Multi-Dimensional Effects of International Trade: The Experience of Chinese Manufacturers

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Abstract

This paper evaluates the effect of importing and exporting on firm-level productivity and intermediate input prices for Chinese manufacturing firms. Using a rich data set from Chinese manufacturers from 2000 to 2006, we find that international trade affects firms through two channels: productivity growth and intermediate input prices. Both importing and exporting tend to increase firm productivity; in contrast, while export leads to higher input prices, importing firms enjoy lower input prices (presumably due to the expanded choice of inputs). We consistently estimate production functions in the presence of unobserved input price dispersion when firms may sell to both domestic and foreign markets. This allows us to jointly recover firm-level productivity and input prices for each firm. We use these values to investigate the sources of gains from international trade at the firm level. We also find that firms with higher productivity and lower input prices are more likely to export and import, and tend to export and import more.

Keywords: *Input Prices, Productivity, International Trade, Gain*

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1 Introduction

Productivity and intermediate (material) input prices are two key characteristics of individual firms. As shown in Ornaghi (2006) and Atalay (2012) using observed input price data and Grieco et al. (2015) using the estimated counterpart, the input prices, like productivity, have large dispersion across firms and are quite persistent over time. Productivity and input prices together largely determine the heterogenous profitability at the firm level. In this paper, we argue that both of these dimensions of heterogeneity influence firms' current and future activities such as participation in international trade, which in turn influence firms' future productivity and input prices. Many papers have been devoted to examine the productivity gains from international trade, such as Aw et al. (2011a) and Greenaway and Kneller (2007) for export, and Kasahara and Rodrigue (2008), Goldberg et al. (2009, 2010), and Kasahara and Lapham (2013) for import. However, much less attention has been paid to investigate the effect of international trade on input prices and how this consequently influences firm heterogenous performance—probably because of the lack of price data on materials inputs. Even in the rare cases where input prices are available, it is not clear whether firms gain anything from the relatively lower price or higher quality of the imported materials, since the observed input prices may (partly) reflects differential input quality.

How does international trade influence firm heterogenous performance through the channels of productivity and input prices? Importing inputs potentially reduces the production cost through lower input prices, higher input quality (Kasahara and Rodrigue, 2008; Goldberg et al., 2009, 2010; Halpern et al., 2011; Ge et al., 2011; Zhang, 2014). In addition, importing inputs may create positive spillovers which improve a firm's future productivity. In contrast, export may increase firm productivity via learning by exporting (Aw et al., 2011a), but it may also adversely increase input prices due to greater input demand. As a result, the overall effect from international trade on firm performance is a mixture of effects through both channels of productivity and input price, which play different roles in production. Ignoring input price heterogeneity may result in serious problem in evaluating the gains from trade. First of all, the productivity estimates are biased if input prices are not taken into consideration, as shown in Grieco et al. (2015). Secondly, even when the productivity is consistently estimated, the evaluation of gain from trade on productivity alone is likely to be biased without controlling for the effect on input price due to omitted variable bias.

In this paper, we provide empirical evidence of gains from international trade in terms of pro-

ductivity and intermediate input prices at the firm level. These gains will further influence firms' import and export decisions and performance in both domestic and export markets. The first step of our study in consistently estimating the firms' production functions in the presence of heterogeneous productivity and input prices. Because export naturally involves firms selling in multiple markets, we extend Grieco et al. (2015) to a multiple-market environment. This extension allows us to estimate the productivity and recover the unobserved quality-adjusted input prices at firm-time level when firms may sell in either the domestic or both domestic and export markets. Equipped with the estimated productivity and input prices, we then explore the different effects of international trade on productivity and input prices, and analyze their implications on firm profitability and decisions on international trade.

We apply our estimator to a panel of six large 2-digit manufacturing industries in China, which matches the manufacturing survey data collected by Chinese National Bureau of Statistics and the custom transaction records collected by the Chinese Customs from 2000 to 2006. The estimated productivity and quality-adjusted input prices have consistent patterns (such as dispersion and persistence) as documented in Grieco et al. (2015). Importantly, several more interesting findings emerge from the perspective of international trade. First, both import and export tend to increase firm productivity, with stronger effect from export. Second, while import decreases the quality-adjusted input prices, export tends to increase input prices probably due to more demanding material input. By regressing the export and import decisions against both productivity and input prices, we find the two have different impacts on trade decisions: firms with higher productivity and lower input prices are more likely to import and export, and import and export more.

Finally, we conduct several constrained counterfactual experiments to examine the relative importance of the productivity gain and input price gain from international trade, in terms of intensive and extensive margins of total revenues for the six industries. The results show that, without the productivity gain of export the next-period productivity is reduced by 1.76%-10.37% on average, leading to a loss in domestic sales by about 11%-62% and foreign sales by about 20%-76% for exporting firms. At the same time, it also reduces both export and import probabilities significantly. This suggests that firms do gain from export via the channel of productivity both in intensive and extensive margins of total sales. However, these productivity gain from export is partially offset by the export effect on input price – the counterfactual analysis shows that export increases input prices by about 1%-10% on average across the six industries, which results in a loss of both extensive and intensive export margins.

In contrast, if there is no gain from import on productivity, the next-period productivity will reduce by about 0.13%-4.25% on average, which leads to a decrease of domestic sales by 1.5%-32% and foreign sales by 1.3%- 43% for exporting firms. Removing the productivity gain from import also reduces both export and import propensities. Compared with export, the productivity gain from import is much lower both in terms of intensive and extensive margins of total sales. Meanwhile, removing the input price gain from import adversely increases firms' input prices dramatically, which in turn lead to a significant loss in both domestic and export sales as well as a substantial decrease in both import and export probabilities. These results indicate that importing firms gain positively in terms of both increased productivity and reduced quality-adjusted material input prices, in contrast to the export gains in which the gains from increased productivity are partially offset by higher input prices.

These findings imply that input price is indeed an important heterogeneous characteristic of Chinese firms. In particular, low input prices, as an external competence, is as important as the firms' internal competence (productivity) in determining firm performance and international trade decisions. Chinese firms in general gain from import from foreign suppliers which help them reduce production cost by offering more competitive quality-adjusted input prices which may come from lower import price, higher import quality, or more variety due to import.

This paper contributes to the existing literature in several directions. First, we extend the methodology developed in Grieco et al. (2015) to the multiple-market case. By estimating the production function consistently, the extended method enables us to recover the firm-level productivity and input prices when firms may sell to more than one market. This extension largely broadens the application of this method, in particular to the framework of international trade which naturally involves sales in multiple markets for exporting firm.

Second, we separately evaluate the gains from international trade via the channels of productivity and input prices. Typically input prices are not available in most firm-level data sets, so traditional methods usually use deflated input expenditure as a proxy of input quantity. Using the productivity recovered from the traditional methods will produce significantly biased gains from international trade for two reasons. First, the productivity and production parameters will be biased due to the ignorance of input price heterogeneity as shown in Grieco et al. (2015). Second, even if the productivity and production parameters are consistently estimated, the estimated productivity gain from international trade will be a mixture of gains of both productivity and input price. As a result, it is necessary to take heterogenous input prices into account in both re-

covering productivity and the analysis of the gains from international trade. Our method corrects the bias by directly estimating the productivity and quality-adjusted material prices at the firm level separately. Consequently, this allows us to evaluate the interaction between international trade and firm heterogeneity in both dimensions of productivity and input prices.

Third, the firm heterogeneity in input prices provides a second driving force, beyond productivity, for the observed correlation between import and export decisions. The empirical results show that, on the one hand, the lowered production cost due to import through both productivity and input price channels will naturally lead to more export. On the other hand, exporting also increase the firm productivity, resulting in stronger incentives for firms to import intermediate inputs with high quality (or equivalently lower quality-adjusted price) as substitute of less competitive domestic materials.

This paper is closely related to a large strand of literature which investigates the gains from import at the firm level. Using recently available micro data it is shown that firms that actively participate in import have relatively higher productivity than those which do not import (Blalock and Veloso, 2007; Amiti and Konings, 2007; Kasahara and Rodrigue, 2008; Bernard et al., 2009; Halpern et al., 2011; Khandelwal and Topalova, 2011). Vogel and Wagner (2010) in contrast find that more productive firms are more likely to import material from abroad. Our results corroborate these previous findings. More interestingly, our findings show that import tends to reduce firm-level input prices, which provides another source of gains from trade. Meanwhile, input price is also a component of firm heterogeneity besides productivity that plays an important role in determining firms' import decisions.

This paper also expands the strand of literature on the productivity gain from export participation. Export participation is expected to have positive efficiency effect at the firm level, because exporters can learn from international firms and are more likely to imitate innovation from abroad. The empirical literature, however, has quite mixed evidence on this question. While some papers find a positive productivity effect of export participation at the firm level (Van Biesebroeck, 2005; De Loecker, 2007; Aw et al., 2011a), other studies find small or even no productivity effect (Clerides et al., 1998; Bernard and Jensen, 1999; Vogel and Wagner, 2010). Our finding shows that exporting can have a mixed effect on firms causing increases in input prices while boosting productivity growth. As a result, even when actually export does have a positive effect on productivity, it is still possible to find it empirically insignificant since it is in fact the mixture of two effects offsetting each other. Our finding does show that, after recognizing the input price effect,

export participation has a significant positive effect on productivity at the firm level.

The remaining of the paper is organized as follows. Section 2 introduces the model. Section 4 reports the estimation result and evaluates how firms benefit from international trade via the channels of productivity and input prices. Section 5 concludes.

2 Model

In this section, we introduce a model of firms' decision-making when firms may sell in two monopolistically competitive output markets: a domestic market and an exporting market. Firms are forward-looking and make their export and import decisions to maximize their discounted total future profit in both domestic market and export market in an infinite-period framework. In each period, given its import and export decisions as well as the fixed capital stock, each firm chooses labor and material inputs to maximize its current-period profit. That is, the firm's input decisions (labor and material inputs) are static while the import and export decisions are dynamical. Using this model, we show that the approach developed in Grieco et al. (2015) can be generalized to the multiple-market case and consistently estimate the production function and recover firm-level input prices and productivity in the presence of unobserved input price dispersion.

2.1 Theoretical Model

For simplicity we consider the two-market case.[1] In each period, every firm produces a single product and sells in the domestic market for sure, and it can choose whether or not to sell in the export market. We consider a constant elasticity production function (CES) and a Dixit-Stiglitz demand function in each market.[2] Specifically, in each period t, a firm j produces an output quantity Q_{jt} of a single homogeneous output using labor (L_{jt}), intermediate material (M_{jt}), and capital (K_{jt}) via CES production function. Following (de La Grandville, 1989; Klump and de La Grandville, 2000; Klump and Preissler, 2000; de La Grandville and Solow, 2006; León-Ledesma et al., 2010; Grieco et al., 2015), we normalize the production function using geometric mean of inputs and output, denoted as $\overline{Z} = (\overline{Q}, \overline{L}, \overline{M}, \overline{K})$ where $\overline{X} = \sqrt[n]{X_1 X_2 \cdots X_n}$. The

[1] It is straightforward to extend the model introduced in this section to cases with more than two markets.

[2] We can straightforwardly extend this approach to more flexible parametric production and demand functions, as in Grieco et al. (2015). We omit this extension in this paper to save space.

production we consider is

$$Q_{jt} = e^{\omega_{jt}} F(L_{jt}, M_{jt}, K_{jt}; \theta) = e^{\omega_{jt}} \overline{Q} \left[\alpha_L \left(\frac{L_{jt}}{\overline{L}} \right)^{\gamma} + \alpha_M \left(\frac{M_{jt}}{\overline{M}} \right)^{\gamma} + \alpha_K \left(\frac{K_{jt}}{\overline{K}} \right)^{\gamma} \right]^{\frac{1}{\gamma}}, \quad (1)$$

where ω_{jt} is a Hicks-neutral productivity shock observed by the firm (but not by researchers), $P_{L_{jt}}$ and $P_{M_{jt}}$ are the labor price (wage rate) and the material price respectively. The set of parameters to be estimated is $\theta = (\gamma, \alpha_L, \alpha_M, \alpha_K)$. The elasticity of substitution (σ) is determined by γ, where $\gamma = \frac{\sigma - 1}{\sigma}$. The distribution parameters $\alpha_L, \alpha_M, \alpha_K$ are restricted to sum to 1.

Firms are monopolistically competitive and face different demand functions in the domestic and export markets, which we assume are Dixit-Stiglitz,

$$P_{jt}^D = P_t^D \left(Q_{jt}^D \right)^{1/\eta^D}, \quad (2)$$

$$P_{jt}^X = P_t^X \left(Q_{jt}^X \right)^{1/\eta^X}, \quad (3)$$

where P_t^D and P_t^X are industrial demand shifters, Q_t^D and Q_t^X are the quantities demanded, and η^D and η^X are demand elasticities for domestic and export markets, respectively.

2.1.1 Labor and Material Decisions

In this section, we model the firm's optimal choice of inputs – labor and material quantities. Following Grieco et al. (2015), we assume that input prices are exogenously given and the firm's objective is to maximize its profit at the current period t given its decision of whether or not to export in this period as well as the fixed capital stock. Specifically, the firm optimally chooses labor and material quantities, and the quantity of product sold in each market to maximize its current profit, given its productivity, input prices, capital stock, and its import and export status. Firm j's profit maximization problem at time t is:

$$\begin{aligned} \pi_{jt} = \max_{L_{jt}, M_{jt}, Q_{jt}^D, Q_{jt}^X} \quad & P_{jt}^D Q_{jt}^D + e_{jt} P_{jt}^X Q_{jt}^X - P_{L_{jt}} L_{jt} - P_{M_{jt}} M_{jt}, \\ \text{s.t.} \quad & Q_{jt}^D + e_{jt} Q_{jt}^X = \exp(\omega_{jt}) F(L_{jt}, M_{jt}, K_{jt}; \theta), \\ & P_{jt}^D = P_t^D \left(Q_{jt}^D \right)^{1/\eta^D}, \quad P_{jt}^X = P_t^X \left(Q_{jt}^X \right)^{1/\eta^X}. \end{aligned} \quad (4)$$

The export status, e_{jt} has been determined in the beginning of this period before the firm make the optimal input choice: $e_{jt} = 0$ if the firm only sells in the domestic market, and $e_{jt} = 1$ if the firm also sells in the export market. Note that we assume the firm always sells in the domestic

market, because in the data we observe almost all firms sell in the domestic market. The firm can endogenously determine its inputs and output quantity sold in each market as functions of $(\omega_{jt}, K_{jt}, P_{Ljt}, P_{Mjt}, e_{jt})$, by solving this profit maximization problem, and the resulting profit π_{jt} is the maximum profit in the period t.

2.1.2 Import and Export Decisions

Both import and export activities may have an impact on productivity and input prices. We model the productivity and the input prices faced by each firm evolve over time according to two first order Markov processes. The gains from trade in terms of productivity and input prices are incorporated into both evolution processes to model how trade changes the future path of productivity and input prices. The difference of the gain is that, while trade has a lagged effect on productivity, it affects the input prices immediately.[3] We want to capture two ideas with this specification. First, it takes time for firms to adopt and digest the new technologies acquired from international trade. Second, we allow that imported materials has different quality-adjusted prices so the imported inputs immediately affect the input cost via the mixture of the domestic and imported materials.[4] Also, the input market is efficient such that increased input demand due to export affects input prices in the same period. For completeness of the model, we also allow the wage rate to evolve in the similar way. Specifically, the evolution processes are assumed as follows:

$$\begin{aligned}
\omega_{jt+1} &= \rho(\omega_{jt}, e_{jt}, i_{jt}) + \epsilon^{\omega}_{jt+1}, \\
P_{M_{jt}} &= \chi(P_{M_{jt-1}}, e_{jt}, i_{jt}) + \epsilon^{m}_{jt}, \\
P_{L_{jt}} &= \zeta(P_{L_{jt-1}}, e_{jt}, i_{jt}) + \epsilon^{\ell}_{jt},
\end{aligned}$$

where e_{jt} and i_{jt} are the export and import status (0 or 1) of firm j in period t. The $\epsilon's$ are corresponding i.i.d. shocks in each evolution process, respectively. We are interested in how the import and export activities influence productivity and input prices, which consequently determines firms' profitability. Observing its state $s_{jt} = (\omega_{jt}, K_{jt}, P_{M_{jt-1}}, P_{L_{jt-1}})$, the firms' import and export decisions are made at the beginning of each period, before making labor and

[3] We tested for different timing assumptions about the effect, and also considered Markov processes of a higher order, but our result is quite robust to these changes.

[4] In this sense, the resulting material price faced by the firm is endogenous – how much imported material used affects the "average" material price. The method proposed in Grieco et al. (2015) still works as long as the prices of domestic and imported material are exogenous. The reason is that in Grieco et al. (2015) we have shown that our method can be generalized to multi-input cases where firms are allowed to choose different types of inputs.

material decisions and observing the i.i.d. shocks of productivity and input prices. The firm's optimal choice of import and export decisions, e_{jt} and i_{jt}, are characterized by the following Bellman equation:

$$\begin{aligned} V(s_{jt}) &= \max_{e_{jt}, i_{jt}, I_{jt}} \{\pi_{jt} + \delta E[V(s_{jt+1})]\} \\ s.t. \quad \omega_{jt+1} &= \rho(\omega_{jt}, e_{jt}, i_{jt}) + \epsilon^{\omega}_{jt}, \\ P_{M_{jt}} &= \chi(P_{M_{jt-1}}, e_{jt}, i_{jt}) + \epsilon^{m}_{jt}, \\ P_{L_{jt}} &= \zeta(P_{L_{jt-1}}, e_{jt}, i_{jt}) + \epsilon^{\ell}_{jt}, \\ K_{jt+1} &= (1-\tau)K_{jt} + I_{jt}. \end{aligned}$$

Where I_{jt} is the investment in physical capital, δ is the discount factor for future value, and τ is the discount factor for capital stock. The expectation is taken over the three i.i.d. shocks on productivity, material input prices, and wage rate. This dynamic programming problem implies policy functions of firms' dynamic trade decisions besides investment choice,

$$\begin{aligned} e_{jt} &= \psi(\omega_{jt}, P_{M_{jt-1}}, P_{L_{jt-1}}, K_{jt}), \\ i_{jt} &= \phi(\omega_{jt}, P_{M_{jt-1}}, P_{L_{jt-1}}, K_{jt}). \end{aligned} \tag{5}$$

In general, higher productivity (ω_{jt-1}) increases both import and export; a higher material input price ($P_{M_{jt-1}}$) increases the propensity of import but decreases the propensity of export; a higher wage rate ($P_{L_{jt-1}}$) also discourages export, but its effect on import is mixed because on the one hand a higher wage rate will reduce output which decreases input demand and import, on the other hand it increases input demand and import if labor and material are substitutes.

2.2 Econometric Model

In this subsection, we focus on the firm's static decisions about input and output given its export and import decisions. We show that we can consistently estimate production functions in the scenario of international trade when the researchers do not observe material prices, by extending Grieco et al. (2015) to the two-market case. The estimator utilizes the structure implied by the firms' labor and material choices discussed in the above subsection. More importantly, we can recover the productivity and quality-adjusted material input price for each firm in each period. This allows us to evaluate the gains from international trade via changes in productivity and input prices separately, as implied by the theoretical analysis. For expositional purpose, we focus on

firms selling in both domestic and export markets first. Then we show that the implied estimation equation also directly applies to cases with firms selling at single or multiple markets.

When a firm sells both domestic market and abroad, the profit maximization problem defined in (4) implies the following four first order conditions, after replacing P_{jt}^D and P_{jt}^X by the demand functions. The first order conditions with respect to Q_{jt}^D and Q_{jt}^X are,

$$\frac{\partial \mathcal{L}}{\partial Q_{jt}^D} = \frac{1+\eta^D}{\eta^D}(Q_{jt}^D)^{1/\eta^D} P_t^D - \lambda = 0, \tag{6}$$

$$\frac{\partial \mathcal{L}}{\partial Q_{jt}^X} = \frac{1+\eta^X}{\eta^X}(Q_{jt}^X)^{1/\eta^X} P_t^X - \lambda = 0, \tag{7}$$

where λ is the lagrange multiplier for the production constraint. The first order conditions with respect to labor and material quantities are,

$$\frac{\partial \mathcal{L}}{\partial L_{jt}} = -P_{L_{jt}} + \lambda \frac{\partial F}{\partial L_{jt}} = 0, \tag{8}$$

$$\frac{\partial \mathcal{L}}{\partial M_{jt}} = -P_{M_{jt}} + \lambda \frac{\partial F}{\partial M_{jt}} = 0. \tag{9}$$

Thus, to maximize its current profit, the firm solves the four first order conditions, (6) to (9), together with the production function (1) for $(L_{jt}, M_{jt}, Q_{jt}^D, Q_{jt}^X, \lambda)$. There are five equations with five unknowns which implies a unique solution for the firm's problem under regularity conditions.

For researchers, we want to recover $(M_{jt}, P_{M_{jt}}, Q_{jt}^D, Q_{jt}^X, \omega_{jt}, \lambda)$ after observing the information available in a typical dataset, including $K_{jt}, L_{jt}, E_{L_{jt}}, E_{M_{jt}}$, R_{jt}^D, and R_{jt}^X, where $E_{L_{jt}}, E_{M_{jt}}$ are expenditure on labor and material respectively. Besides the first order conditions and the production function, we have the expenditure identity as one additional equation:

$$E_{M_{jt}} = M_{jt} P_{M_{jt}}. \tag{10}$$

Thus, there are six equations with six unknowns — we can uniquely recover all variables of interest from these available data under regular conditions. To see how to achieve this, first note that we can follow Grieco et al. (2015) to recover M_{jt}. Note that for CES production function,

$$\frac{\partial F}{\partial L_{jt}} = \alpha_L \left(\frac{L_{jt}}{\overline{L}}\right)^{\gamma-1} \frac{1}{\overline{L}} e^{\omega_{jt}} \overline{Q} \left[\alpha_L \left(\frac{L_{jt}}{\overline{L}}\right)^{\gamma} + \alpha_M \left(\frac{M_{jt}}{\overline{M}}\right)^{\gamma} + \alpha_K \left(\frac{K_{jt}}{\overline{K}}\right)^{\gamma}\right]^{\frac{1}{\gamma}-1},$$

$$\frac{\partial F}{\partial M_{jt}} = \alpha_M \left(\frac{M_{jt}}{\overline{M}}\right)^{\gamma-1} \frac{1}{\overline{M}} e^{\omega_{jt}} \overline{Q} \left[\alpha_L \left(\frac{L_{jt}}{\overline{L}}\right)^{\gamma} + \alpha_M \left(\frac{M_{jt}}{\overline{M}}\right)^{\gamma} + \alpha_K \left(\frac{K_{jt}}{\overline{K}}\right)^{\gamma}\right]^{\frac{1}{\gamma}-1}.$$

Plug them into (8) and (9), take the ratio of the two, and utilize the expenditure identities, $E_{L_{jt}} = L_{jt}P_{L_{jt}}$ and $E_{M_{jt}} = M_{jt}P_{M_{jt}}$, and we can solve for material quantity:

$$\frac{M_{jt}}{\overline{M}} = \left[\frac{\alpha_L E_{M_{jt}}}{\alpha_M E_{L_{jt}}}\right]^{\frac{1}{\gamma}} \frac{L_{jt}}{\overline{L}}. \tag{11}$$

This equation is exactly the same as the one used to recover material quantity in Grieco et al. (2015). Under similar conditions, the material quantity can be recovered from observables ($E_{L_{jt}}$, $E_{M_{jt}}$, and L_{jt}) up to unknown parameters. Also, $P_{M_{jt}}$ is naturally derived using the expenditure identity.

To recover ω_{jt}, we take the ratio of (6) and (7) and solve for the relationship between the output sold domestically and abroad,

$$Q^X_{jt} = z(Q^D_{jt})^{\eta^X/\eta^D}, \tag{12}$$

where $z = (\frac{1+\eta^X}{1+\eta^D}\frac{P^D_t}{P^X_t})^{\eta^X}$. Substitute it into the production function (with material quantity replaced by (11)), we have

$$z(Q^D_{jt})^{\eta^X/\eta^D} + Q^D_{jt} = e^{\omega_{jt}}\overline{Q}\left[\alpha_L\left(\frac{L_{jt}}{\overline{L}}\right)^{\gamma}\left(1+\frac{E_{M_{jt}}}{E_{L_{jt}}}\right) + \alpha_K\left(\frac{K_{jt}}{\overline{K}}\right)^{\gamma}\right]^{\frac{1}{\gamma}}. \tag{13}$$

So, this provides us with one equation about unknown (Q^D_{jt}, ω_{jt}). The labor first order condition provides us another. To see this, substitute (6) into (8), we have:

$$\frac{1+\eta^D}{\eta^D}(Q^D_{jt})^{1/\eta_D}P^D_t\alpha_L\left(\frac{L_{jt}}{\overline{L}}\right)^{\gamma-1}\frac{1}{\overline{L}}e^{\omega_{jt}}\overline{Q}\left[\alpha_L\left(\frac{L_{jt}}{\overline{L}}\right)^{\gamma}\left(1+\frac{E_{M_{jt}}}{E_{L_{jt}}}\right) + \alpha_K\left(\frac{K_{jt}}{\overline{K}}\right)^{\gamma}\right]^{\frac{1}{\gamma}-1} = P_{L_{jt}}. \tag{14}$$

It is proved that (13) and (14) admit a unique solution of (ω_{jt}, Q^D_{jt}) as long as $\eta^D, \eta^X < -1$, although in general there is no closed-form solution. That is, (13) and (14) imply a one-to-one mapping from the observable variables to (ω_{jt}, Q^D_{jt}), and consequently, (ω_{jt}, Q^D_{jt}) can be written as a unique implicit function of observables. As a result, Q^X_{jt} is also recovered from (12) as a function of observables. Therefore, we have shown that we are able to recovered $(M_{jt}, P_{M_{jt}}, Q^D_{jt}, Q^X_{jt}, \omega_{jt})$ uniquely from the observable data.

The estimation equation is constructed by plugging all these recovered variables into the revenue equations in the domestic and export markets which have not been used yet:

$$R^D_{jt} = P^D_t\left(Q^D_{jt}\right)^{1/\eta^D+1}, \quad R^X_{jt} = P^X_t\left(Q^X_{jt}\right)^{1/\eta^X+1}.$$

After the same algebra in Grieco et al. (2015), we arrive the following simple equation:

$$\frac{1+\eta^D}{\eta^D}R^D_{jt} + \frac{1+\eta^X}{\eta^X}R^X_{jt} = \left[E_{M_{jt}} + E_{L_{jt}}\left(1 + \frac{\alpha_K}{\alpha_L}\left(\frac{K_{jt}/\overline{K}}{L_{jt}/\overline{L}}\right)^{\gamma}\right)\right]. \tag{15}$$

It is worth noting that this equation is a natural extension of Equation (8) in Grieco et al. (2015) to two markets. When the firm does not sell in the export market (i.e., $R^X_{jt} = 0$), the above equation becomes the one in Grieco et al. (2015). As a result, if we denote $R^X_{jt} = 0$ when the firm does not sell in the export market, (15) also holds when the firm only sells in the domestic market. It is also straightforward to extend (15) to more than two markets.

Thus, the above prediction implies an empirical estimation equation, by adding measurement errors, u^D_{jt} and u^X_{jt}, to the recorded revenues in each market:

$$R^D_{jt} = -\left(\frac{\eta^D}{1+\eta^D}\frac{1+\eta^X}{\eta^X}\right)R^X_{jt} + \frac{\eta^D}{1+\eta^D}\left[E_{M_{jt}} + E_{L_{jt}}\left(1 + \frac{\alpha_K}{\alpha_L}\left(\frac{K_{jt}/\overline{K}}{L_{jt}/\overline{L}}\right)^{\gamma}\right)\right] + u_{jt}, \tag{16}$$

where $u_{jt} = u^D_{jt} + \frac{\eta^D}{1+\eta^D}\frac{1+\eta^X}{\eta^X}u^X_{jt}$. Note that the measurement errors in R^D_{jt} and R^X_{jt} do not influence the derivation above, because the whole derivation process, except the final estimation equation (15), does not utilize the revenue data. Following Grieco et al. (2015), it is easy to show that all parameters (including both η's) are identified with two additional constraints naturally implied by the model.[5] The first additional constraint is the sum-up assumption,

$$\alpha_L + \alpha_M + \alpha_K = 1. \tag{17}$$

The second is the input expenditure aggregation equation resulted directly from taking the geometric mean of first order conditions for labor and material quantities of all firms and taking ratios of the two aggregated first order conditions,

$$\frac{\overline{E}_L}{\overline{E}_M} = \frac{\alpha_L}{\alpha_M}, \tag{18}$$

where $\overline{E}_L$ and $\overline{E}_M$ are the geometric mean of labor expenditure and material expenditure for all firms, respectively. They can be computed directly from the data. In the empirical application,

[5] Of course, to identify both η^D and η^X, we need to assume that each market has at least one firm selling at that market.

we estimate (16) using non-linear least square (NLLS) with constraints (17) and (18),

$$\hat{\beta} = \text{argmin}_{\beta} \sum_{jt} \left\{ R^D_{jt} + \left(\frac{\eta^D}{1+\eta^D} \frac{1+\eta^X}{\eta^X} \right) R^X_{jt} - \frac{\eta^D}{1+\eta^D} \left[E_{M_{jt}} + E_{L_{jt}} \left(1 + \frac{\alpha_K}{\alpha_L} \left(\frac{K_{jt}/\overline{K}}{L_{jt}/\overline{L}} \right)^{\gamma} \right) \right] \right\}^2$$
$$\text{subject to (17) and (18)}, \tag{19}$$

where the parameter set $\beta = (\alpha_L, \alpha_M, \alpha_K, \eta_D, \eta_X, \gamma)$. Since this estimation equation holds no matter how many markets the firm sells to, we can include all firms in the estimation – no matter whether they export or not, or how many markets they export to.

As a special case, if all markets share the same demand elasticity, $\eta^D = \eta^X$, then estimating the model using the single market model is consistent even when the firm actually sells in multiple markets. However, if the demand elasticity differs across markets, $\eta^D \neq \eta^X$, then it is straightforward to see that the single market model will produce biased estimates in demand elasticity, other production parameters, and as well as the recovered productivity and input prices.

2.3 CCP Estimation of Import and Export Decisions

Estimation procedure:

1. Estimate conditional probability: $\Pr\{ie_{jt}|s_{jt}\}$. Here ie_{jt} represents the four combinations of discrete import and export decisions, $(0,0), (0,1), (1,0), (1,1)$.
   We may use multinomial logit to estimate it.

2. Estimate the state transition probability function (density function): $f(s_{jt+1}|s_{jt}, ie_{jt})$. This can be done by estimating the transition function of state variables first as in Section 4, and then compute the density function.

3. Estimate the choice-specific value $v(s_{jt}, ie_{jt})$ and ex-ante value $v(s_{jt})$. We estimate $v(s_{jt})$ first and then the other. There are two ways to estimate $v(s_{jt})$: linear solution and simulation. Because our state is large and continuous, we may prefer using simulation-based approach here. The idea is to simulate a series of static payoffs until long enough periods given the state transition function and CCP, and compute the accumulated discounted present value of these static payoffs as an approximation of $v(s_{jt})$. All of these are done for one set of model parameters.

   The technical detail is summarized as follows.

(a) Given a state $s_{jt} = (\omega_{jt}, K_{jt}, P_{M_{jt-1}}, P_{L_{jt-1}})$, draw one (ie_{jt}) from CCP and compute the static payoff $\pi(s_{jt}, ie_{jt})$ for period t. $\pi(s_{jt}, ie_{jt})$ depends on the discrete choice result. In our setup, it includes the firm profit (net of discrete cost choice), and the fixed costs of discrete choice. The model parameter θ is buried in $\pi(s_{jt}, ie_{jt})$. θ can include the sunk cost parameters and/or any unknown parameters in the profit function.

(b) Draw the iid errors, $(\epsilon^{\omega}_{jt+1}, \epsilon^{PM}_{jt+1}, \epsilon^{PL}_{jt+1})$, for the state variables. Update the state to s_{jt+1} from s_{jt}. Compute the static payoff for date $t+1$ as above. Continue this until large enough T periods and approximate the ex-ante firm value by

$$\hat{v}^n(s_{jt}) = \sum_{\tau=t}^{T} \beta^{(\tau-t)} \pi(s_{j\tau}, ie_{j\tau})$$

Here the superscript n represents the $n-th$ simulation. The choice of T must be large enough such that the discounted static payoff after that date does not affect the approximated firm value substantially.

(c) Do (a) and (b) for all states on the grid points.

(d) Repeat this for N times. Take the mean of $\hat{v}(s_{jt})^n$ as an approximation of the ex-ante firm value,

$$\hat{v}(s_{jt}) = \frac{1}{N} \sum_{n=1}^{N} \hat{v}^n(s_{jt})$$

Then the choice-specific value $v(s_{jt}, ie_{jt})$ can be estimated using

$$\hat{v}(s_{jt}, ie_{jt}) = \pi(s_{jt}, ie_{jt}) + \beta \int_{s_{jt+1}} \hat{v}(s_{jt}) f(s_{jt+1}|s_{jt}, ie_{jt}).$$

4. Smoothen $\hat{v}(s_{jt}, ie_{jt})$ to find the choice-specific value at the data points. We may regression smoothing or spline to do it.

5. Construct the likelihood function. Given $\hat{v}(s_{jt}, ie_{jt})$, we can construct the model-predicted choice probability as follows,

$$\Pr\{ie_{jt}|s_{jt}, \theta\} = \frac{\exp(\hat{v}(s_{jt}, ie_{jt}))}{\sum_{ie} \exp(\hat{v}(s_{jt}, ie))}. \tag{20}$$

The likelihood function can be constructed accordingly and used to estimate the model

parameters θ.

6. Correct CCP. After estimating model parameter θ, the model predicted choice probability implied by (20) may differ from the offline estimate. We correct the CCP using the model predicted choice probability, by replacing $\hat{\theta}$ into equation (20).

3 Data

The model developed above is used to first estimate the productivity and material input prices at the firm level, which then used to analyze the firm-level gains from international trade through productivity channel and input prices channel separately. We examine firms from six two-digit large manufacturing industries in China.

The firm level data used in the empirical analysis come from two sources. The first dataset is the firm-level manufacturing survey data collected yearly by National Bureau of Statistics in China. It covers private firms with annual sales above five million RMB and all state-owned firms. The survey records detailed information on total sales, export sales, number of workers, wage expenditure, material expenditure, book value of capital stock, as well as other firm characteristics such as age and ownership at the firm level. The other dataset used in the estimation is the Chinese custom records of import and export from Chinese Customs, which covers every transaction of import and export associated with Chinese firms. This dataset provides information about the import and export values and other variables such as sources or destination countries and the type of international trade.[6] Although we aggregate such detailed transaction level data by firm and year, our plan of the next stage research is to extend the analysis to investigate the heterogenous gains from trade by the source or destination country as well as the type of international trade. We link these two datasets together to form an unbalanced panel containing both production information and import and export information at the firm level for the empirical analysis. The merged data set covers years from 2000 to 2006. During this period, Chinese firms expanded quickly in the international markets in terms of both import and export, as a result of China's entry of WTO in 2001. So this panel data provides a natural background to study Chinese firms' gains from international trade afterwards the entry of WTO.

We use six two-digit SIC industries in the estimation: textile, leather-related products, raw chemical materials and products, rubber products, transport equipments, and electronic and communication equipments. All these industries are large and important industries in China,

[6] We observe detailed description of trade types, such as ordinary trade and processing trade.

with the number of observations in each industry ranging from 19,670 to 145,286 in total in the seven years. All these industries are intensive in export and import. Table 1 summarizes the statistics of major variables used in the empirical analysis. The share of export observations in the six industries ranges from about 18%-51% on average in the data period, while about 8%-23% observations were importing. In total, the exported products account for about 8%-47% of total revenue. The imported products account for a much smaller share of the industrial-level total expenditure on intermediate inputs, about 2%-7% in the six industries. If we only look at the importing firms, then the import accounts for about 18%-33% of the total expenditure on intermediate inputs. These summary statistics suggest that import and export play an important role in the production and sales decisions for Chinese manufacturing firms.

4 Estimation Results

We estimate the production function for each of the six industries, and the estimates are reported in Table 2. All key parameters are significant. The material parameters, α_M, ranges from 0.85-0.90, which is consistent with the level of material share used in the production of Chinese firms, as shown in Table 1. The relative value of capital and labor parameters, α_K and α_L, are generally consistent with the labor intensity in these industries. The implied labor share relative to the total expenditure on labor and capital (but excluding material) ranges from 57% in the capital intensive Raw Chemicals industry to 79% in the labor intensive Leather industry. The magnitude is similar to those estimated in the literature using other methods and data. The elasticity of substitution is larger than 1, which is quite consistent with Grieco et al. (2015) using Colombia plant level data in a single-market model. More importantly, the elasticity of demand in the domestic market differs significantly from that in the export market at the 1% level, showing that firms face very different market conditions in different markets. Such demand elasticity difference implies the necessity of extending the single-market model in Grieco et al. (2015) into the multiple-market case: by not taking this difference into account, the single-market model will generate bias in parameter estimates as well as in the recovered productivity and material input prices.

Given the parameter estimates of production and demand functions, we then can recover the productivity and input prices for each firm in each year. Specifically, we compute the material prices from the material expenditure identity, $E_{Mjt} = P_{Mjt}M_{jt}$, after solving out the (normalized) material quantity from (11). We compute the productivity, ω_{jt}, numerically by solving for

(Q_{jt}^D, ω_{jt}) jointly using (13) and (14).[7] Table 3 summaries the correlation between productivity, material price, and wage rate. They are positively correlated with each other, which is consistent with Kugler and Verhoogen (2012) using the observed material price data and Grieco et al. (2015) using the input prices recovered based on a single-market model.

In order to further check the validity of our recovered input prices, we compare the implied correlation between the recovered material input prices and firm employment and compare it with Kugler and Verhoogen (2012). Figure 1 plots the recovered material prices against employment level, both in logarithm terms and normalized by year mean, for each of the six industries. They are positively correlated, which is consistent with Figure 2 of Kugler and Verhoogen (2012). The slopes range from 0.15-0.45, which is slightly larger than that reported in Kugler and Verhoogen (2012), probably due to different data we use in the analysis.

In Figure 2 and 3, we plot the dispersion of input prices and productivity for each industry. It is shown that both productivity and input prices have reasonably large dispersion across firms within a industry. The interquartile range for input prices ranges from 1.37 (Leather) to 3.77 (Raw Chemical). This implies that even in the Leather industry, where the material prices have the least dispersion, the material price at the 75th percentile is 3.44 times higher than that of the 25th percentile. The dispersion of productivity is consistently smaller than the material prices in all industries. The interquartile range lies between 1.13 and 2.50. Such large firm heterogeneity in both productivity and material input prices gives rise to different firm performance, as well as different gains from export and import which will be analyzed in the following subsection.

4.1 Decomposition of Productivity and Input Price Gain from Trade

In the context of an open economy, the participation of international trade at the firm level can affect firm performance via productivity and/or input prices. As productivity is more persistent than input prices, gains from trade on the two different dimensions of firm heterogeneity have different implications on firm performance in the long run. Thus, it is crucial to understand what firms exactly gain from trade. In this section, we will investigate the effect of international trade on productivity and input prices separately, and then we examine how productivity and input prices influence firms' import and export decisions in the following section.

Following Section 2, we further specify the gains from international trade on productivity and

[7] Note here $R_{jt}^X = 0$ if firm j did not export in period t.

input prices as parametric (linear) functions,

$$\omega_{jt} = \rho_0 + \rho_w \omega_{jt-1} + (\rho_e + \rho_{e\omega}\omega_{jt-1})\, e_{jt-1} + (\rho_i + \rho_{i\omega}\omega_{jt-1})\, i_{jt-1} + \rho_z Z^{\omega}_{jt} + \epsilon^{\omega}_{jt}, \tag{21}$$

$$\ln P_{M_{jt}} = \chi_0 + \chi_p \ln P_{M_{jt-1}} + \left(\chi_e + \chi_{ep} \ln P_{M_{jt-1}}\right) e_{jt} + \left(\chi_i + \chi_{ip} \ln P_{M_{jt-1}}\right) i_{jt} + \chi_z Z^{m}_{jt} + \epsilon^{m}_{jt}, \tag{22}$$

where all ρ's and χ's are the parameters governing the evolution of productivity and input prices over time, and Z^{ω}_{jt} and Z^{p}_{jt} are other controlling variables including firm age, location, ownership, and year dummies. We are particularly interested in two sets of parameters. The first set includes the coefficients of export and import status in both equations, namely, $\rho_e, \rho_i, \chi_e, \chi_i$. They measure the homogenous part of gains from trade on productivity and input prices. The second set contains the coefficients of the four terms interacting with export and import status, namely, $\rho_{e\omega}, \rho_{i\omega}, \chi_{ep}, \chi_{ip}$. They measure the heterogenous part of gains from trade on productivity and input prices that is related to past productivity and input prices. The heterogenous part allows the possibility that firms with different productivity and input prices gain differently from trade.

Table 4 reports the estimation results for the productivity evolution (21). In the regression, we also control for year dummy, firm age, and ownership. We find that the productivity is quite persistent over time. On average over 50% of the productivity carries over to the next period, as captured in the parameter ρ_ω. The parameter ρ_i is positive and significant, meaning that the homogenous part of productivity gain from import is positive. However, $\rho_{i\omega}$ is not significant in five out of the six industries. The exception is Transport Equipments, in which $\rho_{i\omega}$ is negative implying a decreasing return of import on productivity. However, given the magnitude of productivity, the homogenous effect dominates the heterogeneous one in all industries, thus the overall productivity gain from import is still positive and significant. This suggests that import generally increases firm productivity in the future.

The homogenous effect from export on productivity, as captured by ρ_e, is positive in two of the six industries. In contrast, the heterogeneous effect, as captured by $\rho_{e\omega}$, is positive and significant in five of the six industries. This means that, in these industries, more productive firms gain more in productivity from export. In total, the sum of homogenous and heterogenous effects are always positive in all these industries, implying that export increases firm productivity, although the effect is heterogeneous.

Similarly, the estimation results for the input price evolution (22) are reported in Table 5. We also control for year dummy, firm age, and ownership in the regression. The material price is also very persistent over time. The coefficient on the lagged price in logarithm ranges between 0.30-0.53. Thus, conditional on other firm characteristics, firms that are able to secure low prices today are likely to be able to secure them again in the future. However, the persistence is lower than that of productivity. This is reasonable because productivity, as an internal firm characteristics, is relatively less variant over time than material price, which suffers more shocks from input markets.

There are two interesting points to take away from Table 5. First, export has a positive impact on material prices, as captured by the positive coefficients (χ_e and χ_{pe}) of export status and the interaction term of export status and lagged material price. All of these coefficients are positive and significant at the 1% level, except the Transport Equipment industry in which χ_e is insignificant. The positive interaction term, χ_{pe}, implies that the effect of export on material price is heterogenous – firms with higher material prices suffer more from the increased material price due to export. This is intuitive since exporting firms are usually more demanding in material input which leads to higher input prices.

Second, import has a negative effect on material prices. In all of the industries, the coefficient on import status χ_i is negative and significant at 1% level. The coefficient on the interaction term of import status and history material price, χ_{pi}, is insignificant in five of the six industries we investigated and in the other one it is negative and significant. These results together implies that import reduces material price dramatically. This result is economically intuitive. As documented in Kasahara and Rodrigue (2008), Goldberg et al. (2009, 2010), and Halpern et al. (2011), import of material inputs can increase the quality and variety of available inputs, or reduces the material price. Consequently this implies lower quality-adjusted material prices. This finding also corroborates Zhang (2014) who finds that importing firms have a higher price-adjusted quality of material inputs in a more restricted setup assuming constant price-adjusted quality across firms and over time using a plant level dataset from Colombia. The completely different effects of import on productivity and material prices further confirm that productivity and input prices are two different firm characteristics, which influence firm decisions via different channels and should be given equal attention when analyzing firm decisions and performance. [8]

[8] As the next step of this paper (to be added), we are going conduct a comparison: what if we ignore the input price heterogeneity? The estimate of productivity gain from trade will be biased due to the biased parameter estimates, and more importantly the productivity gain from trade will pick up the input price gain and thus is biased.

4.2 Heterogeneous Impact of Productivity and Input Prices on Trade Decisions

In this section, we investigate the differential impacts of productivity and input prices on firms' import and export decisions. The estimation is based on the policy functions implied by firms' dynamic decisions, as specified in (5). In particular, we investigate the linear policy functions for import and export decisions. The parametric specification we estimate is

$$\Pr(e_{jt} = 1) = \psi_0 + \psi_e e_{jt-1} + \psi_i i_{jt-1} + \psi_\omega \omega_{jt} + \psi_p \ln(P_{M_{jt-1}}) + \psi_\ell \ln(P_{L_{jt-1}}) + \psi_k \ln(K_{jt}), \quad (23)$$

$$\Pr(i_{jt} = 1) = \phi_0 + \phi_e e_{jt-1} + \phi_i i_{jt-1} + \phi_\omega \omega_{jt} + \phi_p \ln(P_{M_{jt-1}}) + \phi_\ell \ln(P_{L_{jt-1}}) + \phi_k \ln(K_{jt}),$$

where ϵ^i_{jt} and ϵ^e_{jt} are i.i.d. idiosyncratic shocks to the import and export decisions, and $\mathbf{1}(\cdot)$ is an indicator function. In the regressions, we also control for firm age, ownership dummy, and year dummy.

Table 6 reports how firm heterogeneity in productivity and input prices influences export decisions differently. The first column for each industry reports the main estimates from a linear probability model, with the binary export status as the dependent variable. First, we find that productivity has a significant and positive effect on export probability, as captured by the estimate of ψ_ω. ψ_ω ranges from 0.068 to 0.343 in the six industries, implying that a 1% increase of the lagged productivity increases export probability in this period by 0.068% to 0.343%. Second, the material price has a negative effect on the export probability. The parameter ψ_p ranges from -0.057 to -0.233. This implies that a 1% increase of the lagged material price reduces the export probability in this period by about 0.057% to 0.233%. Similarly, we see that higher lagged wage rate also reduces export probability. This is reasonable because higher material price and wage rate mean higher marginal production cost, which reduces profitability in the export market. The significant and opposite effects of productivity and input prices imply that both material price and wage rate are important sources of firm heterogeneity, besides productivity, in determining firm export behavior. Moreover, the high correlation between productivity and material price implies that, even if the productivity is correctly recovered, the impact of productivity on export probability will be substantially biased if the material price (and/or wage rate) is omitted in the regression.

Other parameter estimates are all within reasonable range. The coefficient of the lagged export, ψ_e, ranges from 0.560 to 0.666, implying a strong persistence of export status due to sunk/fixed export costs (Aw et al. (2011b)). The lagged import status also has a positive impact on the

probability of exporting, as captured by ψ_i. ψ_i ranging from 0.092 to 0.151, implying an increase of exporting probability by 9.2% to 15.1% if the firm imported in the last period.

In order to check the robustness, we also estimate a Tobit model using export share (the ratio of export and total sales) as the dependent variable. The results are quite similar. In particular, the lagged productivity term increases export share; the lagged material price and wage rate both reduce the export share. All these results suggest that productivity and input prices are two important sources of firm heterogeneity and they have different implications on firm export decisions.

Table 7 summarizes how productivity and material prices, together with other factors, determine firms' import decisions. In the first column for each industry, we estimate a linear probability model of firms' import decisions. Several points stand out. First, productivity may or may not have an impact on the probability of import: as captured by the parameter ϕ_ω, the lagged productivity increases the import probability in three out of the six industries, while in the other three industries there is no significant impact. Second, firms with higher material price are less likely to import, as indicated by the negative coefficient on the lagged material price. This is the result of two offsetting effects. On the one hand, firms with higher material price may have higher incentive to import inputs from abroad in order to take the advantage of lower quality-adjusted prices. On the other hand, as Table 5 suggests, firms with a high material price actually gains less from import – this is consistent with the persistence of input price and the observation that firms are likely to import a small portion in the beginning. The estimates of ϕ_p suggests that the latter effect is at least as large as the former. Third, wage rate has positive effect on import. One explanation is that labor and material sometimes are substitutes – when firms face high wage rate, they tend to import some intermediate inputs to substitute labor input.

Besides, we also find some other interesting and intuitive results. Import status is very persistent, as shown by the estimated coefficient on the lagged import status which is positive and large ranging between 0.70-0.82. Lagged export status also increases the probability of import, as captured by the positive ϕ_e. Large firms, as represented by larger capital stock, tend to import more. However, ϕ_ω is positive and significant in four out of the six industries, but is insignificant in others. This implies that productivity may have a non-negative impact on importing probability. Furthermore, we estimate a Tobit model as a robustness check. The results are reported in the second column of Table 7 for each industry. The results are consistent with the linear probability models.

4.3 Intensive and Extensive Margins of Productivity and Input Price Gain from Trade

After decompose the gain from trade into dimensions of productivity and input price and analyze of heterogeneous impact of productivity and input prices on trade decisions, we are ready to evaluate productivity and input price gains in terms of both intensive and extensive margin of total revenue. The questions we pursuit here are as follows: if there were no gain from trade on productivity or input price, how do firms export and import probabilities change (i.e., extensive margin)? Consequently, conditional on the current export and import decisions, how do the domestic revenue and export revenue change (i.e., intensive margin)? We measure these margins with a set of counterfactual experiments.

To evaluate the intensive margin, we shut down the trade effect on productivity and input price and measure the changes of domestic revenue and export revenue respectively. Specifically, to quantify the intensive margin of productivity gain from export, we eliminate the gain by setting ρ_e and $\rho_{e\omega}$ as zero in (21). Thus, the productivity of firm j at period t changes by $(\rho_e + \rho_{e\omega}\omega_{jt-1})$ if the firm exported in period $t-1$.[9] As shown in Table 8, the average productivity drop is significant in all industries: it ranges from 1.76% (Electronic and Communication Equipments) to 10.37% (Textile). Given the counterfactual productivity, together with other recovered parameters and variables including material prices, wage rate, and capital stock, we solve for R^D_{jt} and R^X_{jt} from the firm's profit maximization problem, conditional on its export status.[10] The average relative changes (in percentage) of both domestic and export revenue is reported in Table 8. The drop of revenue is quite shape: it ranges from 10.66% to 62.03% for domestic revenue and from 19.27% to 76.25% for export revenue. The drop of export revenue is larger because of the more elastic demand in the export market.

We conduct a similar experiment with respect to the export effect on material prices, and find that as material prices decrease both domestic and export revenue increase. Although the magnitude of the revenue changes depends on the changes of material prices directly, the removal of the input price gain from export is the only source of input price decrease. Thus, the comparison of the magnitudes of the revenue changes caused by changes of productivity and input price suggests that the gains from export on productivity and input price are quite heterogeneous across industries. In particular, the intensive margin of input price gain from export is significantly higher than that

[9] For firms did not export in period $t-1$ their productivity remain the same.

[10] Again, if the firm did not export in period t then R^X_{jt} remain as zero.

of productivity gain in Textile, Leather, Rubber, and Electronic and Communication Equipments, while in Raw Chemical and Transport Equipment, the relationship reverses.

Then in a similar set of experiments, we eliminate the gains from import to evaluate its intensive margin. Compared with the previous experiments, this gives rise to a very different influence on productivity and input prices. For example, in Transport Equipment while the productivity decreases by 0.79% the input price increases by 15.39%. As a result, the intensive margin of input price gain from import is significantly higher in Raw Chemical, Rubber, Transport Equipment, and Electronic and Communication Equipments. Comparing the results in Table 6 and 7 we can see that the intensive margin of gains from export in larger than that from import in Textile, Leather, Rubber, and Electronic and Communication Equipments, while in Raw Chemical and Transport Equipment, the relationship reverses.

To evaluate the extensive margin, we conduct the same exercises but measure the changes of import and export probabilities. For example, when the productivity gain from export is removed, the drop in productivity implies a decrease in both export and import probabilities via (23) and (24). The average decrease of these probabilities across exporting firms are reported in the first column of each industry in Table 8: the drop of export probability ranges from 0.16% in Electronic and Communication Equipments industry and 2.01% in Leather industry. Note that these numbers look small since they are in the absolute level (measuring a direct change of export probability). However, they are quite reasonable given that observations of exporting firms only account for 17.84% to 51.14% of total observations. Accordingly, the decreases of import probabilities range from 0.005% to 0.49%. It is obvious that the influence on the export probability is stronger than that on the import probability. This is consistent with the result shown in the coefficient estimates (ψ_ω and ϕ_ω) in Table 6 and 7: productivity is a more effective determinant for export than for import.

We conduct a similar experiment with respect to the export effect on material prices, and find that as material prices decrease both export and import probabilities increase. However, the export probability consistently increases more significantly than import probability: the increase of export probability ranges from 0.070% to 1.90% while 0.002% to 0.49% for the increase of import probability. Comparing these numbers to the counterpart that caused by productivity changes, we find that the productivity gain from export is stronger in terms of extensive margin than the input price gain from export (with Communication Equipments industry as an exception). In contrast, the counterpart of Table 7 shows that, in general, the input price gain from import is

more significant in terms of extensive margin than the productivity gain from import.

5 Conclusion

This paper analyzes the gains from international trade in terms of both productivity and intermediate input prices. Because of the data limitation, input prices do not receive equal attention as productivity in the previous analysis of gains from trade. This is likely to bias the gains from trade for two reasons. First, when input prices are not available in most firm-level data sets, the traditional method usually uses deflated input expenditure as proxy of input quantity, which leads to biased productivity estimates. Second, even if the productivity is consistently estimated, without controlling for input prices, the estimated productivity gain from trade will be a mixture of actual gain of both productivity and input prices from trade. In this paper, we solve these problems by extending the methodology developed in Grieco et al. (2015) to the multiple-market case. This allows us to consistently estimate production functions and recover the firm-level productivity and input prices in the presence of input price dispersion when intermediate input quantities are not observed.

We apply the method to a rich data set for six two-digit large Chinese manufacturing industries from 2000 to 2006. With the recovered firm level productivity and input prices, we decompose the gains from international trade into the channels of productivity and input prices separately. We find that both import and export tend to increase firm productivity, with stronger effect from export. While import decreases the quality-adjusted input prices, export tends to increase input prices. By regressing the export and import decisions against both productivity and input prices, we find the two have opposite impacts on trade decisions: firms with higher productivity and lower input prices are more likely to import and export, and import and export more.

We further conduct counterfactual analysis to examine the relative importance of the productivity gain and input price gain from international trade. The results show that firms do gain from export via the channel of productivity in terms of both intensive and extensive margins. However, the productivity gain from export is partially offset by the adverse export effect on input price. In contrast, importing firms gain positively in terms of both increased productivity and reduced quality-adjusted material prices.

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Appendices

Figure 1: Relation Between Material Price and Employment (deviation from year means)

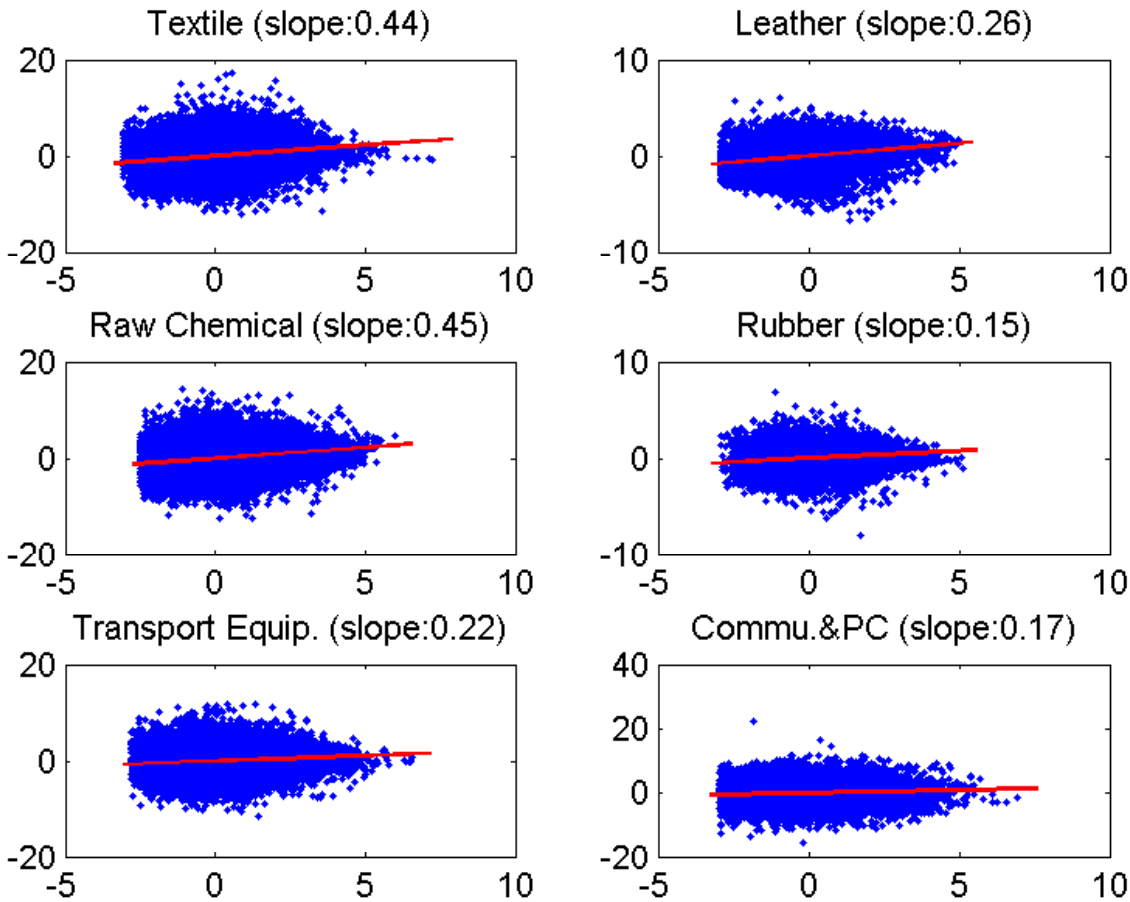

Figure 2: Distributions of Material Price in logarithm

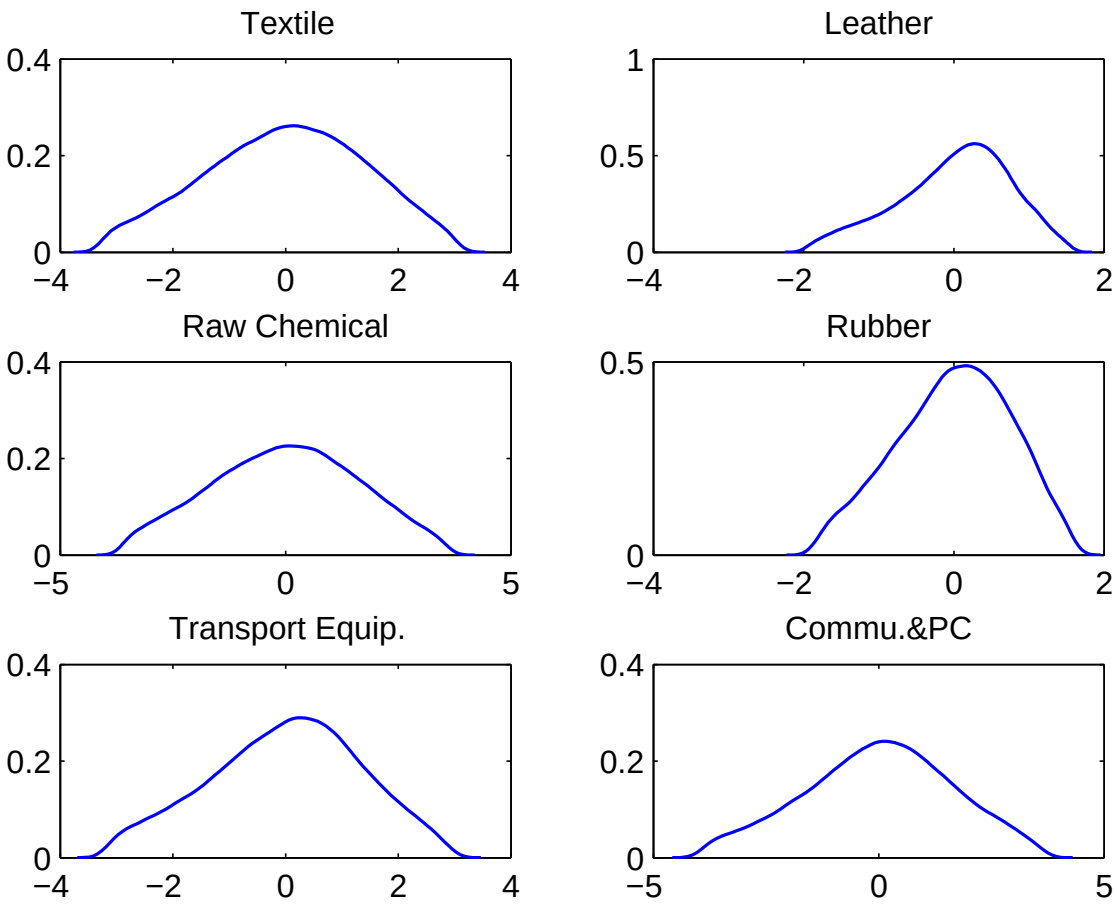

Figure 3: Distributions of Productivity

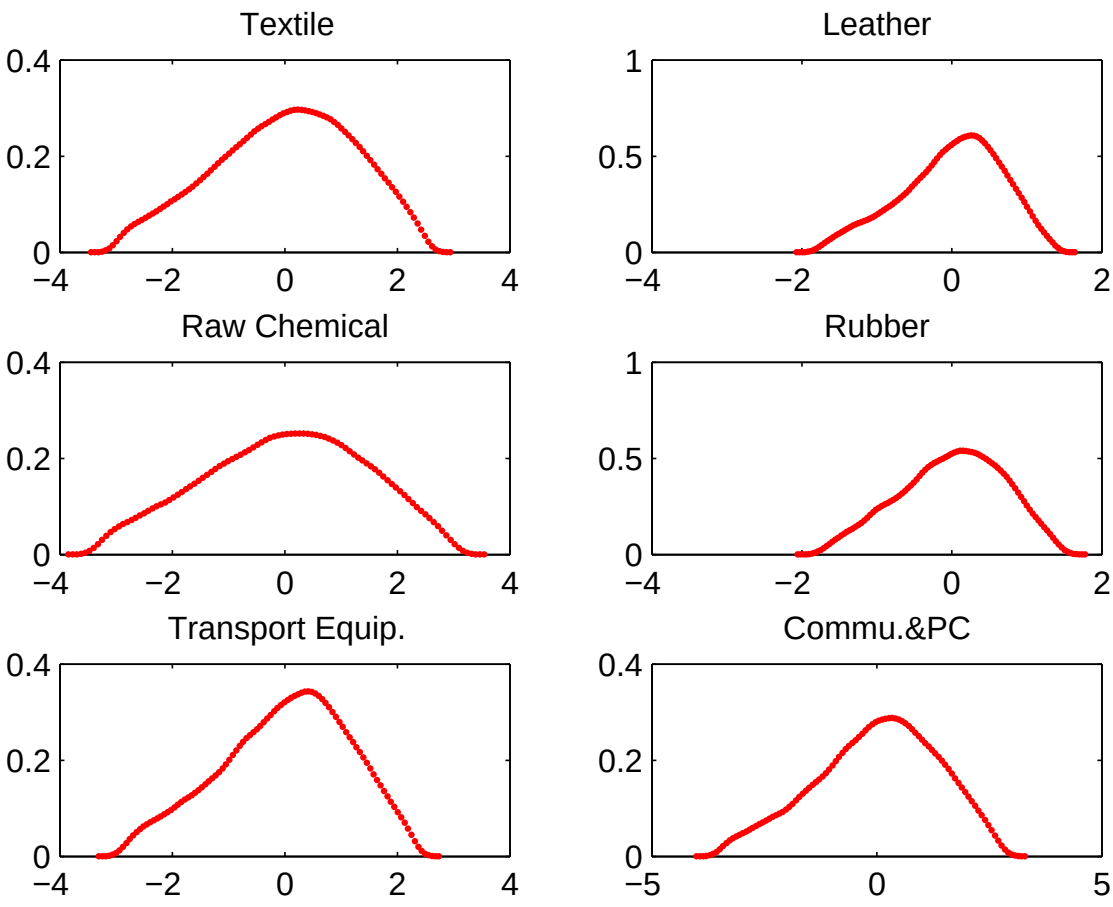

Table 1: Summary Statistics of Six Industries

Parameter	Textile	Leather	Raw Chemical	Rubber	Transport Equip.	Commu.&PC
Total Sales	47.473	45.855	71.723	60.072	121.997	188.259
Export	11.962	23.230	6.522	14.469	13.906	101.415
Labor Quantity	294	358	209	288	343	411
Wage Expenditure	2.941	4.203	3.074	3.411	5.963	8.082
Material Expenditure	40.396	38.668	59.870	50.818	103.462	163.854
Capital Stock	18.472	8.172	36.220	26.671	42.043	38.248
Exporting Obs (%)	31.383	51.148	17.842	27.214	19.064	37.856
Importing Obs (%)	8.564	17.067	7.691	14.052	9.629	23.214
Export-Revenue Share (%, all firms)	22.1	45.7	7.7	16.2	8.9	25.3
Import-material Expenditure Share (%, all firms)	1.566	4.158	1.811	4.119	1.830	7.634
Export-Revenue Share (%, exporting firms)	70.3	89.3	43.0	59.5	46.7	66.8
Import-material Expenditure Share (%, import firms)	18.285	24.363	23.551	29.310	19.004	32.883
Number of Obs	145,286	40,060	123,761	19,670	75,294	66,394

All values in this table are in million RMB.

Table 2: Production Function Estimates

Parameter	Textile	Leather	Raw Chemical	Rubber	Transport Equip.	Commu.&PC
η^D	-7.925	-6.981	-6.847	-6.713	-7.620	-6.791
	(0.051)	(0.081)	(0.043)	(0.100)	(0.077)	(0.077)
η^X	-11.280	-11.474	-8.770	-10.952	-11.454	-11.997
	(0.186)	(0.290)	(0.221)	(0.556)	(0.443)	(0.352)
σ	1.521	2.445	1.509	2.340	1.584	1.500
	(0.022)	(0.120)	(0.017)	(0.159)	(0.028)	(0.024)
α_L	0.074	0.098	0.055	0.084	0.088	0.097
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
α_M	0.894	0.875	0.905	0.886	0.866	0.850
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
α_K	0.032	0.026	0.041	0.030	0.046	0.053
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)

Table 3: Correlation between Variables

Correlation	Textile	Leather	Raw Chemical	Rubber	Transport Equip.	Commu.&PC
$\text{corr}(\omega, P_M)$	0.836	0.901	0.799	0.895	0.824	0.778
$\text{corr}(\omega, P_L)$	0.335	0.639	0.359	0.673	0.398	0.347
$\text{corr}(\omega, K)$	0.030	0.103	0.069	0.101	0.057	0.029
$\text{corr}(K, E_M)$	0.911	0.709	0.710	0.757	0.831	0.350
$\text{corr}(K, E_L)$	0.852	0.648	0.400	0.729	0.810	0.449

Table 4: Productivity Regression Result

Parameter	Textile	Leather	Raw Chemical	Rubber	Transport Equip.	Commu.&PC
ρ_0	0.717	0.813	0.766	0.922	0.565	0.551
	(0.028)	(0.029)	(0.033)	(0.043)	(0.033)	(0.040)
ρ_ω	0.531	0.451	0.586	0.484	0.573	0.596
	(0.003)	(0.007)	(0.003)	(0.009)	(0.004)	(0.006)
ρ_e	0.041	0.094	-0.012	0.049	-0.021	-0.004
	(0.013)	(0.018)	(0.019)	(0.038)	(0.020)	(0.023)
ρ_i	0.087	0.063	0.026	0.050	0.129	0.028
	(0.022)	(0.025)	(0.028)	(0.048)	(0.028)	(0.024)
$\rho_{\omega e}$	0.077	-0.000	0.058	0.028	0.044	0.018
	(0.006)	(0.011)	(0.008)	(0.019)	(0.010)	(0.009)
$\rho_{\omega i}$	-0.007	-0.014	0.003	-0.016	-0.066	-0.018
	(0.009)	(0.013)	(0.010)	(0.022)	(0.012)	(0.009)
yr2002	0.060	0.090	0.010	0.033	0.037	0.023
	(0.018)	(0.020)	(0.020)	(0.027)	(0.021)	(0.031)
yr2003	0.065	0.153	0.057	0.099	0.028	0.009
	(0.018)	(0.020)	(0.021)	(0.028)	(0.022)	(0.031)
yr2004	0.168	0.267	0.144	0.197	0.149	0.172
	(0.018)	(0.020)	(0.021)	(0.028)	(0.021)	(0.031)
yr2005	0.095	0.251	0.065	0.147	0.023	0.034
	(0.017)	(0.019)	(0.019)	(0.025)	(0.020)	(0.028)
yr2006	0.135	0.321	0.098	0.175	0.116	0.211
	(0.017)	(0.018)	(0.019)	(0.025)	(0.020)	(0.027)

Table 5: Material Price Regression Result

Parameter	Textile	Leather	Raw Chemical	Rubber	Transport Equip.	Commu.&PC
χ_0	-2.197	-2.349	-3.066	-2.286	-1.986	-2.574
	(0.278)	(0.098)	(0.223)	(0.107)	(0.152)	(0.297)
χ_p	0.474	0.317	0.509	0.301	0.502	0.531
	(0.003)	(0.006)	(0.003)	(0.007)	(0.004)	(0.006)
χ_e	0.106	0.116	0.029	0.077	0.009	0.119
	(0.010)	(0.009)	(0.014)	(0.014)	(0.015)	(0.020)
χ_i	-0.047	-0.025	-0.248	-0.059	-0.130	-0.096
	(0.015)	(0.011)	(0.020)	(0.017)	(0.021)	(0.021)
χ_{pe}	0.097	0.031	0.031	0.064	0.033	0.057
	(0.005)	(0.008)	(0.007)	(0.014)	(0.009)	(0.008)
χ_{pi}	-0.007	0.014	-0.010	-0.028	-0.058	0.008
	(0.008)	(0.010)	(0.009)	(0.016)	(0.010)	(0.009)
χ_k	-0.054	-0.028	-0.052	-0.027	-0.082	-0.065
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.005)
χ_w	1.279	1.008	1.262	1.022	1.051	0.989
	(0.010)	(0.009)	(0.010)	(0.012)	(0.011)	(0.014)

Table 6: Export Decision/Share Regressions

Parameter	Textile		Leather		Raw Chemical		Rubber		Transport Equip.		Commu.&PC	
	Export	Export Sh.	Export	Export Sh.	Export	Export Sh.	Export	Export Sh.	Export	Export Sh.	Export	Export Sh.
ψ_0	0.112	-0.575	0.137	-0.268	0.076	-0.481	0.013	-0.739	0.138	-0.629	0.313	0.103
	(0.012)	(0.025)	(0.030)	(0.047)	(0.011)	(0.028)	(0.038)	(0.084)	(0.014)	(0.037)	(0.017)	(0.027)
ψ_e	0.673	1.032	0.608	0.928	0.678	0.909	0.661	0.981	0.653	0.949	0.584	0.740
	(0.003)	(0.007)	(0.007)	(0.011)	(0.003)	(0.008)	(0.009)	(0.021)	(0.004)	(0.011)	(0.005)	(0.009)
ψ_i	0.106	0.154	0.092	0.099	0.112	0.126	0.150	0.229	0.121	0.184	0.125	0.164
	(0.005)	(0.008)	(0.008)	(0.011)	(0.005)	(0.009)	(0.011)	(0.018)	(0.006)	(0.012)	(0.006)	(0.008)
ψ_ω	0.130	0.325	0.311	0.665	0.065	0.152	0.264	0.793	0.091	0.318	0.099	0.187
	(0.007)	(0.016)	(0.022)	(0.034)	(0.006)	(0.016)	(0.026)	(0.057)	(0.008)	(0.024)	(0.008)	(0.014)
ψ_p	-0.103	-0.246	-0.203	-0.380	-0.053	-0.111	-0.176	-0.513	-0.069	-0.255	-0.069	-0.129
	(0.006)	(0.014)	(0.017)	(0.027)	(0.005)	(0.014)	(0.020)	(0.046)	(0.006)	(0.020)	(0.006)	(0.011)
ψ_ℓ	-0.010	-0.050	-0.118	-0.324	-0.013	-0.085	-0.096	-0.364	-0.032	-0.103	-0.067	-0.182
	(0.003)	(0.007)	(0.010)	(0.015)	(0.003)	(0.007)	(0.012)	(0.026)	(0.004)	(0.011)	(0.005)	(0.007)
ψ_k	-0.007	-0.061	-0.013	-0.046	0.010	0.007	-0.004	-0.059	0.011	-0.007	0.017	0.015
	(0.001)	(0.002)	(0.002)	(0.003)	(0.001)	(0.002)	(0.003)	(0.006)	(0.001)	(0.003)	(0.001)	(0.002)

Table 7: Import Decision/Share Regressions

Parameter	Textile		Leather		Raw Chemical		Rubber		Transport Equip.		Commu.&PC	
	Import	Import Sh.	Import	Import Sh.	Import	Import Sh.	Import	Import Sh.	Import	Import Sh.	Import	Import Sh.
ϕ_0	0.079	-0.483	0.027	-0.556	0.070	-0.517	0.092	-0.488	0.106	-0.357	0.089	-0.438
	(0.007)	(0.019)	(0.018)	(0.037)	(0.006)	(0.022)	(0.022)	(0.056)	(0.008)	(0.020)	(0.011)	(0.020)
ϕ_e	0.032	0.090	0.033	0.094	0.025	0.074	0.035	0.098	0.032	0.060	0.029	0.071
	(0.002)	(0.005)	(0.004)	(0.009)	(0.002)	(0.005)	(0.005)	(0.013)	(0.003)	(0.005)	(0.004)	(0.006)
ϕ_i	0.699	0.466	0.792	0.575	0.799	0.556	0.812	0.564	0.763	0.423	0.822	0.633
	(0.003)	(0.005)	(0.005)	(0.008)	(0.003)	(0.007)	(0.006)	(0.013)	(0.004)	(0.006)	(0.004)	(0.007)
ϕ_ω	0.020	0.074	0.064	0.162	-0.001	0.023	0.014	0.164	0.008	0.015	0.027	0.086
	(0.004)	(0.013)	(0.013)	(0.026)	(0.003)	(0.013)	(0.015)	(0.037)	(0.005)	(0.013)	(0.005)	(0.011)
ϕ_p	-0.017	-0.061	-0.052	-0.130	-0.002	-0.038	-0.016	-0.156	-0.008	-0.023	-0.023	-0.085
	(0.004)	(0.011)	(0.011)	(0.021)	(0.003)	(0.011)	(0.012)	(0.030)	(0.004)	(0.011)	(0.004)	(0.009)
ϕ_ℓ	0.008	0.013	-0.008	-0.023	0.016	0.067	0.013	0.006	0.010	0.048	0.003	0.023
	(0.002)	(0.005)	(0.006)	(0.011)	(0.001)	(0.005)	(0.007)	(0.017)	(0.002)	(0.006)	(0.003)	(0.005)
ϕ_k	0.010	0.029	0.008	0.016	0.005	0.013	0.007	0.006	0.009	0.023	0.010	0.018
	(0.001)	(0.002)	(0.001)	(0.003)	(0.000)	(0.002)	(0.002)	(0.004)	(0.001)	(0.002)	(0.001)	(0.002)

Table 8: Change of Revenue (in percentage) and Trade Probability if Gain from Export on Productivity and Input Price

No Effect on:	Textile		Leather		Raw Chemical		Rubber		Transport Equip.		Commu.&PC	
	ω	P_M	ω	P_M	ω	P_M	ω	P_M	ω	P_M	ω	P_M
$\Delta \exp(\omega)$ or P_M	-10.372	-9.117	-6.587	-11.257	-5.882	-3.638	-6.663	-8.550	-2.984	-1.098	-1.760	-10.072
ΔR^D	-62.029	79.341	-38.980	74.824	-38.422	17.557	-38.536	48.747	-23.806	7.002	-10.662	47.253
ΔR^X	-76.246	137.990	-57.895	165.966	-47.496	23.969	-57.165	99.708	-34.901	11.272	-19.269	108.502
$\Delta \Pr(e)$	-1.388	0.902	-2.019	1.902	-0.371	0.159	-1.649	1.255	-0.251	0.070	-0.162	0.608
$\Delta \Pr(i)$	-0.208	0.145	-0.417	0.488	0.005	0.006	-0.090	0.111	-0.022	0.008	-0.044	0.202

Table 9: Change of Revenue (in percentage) and Trade Probability if Gain from Import on Productivity and Input Price

No Effect on:	Textile		Leather		Raw Chemical		Rubber		Transport Equip.		Commu.&PC	
	ω	P_M	ω	P_M	ω	P_M	ω	P_M	ω	P_M	ω	P_M
$\Delta \exp(\omega)$ or P_M	-4.251	5.157	-2.530	2.343	-2.134	28.717	-1.196	7.180	-0.794	15.359	-0.129	10.234
ΔR^D	-31.775	-20.226	-17.426	-8.701	-13.816	-62.434	-7.623	-23.785	-3.018	-42.159	-1.475	-28.605
ΔR^X	-43.310	-28.497	-28.488	-14.731	-17.927	-72.773	-12.900	-37.695	-4.723	-57.874	-1.254	-47.261
$\Delta \Pr(e)$	-0.505	-0.409	-0.741	-0.411	-0.125	-1.149	-0.294	-1.077	-0.101	-0.787	-0.023	-0.617
$\Delta \Pr(i)$	-0.076	-0.066	-0.153	-0.105	0.002	-0.044	-0.016	-0.096	-0.009	-0.086	-0.006	-0.205