Productivity Implication of Importing Intermediate and Fixed Cost of Import: Evidence from Chinese Firm-Level Data

Kensuke Suzuki*

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1 Motivation

Firm's decision on importing intermediate inputs and its productivity implication have been widely discussed in the literature of development economics and international trade. Provided the empirical regularity from firm-level data showing that importers are likely to be larger and more productive than non-importers (Bernard et al., 2012), these studies build upon a model with firm heterogeneity in productivity.

In the standard Melitz type of firm heterogeneity model, selection of firms into importing can be explained by the existence of fixed and sunk costs of import, i.e., firm needs to incur the sunk and fixed cost to initiate and keep foreign sourcing. Only firms that are sufficiently productive find it profitable to import intermediate goods.

However, this productivity sorting is not perfect in the data. Looking at Chinese firm-level data, I found that productivity distributions of importers and non-importers are substantially overlapping.[1] In other words, there are large mass of high productive, but not importing firms. This imperfect sorting can be attributed to the heterogeneity of fixed and sunk cost of import.[2] For example, conditional on firm's productivity, a firm which draws higher fixed cost would not be able to import intermediate goods from abroad.

Given this emphasis, in this study, I introduce the stochastic formulation of fixed and sunk cost of import into the structural model of firm's importing behavior. I estimate the model using Chinese firm level data. This will allow us to assess how importing intermediate inputs affects the evolution of firm's productivity and how heterogeneous the fixed and sunk costs of import are.

2 Theoretical Framework

The basic framework of the model is based on Kasahara and Rodrigue (2008). The full description of the model is presented in Appendix A. I assume that intermediate inputs are aggregated by the

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[1] In Appendix C, I present the tentative result for the production function estimation *à la* Levinsohn and Petrin (2003). Figure 1 and 2 show the productivity distributions (histograms) of importers and non-importers.

[2] The other rationale would be the possibility of vertical integration by the high productive firms, which is beyond the scope of this study.

standard CES aggregator. Since importers would be able to access wider variety of inputs than non-importers, this captures the static benefit of importing intermediate inputs. Provided that the dataset does not contain product-level intermediate inputs, I assume an equilibrium where all the intermediate inputs are used symmetrically. This allows us to distinguish importers from non-importers by the relative measure of total intermediate inputs to domestically produced intermediate inputs. Importing also has dynamic implication, i.e., the evolution of firm's productivity depends on the previous period productivity and import decision. This captures the *learning by importing effect*. The major departure from Kasahara and Rodrigue's model is that I introduce stochastic specification of fixed and sunk cost of import, i.e., a firm draws a relevant cost (i.e., startup sunk cost or fixed cost) of import depending on the previous period import decision. This formulation is inspired by Bai et al. (2017). Upon observing the cost, a firm solves dynamic optimization problem and decide whether to import.

3 Data

I use two Chinese data sets. The first one consist of firm-level data from the Annual Survey of Industrial Production (ASIP) from 1998 to 2007 conducted by the Chinese government's National Bureau of Statistics. The data contains information on the firm's industry of production, ownership type, employment, capital stocks, and revenues. The second data set is Chinese Customs transaction-level data. It records the universe of transaction by Chinese firms that participated in international trade over the 2000–2006 period. Detailed description is available in Appendix C.1.

In the empirical analysis, I focus on the manufacturing of electrical machinery (#31 of 2-digit ISIC Rev.3). I choose this industry after taking into account the number of observations in the dataset, importing firm share, and change in importer share over the sample period. Appendix C.2 provides more detailed explanation. Observing changes in firm's importing status is important because the distributions of fixed and sunk cost of import are identified from the switch from importer to non-importer and *vise versa*.

4 Empirical Strategy

I will briefly describe the empirical components of this study. Estimation consists of two steps.

Stage 1: Elasticity of Substitution and Productivity

The detailed procedure is presented in Appendix B.1. First, we estimate the elasticity of substitution by running the OLS:

$$TVC_{it} = \frac{\sigma - 1}{\sigma} r_{it}$$

where TVC_{it} is total variable cost of firm i at period t, r_{it} is revenue, and σ is elasticity of substitution across final goods. Then, we estimate the productivity using the control function technique of Levinsohn and Petrin (2003). We estimate the log revenue function

$$\ln(r_{it}) = \phi_0 + \sum_{t=1}^{T} \phi_t D_t + h(k_{it}, x_{it}, n_{it}) + u_{it}$$

where k_{it} and x_{it}, respectively, are log of capital stock and total intermediate inputs. n_{it} is total intermediate inputs divided by domestic intermediate inputs, which proxies the relative measure of total intermediate inputs to domestic intermediate inputs. I approximate $h(\cdot)$ by 3rd-degree polynomial of its argument. Using the OLS estimates on ϕ's and the value of $h(\cdot)$, I estimate the following equation, which is derived from the evolution of productivity, by the nonlinear least squares:

$$-\frac{1}{1-\hat{\sigma}}\hat{h}(k_{it}, n_{it}, x_{it}) = \alpha_0 + \sum_{s=1}^{3} \alpha_s \left(-\frac{1}{1-\hat{\sigma}}\hat{h}(k_{it-1}, n_{it-1}, x_{it-1}) + \beta_k k_{it-1} \right)^s + \alpha_4 d_{it-1} - \beta_k k_{it} + \xi_{it}$$

where d_{it} is import dummy which takes 1 if a firm i is importer in period t. This gives a conditional distribution of $F(\omega'|\omega, \mathbf{d})$ which is used in the stage 2 estimation.

Stage 2: Dynamic Estimation

In the second stage, I estimate the distribution parameters of fixed and sunk cost using the maximum likelihood following Bai et al. (2017). I will present the sketch of the algorithm, which is explained in detail in Appendix B.2.

1. Give an initial guess of the exponential distribution parameter for sunk/fixed cost of import.
2. Solve the value functions of importer and non-importers using the value function iteration. In this step, I calculate the continuation values of importer and non-importer using $F(\omega'|\omega, \mathbf{d})$ obtained previously. Choice probability (to become or stay as importer/non-importer) can be computed given distribution of fixed and sunk cost.
3. Evaluate the likelihood function of every observation.

For the discretization of the state space, I follow Aw et al. (2011).

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Appendix A The Model

A.1 Demand side

Utility function is canonical CES:

$$U_t = U\left(\{q_{it}\}_{i\in\Omega}\right) = \left[\int_{i\in\Omega} (q_{it})^{\frac{\sigma-1}{\sigma}}\, di\right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

Suppose that elasticity of substitution σ is same for all market. CES price index is

$$P_t = \left[\int_{i\in\Omega} (p_{it})^{1-\sigma}\, di\right]^{\frac{1}{1-\sigma}} \tag{2}$$

Firm-level demand is

$$q_{it} = \left(\frac{p_{it}}{P_t}\right)^{-\sigma} \frac{Y_t}{P_t} \tag{3}$$

where Y_t is total expenditure.

A.2 Pricing rule

With monopolistic competition, firm's pricing rule is

$$p_{it} = \frac{\sigma}{\sigma-1} MC_{it} \tag{4}$$

A.3 Supply side

I follow Kasahara and Rodrigue (2008) for the specification of production function. Output of plant i at time t is

$$Y_{it} = \exp(\omega_{it}) K_{it}^{\beta_k} L_{it}^{\beta_\ell} \left[\int_0^{N(d_{it})} x(j)^{\frac{\theta-1}{\theta}}\, dj\right]^{\frac{\theta}{\theta-1}\beta_x} \tag{5}$$

where $\exp(\omega_{it})$ is Hicks-neutral productivity, K_{it} is capital input, L_{it} is labor input. $x(j)$ is intermediate input. $N(d_{it})$ is the measure of intermediate input which depends on importing status d_{it}. $d_{it} = 1$ if a plant i uses imported inputs and 0 otherwise:

$$N(d_{it}) = \begin{cases} N_{ft} & \text{if } d_{it} = 1 \\ N_{ht} & \text{otherwise} \end{cases}$$

Horizontally differentiated materials in the production function is a common specification used to analyze a change in the total factor productivity in the international trade and the growth literature.

Consider the equilibrium where all intermediate goods are symmetrically produced $x(j) = \overline{x}$.

$$Y_{it} = \exp(\omega_{it}) N(d_{it})^{\frac{1}{\theta-1}\beta_x} K_{it}^{\beta_k} L_{it}^{\beta_\ell} X_{it}^{\beta_x} \tag{6}$$

where $X_{it} = N(d_{it})\overline{x}$. Suppose that production function is constant return to scale in K_{it}, L_{it} and X_{it}, i.e., $\beta_l + \beta_\ell + \beta_x = 1$.

By solving firm's cost minimization problem, I obtain cost function

$$C(Y_{it}) = \exp(-\omega_{it}) N(d_{it})^{-\frac{\beta_x}{\theta-1}} B_0 r_{it}^{\beta_k} w_{it}^{\beta_\ell} p_{it}^{\beta_x} Y_{it} \tag{7}$$

where r_{it}, w_{it}, and p_{it}, respectively, are firm-time specific factor prices and $B_0 \equiv \beta_k^{-\beta_k} \beta_\ell^{-\beta_\ell} \beta_x^{-\beta_x}$ is constant. Since the firm-time specific factor price is not observable, a time dummy D_t captures them.

We do not know the exact value of $N(d_{it})$. However, under the assumption of symmetrically produced intermediate inputs, we can calculate the ratio of total intermediate inputs to domestic intermediate inputs, which is equal to the ratio of the measure of total intermediate inputs available in the world to the measure of domestically produced intermediate inputs.

$$n_{it} \equiv \frac{X_{it}}{X_{it}^h} = \frac{X_{it}}{X_{it} - X_{it}^f} = \frac{N_{it}(1)\overline{x}}{N_{it}(0)\overline{x}} = \frac{N_{it}(1)}{N_{it}(0)} \tag{8}$$

X_{it} is the total intermediate input, X_{it}^h is the domestic intermediate input, and X_{it}^f is the total imported intermediate inputs. If a firm is non-importer, $n_{it} = 1$. Furthermore, following Bai et al. (2017), the capital stock is thought of as a firm-level cost shifter. Econometric specification of the marginal cost is:

$$\ln(MC_{it}) = \eta_0 + \eta_k k_{it} + \eta_t D_t + \eta_n n_{it} - \omega_{it} \tag{9}$$

By combining firms pricing rule obtained in equation (4), we can compute the individual firm's revenue

$$\begin{aligned} r_{it} &= p_{it} q_{it} \\ &= \frac{\sigma}{\sigma-1} MC_{it} \left(\frac{\sigma}{\sigma-1} MC_{it} \right)^{-\sigma} P_t^{\sigma-1} Y_t \\ &= \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} (MC_{it})^{1-\sigma} \underbrace{\frac{Y_t}{P_t^{1-\sigma}}}_{\equiv \Phi_t} \\ &= r_{it}(\Phi_t, k_{it}, n_{it}, \omega_{it}) \end{aligned} \tag{10}$$

Let $a \equiv (1-\sigma)\ln\left(\frac{\sigma}{\sigma-1}\right)$. Log revenue is:

$$\begin{aligned} \ln(r_{it}) &= (1-\sigma)\ln\left(\frac{\sigma}{\sigma-1}\right) + (1-\sigma)\ln(MC_{it}) + \ln(\Phi_t) \\ &= a + (1-\sigma)\Big\{ \eta_0 + \eta_k k_{it} + \eta_t D_t + \eta_n n_{it} - \omega_{it} \Big\} + \ln(\Phi_t) \end{aligned} \tag{11}$$

Given the assumption on the Dixit-Stiglitz form of consumer preferences and monopolistic competition, firm's operation profit is constant share of revenue

$$\pi_{it} = \frac{1}{\sigma} r_{it}(\Phi_t, k_{it}, n_{it}, \omega_{it}) \tag{12}$$

The short-run profit together with firm's draw from the sunk cost and fixed cost distributions and the evolution of productivity determine firm's decisions to import.

A.4 Evolution of productivity

In each period, firms observe their current productivity ω_{it} and previous period import status. Productivity ω_{it} evolves overtime as a Markov process that depends on the previous productivity and the firm's import decision; i.e., there exists a *learning-by-importing* effect. This evolution process is approximated by the cubic polynomial:

$$\begin{aligned} \omega_{it} &= g(\omega_{it-1}, d_{it-1}) + \xi_{it} \\ &= \alpha_0 + \sum_{s=1}^{3} \alpha_s (\omega_{it-1})^s + \alpha_4 d_{it-1} + \xi_{it} \end{aligned} \tag{13}$$

where ξ_{it} is iid shock with mean 0 and variance σ_ξ^2. This shock is independent of previous productivity and previous import decision. $d_{it-1} = \{0, 1\}$ is a dummy variable that indicate firm's import decision in last period.

By allowing the choice of import to endogenously affect the evolution of productivity, I can separate the role of learning-by-importing and the sorting by productivity.

Firms may choose to import if they expect their productivity to grow quickly with importing even though it is not profitable in the static sense. Productivity differences that might have existed prior to entry into import markets are controlled for through the lagged productivity term.

A.5 Dynamic decisions

At the beginning of each period, firm i observes the current state

$$s_{it} = (\omega_{it}, d_{it-1}, \Phi_t, \mathbf{w}_{it}) \tag{14}$$

where Φ_t capture the price index in the market and $\mathbf{w}_{it}$ is firm-time specific factor prices. These two elements are not chosen by firm.

Firm draws its fixed and sunk cost for import and chooses whether to import or not. I allow the distributions of the two costs to differ depending on the firm's past importing status. These costs are drawn from separate independent distributions, which are assumed to be exponentially distributed. If a firm was non-importer last period and decides to import this period (i.e., $d_{it-1} = 0$ and $d_{it} = 1$), the firm draws a sunk cost $\gamma^S \sim G^S$, where G^S is exponential distribution with parameter λ^S. If a firm was importer last period and continues to import (i.e., $d_{it-1} = 0$ and $d_{it} = 1$), the firms draws a fixed cost $\gamma^F \sim G^F$ from the exponential distribution G^F with parameter λ^F. All sunk cost are paid in the current period. Choice of import involves comparing the difference in payoff. Firms pay only the sunk cost (not the fixed cost) when switching to importer and only the fixed cost (not the sunk cost) when remaining as importer.

Firm's value function before observing fixed cost and sunk cost is, by choosing $d_{it} = \{0, 1\}$

$$V(s_{it}) = \int \max_{d_{it}} \Big\{ u(d_{it}, s_{it}|\gamma_{it}) + \delta \mathbb{E}_t \left[V(s_{it+1}, d_{it}) \right] \Big\} dG^{\gamma} \tag{15}$$

where $u(d_{it}, s_{it}|\gamma_{it})$ is current period payoff that depends on the choice of import, the current state, and the relevant fixed and sunk cost. For the notational simplicity, let $d_{it}^N = (1 - d_{it})$ and $d_{it}^I = d_{it}$.

$$u(d_{it}, s_{it}|\gamma_{it}) = d_{it}^N \pi_{it}^N + d_{it}^I \left[\pi_{it}^I - (d_{it-1}^N \gamma_{it}^S + d_{it-1}^I \gamma_{it}^F) \right] \tag{16}$$

where operational profit before paying the fixed or sunk cost is import-decision-specific:

$$\pi_{it}^m = \frac{1}{\sigma} r_{it}^m = \left[\frac{\sigma}{\sigma - 1} MC_{it} \left(\mathbf{w}_{it} | d_{it}^m = 1 \right) \right]^{1-\sigma} \frac{Y_t}{P_t^{1-\sigma}}, \quad m = \{N, I\} \tag{17}$$

$\mathbb{E}_t \left[V(s_{it+1}, d_{it}) \right]$ is continuation value:

$$\mathbb{E}_t \left[V(s_{it+1}, d_{it}) \right] = \int_{\omega'} V(s') dF(\omega' | \omega_{it}, d_{it}) \tag{18}$$

where $F(\omega' | \omega_{it}, d_{it})$ is defined by the productivity evolution as in equation (13).

For any state vector s_{it+1}, denote the choice specific continuation value from choosing $d_{it}^m = 1$ for $m = \{N, I\}$ as $\mathbb{E}_t V_{it+1}^m = \mathbb{E}_t \left[V(s_{it} | d_{it}^m = 1) \right]$. Firm's import decisions depend on the difference in the pairwise marginal benefits between two options (importing and non-importing) and the associated fixed/sunk cost of import. Marginal benefit of being importer (I) versus being a non-importer (N) is

$$\Delta IN_{it} = \pi^I - \pi^N + \delta \left[\mathbb{E}_t V_{t+1}^I - \mathbb{E}_t V_{t+1}^N \right] \tag{19}$$

Given the distributions of sunk and fixed cost of import, the marginal benefit and import status in last period pin down the switching probability. For any set of realized import cost $\boldsymbol{\gamma}_{it} = \left(\gamma_{it}^S, \gamma_{it}^F \right)$, we can calculate the differences in life-time payoff between non-importer and importer, which is unconditional on the previous period import status.

$$y_{it}^{IN} = \Delta IN_{it} - \mathbb{1}\{d_{it-1}^N = 1\} \gamma_{it}^S - \mathbb{1}\{d_{it-1}^I = 1\} \gamma_{it}^F \tag{20}$$

Therefore, the unconditional choice probability between nonimporter and importer is

$$\Pr\left(y_{it}^{IN} \geq 0 \right) = \Pr\left(\mathbb{1}\{d_{it-1} = N\} \gamma_{it}^S + \mathbb{1}\{d_{it-1} = I\} \gamma_{it}^F \leq \Delta IN_{it} \right) \tag{21}$$

Conditioning on the previous import status, the probability of changing (or not changing) the import status can be expressed as follows. For example, P_{it}^{NI} is the probability that firm i which is non-importer (N) in period $t-1$ becomes importer (I) in period t. For a previous non-importer, the probability to stay as non-importer and to switch to importer, respectively, are given by:

$$\begin{aligned} P_{it}^{NN} &= \Pr\left(y_{it}^{IN}|_{d_{it-1}^{N}=1} \leq 0\right) = \Pr\left(\gamma_{it}^{S} \geq \Delta IN_{it}\right) \\ P_{it}^{NI} &= \Pr\left(y_{it}^{IN}|_{d_{it-1}^{I}=1} > 0\right) = \Pr\left(\gamma_{it}^{S} < \Delta IN_{it}\right) \end{aligned} \tag{22}$$

Therefore, we can write the Bellman's equation for the previous non-importer as follows:

$$V_{it}^{N} = P_{it}^{NN}\left(\pi_{it}^{N} + \delta \mathbb{E}_t V_{it+1}^{N}\right) + P_{it}^{NI}\left(\pi_{it}^{I} - \mathbb{E}\left[\gamma_{it}^{S}|\gamma_{it}^{S} < \Delta IN_{it}\right] + \delta \mathbb{E}_t V_{it+1}^{I}\right) \tag{23}$$

Note that superscript of V_{it}^{N} indicates the import status in period $t-1$. The expectation of sunk cost is conditional on $\gamma_{it}^{S} < \Delta IN_{it}$ since this is the only case which is relevant for switching firm.

Analogously, we can get the probability to stay as importer and to switch to non-importer for a previous importer:

$$\begin{aligned} P_{it}^{II} &= \Pr\left(y_{it}^{IN}|_{d_{it-1}^{I}=1} > 0\right) = \Pr\left(\gamma_{it}^{F} < \Delta IN_{it}\right) \\ P_{it}^{IN} &= \Pr\left(y_{it}^{IN}|_{d_{it-1}^{I}=1} \leq 0\right) = \Pr\left(\gamma_{it}^{F} \geq \Delta IN_{it}\right) \end{aligned} \tag{24}$$

The Bellman's equation for a previous importer can be written as

$$V_{it}^{I} = P_{it}^{II}\left(\pi_{it}^{I} - \mathbb{E}\left[\gamma_{it}^{F}|\gamma_{it}^{F} < \Delta IN_{it}\right] + \delta \mathbb{E}_t V_{it+1}^{I}\right) + P_{it}^{IN}\left(\pi_{it}^{N} + \delta \mathbb{E}_t V_{it+1}^{N}\right) \tag{25}$$

I assume that firms make draw from the sunk and fixed costs distribution each period independently.

Appendix B Estimation

B.1 Stage 1: Elasticity and productivity

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Each firm's total variable cost is

$$\begin{aligned} TVC_{it} &= MC_{it} q_{it} \\ &= \frac{\sigma - 1}{\sigma} \underbrace{p_{it} q_{it}}_{\text{revenue}} \end{aligned} \tag{26}$$

Since the total variable cost and revenue are data, I can estimate (26) by OLS to recover the elasticity of substitution. More specifically, I take the sum of wage payment, rental payment, and intermediate goods expenditure as a total variable cost. I use the total sales income as revenue.

Recall the log revenue function

$$\ln(r_{it}) = (1-\sigma)\ln\left(\frac{\sigma}{\sigma-1}\right) + (1-\sigma)\Big\{\eta_0 + \eta_k k_{it} + \eta_t D_t + \eta_n n_{it} - \omega_{it}\Big\} + \ln(\Phi_t)$$

Let $\phi_0 = (1-\sigma)\ln\left(\frac{\sigma}{\sigma-1}\right) + (1-\sigma)\gamma_0$ and $\phi_t = \ln\Phi_t + (1-\sigma)\gamma_t$. Econometric specification for the log revenue function is

$$\ln(r_{it}) = \phi_0 + \sum_{t=1}^{T}\phi_t D_t + (1-\hat{\sigma})(\eta_k k_{it} + \eta_n n_{it} - \omega_{it}) + u_{it} \tag{27}$$

where u_{it} is the iid error (measurement error). Following Levinsohn and Petrin's (2003) method, we control the unobserved productivity using the fact that more productive firms will use more materials.

$$h(k_{it}, x_{it}, n_{it}) \equiv (1-\hat{\sigma})(\eta_k k_{it} + \eta_n n_{it} - \omega^*(k_{it} + n_{it}, x_{it})) \tag{28}$$

I approximate $h(\cdot)$ by a 3rd-degree polynomial of its argument. Now we can rewrite productivity using estimates of ϕ_0, ϕ_t and the value of $\hat{h}(k_{it}, n_{it}, x_{it})$

$$\omega_{it} = -\frac{1}{1-\hat{\sigma}}\hat{h}(k_{it}, n_{it}, x_{it}) + \beta_k k_{it} \tag{29}$$

We have to estimate β_k. Recall productivity evolution:

$$\omega_{it} = \alpha_0 + \sum_{s=1}^{3}\alpha_s(\omega_{it-1})^s + \alpha_4 d_{it-1} + \xi_{it}$$

Substitute for ω_{it} and ω_{it-1} using equation (29) into the productivity evolution equation, we can estimate the remaining parameters by running nonlinear least square for the following equation:

$$-\frac{1}{1-\hat{\sigma}}\hat{h}(k_{it}, n_{it}, x_{it}) = \alpha_0 + \sum_{s=1}^{3}\alpha_s\left(-\frac{1}{1-\hat{\sigma}}\hat{h}(k_{it-1}, n_{it-1}, x_{it-1}) + \beta_k k_{it-1}\right)^s + \alpha_4 d_{it-1} - \beta_k k_{it} + \xi_{it} \tag{30}$$

The variance of error term, σ_ξ^2, is pinned down by the sample variance of the residuals.

B.2 Stage 2: Dynamic Estimation

Following Bai et al. (2017), I employ the following algorithm to estimate the distribution parameters of fixed and sunk cost:

1. Begin with an initial guess of parameters $G\gamma^0 = (\lambda^{S0}, \lambda^{F0})$ where $\lambda^m > 0$, $m = \{S, F\}$, is the exponential distribution parameter for sunk/fixed cost of import.
2. Calculate $F(\omega'|\omega, \mathbf{d})$ based on estimated parameters in the first stage (this step can be done outside the loop)
3. Iterate on the following inner loop to find fixed points of value functions
   (a) Begin with a set of initial guess of value functions $V^{m0}(s)$, $m = \{N, I\}$, where $s = (\omega, \mathbf{d}_{-1}, \mathbf{w})$

(b) Calculate the continuation value for non-importer and importer as defined in equation (18): $\mathbb{E}V^{m0} = \int_{\omega'} V^{m0}(s')dF(\omega'|\omega, d^m = 1)$ with $m = \{S, F\}$.

(c) Update value functions for importer and non-importer according to equation (23) and (25). Choice probability on import is defined in equation (22) and (24). For example, in the case of non-importer's value function

$$V^{N1} = P^{NN}\left(\pi^N + \delta\mathbb{E}V^{N0}\right) + P^{NI}\left(\pi^I - \mathbb{E}\left[\gamma^S|\gamma^S < \Delta IN\right] + \delta\mathbb{E}V^{I0}\right)$$

(d) Iterate the step (a) – (c) until $|V^{m,n+1} - V^m| < \varepsilon$ where ε is predetermined tolerance level.

4. Evaluate the likelihood function of every observation.

For the discretization of the state space, I follow Aw et al. (2011).

Appendix C (Tentative) empirical results

C.1 Data

I use two Chinese data sets. The first one consist of firm-level data from the Annual Survey of Industrial Production (ASIP) from 1998 to 2007 conducted by the Chinese government's National Bureau of Statistics. This survey includes all state-owned enterprises (SOEs) and non SOEs with sales over 5 million Yuan. The data contains information on the firm's industry of production, ownership type, employment, capital stocks, and revenues. The second data set is Chinese Customs transaction-level data. It records the universe of transaction by Chinese firms that participated in international trade over the 2000–2006 period. This custom data includes the value of each transaction (in US dollars) by products in the 8 digit Harmonized System (HS8). Since our theoretical framework does not incorporate product-level import decision, for each firm, I aggregate over all the HS8 imports to get the firm's total import.

C.2 Selecting industry

The dataset contains the firm's industry of production classified by the 4-digit of International Standard Industrial Classification (ISIC) Revision 3. In my empirical analysis, we focus on a particular industry. In selecting the industry to be analyzed, first I label 2-digit ISIC (ISIC2, henceforth) code which corresponds to each of 4-digit code. This aggregation gives 31 ISIC2 industries in the data set.

The sectoral share of the number of firms varies substantially across sectors. As of 2006, 11.27% of the firms is in the manufacturing of machinery while 0.07% of firms is in the manufacturing of tobacco product. Choosing the industry with small number of firms will limit the number of observations. The first column of Table 1 lists the top ten ISIC2 industries in terms of the number of firms. For example, on average, 11.22% of the firms in the sample is in the manufacturing of food products.

Since this paper is interested in firms' importing decisions, I also compute the importer share in each ISIC2 industries and change in importer share over the sample period. Column 2 and 3 of the table, respectively, list the top 10 ISIC2 industries with highest importer share (average across years) and largest change in importer share (from 2000 to 2006). Change in importer share is in percent point.

Table 1: Top 10 ISIC2 Industries in Number of Firms, Importer Share, and Change in Importer Share

Ranking	Sectoral Decomposition of Firm (average)		Importing Firm Share (average)		Change in Importing Firm Share (2000–2006)	
1	15: Food products	11.22%	30: Office machinery	45.61%	30: Office machinery	13.22%
2	29: Machinery	10.48%	32: Communication equipment	36.88%	34: Vehicles	7.19%
3	26: Non-metallic mineral products	8.92%	18: Waring apparel	25.17%	32: Communication equipment	7.18%
4	17: Textiles	7.72%	33: Precision instruments	24.02%	29: Machinery	5.58%
5	28: Fabricated metal products	6.87%	36: Furniture	23.76%	33: Precision instruments	4.02%
6	25: Rubber	5.68%	19: Tanning and dressing of leather	22.97%	11: Extraction of crude petroleum	3.05%
7	18: Waring apparel	5.64%	25: Rubber	18.30%	35: Other transport equipment	2.42%
8	27: Basic metals	5.51%	31: Electrical machinery	14.87%	31: Electrical machinery	2.17%
9	31: Electrical machinery	5.26%	34: Vehicles	14.18%	28: Fabricated metal products	1.45%
10	36: Furniture	4.18%	35: Other transport equipment	13.00%	21: Paper	1.22%

Looking over the table, I choose the manufacturing of electrical machinery (31) which appears in all the columns. This sector accounts, on average, 5.26% of the firms in the sample and 14.87% of them is importer. Furthermore, the importer share increased from 15.61% in 2000 to 17.78% in 2006.

C.3 Data cleaning

I dropped the observations if

- revenue (sales income) is nonpositive
- capital stock (paid in capital) is nonpositive
- intermediate input (in the census) is nonpositive
- import value (in the custom data) exceeds the total intermediate input (in the census)

This reduces the number of observations to 69,689.

In order to eliminate the effect of inflation, I use GDP deflator obtained from the World Bank database to normalize all of the nominal variables. The price level in 2000 is used as reference.

C.4 First Stage Estimation: Elasticity and

First estimate the elasticity of substitution by running the OLS:

$$TVC_{it} = \zeta TS_{it} + \nu_{it} \tag{31}$$

where TVC_{it} is the total variable cost, which is the sum of wage payable, intermediate input purchase for production, and interest payment. TS_{it} is total sales income. OLS estimates are presented in Table 2. From the estimates of ζ, I can recover the elasticity of substitution by $\hat{\sigma} = 1/(1-\hat{\zeta})$. The result implies that elasticity of substitution is 5.25.

Now we estimate the log revenue function (27) by approximating the unknown function $h(\cdot)$ in equation (28) with a third-degree polynomial.

Table 2: Elasticity of Substitution

	(1) Total Variable Cost
Total Sales Income	0.822***
	(1472.65)
Observations	69689
R^2	0.969

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

$$\begin{aligned}\ln(r_{it}) &= \phi_0 + \sum_{t=2001}^{2006} \phi_t D_t + h(k_{it}, x_{it}, n_{it}) + u_{it} \\ &= \phi_0 + \sum_{t=2000}^{2006} \phi_t D_t + \left[\sum_{m=1}^{3} \left(\varphi_k^m k_{it}^m + \varphi_x^m x_{it}^m + \varphi_n^m n_{it}^m \right) \right. \\ &\quad \left. + \varphi_{kx} k_{it} x_{it} + \varphi_{kn} k_{it} n_{it} + \varphi_{xn} x_{it} n_{it} \right] + u_{it} \end{aligned} \tag{32}$$

We estimate equation (32) by OLS. In our dataset, capital stock is recorded as the paid-in capital, which is the sum of capital owned by state, collective, legal person, private, Hong Kong, Macao and Taiwan, and foreigners. n_{it} is defined by X_{it}/X_{it}^h where X_{it} is the total intermediate input purchase and X_{it}^h is X_{it} minus total imported intermediate input purchase X_{it}^f. Since the imported value in the custom data is recorded in dollar amount, using the exchange rate provided in the dataset to convert it to Chinese Yuan. D_t is time dummy, where I take year 2000 as the reference. Table 3 demonstrates the estimated coefficients.

Given the estimates, we can compute the fitted value of $\hat{h}(k_{it}, x_{it,n_{it}})$. For the notational simplicity, let $h_{it} = \frac{-1}{1-\hat{\sigma}}\hat{h}(k_{it}, x_{it,n_{it}})$. We rewrite equation (30) as:

$$h_{it} = \alpha_0 + \sum_{s=1}^{3} \alpha_s \left(h_{it-1} + \beta_k k_{it-1} \right)^s - \beta_k k_{it} + \alpha_4 d_{it-1} + \xi_{it} \tag{33}$$

which I estimate using the nonlinear least squares. Since the right hand side of equation (4) contains the lagged variables, in running the regression, I restrict the observations for which previous year data is available. Estimated coefficients are presented in Table 4.

In the model, β_k is supposed to be positive. However, the estimated coefficient was statistically significantly negative.

Given the estimates, I can recover the productivity by

$$\hat{\omega}_{it} = h_{it} + \hat{\beta}_k k_{it} \tag{34}$$

Figure 1 and 2, respectively, describe the distribution of firms' (log) productivity ω_{it} in 2000 and 2006. Histogram colored with white shows the distribution of importer's productivity and gray histogram shoes the one of non-importers. Two vertical lines indicate the mean productivity for importers and non-importers. It is clear from the figures that importers' productivity is more likely to be higher than non-importers. This is consistent with the empirical regularities found in the previous studies, such as Bernard et al. (2012). As of 2000, mean log productivity for importers is 1.26 while it is 1.06 for non-importers. In 2006, they are 1.30 and 1.11, respectively. The other striking observation is that productivity distributions for importers and non-importers are substantially overlapping. It implies that productivity sorting of importers and non-importers is not perfect in the data. This motivates me to incorporate the stochastic formulation of fixed and sunk cost of import. I will estimate the distribution parameters in the next section.

C.5 Second stage: Dynamic estimation

TO BE CONTINUED

Table 3: First step nonparametric estimatin

	Log revenue
Log capital stock	0.409***
	(17.64)
Log capital stock (squared)	-0.0206***
	(-7.43)
Log capital stock (cubed)	0.00128***
	(10.98)
Log intermediate	-0.209***
	(-11.15)
Log intermediate (squared)	0.111***
	(52.72)
Log intermediate (cubed)	-0.00269***
	(-30.74)
Total/Domestic intermediate ratio	0.00310*
	(2.42)
Total/Domestic intermediate ratio (squared)	-0.000000957*
	(-2.35)
Total/Domestic intermediate ratio (cubed)	1.86e-10*
	(2.08)
Interaction (capital & intermediate)	-0.0307***
	(-32.73)
Interaction (capital & total/domestic ratio)	-0.000228
	(-1.33)
Interaction (intermediate & total/domestic ratio)	0.0000261
	(0.20)
Constant	3.597***
	(41.19)
Year Dummy	Yes
Observations	69689
R^2	0.923

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Evolution of productivity

	(1)
	h
Constant	0.435***
	(23.88)
α_1	0.205***
	(4.29)
α_2	0.471***
	(11.23)
α_3	-0.0893***
	(-7.43)
α_4	0.00960***
	(6.15)
β_k	-0.0291***
	(-36.03)
Observations	44952
R^2	0.818

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 1: Productivity distribution of importers and nonimporters (2000)

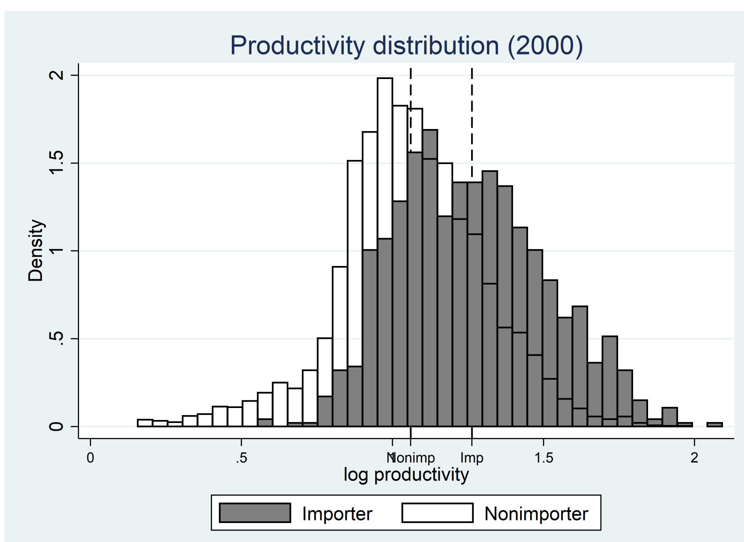

Figure 2: Productivity distribution of importers and nonimporters (2006)