary firms. If we do not distinguish the type of trade, a mismatch can be observed between export quality and firm productivity. Given the type of trade, whether it is processing trade or ordinary trade, the conclusion that the higher is the productivity of a firm, the higher is the quality of its exports still holds. We developed a novel trade model with heterogeneous firms, allowing the firm to endogenously choose its type of trade and product quality, which can explain the findings of our paper.

15 In our sample data, firms engaged in processing trade account for 59% of FIEs, compared to only 19% of non-FIEs. Similarly, the proportion of firms engaged in processing trade to total firms in coastal areas is 47%, while the proportion in inland areas is only 17%.

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Appendix A. Optimal Product Price and Maximum Profit

Given productivity φ, the optimal export price of a processing firm is:

$$p_P^*(c_p,\varphi)=\left(\frac{\sigma}{\sigma-1}\right)A^{*\frac{\alpha}{\beta-(1-\alpha)(\sigma-1)}}\left(\frac{\tau c_p}{\varphi}\right)^{\frac{\beta-\sigma+1}{\beta-(1-\alpha)(\sigma-1)}} \qquad (A1)$$

Similarly, the optimal domestic product price and export price of an ordinary firm are:

$$p_O(c_O,\varphi)=\left(\frac{\sigma}{\sigma-1}\right)A^{\frac{\alpha}{\beta-(1-\alpha)(\sigma-1)}}\left(\frac{c_O}{\varphi}\right)^{\frac{\beta-\sigma+1}{\beta-(1-\alpha)(\sigma-1)}} \qquad (A2)$$

$$p_O^*(c_O,\varphi)=\left(\frac{\sigma}{\sigma-1}\right)A^{*\frac{\alpha}{\beta-(1-\alpha)(\sigma-1)}}\left(\frac{\tau c_O}{\varphi}\right)^{\frac{\beta-\sigma+1}{\beta-(1-\alpha)(\sigma-1)}} \qquad (A3)$$

where $A=\frac{(1-\alpha)(\sigma-1)}{\beta\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}wLP^{\sigma-1}$, and $A^*=\frac{(1-\alpha)(\sigma-1)}{\beta\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}w^*L^*P^{*\sigma-1}$.

After solving the optimal product price and quality of a firm in each market, we can calculate the firm's maximum profit. The maximum export profit of a processing firm is:

$$\pi_P^*(\varphi)=\frac{\beta-(1-\alpha)(\sigma-1)}{(1-\alpha)(\sigma-1)}A^{*\frac{\beta}{\beta-(1-\alpha)(\sigma-1)}}\left(\frac{\varphi}{\tau c_P}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}} \qquad (A4)$$

The maximum domestic profit and export profit of an ordinary firm are:

$$\pi_O(\varphi)=\frac{\beta-(1-\alpha)(\sigma-1)}{(1-\alpha)(\sigma-1)}A^{\frac{\beta}{\beta-(1-\alpha)(\sigma-1)}}\left(\frac{\varphi}{c_O}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}} \qquad (A5)$$

$$\pi_O^*(\varphi)=\frac{\beta-(1-\alpha)(\sigma-1)}{(1-\alpha)(\sigma-1)}A^{*\frac{\beta}{\beta-(1-\alpha)(\sigma-1)}}\left(\frac{\varphi}{\tau c_O}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}} \qquad (A6)$$

where $A=\frac{(1-\alpha)(\sigma-1)}{\beta\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}wLP^{\sigma-1}$, and $A^*=\frac{(1-\alpha)(\sigma-1)}{\beta\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}w^*L^*P^{*\sigma-1}$.

Appendix B. Proof of the Sorting of the Cutoff Productivity Levels

We already know that the variable cost of processing firms is lower than that of ordinary firms, that is, $c_P < c_O$. And these cutoff productivity levels satisfy the following indifference conditions: $\pi_P^*(\widehat{\varphi_P}) = f_P$, $\pi_P^*(\widehat{\varphi_D}) - f_P = \pi_O(\widehat{\varphi_D}) - f_D$, and $\pi_O^*(\widehat{\varphi_X}) = f_X$.

To assist the proof, we define the cutoff productivity level $\widehat{\varphi_O}$ at which an ordinary firm obtains a zero profit in the domestic market, that is, $\pi_O^*(\widehat{\varphi_O}) = f_D$.

We will prove $\widehat{\varphi_P} < \widehat{\varphi_O} < \widehat{\varphi_D} < \widehat{\varphi_X}$ in two stages. Firstly, we prove $\widehat{\varphi_P} < \widehat{\varphi_O} < \widehat{\varphi_D}$. In subsequent proofs, we will solve the necessary and sufficient conditions that guarantee the sorting of the cutoff productivity levels.

According to the definition, $\widehat{\varphi_P} < \widehat{\varphi_O}$ is equivalent to the inequality: $\pi_o(\varphi) - f_D < 0 < \pi_p^*(\varphi) - f_P$, $\forall \varphi \in (\widehat{\varphi_P}, \widehat{\varphi_O})$.

Using equation (A4) and equation (A5), we have:

$$\frac{\pi_P^*(\varphi)}{\pi_O(\varphi)} = \left(\frac{w^* L^* P^{*\sigma-1}}{wLP^{\sigma-1}}\right)^{\frac{\beta}{\beta-(1-\alpha)(\sigma-1)}} \left(\frac{c_O}{\tau c_P}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}} \tag{B1}$$

Let $\kappa \equiv \left(\frac{w^* L^* P^{*\sigma-1}}{wLP^{\sigma-1}}\right)^{\frac{\beta}{\beta-(1-\alpha)(\sigma-1)}} \left(\frac{c_O}{\tau c_P}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}}$, then we have $\pi_P^*(\varphi) = \kappa \pi_O(\varphi)$. So the necessary and sufficient condition for $\widehat{\varphi_P} < \widehat{\varphi_O}$ is:

$$f_P < \kappa f_D \tag{B2}$$

Additionally, we also want $\widehat{\varphi_O} < \widehat{\varphi_D}$ to hold. Let function $F(\varphi) = \pi_P^*(\varphi) - \pi_O(\varphi) - f_P + f_D = (\kappa - 1)\pi_O(\varphi) - f_P + f_D$. Because $\pi_O(\varphi)$ is a monotonically increasing function of productivity φ, the monotonicity of $F(\varphi)$ depends on the value of κ. According to the definition, $F(\widehat{\varphi_O}) = \pi_P^*(\widehat{\varphi_O}) - f_P > 0$, and $F(\widehat{\varphi_D}) = 0$, so the necessary and sufficient condition for $\widehat{\varphi_O} < \widehat{\varphi_D}$ is that $F(\varphi)$ is a monotonically decreasing function of productivity φ, that is:

$$\kappa < 1 \tag{B3}$$

From the above analysis, the necessary and sufficient condition for $\widehat{\varphi_P} < \widehat{\varphi_O} < \widehat{\varphi_D}$ is:

$$\frac{f_P}{f_D} < \kappa < 1 \tag{B4}$$

Secondly, we prove $\widehat{\varphi_D} < \widehat{\varphi_X}$. Using equation (A5) and equation (A6), we have:

$$\frac{\pi_O^*(\varphi)}{\pi_O(\varphi)} = \left(\frac{w^* L^* P^{*\sigma-1}}{wLP^{\sigma-1}}\right)^{\frac{\beta}{\beta-(1-\alpha)(\sigma-1)}} \left(\frac{1}{\tau}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}} \tag{B5}$$

Let $\mu \equiv \left(\frac{w^* L^* P^{*\sigma-1}}{wL\ ^{\sigma-1}}\right)^{\frac{\beta}{\beta-(1-\alpha)(\sigma-1)}} \left(\frac{1}{\tau}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}}$, then we have $\pi_O^*(\varphi) = \mu \pi_O(\varphi)$. Since $\frac{\kappa}{\mu} > 1$ and $\kappa < 1$, we have $0 < \mu < \kappa < 1$.

Let function $H(\varphi) = \pi_O(\varphi) + \pi_O^*(\varphi) - \pi_P^*(\varphi) - f_D - f_X + f_P = (1 + \mu - \kappa)\pi_O(\varphi) - f_D - f_X + f_P$. According to the definition, $H(\widehat{\varphi_D}) = \pi_O^*(\widehat{\varphi_D}) - f_X$, and $H(\widehat{\varphi_X}) = \pi_O(\widehat{\varphi_X}) - \pi_P^*(\widehat{\varphi_X}) - f_D + f_P = -F(\widehat{\varphi_X})$.

Therefore, $\widehat{\varphi_D} < \widehat{\varphi_X}$ is equivalent to $H(\widehat{\varphi_D}) < 0$, and it is also equivalent to $H(\widehat{\varphi_X}) > 0$.

From $H(\widehat{\varphi_D}) < 0$, $\pi_P^*(\widehat{\varphi_D}) - \pi_O(\widehat{\varphi_D}) - f_P + f_D = 0$, that is $\pi_O(\widehat{\varphi_D}) = \frac{f_D - f_P}{1-\kappa}$, and $\pi_O^*(\widehat{\varphi_D}) < f_X$, that is $\pi_O(\widehat{\varphi_D}) < \frac{f_X}{\mu}$. So the necessary and sufficient condition for $H(\widehat{\varphi_D}) < 0$ is $\frac{\mu}{1-\kappa} < \frac{f_X}{f_D - f_P}$.[16]

16 From $H(\widehat{\varphi_X}) > 0$, we have $\pi_O^*(\widehat{\varphi_X}) = f_X$, that is $\pi_O(\widehat{\varphi_X}) = \frac{f_X}{\mu}$, and $\pi_P^*(\widehat{\varphi_X}) - \pi_O(\widehat{\varphi_X}) - f_P + f_D < 0$, that is $\pi_O(\widehat{\varphi_X}) >$

In summary, the necessary and sufficient conditions for $\widehat{\varphi_P} < \widehat{\varphi_O} < \widehat{\varphi_D} < \widehat{\varphi_X}$ are:

$$\frac{f_P}{f_D} < \kappa < 1 \tag{B6}$$

$$\frac{\mu}{1-\kappa} < \frac{f_X}{f_D - f_P} \tag{B7}$$

We assume that the Home and Foreign country are symmetrical, that is $w = w^*$, $L = L^*$, and $P = P^*$. Then, we have $\kappa = \left(\frac{c_O}{\tau c_P}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}}$. Equation (7) implies that $\frac{c_O}{c_P} = \left(\frac{P_{MO}}{P_{MP}}\right)^{\theta} < \lambda$, so $\kappa < \left(\frac{\lambda}{\tau}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}}$. Thus, the sufficient condition for $\frac{f_P}{f_D} < \kappa < 1$ is:

$$\lambda < \frac{1}{2}\tau \tag{B8}$$

$$0 \approx f_P < f_D \tag{B9}$$

Equation (B8) implies that the Home country's input tariff is far less than the Foreign country's output tariff. And Equation (B9) implies that the fixed cost of selling in the Foreign country for processing firms is far less than the fixed cost of selling in the domestic market for ordinary firms.

Since $\frac{\mu}{1-\kappa} < \frac{\kappa}{1-\kappa} = \frac{\left(\frac{c_O}{\tau c_P}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}}}{1-\left(\frac{c_O}{\tau c_P}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}}} < \frac{\lambda^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}}}{\tau^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}} - \lambda^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}}}$, the sufficient condition for $\frac{\mu}{1-\kappa} < \frac{f_X}{f_D - f_P}$ is:

$$f_D - f_P < \left[\left(\frac{\tau}{\lambda}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}} - 1\right] f_X \tag{B10}$$

According to Equation (B8), we have $\left(\frac{\tau}{\lambda}\right)^{\frac{\beta(\sigma-1)}{\beta-(1-\alpha)(\sigma-1)}} - 1 > 1$. If both Equation (B8) and $f_D < f_X$ hold, then Equation (B10) will hold. Therefore, when we assume that the two countries are symmetrical, the sufficient conditions for $\widehat{\varphi_P} < \widehat{\varphi_O} < \widehat{\varphi_D} < \widehat{\varphi_X}$ are:

$$\lambda < \frac{1}{2}\tau \tag{B11}$$

$$0 \approx f_P < f_D < f_X \tag{B12}$$

Q.E.D.

$\frac{f_D - f_P}{1-\kappa}$. So the necessary and sufficient condition for $H(\widehat{\varphi_X}) > 0$ is $\frac{\mu}{1-\kappa} < \frac{f_X}{f_D - f_P}$ too.

Appendix C. Construction of Olley-Pakes TFP

Our augmented Olley-Pakes approach is mainly borrowed from Yu (2015). Because the approach takes China's market environment and special institutional arrangements into account, the measurement of firm productivity is more reliable. Appendix C lists the extensions and main steps of the approach.

Olley & Pakes (1996) assumes that the firm $f's$ investment $\ln I_{ft}$ depends on the unobserved productivity shock Ω_{ft} and its capital stock $\ln K_{ft}$. We extend the investment function by adding other control variables as follows:

$$\ln I_{ft} = I\left(\Omega_{ft}, \ln K_{ft}, PE_{ft}, EX_{ft}, SOE_{ft}, WTO_t\right) \quad (C1)$$

where PE_{ft} is a processing dummy that takes the value one if the firm f has any processing exports in year t and zero otherwise. EX_{ft} is an export dummy indicating whether the firm f exports in year t. SOE_{ft} is a dummy indicating the firm f's status of ownership in year t. Finally, WTO_t is a year dummy, which equals to one after 2001 and zero otherwise.

From the investment decision function $(C1)$, we can write the unobserved productivity shock Ω_{ft} explicitly as the inverse function of (C1):

$$\Omega_{ft} = I^{-1}\left(\ln I_{ft}, \ln K_{ft}, PE_{ft}, EX_{ft}, SOE_{ft}, WTO_t\right) \quad (C2)$$

Equation (C2) can be used to control for the simultaneity bias in the first-step Olley-Pakes estimates. Substituting (C2) into equation (21), we have the following estimation equation:

$$\ln VA_{ft} = \beta_0 + \beta_L \ln L_{ft} + g\left(\ln I_{ft}, \ln K_{ft}, PE_{ft}, EX_{ft}, SOE_{ft}, WTO_t\right) + \epsilon_{ft} \quad (C3)$$

where $g(\cdot) = \beta_K \ln K_{ft} + I^{-1}\left(\ln I_{ft}, \ln K_{ft}, PE_{ft}, EX_{ft}, SOE_{ft}, WTO_t\right)$. We approximate $g(\cdot)$ using fourth-order polynomials in $\ln I_{ft}$, $\ln K_{ft}$ and other dummies.

In the second step, to control for the selection bias, we estimate the firm $f's$ survival probability in year t, $\hat{P}_{ft}$, of a survival indicator on a high-order polynomial in $\ln I_{ft}$ and $\ln K_{ft}$.

In the third step, we estimate the parameter β_K consistently using the following equation by non-linear least squares:

$$\ln VA_{ft} - \widehat{\beta_L} \ln L_{ft} = \beta_K \ln K_{ft} + I^{-1}\left(g_{f,t-1} - \beta_K \ln K_{f,t-1}, \hat{P}_{f,t-1}\right) + \epsilon_{ft} \quad (C4)$$

where function $I^{-1}(\cdot)$ is unknow and is appropriate to use fourth-order polynomials in $g_{f,t-1}$ and $\ln K_{f,t-1}$. Finally, the Olley-Pakes TFP for firm f in year t is:

$$\ln TFP_{ft}^{OP} = \ln VA_{ft} - \widehat{\beta_L} \ln L_{ft} - \widehat{\beta_K} \ln K_{ft} \quad (C5)$$

Appendix D. Supplementary Results

Table D1 Proportion of Different Types of Trade, by Year (%)

Type of trade	2000	2001	2002	2003	2004	2005	2006	2007	Total
Panel A: Percentage of number of firms (firm level)									
Processing firms	1.4	1.5	1.5	1.7	1.9	2.0	2.1	2.1	14.2
Hybrid firms	2.1	2.4	2.7	3.0	4.1	4.5	5.0	5.0	28.8
Ordinary firms	2.8	3.6	4.5	6.0	8.0	9.0	11.2	11.9	57.0
Total	6.3	7.5	8.7	10.7	14.0	15.5	18.3	19.0	100
Panel B: Percentage of number of observations (firm-product-country level)									
Processing firms	0.9	1.1	1.2	1.4	1.7	1.9	2.0	1.9	12.1
Hybrid firms	2.2	2.7	3.4	4.2	5.9	7.1	8.3	8.8	42.6
Ordinary firms	1.5	2.3	3.1	4.5	6.2	7.6	9.8	10.3	45.3
Total	4.6	6.1	7.7	10.1	13.8	16.6	20.1	21.0	100

Table D2 Role of the Extent of Processing Engagement

Dependent variable	$\ln z$	VA_L	TFP_{OLS}	TFP_{FE}	TFP_{OP}	TFP_{LP}	TFP_{ACF}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Pext$	0.262***	-0.039***	-0.039***	-0.047***	-0.057***	-0.043***	-0.041***
	(0.093)	(0.008)	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1349190	95668	95668	90534	68469	95668	95668
R-squared	0.27	0.41	0.28	0.33	0.27	0.45	0.34

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the firm level are in parentheses. In column (1), the dependent variable is export quality, controls are capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises), and fixed effects include product-country fixed effects, industry fixed effects and year fixed effects. In columns (2) to (7), the dependent variables are six productivity indicators, respectively. The controls are firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables of for state-owned enterprises and foreign invested enterprises). The fixed effects include industry fixed effects and year fixed effects.

Table D3 Robustness Check IV: Winsorizing Data at the 1% Level

Dependent variable	$\ln z$							
	All firms		Processing firms		Ordinary firms		Hybrid firms	
Productivity indicator	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln TFP$	0.066	0.067	0.320***	0.345***	0.106***	0.125***	0.261***	0.242***
	(0.051)	(0.066)	(0.108)	(0.118)	(0.023)	(0.025)	(0.058)	(0.063)
$\ln TFP \times Pext$							-0.536***	-0.530***
							(0.146)	(0.185)
$Pext$							2.030***	2.002***
							(0.571)	(0.722)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1349190	996896	159469	120415	593463	425002	559860	418038
R-squared	0.27	0.28	0.37	0.38	0.34	0.36	0.30	0.31

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the firm level are in parentheses. All columns include controls and fixed effects. The controls are firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). The fixed effects include product-country fixed effects, industry fixed effects and year fixed effects.

Table D4 Robustness Check V: Changing the Criteria of Capital-Intensive Sectors

Dependent variable	$\ln z$							
	All firms		Processing firms		Ordinary firms		Hybrid firms	
Productivity indicator	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln TFP$	0.005	0.002	0.316**	0.345**	0.167***	0.181***	0.357***	0.324***
	(0.087)	(0.112)	(0.140)	(0.150)	(0.030)	(0.036)	(0.082)	(0.087)
$\ln TFP \times Pext$							-0.800***	-0.772***
							(0.169)	(0.217)
$Pext$							3.001***	2.919***
							(0.695)	(0.903)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	746460	562986	102650	79882	293301	214993	326118	245912
R-squared	0.26	0.27	0.35	0.36	0.34	0.35	0.29	0.30

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the firm level are in parentheses. All columns include controls and fixed effects. The controls are firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). The fixed effects include product-country fixed effects, industry fixed effects, and year fixed effects.

Table D5 Robustness Check VI: Clustering at the CIC 4-Digit Level

Dependent variable	$\ln z$							
	All firms		Processing firms		Ordinary firms		Hybrid firms	
Productivity indicator	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}	TFP_{OLS}	TFP_{OP}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\ln TFP$	0.056	0.057	0.305*	0.335*	0.108***	0.126***	0.270***	0.245***
	(0.078)	(0.090)	(0.170)	(0.174)	(0.032)	(0.033)	(0.070)	(0.070)
$\ln TFP \times Pext$							-0.572***	-0.558***
							(0.172)	(0.199)
$Pext$							2.171***	2.104***
							(0.642)	(0.709)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1349190	996896	159469	120415	593463	425002	559,995	417,723
R-squared	0.27	0.28	0.38	0.38	0.34	0.36	0.30	0.32

Note: Significant at *10%, **5% and ***1%. Robust standard errors corrected for clustering at the CIC 4-digit level are in parentheses. All columns include controls and fixed effects. The controls are firm size, capital intensity, average wage per worker, and type of ownership (i.e., dummy variables for state-owned enterprises and foreign invested enterprises). The fixed effects include product-country fixed effects, industry fixed effects, and year fixed effects.