

# Imported Inputs and Sectoral Wage Dispersion <sup>\*</sup>

Zheli He and Feiran Zhang<sup>†</sup>

September 2017

## Abstract

This paper proposes a new mechanism through which trade liberalization affects income inequality within a country: the use of imported inputs. Intuitively, a firm with higher initial productivity is better at using higher quality foreign inputs. This justifies paying the fixed costs for a larger set of imported inputs when input tariff liberalization decreases their relative price. The firm becomes more import intensive, which enhances its productivity advantage. As a result, the firm hires higher quality workers, produces higher quality products and pays higher wages to its workers, increasing within-sector wage dispersion. We find that both the mean and the dispersion of the distribution of firm productivity, markup and size went up during a period when China reduced its tariffs on imported inputs. More importantly, these results still hold when we consider the subset of firms that survived throughout the sample period, from 1998 to 2007. In addition, we develop a partial-equilibrium, heterogeneous-firm model with endogenous imported inputs and labor quality choice that is consistent with these observations. Finally, we provide empirical evidence that supports the model's prediction that the differential change in the import intensity of firms with different productivity levels explains these patterns.

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<sup>\*</sup>We would like to thank Donald Davis, Amit Khandelwal, Eric Verhoogen, Jonathan Vogel and David Weinstein for their invaluable advice and support. We also thank Matthieu Bellon, Pablo Fajgelbaum, Reka Juhasz, Ryan Kim, Antonio Miscio, Ildiko Magyari, Paul Piveteau, Stephen Redding, Lin Tian and other seminar participants at Columbia University for helpful comments and discussions. All remaining errors are our own.

<sup>†</sup>220 South 40th Street, Suite 250, Philadelphia, PA 19104. Email: zh2178@wharton.upenn.edu (Zheli He). Department of Economics, Columbia University, 1022 International Affairs Building, 420 West 118th Street, New York, NY 10027. Email: fz2179@columbia.edu (Feiran Zhang).

# 1 Introduction

The traditional Heckscher-Ohlin model predicts that countries export goods that use intensively the factor they are most abundantly endowed with. According to the Stolper-Samuelson theorem, trade increases the relative return to unskilled labor in developing countries, decreasing wage inequality. However, that prediction is at odds with many empirical findings. Take China as an example, the overall wage inequality, measured as the difference between the 90th and the 10th percentile of the log wage distribution, has been going up consistently in the last two decades, as found in [Han et al. \(2012\)](#). This period of rapid wage inequality increase coincided with China's implementation of dramatic economic reforms and an open door policy that promoted its trade with the rest of the world. So two important questions arise: did trade liberalization contribute to China's rising wage inequality? If so, through which channels?

New theoretical developments have been made to provide insights into the effects of trade on wage inequality. Most prominently, [Verhoogen \(2008\)](#) proposes the quality-upgrading mechanism as an explanation. In his model with heterogeneous plants and quality differentiation, an exchange-rate devaluation leads more productive Southern plants to increase exports, upgrade quality, and raise wages relative to less productive ones, increasing within-sector wage dispersion. In this chapter, we propose an alternative mechanism: the use of imported inputs. Intuitively, a firm with higher initial productivity is better at using higher quality foreign inputs. This justifies paying the fixed cost for a larger set of imported inputs when input tariff liberalization decreases their relative price. The firm becomes more import intensive, which enhances its productivity advantage. As a result, the firm hires higher

quality workers, produces higher quality products and pays higher wages to its workers, increasing within-sector wage dispersion. We aim to empirically distinguish these mechanisms in the data, as they each have different welfare and policy implications.

First, we use ASIF (Annual Survey of Industrial Firms) from China’s National Bureau of Statistics that report key operational data on Chinese manufacturing firms to document some stylized facts that are both new and interesting. We find that both the mean and the dispersion of the distribution of firm productivity, markup and size went up during a period when China reduced its tariffs on imported inputs. More importantly, these results still hold when we consider the subset of firms that survived throughout the sample period, from 1998 to 2007. Therefore, openness to trade has fundamental effects on the underlying characteristics of firms. Most of recent models of firm heterogeneity assume that these characteristics are fixed and examine the impact of trade on aggregate variables, for example, the average productivity of firms in the economy as a result of change in the composition of surviving firms. On the contrary, we study the differential impact of trade liberalization on heterogeneous firms allowing these characteristics to be endogenous.

We measure firm-level TFP based on OLS, Olley and Pakes, Levinsohn and Petrin, and Akerberg, Caves and Frazer to ensure that our estimate of firm productivity is as accurate as possible. For firm-level markup calculation, we adopt [De Loecker and Warzynski \(2012\)](#), which is the best available method that we can use given our data limitations. We consider both a Cobb-Douglas gross output production function, and more generally, a translog gross output production function, which matches the data much better. Finally, we measure firm size both in terms of output value and total employment as a robustness check. The empirical patterns are very similar when we use different approaches to measure these three

key firm-level variables.

Second, we develop a partial equilibrium, heterogeneous firm model with endogenous imported inputs and labor quality choice that is consistent with these observations. On the demand side, we adopt the “quality-Melitz” model in [Kugler and Verhoogen \(2012\)](#), where higher price decreases demand but higher quality increases demand. On the supply side, firms differ from each other in the usual dimension of productivity, as in [Melitz \(2003\)](#). In our model, firms combine labor and intermediate inputs to produce physical quantity, in the spirit of [Amiti et al. \(2014\)](#). Output quality, on the other hand, is determined by labor and input qualities, and the advantage of imported inputs over domestic counterparts is augmented by a firm’s own productivity. Since [Amiti et al. \(2014\)](#) focus on exchange rate pass-through, and assume that firms do not foresee fluctuations in exchange rates, they hold the set of imported inputs of each firm fixed. We, on the other hand, study precisely how firms adjust the set of foreign varieties they import in response to input tariff liberalization and changes in firm-level variables that follow. Consequently, our model deviates from theirs in obvious ways, which we explain in more detail in the theory section.

Finally, we use Chinese Customs Data on imports and exports, which provide detailed information on the universe of China’s firm-level trade transactions for the years 2000 to 2006, to highlight firms’ different responses to a dramatic decrease in import tariffs. These observations emphasize the large and growing importance of trade in intermediates, and provide some empirical evidence that supports our hypothesis that the differential change in import intensity of firms with different productivity levels in response to input tariff liberalization explains the increase in both the average and the dispersion of firm-level variables that are observed in the data.

Although the main focus of this chapter is to show that input tariff liberalization affects firms at different levels of productivity in a heterogeneous way, which drives their performance further apart, our results have broader implications. Essentially, we provide a framework in which the differential impact of any element of globalization that leads to a decrease in the marginal cost of production on firm-level characteristics can be analyzed. Our detailed and very disaggregated transaction-level trade data allow us to quantify the impact of such a change during a period when the change was very large in magnitude.

## 2 Related Literature

This chapter is related to several strands of literature. First, there have been studies on the labor market effects of international trade based on recent models of firm heterogeneity, and they ask how trade liberalization affects wages and wage inequality. For example, [Amiti and Davis \(2012\)](#) develop a model, which predicts that a fall in output tariffs lowers wages at import-competing firms but boosts wages at exporting firms, and that a fall in input tariffs raises wages at import-using firms relative to those that only source inputs locally. They find support for the model's predictions in Indonesian manufacturing census data for the period 1991-2000. Like us, they take explicit account of firm-level heterogeneity and importance of trade in intermediates. Extending the heterogeneous firm model of trade and inequality from [Helpman et al. \(2010\)](#), [Helpman et al. \(2017\)](#) show that much of overall wage inequality arises within sector-occupations and for workers with similar observable characteristics, and wage dispersion between firms is related to firm employment size and trade participation. They again emphasize the importance of employing recent models of

firm heterogeneity in analyzing the contribution of trade to the cross-section dispersion of firms. Frías et al. (2012), on the other hand, offer some empirical evidence that sorting on individual worker ability is not enough to explain the relationship between exporting and wages at the plant level. They use a combination of employer-employee and plant-level data from Mexico, and show that approximately two-thirds of the higher level of wages in larger, more productive plants is explained by higher levels of wage premia, and that nearly all of the differential within-industry wage change is explained by changes in wage premia. They use the late-1994 Mexican peso devaluation as a source of exogenous variation in the incentive to export, while we use import tariff reductions due to China’s accession to the WTO in December 2001 as our exogenous variation. On the contrary, Krishna et al. (2012) find an insignificant differential effect of trade openness on wages at exporting firms relative to domestic firms, using detailed information on worker and firm characteristics to control for compositional effects and allowing for the endogenous assignment of workers to firms. While these papers focus on the effects of trade liberalization on the labor market, we look at other firm-level characteristics, and ask how they are affected, and the resulting implications on wage inequality in China.

Second, our theoretical model borrows insights from a burgeoning research literature on firm import behavior, which has not been extensively studied before. Most importantly, evidence has been found in a wide range of countries that firm productivity rises when a firm imports new input varieties. For example, Kasahara and Rodrigue (2008) conclude that becoming an importer of foreign intermediates improves productivity using plant-level Chilean manufacturing panel data. At the same time, Halpern et al. (2015) find that importing all foreign varieties would increase firm productivity by 12 percent, and that during

1993-2002, one-third of the productivity growth in Hungary was due to imported inputs by estimating a model of importers in Hungarian micro data and conducting counterfactual policy analysis. [Bas and Strauss-Kahn \(2014\)](#), on the other hand, use a firm-level database of imports provided by French Customs for the 1995-2005 period, and find a significant impact of higher diversification and increased number of imported input varieties on firm-level TFP and export scope. They argue that importing more varieties of intermediate inputs increases firm productivity and thereby makes a firm more able to overcome the fixed export costs. Our model predicts that a firm with higher initial productivity has a stronger incentive to expand its set of imported varieties when it faces lower tariff rates, which then makes it even more productive, explaining the empirical patterns observed in the data.

Third, we want to point out that these findings cannot be explained by any previous studies on heterogeneous firms. We discuss briefly a few important papers on the subject. To start with, the workhorse model developed in [Melitz \(2003\)](#) assumes that the preferences of a representative consumer are given by a C.E.S. utility function over a continuum of goods, so each firm chooses the same profit maximizing markup which is constant. After paying fixed entry costs, firms draw their initial productivity parameter, which does not change over time. As a result, the mean and the dispersion of the productivity distribution of a balanced panel of firms remain the same, which is not what we observe in the data. Gains from trade in this model come from expansion in product varieties, and more importantly, the self-selection of more efficient firms into exporting. Relaxing the C.E.S. assumption, [Arkolakis et al. \(2015\)](#) study how variable markups affect the gains from trade liberalization under monopolistic competition, and they show that the welfare effect of a small trade shock is given by  $\partial \ln W = -(1 - \eta) \frac{\partial \ln \lambda}{\epsilon}$ , where  $\lambda$  is the share of expenditure on domestic goods,

and  $\epsilon$  is an elasticity of imports with respect to variable trade costs, and  $\eta$  is a structural parameter that depends, among other things, on the elasticity of markups with respect to firm production. Although they consider variable markups like us, they assume that firm-level productivity is the realization of a random variable drawn independently across firms from a distribution, which is unbounded Pareto, and it is fixed over time. Instead of a counterfactual analysis that focuses on the welfare effect of a particular shock, [Feenstra and Weinstein \(2010\)](#) use a translog demand system to measure the effects of new varieties and variable markups on the change in the U.S. consumer price index between 1992 and 2005. That is, they use observed trade data to infer changes in particular components of the U.S. price index. Their results highlight the importance of taking into account the implications of pro-competitive effect of trade. However, they ignore the impact of trade on productivity since that is not the main focus of their paper. On the other hand, [Feenstra \(2014\)](#) shows that self-selection of more efficient firms into exporting is the only source of welfare gains when using a Pareto distribution for productivity with a support that is unbounded above. He restores a role for product variety and pro-competitive gains from trade, but still assumes that firms receive a random draw of productivity from a Pareto distribution, which does not change. Finally, borrowing insights from [Melitz \(2003\)](#) that trade openness increases volatility by making the economy more granular since only the largest and most productive firms export, while smaller firms shrink or disappear, [Di Giovanni and Levchenko \(2013\)](#) show that when the distribution of firm sizes follows a power law with an exponent close to -1, the idiosyncratic shocks to large firms have an impact on aggregate output volatility. In their model, these firm-level idiosyncratic shocks may explain the observed increase in dispersion of firm size distribution, but they do not provide a microfoundation to explain why both the



mean and the standard deviation of the distribution go up in a systematic way since they assume i.i.d. transitory shock. Essentially, these theoretical papers consider the effect of a change in the exogenous distribution of firm productivity, while we take firm productivity as an endogenous variable. Therefore, we are able to add something new and interesting to the conversation about the impact of trade based on recent models of firm heterogeneity.

### 3 Data

The first dataset, Chinese Customs Data on imports and exports, provides detailed information on the universe of China’s firm-level trade transactions for the years 2000 to 2006. In addition to firm identifiers, this dataset includes information on many important transaction characteristics, including customs regime (e.g. processing trade or ordinary trade), 8-digit HS product code, transaction value, quantity, and source or destination country. Using firm identifiers provided in the dataset, we construct key variables that describe firm-level imports and exports. Figure I illustrates the customs declaration form that a firm has to fill out if it intends to import from or export to foreign countries.

The second key dataset is from China’s National Bureau of Statistics, which conducts firm-level surveys on manufacturing enterprises. These data collected from Chinese firms include key operational information, such as firm employment, ownership type (e.g. state-owned enterprise, foreign invested firm, or private firm), sales value, R&D expenditure and industry. Merging the firm-level data with the transaction-level data is challenging because firm identifiers used in the two datasets are different. Nevertheless, since both datasets include extensively detailed firm contact information (e.g. company name, telephone number,

Figure I: Customs Declaration Form

预录入编号: 1234567890

中华人民共和国海关进口货物报关单

海关编号: 1234567890

进口口岸: clearing custom

经营单位: company

备案号: 1234567890

进口日期: date imported

收货单位: 1234567890

运输方式: transportation

贸易方式: trade type

许可证号: 1234567890

启运国(地区): 1234567890

包装种类: 1234567890

批准文号: 1234567890

成交方式: 1234567890

运费: 1234567890

合同协议号: 1234567890

件数: 1234567890

毛重(千克): 1234567890

净重(千克): 1234567890

集装箱号: 1234567890

随附单证: 1234567890

标记唛码及备注: 1234567890

用途: 1234567890

项号	商品编号	商品名称规格型号	数量及单位	原产国(地区)	单价	总价	币种	税率
HS8 code	product name	quantity and unit of measurment	source country	value	currency			
1	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890

zip code, contact person), we merge them using zip codes and the last seven digits of a firm's phone number, following Yu (2015). In this way, we are able to generate firm-level observations that combine information on the trade with the operational activities of Chinese firms. Table I compares some of the main characteristics of merged and unmerged firms, and they look very similar on average in terms of employment, sales, value added per worker and TFP, mitigating our concern about sample selection bias.

Table I: Comparison of Merged with Unmerged Firms in the Data

	Merged Firms	Unmerged Firms
Log Employment	5.37 [1.13]	5.27 [1.17]
Log Sales	10.6 [1.30]	10.33 [1.31]
Value Added per Worker	87.32 [203.32]	71.58 [147.69]
TFP (Olley Pakes)	4.22 [1.15]	4.12 [1.12]

## 4 Stylized Facts

To motivate our theoretical model, we first present some stylized facts about the change in firm-level productivity, markup and size during a period of large scale trade liberalization. We focus on a balanced panel, that is, the set of manufacturing firms that survived the entire sample period, from 2000 to 2006, since we are interested in the within-firm change due to open trade. Unlike most previous literature that only looks at how these variables change on average, we also consider the change in dispersion, and argue that the sample mean is no longer sufficient to explain the impact of trade liberalization on firm performance and the resulted wage inequality within a country. We find that both the mean and the standard deviation of these three variables go up during this period.

### 4.1 Productivity

We measure firm-level TFP based on a few different approaches. Besides simple OLS, we first use Olley and Pakes (OP), a method for robust estimation of the production function allowing for endogeneity of the inputs, selection and unobserved permanent differences across firms. Essentially, they use investment to proxy for firm productivity shock in the first stage, and then use semi-parametric selection correction to correct for endogenous exit. We extend the traditional OP procedure by including an exporter dummy, following [Amiti and Konings \(2007\)](#). Second, we use Levinsohn and Petrin (LP), which instead of investment, use material expenditures as proxy for productivity shock, since investment is zero for many firms. Finally, we adopt Akerberg, Caves and Frazer, a GMM procedure using orthogonality of lagged labor and productivity shock. They argue that labor and investment in OP, or labor and material

expenditures in LP are likely to be collinear. All of these approaches give us very similar measures of TFP, so we report only the results based on OP and LP. However, we want to point out that these TFP measures are still subject to the usual criticism, that is, they are a residual that lumps together many things: technical efficiency, markups, input and output quality and measurement error. We do not address these issues directly here since that is not the focus of this chapter. With better data, on the other hand, a more robust measure of firm-level TFP is possible.<sup>1</sup> Note that there is an increase in both the mean and the dispersion of firm-level productivity.

Table II: Productivity, 1999-2007 Pooled

Specification	Average TFP (Standard Deviation)	Median TFP
LP	3.68 (1.09)	3.7
OP	4.61 (1.02)	4.59

Table III: Productivity, 1999

Specification	Average TFP (Standard Deviation)	Median TFP
LP	3.32 (1.03)	3.37
OP	4.16 (0.92)	4.18

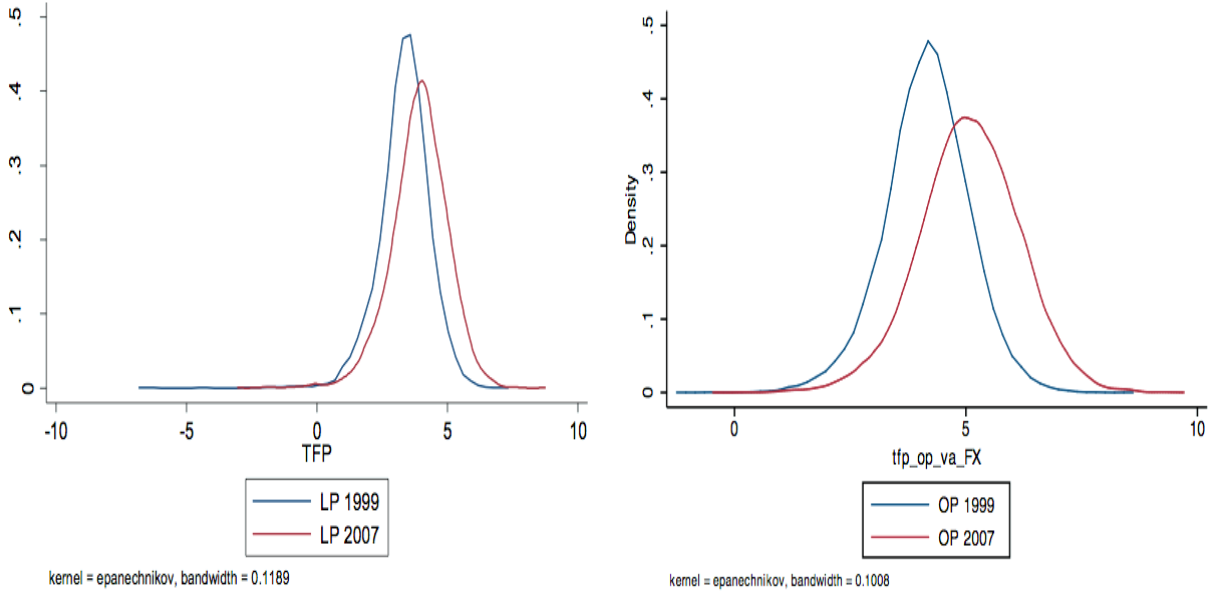
Table IV: Productivity, 2007

Specification	Average TFP (Standard Deviation)	Median TFP
LP	4.00 (1.18)	4.03
OP	5.08 (1.09)	5.09

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<sup>1</sup>See De Loecker (2013).

Figure II: Balanced Panel TFP Estimation  
Panel A: Levinsohn-Petrin      Panel B: Olley-Pakes



## 4.2 Markup

To estimate firm-level markups, we adopt the method in [De Loecker and Warzynski \(2012\)](#). Their approach relies on cost-minimizing producers and the existence of at least one variable input of production. This empirical framework relies on the estimation of a production function and provides estimates of plant-level markups without specifying how firms compete in the product market. There are several advantages in using their method. First, their markup estimates are obtained using standard production data where output, total expenditures on variable inputs, and revenue at the plant level are observed. Second, and more importantly, we are able to relax a few key assumptions maintained in previous empirical work. For example, we do not need to impose constant returns to scale, or to observe and measure the user cost of capital.

Below is a brief summary of their empirical model. Suppose a firm  $i$  at time  $t$  produces

output using the following production technology:

$$Q_{it} = Q_{it}(X_{it}^1, \dots, X_{it}^V, K_{it}, \omega_{it}) \quad (1)$$

Assuming that producers active in the market are cost minimizing, we can therefore consider the associated Lagrangian function:

$$L(X_{it}^1, \dots, X_{it}^V, K_{it}, \lambda_{it}) = \sum_{v=1}^V P_{it}^{X^v} X_{it}^v + r_{it} K_{it} + \lambda_{it} (Q_{it} - Q_{it}(\cdot)) \quad (2)$$

where  $P_{it}^{X^v}$  and  $r_{it}$  denote a firm's input price for a variable input  $v$  and capital, respectively.

The first-order condition for any variable input free of any adjustment costs is:

$$\frac{\partial L_{it}}{\partial X_{it}^v} = P_{it}^{X^v} - \lambda_{it} \frac{\partial Q_{it}(\cdot)}{\partial X_{it}^v} = 0 \quad (3)$$

where the marginal cost of production at a given level of output is  $\lambda_{it}$ , since  $\frac{\partial L_{it}}{\partial Q_{it}} = \lambda_{it}$ .

Rearranging terms and multiplying both sides by  $\frac{X_{it}}{Q_{it}}$  generates the following expression:

$$\frac{\partial Q_{it}(\cdot)}{\partial X_{it}^v} \frac{X_{it}^v}{Q_{it}} = \frac{1}{\lambda_{it}} \frac{P_{it}^{X^v} X_{it}^v}{Q_{it}} \quad (4)$$

Define the markup,  $\mu_{it}$ , as  $\mu_{it} = \frac{P_{it}}{\lambda_{it}}$ , we can rewrite equation (3.4) as:

$$\theta_{it}^X = \mu_{it} \frac{P_{it}^X X_{it}}{P_{it} Q_{it}} \quad (5)$$

where the output elasticity w.r.t an input  $X$  is denoted by  $\theta_{it}^X$ . As a result, we obtain an expression of the markup as follows:

$$\mu_{it} = \theta_{it}^X (\alpha_{it}^X)^{-1} \quad (6)$$

where  $\alpha_{it}^X$  is the share of expenditures on input  $X_{it}$  in total sales,  $P_{it}Q_{it}$ .

Empirically, we consider two variations of the production function, a Cobb-Douglas gross output production function and a translog gross output production function. In the second case, the production function we take to the data, and estimate for each industry separately, is given by:

$$\begin{aligned} y_{it} = & \beta_l l_{it} + \beta_m m_{it} + \beta_k k_{it} + \beta_{ll} l_{it}^2 + \beta_{mm} m_{it}^2 + \beta_{kk} k_{it}^2 + \beta_{lm} l_{it} m_{it} + \beta_{lk} l_{it} k_{it} + \beta_{mk} m_{it} k_{it} \\ & + \beta_{mkl} m_{it} k_{it} l_{it} + \omega_{it} + \epsilon_{it} \end{aligned} \quad (7)$$

where  $\epsilon_{it}$  are unanticipated shocks to production and i.i.d. shocks including measurement error.

We follow [Levinsohn and Petrin \(2003\)](#) and rely on material demand,

$$m_{it} = m_t(k_{it}, \omega_{it}, z_{it}) \quad (8)$$

to proxy for productivity by inverting  $m_t(\cdot)$ , where we collect additional variables potentially affecting optimal input demand choice in the vector  $\mathbf{Z}_{it}$ . We include a firm's export status, for instance, in the control function.

In the first stage, we run:

$$y_{it} = \phi_t(l_{it}, k_{it}, m_{it}, z_{it}) + \epsilon_{it} \quad (9)$$

where we obtain estimates of expected output ( $\widehat{\phi_{it}}$ ) and  $\epsilon_{it}$ . Expected output is given by:

$$\begin{aligned}
\phi_{it} = & \beta_l l_{it} + \beta_m m_{it} + \beta_k k_{it} + \beta_{ll} l_{it}^2 + \beta_{mm} m_{it}^2 + \beta_{kk} k_{it}^2 + \beta_{lm} l_{it} m_{it} + \beta_{lk} l_{it} k_{it} + \beta_{mk} m_{it} k_{it} \\
& + \beta_{mkl} m_{it} k_{it} l_{it} + h_t(m_{it}, k_{it}, z_{it})
\end{aligned} \tag{10}$$

The second stage provides estimates for all production function coefficients by relying on the law of motion for productivity:

$$\omega_{it} = g_t(\omega_{it-1}) + \zeta_{it} \tag{11}$$

After the first stage, we can compute productivity for any value of  $\beta$ , where

$$\beta = (\beta_l, \beta_k, \beta_m, \beta_{ll}, \beta_{kk}, \beta_{mm}, \beta_{lm}, \beta_{lk}, \beta_{mk}, \beta_{mkl})$$

using  $\omega_{it}(\beta) = \hat{\phi}_{it} - \beta_l l_{it} - \beta_m m_{it} - \beta_k k_{it} - \beta_{ll} l_{it}^2 - \beta_{mm} m_{it}^2 - \beta_{kk} k_{it}^2 - \beta_{lm} l_{it} m_{it} - \beta_{lk} l_{it} k_{it} - \beta_{mk} m_{it} k_{it} - \beta_{mkl} m_{it} k_{it} l_{it}$ .

By nonparametrically regressing  $\omega_{it}(\beta)$  on its lag,  $\omega_{it-1}(\beta)$ , we recover the innovation to productivity given  $\beta$ ,  $\zeta_{it}(\beta)$ .

We can now form moments to obtain our estimates of the production function parameters:



$$\mathbb{E} \left( \zeta_{it}(\beta) \begin{pmatrix} l_{it-1} \\ m_{it-1} \\ k_{it} \\ l_{it-1}^2 \\ m_{it-1}^2 \\ k_{it}^2 \\ l_{it-1}m_{it-1} \\ l_{it-1}k_{it} \\ m_{it-1}k_{it} \\ l_{it-1}m_{it-1}k_{it} \end{pmatrix} \right) = 0 \quad (12)$$

We apply the standard GMM techniques and rely on block bootstrapping for the standard errors.

Output elasticities are computed using the estimated coefficients of the production function. For instance, output elasticity for material is given by:

$$\hat{\theta}_{it}^M = \beta_m + 2\beta_m m_{it} + \beta_{lm} l_{it} + \beta_{mk} k_{it} + \beta_{mkl} k_{it} l_{it} \quad (13)$$

As mentioned above, we do not observe the correct expenditure share for material,  $m_{it}$ , directly since we only observe  $\tilde{Q}_{it}$ , which is given by  $Q_{it} \exp(\epsilon_{it})$ . The first stage of our procedure does provide us with an estimate of  $\epsilon_{it}$ . and we use it to compute the expenditure share as follows:

$$\hat{\alpha}_{it}^M = \frac{P_{it}^M m_{it}}{P_{it} \frac{\tilde{Q}_{it}}{\exp(\hat{\epsilon}_{it})}} \quad (14)$$

We obtain an estimate of markup for each firm  $i$  at each point in time  $t$  using (3.6) as  $\mu_{it} = \hat{\theta}_{it}^M (\hat{\alpha}_{it}^M)^{-1}$ , while allowing for considerable flexibility in the production function, consumer demand, and competition. The estimation procedure is essentially the same when we consider a Cobb-Douglas gross output production function. We simply drop higher-order and interaction terms. We assume labor to be either a fully flexible input, that is, a control variable correlated with contemporaneous productivity shock, where we use lagged labor as instrument, or a predetermined variable, that is, a state variable, independent of contemporaneous shock, when we take into account hiring and firing costs, and we use itself as an instrument.

Table V: Markup, 1999-2007 Pooled

Specification	Average Markup (Standard Deviation)	Median Markup
CD (L as control variable)	1.19 (0.27)	1.24
CD (L as state variable)	1.25 (0.23)	1.27
TL (L as control variable)	1.21 (0.13)	1.18

Table VI: Markup, 1999

Specification	Average Markup (Standard Deviation)	Median Markup
CD (L as control variable)	1.16 (0.26)	1.20
CD (L as state variable)	1.22 (0.22)	1.23
TL (L as control variable)	1.13 (0.09)	1.11

Table VII: Markup, 2007

Specification	Average Markup (Standard Deviation)	Median Markup
CD (L as control variable)	1.25 (0.30)	1.29
CD (L as state variable)	1.31 (0.26)	1.32
TL (L as control variable)	1.30 (0.16)	1.28

We get quite similar estimates of markups across different specifications. When we compare markups across the years, especially at the beginning and at the end of our sample period, it becomes clear that there is a substantial increase in both the mean and the dis-

persion of the distribution of markups, most evident in the case of a translog gross value production function.

Figure III: Balanced Panel Markup Estimation I  
1999-2007

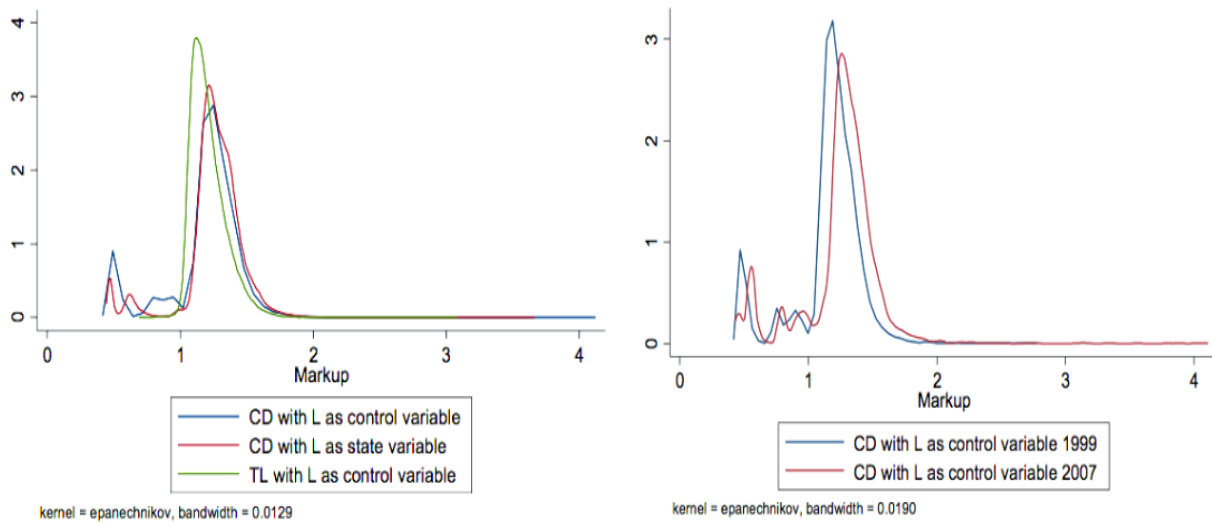
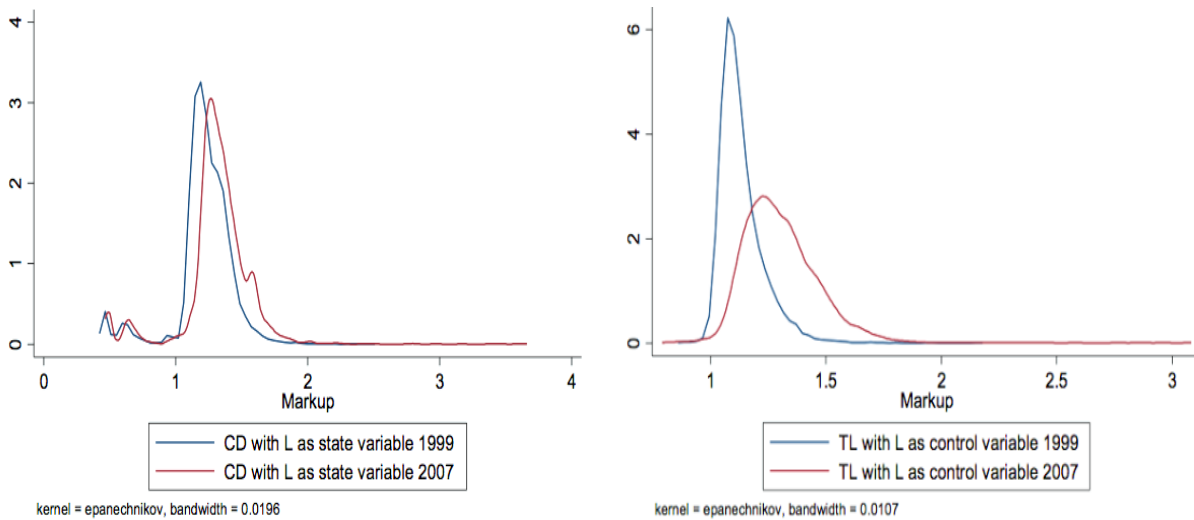


Figure IV: Balanced Panel Markup Estimation II  
1999 vs. 2007



### 4.3 Firm Size

We measure firm size in terms of log output value, both in nominal terms and deflated by 4-digit industry output deflator, and in terms of log employment. Its change follows the same pattern as firm productivity and markups, that is, both the mean and the dispersion of its distribution go up.

Table VIII: Firm Size, 1999-2007 Pooled

Specification	Mean (Standard Deviation)	Median
Log (nominal output value)	10.62 (1.35)	10.45
Log (deflated output value)	10.64 (1.34)	10.47
Log (employment)	5.41 (1.12)	5.32

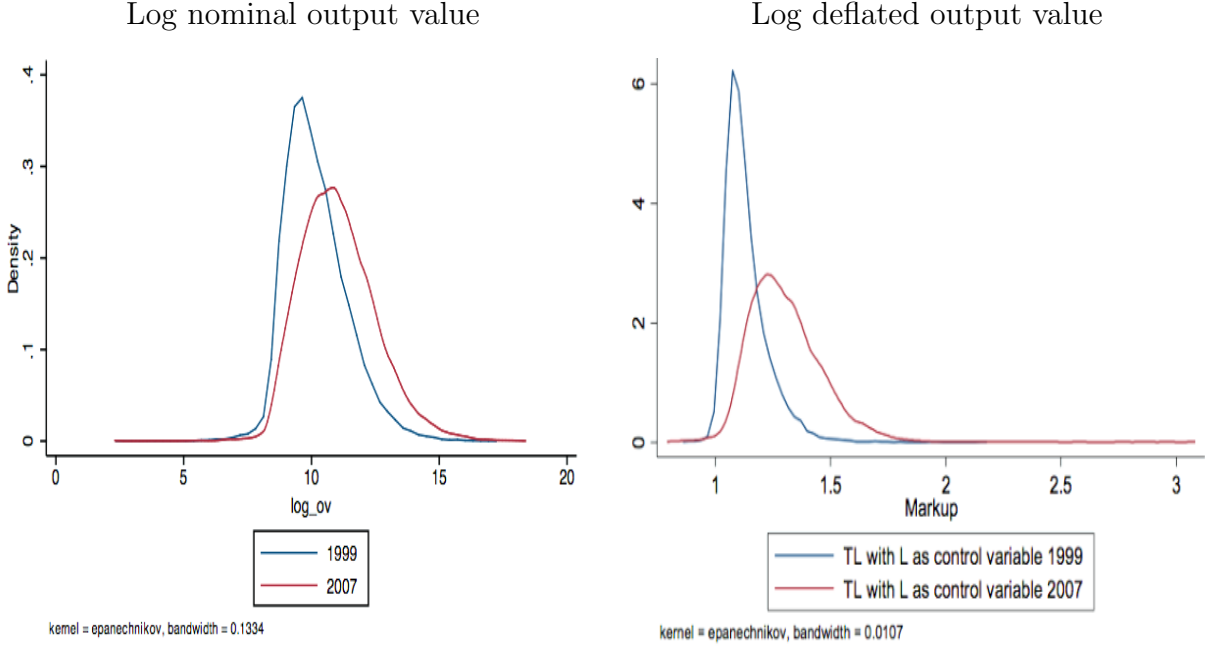
Table IX: Firm Size, 1999

Specification	Mean (Standard Deviation)	Median
Log (nominal output value)	10.18 (1.22)	10
Log (deflated output value)	10.21 (1.22)	10.03
Log (employment)	5.36 (1.13)	5.26

Table X: Firm Size, 2007

Specification	Mean (Standard Deviation)	Median
Log (nominal output value)	11.04 (1.49)	10.91
Log (deflated output value)	11 (1.48)	10.87
Log (employment)	5.4 (1.15)	5.3

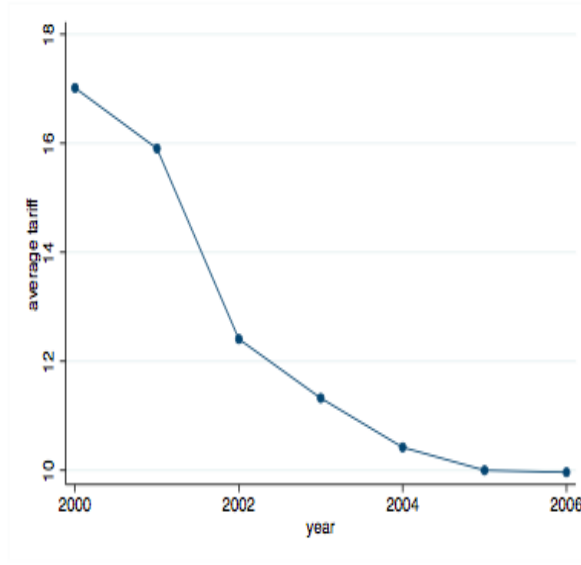
Figure V: Balanced Panel Firm Size Estimation



## 5 Tariff Reductions and Imported Inputs

Since China joined the WTO in December 2001, it lowered its average tariff significantly, from 16% to a little above 12% within one year from 2001 to 2002, and the average tariff kept declining steadily over the entire sample period. The last year in our sample, 2006, saw an average tariff rate of only about 10%. It is indeed one of the most dramatic trade liberalization episodes in China's history. As a commitment to its WTO accession, China also agreed to eliminate all quotas, licenses, tendering requirements and other non-tariff barriers to imports of manufactured goods by 2005.

Figure VI: Average Tariff at HS-8 Level



Source: Trade Analysis and Information System (TRAINS) and WTO tariff database

To motivate our theoretical model, we look at how heterogeneous firms at different productivity levels adjust their set of imported varieties during this period of dramatic input tariff liberalization. We find in the data that firms that belong to a higher quartile of the productivity distribution expanded the number of foreign varieties that they imported by more. This observation leads to an important feature of our model, which we explain in the theory section.

We also see in the data that firms on average increased the number of their imported products and source countries significantly between 2001 and 2002, when they experienced the biggest tariff reductions. They kept expanding their imported varieties (product-country pairs) until 2004, which then tapered off. Firms typically import a large number of products from a number of countries, and therefore, we assume that firms can import a continuum of foreign varieties if they find it beneficial.

Table XI: Firm Productivity and Newly Imported Varieties

<b>2001</b>		<b>2002</b>	
Productivity Quartile	Mean of Newly Imported Varieties	Productivity Quartile	Mean of Newly Imported Varieties
Q1	3.95	Q1	5.35
Q2	4.21	Q2	5.42
Q3	4.48	Q3	6.75
Q4	8.17	Q4	10.72
<b>2003</b>		<b>2004</b>	
Productivity Quartile	Mean of Newly Imported Varieties	Productivity Quartile	Mean of Newly Imported Varieties
Q1	5.21	Q1	4.77
Q2	6.38	Q2	5.84
Q3	7.78	Q3	7.49
Q4	13	Q4	12.79
<b>2005</b>		<b>2006</b>	
Productivity Quartile	Mean of Newly Imported Varieties	Productivity Quartile	Mean of Newly Imported Varieties
Q1	4.27	Q1	3.62
Q2	5.61	Q2	5.14
Q3	7.08	Q3	6.81
Q4	12.24	Q4	11.21

Table XII: Number of Imported Products, Source Countries and Varieties

<b>2001</b>				<b>2002</b>			
	Products	Source Countries	Varieties		Products	Source Countries	Varieties
Mean	158	16	278	Mean	181	18	331
Median	92	14	127	Median	105	15	145
<b>2003</b>				<b>2004</b>			
	Products	Source Countries	Varieties		Products	Source Countries	Varieties
Mean	183	19	348	Mean	188	19	370
Median	108	15	153	Median	108	15	155
<b>2005</b>				<b>2006</b>			
	Products	Source Countries	Varieties		Products	Source Countries	Varieties
Mean	179	19	363	Mean	157	19	327
Median	102	15	146	Median	90	15	137

## 6 Model

In this section, we present a partial equilibrium, heterogeneous firm model with endogenous imported input and labor quality choice to account for the aforementioned empirical findings. On the demand side, we adopt the “quality-Melitz” model in [Kugler and Verhoogen \(2012\)](#), where higher price decreases demand but higher quality increases demand. On the supply side, firms differ from each other in the usual dimension of productivity, as in [Melitz \(2003\)](#). In our model, firms combine labor and intermediate inputs to produce physical quantity, in the spirit of [Amiti et al. \(2014\)](#). Output quality, on the other hand, is determined by labor and input quality, and the advantage of imported inputs over domestic counterparts is augmented by a firm’s own productivity.

### 6.1 Demand

Similar to [Kugler and Verhoogen \(2012\)](#), a representative consumer has the following constant-elasticity-of-substitution (CES) utility function:

$$U = \left[ \int_{i \in I} (q_i \cdot y_i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}} \quad (15)$$

where  $I$  denotes the set of all differentiated varieties available;  $i \in I$  indexes a particular variety;  $\sigma > 1$  is the constant elasticity of substitution between different varieties;  $y_i$  is the quantity of variety  $i$  consumed;  $q_i$  is the output quality of variety  $i$ , chosen by the firm producing variety  $i$  and assumed to be observable to all.



Consumer optimization yields the following demand function for variety  $i$ :

$$y_i = Y P^\sigma q_i^{\sigma-1} p_i^{-\sigma} \quad (16)$$

where  $p_i$  is the price of variety  $i$  charged by the firm;  $Y = U = \left[ \int_{i \in I} (q_i \cdot y_i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}}$  is the quality-adjusted aggregate consumption in the economy;  $P = \left[ \int_{i \in I} \left( \frac{p_i}{q_i} \right)^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}$  is the quality-adjusted ideal price index. This demand function is increasing in the quality and decreasing in the price.

## 6.2 Production

There is a continuum of firms of measure  $|I|$ , each producing one differentiated variety. Without any ambiguity, we also use  $i$  to index the firm producing variety  $i$ . Firms differ from each other in their productivity,  $\varphi_i$ , drawn from a known distribution upon entering the market and are thereafter fixed, as in [Melitz \(2003\)](#).<sup>2</sup>

Let us consider a particular firm  $i$ . Its production can be summarized by two production functions - one characterizing the production of physical quantity,  $y_i$ , and the other characterizing the production of output quality,  $q_i$ . The production of physical quantity is summarized by a Cobb-Douglas production function:

$$y_i = \varphi_i L_i^{1-\phi} X_i^\phi \quad (17)$$

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<sup>2</sup>Here we assume the support of the distribution is bounded below by 1. This assumption is made mainly to eliminate scenarios in which low productivity firms make high quality foreign inputs less efficient than low quality domestic inputs.

$$X_i = \exp \left\{ \int_0^1 \gamma_j \log(X_{ij}) dj \right\} \quad (18)$$

$$X_{ij} = Z_{ij} + \varphi_i^b a_j M_{ij} \quad (19)$$

$L_i$  is the amount of labor used.  $0 < 1 - \phi < 1$  is the labor share of variable costs.  $X_i$  is the intermediate input aggregated from a continuum of inputs of measure 1, indexed by  $j$ .  $\gamma_j > 0$  is the importance of input  $j$  among all intermediate inputs, with  $\int_0^1 \gamma_j dj = 1$ .  $X_{ij}$  is the amount of input  $j$  used. For each input  $j$ , there are both domestic and foreign varieties denoted by  $Z_{ij}$  and  $M_{ij}$  respectively, which are perfect substitutes. The foreign variety has a natural advantage,  $a_j > 1$ , over its domestic counterpart. However, the actual advantage,  $\varphi_i^b a_j$ , is the natural advantage augmented by a firm's productivity, implying that more productive firms are able to use the same foreign input more efficiently than less productive ones.  $b > 0$ , is a parameter that governs the differential efficiency of foreign input use between firms at different levels of productivity - the larger  $b$  is, the greater the differential efficiency.

The production of output quality is summarized by a constant-returns-to-scale super-modular function in labor quality and intermediate input quality:

$$q_i = \left[ (1 - \phi) c^\theta + \phi \int_0^1 \gamma_j b_j^\theta dj \right]^{\frac{1}{\theta}} \quad (20)$$

$$b_j = \begin{cases} 1 & j \in J_i^Z \\ \varphi_i^b a_j & j \in J_i^M \end{cases} \quad (21)$$

$c$  is the labor quality chosen by the firm;<sup>3</sup>  $b_j$  is the quality of intermediate input  $j$ ;  $J_i^Z$  represents the set of inputs for which domestic varieties are used, and  $J_i^M = [0, 1] \setminus J_i^Z$  represents the set of inputs for which foreign varieties are imported;  $\theta < 0$  captures the constant degree of complementarity between labor quality and intermediate input quality. A more negative  $\theta$  represents a stronger complementarity. With this specification, firms using higher quality foreign inputs also have a greater incentive to use higher quality labor to complement them.

We assume there is only domestic labor market, given the low international mobility of labor relative to capital and intermediate inputs. Workers,  $l$ , are ex-ante homogeneous with wages normalized to 1. There exists a sector that transforms homogeneous labor into different quality, with the production function:  $F(l, c) = \frac{l}{c}$ . This implies that the marginal cost of producing one unit of labor with quality  $c$  is  $c \cdot 1 = c$ . Labor market is assumed to be perfectly competitive, hence the price of labor of quality  $c$  is  $p_L(c) = c$ .

For intermediate input  $j$ , there are domestic market and foreign market. Firms are price takers in both. The equilibrium prices of domestic variety and foreign variety are  $p_j^Z$  and  $p_j^M$  respectively.<sup>4</sup> However, on top of the price,  $p_j^M$ , there are variable trade costs,  $\tau_j \geq 1$ , in the form of iceberg costs. In other words, for a firm to acquire one unit of foreign variety of input  $j$ , it has to pay for  $\tau_j$  units at the costs of  $\tau_j p_j^M$ .

We assume that there are no fixed costs of importing at each input level.<sup>5</sup> However, each

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<sup>3</sup>Labor quality,  $c$ , is a continuous variable with positive support. It is perfectly observable to firms, so we abstract from any asymmetric information problems.

<sup>4</sup>Both are expressed in terms of a home currency. Exchange rates are not the focus of this chapter.

<sup>5</sup>This is mainly to avoid the problem of multiple equilibria. [Amiti et al. \(2014\)](#) have fixed costs of importing at each input level. But they fix the set of imported inputs before the choice of output in equilibrium, because the exchange rate shocks in their paper are assumed to be unforeseen. In this chapter, however, we wish to allow both output and the set of imported inputs to respond to a change in the variable trade costs. The addition of fixed costs of importing at each input level will thus introduce multiple equilibria.

firm has to pay fixed import costs,  $f_M$ , if it switches from not importing at all to importing some inputs. There are also fixed costs of production,  $f$ , each period.

## 6.3 Equilibrium

In order to solve the firm's profit maximization problem, we follow the strategy in [Amiti et al. \(2014\)](#). We break down the problem into two stages. In the first stage, we hold the set of imported inputs,  $J_i^M$ , fixed and solve the optimization problem conditional on  $J_i^M$ . In the second stage, we allow  $J_i^M$  to vary so that we can pin down the optimal set of imported inputs,  $J_i^{M*}$ .

### 6.3.1 Stage 1: Profit Maximization Conditional on a Fixed Set of Imported Inputs

In this stage, we fix the set of imported inputs,  $J_i^M \neq \emptyset$ .<sup>6</sup> Then the firm's profits can be written as:

$$\begin{aligned}\Pi_i &= p_i \cdot y_i - p_L(c) \cdot L - \int_{J_i^Z} (p_j^Z \cdot Z_{ij}) dj - \int_{J_i^M} (\tau_j p_j^M \cdot M_{ij}) dj - f_M - f \\ &= Y^{\frac{1}{\sigma}} P q_i^{\frac{\sigma-1}{\sigma}} y_i^{\frac{\sigma-1}{\sigma}} - c \cdot L - \int_{J_i^Z} (p_j^Z \cdot Z_{ij}) dj - \int_{J_i^M} (\tau_j p_j^M \cdot M_{ij}) dj - f_M - f\end{aligned}\quad (22)$$

The second equality comes from substituting the price,  $p_i = Y^{\frac{1}{\sigma}} P q_i^{\frac{\sigma-1}{\sigma}} y_i^{-\frac{1}{\sigma}}$ , using the demand function and  $p_L(c) = c$ , into the first equality.

---

<sup>6</sup>We restrict attention to firms that import. The determination of the cutoff,  $\varphi_{nm}$ , below which firms never import is discussed in the next section, by comparing the firm's profits given its optimal set of imported inputs with those when it does not import any inputs.

The conditional profit maximization problem is thus:

$$\begin{aligned} \max_{y_i, q_i, c, L_i, X_i, \{Z_{ij}\}, \{M_{ij}\}} \Pi_i &= Y^{\frac{1}{\sigma}} P q_i^{\frac{\sigma-1}{\sigma}} y_i^{\frac{\sigma-1}{\sigma}} - c \cdot L - \int_{J_i^Z} (p_j^Z \cdot Z_{ij}) dj - \int_{J_i^M} (\tau_j p_j^M \cdot M_{ij}) dj \\ &\quad - f_M - f \end{aligned} \quad (23)$$

$$s.t : \quad y_i = \varphi_i L_i^{1-\phi} X_i^\phi \quad (24)$$

$$X_i = \exp \left\{ \int_{J_i^Z} \gamma_j \log(Z_{ij}) dj + \int_{J_i^M} \gamma_j \log(\varphi_i^b a_j M_{ij}) dj \right\} \quad (25)$$

$$q_i = \left[ (1-\phi) c^\theta + \phi \left( \int_{J_i^Z} \gamma_j dj + \int_{J_i^M} \gamma_j \varphi_i^{b\theta} a_j^\theta dj \right) \right]^{\frac{1}{\theta}} \quad (26)$$

Let the Lagrange multipliers associated with (3.24), (3.25) and (3.26) be  $\lambda, \psi, \chi$  respectively.

Firm optimization yields the following first-order conditions:

$$\frac{\sigma-1}{\sigma} Y^{\frac{1}{\sigma}} P q_i^{\frac{\sigma-1}{\sigma}} y_i^{-\frac{1}{\sigma}} = \lambda \quad (27)$$

$$\frac{\sigma-1}{\sigma} Y^{\frac{1}{\sigma}} P q_i^{-\frac{1}{\sigma}} y_i^{\frac{\sigma-1}{\sigma}} = \chi \quad (28)$$

$$L_i = \chi (1-\phi) q_i^{1-\theta} c^{\theta-1} \quad (29)$$

$$c = \lambda (1-\phi) \frac{y_i}{L_i} \quad (30)$$

$$\psi = \lambda \phi \frac{y_i}{X_i} \quad (31)$$

$$p_j^Z = \psi X_i \frac{\gamma_j}{Z_{ij}}, \quad \forall j \in J_i^Z \quad (32)$$

$$\tau_j p_j^M = \psi X_i \frac{\gamma_j}{M_{ij}}, \quad \forall j \in J_i^M \quad (33)$$

We can solve for the optimal labor quality, output quality, output quantity and profits,

conditional on  $J_i^M$ , as follows:

$$c = q_i = \left[ \int_{J_i^Z} \gamma_j dj + \int_{J_i^M} \gamma_j \varphi_i^{b\theta} a_j^\theta dj \right]^{\frac{1}{\theta}} \quad (34)$$

$$y_i = \left( \frac{\sigma - 1}{\sigma} \right)^\sigma (1 - \phi)^{(1-\phi)\sigma} \phi^{\phi\sigma} Y P^\sigma \cdot \varphi_i^\sigma \cdot q_i^{\phi\sigma-1} B_i^{\phi\sigma} \quad (35)$$

$$\begin{aligned} \Pi_i &= \frac{1}{\sigma} \left( \frac{\sigma - 1}{\sigma} \right)^{\sigma-1} (1 - \phi)^{(1-\phi)(\sigma-1)} \phi^{\phi(\sigma-1)} Y P^\sigma \cdot \varphi_i^{\sigma-1} \cdot (q_i B_i)^{\phi(\sigma-1)} \\ &\quad - f_M - f \end{aligned} \quad (36)$$

where  $B_i = \exp \left\{ \int_0^1 \gamma_j \log \frac{\gamma_j}{p_j^Z} dj + \int_{J_i^M} \gamma_j \log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} dj \right\}$ .

The first equation postulates that, conditional on the same set of imported inputs, firms with higher productivity can make more out of foreign inputs and thus hire higher quality labor to complement them, ultimately producing higher quality outputs. Conditional on the same productivity, firms that import a larger set of inputs also hire higher quality labor due to the increase in the quality of intermediate inputs, and also produce higher quality outputs. As a result, these firms pay higher wages to its workers.

### 6.3.2 Stage 2: Determination of the Optimal Set of Imported Inputs

In this stage, we formulate a recursive algorithm that pins down the optimal set of imported inputs. Before that, let us consider a firm with its current set of imported inputs,  $J_i^M$ , contemplating on whether to import foreign variety for input  $j$ . In other words, input  $j$  is moved from the set  $J_i^Z$  to  $J_i^M$ . After the endogenous adjustment of labor quality, output

quality and quantity, the resulting change in profits is given by:

$$\begin{aligned} d\Pi_i &= A\varphi_i^{\sigma-1} \cdot d \left[ (q_i B_i)^{\phi(\sigma-1)} \right] \\ &= A\varphi_i^{\sigma-1} \cdot \phi(\sigma-1) (q_i B_i)^{\phi(\sigma-1)} \cdot \gamma_j \left[ \frac{1}{\theta} q_i^{-\theta} (\varphi_i^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} \right] \end{aligned} \quad (37)$$

where  $A = \frac{1}{\sigma} \left( \frac{\sigma-1}{\sigma} \right)^{\sigma-1} (1-\phi)^{(1-\phi)(\sigma-1)} \phi^{\phi(\sigma-1)} Y P^\sigma$  contains only constants and macroeconomic variables that the firm takes as exogeneously given. Under the assumptions on the parameters, the sign of  $d\Pi_i$  is given by:

$$\text{sign}(d\Pi_i) = \text{sign} \left( \frac{1}{\theta} q_i^{-\theta} (\varphi_i^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} \right) \quad (38)$$

Note that since we do not have fixed costs of importing at each input level, the sign of  $d\Pi_i$  is independent of the scale of production, thus avoiding the problem of multiple equilibria. The first term,  $\frac{1}{\theta} q_i^{-\theta} (\varphi_i^{b\theta} a_j^\theta - 1)$ , is always positive, representing the benefits of importing an extra input  $j$  on output quality, and hence, total revenue. These benefits are increasing in output quality,  $q_i$ , due to complementarity between quality of newly imported input  $j$  and quality of existing imported inputs in  $J_i^M$ . This implies that there is no crowding out effect - importing more inputs does not make importing other inputs less desirable. In fact, there is crowding in - importing more inputs increases the benefits of importing an extra input, thus increasing the likelihood of importing that input. These benefits are also increasing in firm productivity,  $\varphi_i$ , because more productive firms can make more out of the same imported input  $j$ .<sup>7</sup> The second term,  $\log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M}$ , can be either positive or negative, depending on

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<sup>7</sup>Here, we condition on fixed output quality,  $q_i$ . This result holds more strongly if  $q_i$  is an increasing function in  $\varphi_i$ .

the advantage-and-trade-cost-adjusted relative price. If foreign variety is relatively cheaper than domestic variety,  $\frac{\tau_j p_j^M}{\varphi_i^b a_j} \leq p_j^Z$ , then  $\log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} \geq 0$ . As a result, conditional on already importing some inputs, that is, the firm has already paid the fixed costs of importing at the first unit,  $f_M$ , it is always willing to import such input  $j$  because importing is both quality-enhancing and cost-saving.

Next, we characterize the optimal set of imported inputs. Unlike the framework in [Amiti et al. \(2014\)](#), which has a cutoff implicitly defined because the marginal cost of importing is fixed and the marginal benefit of importing is monotonically decreasing, our model does not have a sorting of the inputs nor an implicitly defined cutoff. Instead, we define the optimal set recursively and sequentially using an algorithm. We prove the optimality of the defined set and some of its other desirable properties in the next subsection. For expository simplicity, let us define:

$$q_i(S) = \left[ \int_{S^c} \gamma_j dj + \int_S \gamma_j \varphi_i^{b\theta} a_j^\theta dj \right]^{\frac{1}{\theta}} \quad (39)$$

as the conditional optimal output quality for firm  $i$  that imports the set of inputs,  $S \subseteq [0, 1]$ , and uses domestic varieties for the complementary set,  $S^c = [0, 1] \setminus S$ .

An immediate lemma is:

**Lemma 1** For any two sets,  $S_1 \subset S_2 \subseteq [0, 1]$ , and some firm  $i$  with productivity  $\varphi_i$ ,  $q_i(S_1) < q_i(S_2)$ . For any two firms  $i$  and  $i'$  with productivity  $\varphi_i < \varphi_{i'}$  and any set  $S \subseteq [0, 1]$ ,  $q_i(S) < q_{i'}(S)$ . Combining the two results, we also have  $q_i(S_1) < q_{i'}(S_1) < q_{i'}(S_2)$ .

The proof is trivial once it is noted that  $\varphi_i^b a_j > 1$ .



**Recursive algorithm of computing the optimal set of imported inputs,  $J_i^{M*}$ , conditional on having paid  $f_M$**

For firm  $i$  with productivity  $\varphi_i$ , its optimal set of imported inputs,  $J_i^{M*}$ , can be computed as the following:

Step 1: Define  $J_{i0} = \left\{ j \in [0, 1] \mid \frac{\tau_j p_j^M}{\varphi_i^b a_j} \leq p_j^Z \right\}$ . Based on the argument above, importing these foreign inputs is both quality-enhancing and cost-saving. Therefore, it is always beneficial to import them once  $f_M$  is paid. Hence,

$$J_{i0} \subseteq J_i^{M*}$$

Step 2: Define  $J_{i1} = \left\{ j \in [0, 1] \cap J_{i0}^c \mid \frac{1}{\theta} [q_i(J_{i0})]^{-\theta} (\varphi_i^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} \geq 0 \right\}$ . Since there is only crowding in effect of importing more inputs and importing inputs in  $J_{i1}$  increases profits, it is optimal for the firm to import them.

$$J_{i1} \subseteq J_i^{M*}$$

Step 3: Define  $J_{i2} = \left\{ j \in [0, 1] \cap J_{i0}^c \cap J_{i1}^c \mid \frac{1}{\theta} [q_i(J_{i0} \cup J_{i1})]^{-\theta} (\varphi_i^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} \geq 0 \right\}$ .

By the same logic,

$$J_{i2} \subseteq J_i^{M*}$$

Repeat these steps until for some  $N \in \mathbb{N}$  such that,

$$J_{iN} = \left\{ j \in [0, 1] \cap \left( \bigcap_{n=0}^{N-1} J_{in}^c \right) \mid \frac{1}{\theta} \left[ q_i \left( \bigcup_{n=0}^{N-1} J_{in} \right) \right]^{-\theta} (\varphi_i^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} \geq 0 \right\} = \emptyset$$

implying that there is no input, which the firm has not yet imported, that can increase profits. Then we claim the optimal set of imported inputs is:

$$J_i^{M*} = \bigcup_{n=0}^{N-1} J_{in}$$

### 6.3.3 Determination of No-import Cutoff

Due to the existence of the fixed costs of importing,  $f_M$ , at the first unit, not every firm engages in importing. Firms below a productivity threshold,  $\varphi_{nm}$ , do not import any input while firms above that threshold do. This threshold is determined by comparing the profits if the firm imports with those if it does not. The marginal firm with productivity  $\varphi_{nm}$  is indifferent between importing and not.

The profits of firm  $i$  if it imports are given by:

$$\Pi_i(\text{importing}) = A\varphi_i^{\sigma-1} \cdot (q_i(J_i^{M*}) B_i(J_i^{M*}))^{\phi(\sigma-1)} - f_M - f \quad (40)$$

where  $J_i^{M*}$  is the optimal set of imported inputs given productivity  $\varphi_i$ .

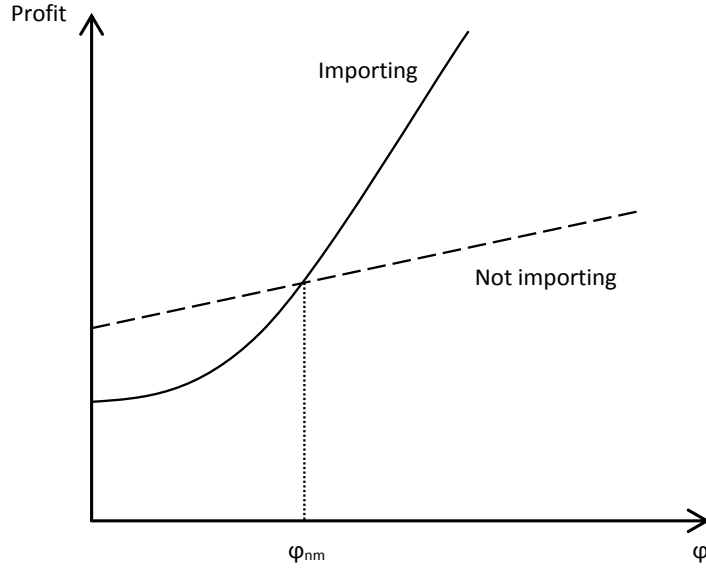
The profits of firm  $i$  if it does not import are given by:

$$\begin{aligned} \Pi_i(\text{not importing}) &= A\varphi_i^{\sigma-1} \cdot (q_i(\emptyset) B_i(\emptyset))^{\phi(\sigma-1)} - f \\ &= A\varphi_i^{\sigma-1} \cdot \exp \left\{ \phi(\sigma-1) \int_0^1 \gamma_j \log \frac{\gamma_j}{p_j^Z} dj \right\} - f \end{aligned} \quad (41)$$

Note that  $(q_i(J_i^{M*}) B_i(J_i^{M*}))^{\phi(\sigma-1)} > (q_i(\emptyset) B_i(\emptyset))^{\phi(\sigma-1)} = \exp \left\{ \phi(\sigma-1) \int_0^1 \gamma_j \log \frac{\gamma_j}{p_j^Z} dj \right\}$  because of the optimality of  $J_i^{M*}$ . Even though both  $\Pi_i(\text{importing})$  and  $\Pi_i(\text{not importing})$

are increasing in  $\varphi_i$ , the former increases much faster than the latter, but the former starts at a lower value due to the existence of  $f_M$ . Hence, as illustrated by the figure below, the two profit lines have one intersection,  $\varphi_{nm}$ , after which importing inputs generates higher profits than not importing. This pins down the no-import cutoff.

Figure VII: No-import Cutoff



## 6.4 Model Implications

In this section, we outline some of the properties implied by the model that guide our empirical investigations. Some of these properties come naturally out of the model while others require additional assumptions on the parameters of the model.

### 6.4.1 No-import Cutoff

We first examine how the set of firms that engage in importing respond to trade liberalization in the form of import tariff reductions. Clearly the profit schedule of not importing,  $\Pi_i(\text{not importing})$ , does not change with import tariff reductions. The profit schedule of importing,  $\Pi_i(\text{importing})$ , does, but this change may or may not affect the no-import cutoff, depending on the nature of import tariff reductions. We summarize our findings in the following proposition.

**Proposition 1:** Suppose there is trade liberalization in the form of import tariff reductions summarized by  $\{d\tau_j \leq 0, j \in [0, 1]\}$ . The no-import cutoff will either decrease,

$\varphi_{nm'} < \varphi_{nm}$ , or remain unchanged,  $\varphi_{nm'} = \varphi_{nm}$ . The former is true if and only

if the original marginal firm with productivity  $\varphi_{nm}$  has a strictly larger optimal set

of imported inputs,  $J_{nm}^{M*}(\{\tau_j + d\tau_j\}_{j=0}^1) \supset J_{nm}^{M*}(\{\tau_j\}_{j=0}^1)$ , or the same optimal set,

$J_{nm}^{M*}(\{\tau_j + d\tau_j\}_{j=0}^1) = J_{nm}^{M*}(\{\tau_j\}_{j=0}^1)$ , but there exists some  $j \in J_{nm}^{M*}(\{\tau_j\}_{j=0}^1)$  such

that  $d\tau_j < 0$ . The latter is true if and only if the optimal set does not change,

$J_{nm}^{M*}(\{\tau_j + d\tau_j\}_{j=0}^1) = J_{nm}^{M*}(\{\tau_j\}_{j=0}^1)$ , and for all  $j \in J_{nm}^{M*}(\{\tau_j\}_{j=0}^1)$ ,  $d\tau_j = 0$ .

An immediate result is that if there is a uniform decrease in import tariffs, the no-import cutoff decreases. More generally, if there is a decrease in tariff on some input in the optimal set of imported inputs of the original marginal firm, the cutoff decreases. This result is consistent with empirical findings that following trade liberalization, previously non-importing firms in the balanced panel start to import higher quality foreign inputs.

### 6.4.2 Optimal Set of Imported Inputs

Since the optimal set of imported inputs is at the center of our model, determining equilibrium labor quality, output quality and quantity, we investigate the properties of this set.

**Proposition 2:** All other things being equal, a more productive firm imports a weakly larger set of foreign inputs. Specifically, if  $\varphi_i < \varphi_{i'}$ , then  $J_i^{M*} \subseteq J_{i'}^{M*}$ .

*Proof.* Let us consider the recursive algorithms for the two firms. Let  $N_1$  and  $N_2$  be defined as in the algorithm for firm  $i$  and  $i'$  respectively. There are three possible cases:  $N_1 = N_2$ ,  $N_1 < N_2$  and  $N_1 > N_2$ . We prove the proposition in the three cases separately.

First, suppose  $N_1 = N_2 = N$ . To prove  $J_i^{M*} \subseteq J_{i'}^{M*}$ , we just need to prove in each step,  $\bigcup_{m=0}^n J_{im} \subseteq \bigcup_{m=0}^n J_{i'm}$  for all  $n \in \{0, 1, \dots, N-1\}$ . Clearly when  $n = 0$ ,  $J_{i0} = \left\{ j \in [0, 1] \mid \frac{\tau_j p_j^M}{\varphi_i^b a_j} \leq p_j^Z \right\} \subseteq \left\{ j \in [0, 1] \mid \frac{\tau_j p_j^M}{\varphi_{i'}^b a_j} \leq p_j^Z \right\} = J_{i'0}$  because  $\varphi_i < \varphi_{i'}$ . Now suppose  $\bigcup_{m=0}^n J_{im} \subseteq \bigcup_{m=0}^n J_{i'm}$  holds for some  $n \in \{0, 1, \dots, N-2\}$ . Consider in step  $n+1$ , some arbitrary input  $j \in J_{in+1}$ . If  $j \in \bigcup_{m=0}^n J_{i'm}$ , then it becomes trivial that  $j \in \bigcup_{m=0}^{n+1} J_{i'm}$ . So suppose  $j \notin \bigcup_{m=0}^n J_{i'm}$ , but we know that  $\frac{1}{\theta} q_i \left( \bigcup_{m=0}^n J_{im} \right)^{-\theta} (\varphi_i^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} \geq 0$  by definition of  $J_{in+1}$ ; and  $\bigcup_{m=0}^n J_{im} \subseteq \bigcup_{m=0}^n J_{i'm}$  with  $\varphi_i < \varphi_{i'}$  implies  $q_i \left( \bigcup_{m=0}^n J_{im} \right) < q_{i'} \left( \bigcup_{m=0}^n J_{i'm} \right)$  by Lemma 1. Therefore

$$\frac{1}{\theta} q_{i'} \left( \bigcup_{m=0}^n J_{i'm} \right)^{-\theta} (\varphi_{i'}^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_{i'}^b a_j p_j^Z}{\tau_j p_j^M} > \frac{1}{\theta} q_i \left( \bigcup_{m=0}^n J_{im} \right)^{-\theta} (\varphi_i^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} \geq 0$$

Hence  $j \in J_{i'n+1} \subseteq \bigcup_{m=0}^{n+1} J_{i'm}$ . This proves  $J_{in+1} \subseteq \bigcup_{m=0}^{n+1} J_{i'm}$ , but by assumption,  $\bigcup_{m=0}^n J_{im} \subseteq \bigcup_{m=0}^n J_{i'm} \subseteq \bigcup_{m=0}^{n+1} J_{i'm}$ , so we have  $\bigcup_{m=0}^{n+1} J_{im} = J_{in+1} \cup \left( \bigcup_{m=0}^n J_{im} \right) \subseteq \bigcup_{m=0}^{n+1} J_{i'm}$ .

By mathematical induction, we have shown that  $\bigcup_{m=0}^n J_{im} \subseteq \bigcup_{m=0}^n J_{i'm}$  for all  $n \in \{0, 1, \dots, N-1\}$ .

Evaluating this expression at  $N - 1$ , we have proven  $J_i^{M*} \subseteq J_{i'}^{M*}$ .

The case  $N_1 < N_2$  is trivial because we have shown already that  $J_i^{M*} = \bigcup_{n=0}^{N_1-1} J_{in} \subseteq \bigcup_{n=0}^{N_1-1} J_{i'n} \subseteq \left( \bigcup_{n=0}^{N_1-1} J_{i'n} \right) \cup \left( \bigcup_{n=N_1}^{N_2-1} J_{i'n} \right) = J_{i'}^{M*}$ .

Now, we consider  $N_1 > N_2$ . We have shown in the first case that  $\bigcup_{n=0}^{N_2-1} J_{in} \subseteq \bigcup_{n=0}^{N_2-1} J_{i'n} = J_{i'}^{M*}$ . Now consider any arbitrary  $j \in J_{iN_2}$ .  $j$  satisfies  $\frac{1}{\theta} q_i \left( \bigcup_{n=0}^{N_2-1} J_{in} \right)^{-\theta} (\varphi_i^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} \geq 0$ , and we know  $q_i \left( \bigcup_{n=0}^{N_2-1} J_{in} \right) < q_{i'} \left( \bigcup_{n=0}^{N_2-1} J_{i'n} \right)$  by Lemma 1. So

$$\frac{1}{\theta} q_{i'} \left( \bigcup_{n=0}^{N_2-1} J_{i'n} \right)^{-\theta} (\varphi_{i'}^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_{i'}^b a_j p_j^Z}{\tau_j p_j^M} > \frac{1}{\theta} q_i \left( \bigcup_{n=0}^{N_2-1} J_{in} \right)^{-\theta} (\varphi_i^{b\theta} a_j^\theta - 1) + \log \frac{\varphi_i^b a_j p_j^Z}{\tau_j p_j^M} \geq 0$$

Hence by definition  $j \in J_{i'N_2}$  or  $j \in \bigcup_{n=0}^{N_2-1} J_{i'n}$ . The former is impossible because  $J_{i'N_2} = \emptyset$ , so  $j \in \bigcup_{n=0}^{N_2-1} J_{i'n}$ . This proves  $J_{iN_2} \subseteq \bigcup_{n=0}^{N_2-1} J_{i'n}$ . With  $\bigcup_{n=0}^{N_2-1} J_{in} \subseteq \bigcup_{n=0}^{N_2-1} J_{i'n}$ , we show  $\bigcup_{n=0}^{N_2} J_{in} = \left( \bigcup_{n=0}^{N_2-1} J_{in} \right) \cup J_{iN_2} \subseteq \bigcup_{n=0}^{N_2-1} J_{i'n} = J_{i'}^{M*}$ . Repeat this argument for  $n = N_2 + 1, \dots, N_1 - 1$ , we can show that  $J_i^{M*} = \bigcup_{n=0}^{N_1-1} J_{in} \subseteq J_{i'}^{M*}$ .

**Proposition 3:** All other things being equal, a reduction in variable trade costs,  $\tau_j$ , for input  $j$  increases the likelihood of importing that input for a firm that previously does not import it. Furthermore, it also increases the likelihood of importing other inputs that are not imported before by the firm, if input  $j$  is now imported.

Proposition 3 is quite intuitive because a reduction in variable trade costs  $\tau_j$  decreases the costs of importing  $j$  while keeping benefits unchanged. Hence the firm is more likely to import  $j$ . Conditional on  $j$  being imported after the reduction in  $\tau_j$ , the set of imported inputs expands and the output quality increases, further increasing the benefits of importing other inputs due to the crowding in effect. Hence, the likelihood of the firm importing other

inputs increases.

Proposition 3 can be generalized to reductions in multiple/all variable trade costs. The increase in the likelihood is much bigger if the variable trade costs of many inputs that are previously not imported by the firm decrease at the same time.

### 6.4.3 Labor Quality, Output Quality, and Wages

Recall that for firms above the no-import threshold,  $\varphi_{nm}$ , the optimal labor quality and output quality are given by:

$$c = q_i = \left[ \int_{J_i^{Z*}} \gamma_j dj + \int_{J_i^{M*}} \gamma_j \varphi_i^{b\theta} a_j^\theta dj \right]^{\frac{1}{\theta}}$$

where  $J_i^{Z*} = [0, 1] \setminus J_i^{M*}$  is the equilibrium set of domestic inputs.

By proposition 2, we know that a more productive firm imports a weakly larger set of foreign inputs. Hence, it is obvious from the above expression that this more productive firm uses strictly higher quality labor and produces strictly higher quality output. Since equilibrium labor quality is higher for a more productive firm, it also pays higher wages because  $p_L(c) = c$ .

Trade liberalization in the form of tariff reductions increases the set of imported inputs for some, if not all, firms, by proposition 3. These firms switch to higher quality foreign inputs, and hire higher quality labor to complement them. As a result, they produce higher quality output and pay higher wages.

Suppose the tariff reductions induce a decrease in the no-import cutoff as in the first case in proposition 1. Then for those firms with productivities  $\varphi_i$  between  $\varphi_{nm'}$  and  $\varphi_{nm}$ , they

switch from not importing at all to importing some foreign inputs. Their labor quality and output quality increase from  $c = q_i = \left[ \int_0^1 \gamma_j dj \right]^{\frac{1}{\theta}} = 1$  to  $\left[ \int_{J_i^{Z*}} \gamma_j dj + \int_{J_i^{M*}} \gamma_j \varphi_i^{b\theta} a_j^\theta dj \right]^{\frac{1}{\theta}} > 1$ . This increase is larger, the more productive the firm is, because  $\varphi_i$  and  $J_i^{M*}$  are both larger by proposition 2. As a result, they also pay higher wages after trade liberalization.

For those firms that never import - firms with  $\varphi_i < \varphi_{nm'} \leq \varphi_{nm}$ , there is no change in the labor quality, output quality and wages before and after trade liberalization. They are consistently using the low skill labor,  $c = 1$ , producing low quality output,  $q_i = 1$ , and paying low wages,  $p_L(1) = 1$ .

#### 6.4.4 Firm Profits

In terms of firm profits, we have a set of similar predictions.

Conditional on the same set of imported inputs, a more productive firm has higher profits because of its higher  $\varphi_i$  and higher  $q_i$ . By proposition 2, it also imports a weakly larger set of inputs. It chooses to do so because by importing more, its profits increase. Therefore, we have shown that a more productive firm enjoys higher profits. Trade liberalization in the form of input tariff reductions generates higher profits for any firms, provided that they are importing inputs after trade liberalization. This increase in profits comes from two potential sources. After trade liberalization but conditional on the same set of imported inputs, firm profits are at least as large as before. It makes strictly larger profits if there is a reduction in tariff on at least one of its imported inputs. Furthermore, the firm chooses to import a weakly larger set of imported inputs by proposition 3. It chooses to do so only if its profits increase, evident from the recursive algorithm.

However, who enjoys a bigger increase in profits in the face of the same tariff reductions



is a much tougher question to answer. If we restrict our attention to firms that are new importers - those with productivity,  $\varphi_i \in [\varphi_{nm'}, \varphi_{nm})$ , then it is clear that the more productive firms have a larger increase in profits than the less productive ones. It is not clear, however, if we wish to compare profits of an existing importer with those of a new importer. It is possible that the former increase by more if we impose additional assumptions on  $\{a_j\}$ , the natural advantage of foreign varieties over their domestic counterparts, or if the differential efficiency,  $b$  is large enough.

#### 6.4.5 Total Factor Productivity

For firm  $i$  with  $\varphi_i \geq \varphi_{nm}$ , its total factor productivity (TFP) is defined as:

$$\begin{aligned}
TFP_i &\equiv \frac{y_i}{L_i^{1-\phi} \exp \left\{ \phi \left( \int_{J_i^{Z*}} \gamma_j \log Z_{ij} dj + \int_{J_i^{M*}} \gamma_j \log M_{ij} dj \right) \right\}} \\
&= \varphi_i \cdot \exp \left\{ \phi \int_{J_i^{M*}} \gamma_j \log \varphi_i^b a_j dj \right\} \\
&= \varphi_i^{1+b\phi \int_{J_i^{M*}} \gamma_j dj} \cdot \exp \left\{ \phi \int_{J_i^{M*}} \gamma_j \log a_j dj \right\}
\end{aligned} \tag{42}$$

TFP is greater than  $\varphi_i$  because the use of imported inputs enhances firm productivity by the factor  $\varphi_i^{b\phi \int_{J_i^{M*}} \gamma_j dj} \cdot \exp \left\{ \phi \int_{J_i^{M*}} \gamma_j \log a_j dj \right\} > 1$ . It is also obvious that a firm with higher baseline productivity,  $\varphi_{i'} > \varphi_i$ , ends up with higher  $TFP_{i'} > TFP_i$ . Specifically, from proposition 2, we know that  $J_{i'}^{M*} \supseteq J_i^{M*}$ . Let  $H = J_{i'}^{M*} \setminus J_i^{M*} = J_{i'}^{M*} \cap (J_i^{M*})^c \supseteq \emptyset$  be the difference between the two sets. Then the TFP ratio is given by:

$$\begin{aligned}
\frac{TFP_{i'}}{TFP_i} &= \frac{\varphi_{i'}^{1+b\phi \int_{J_i^{M*}} \gamma_j dj} \cdot \exp \left\{ \phi \int_{J_i^{M*}} \gamma_j \log a_j dj \right\}}{\varphi_i^{1+b\phi \int_{J_i^{M*}} \gamma_j dj} \cdot \exp \left\{ \phi \int_{J_i^{M*}} \gamma_j \log a_j dj \right\}} \\
&= \left( \frac{\varphi_{i'}}{\varphi_i} \right)^{1+b\phi \int_{J_i^{M*}} \gamma_j dj} \cdot \varphi_{i'}^{b\phi \int_H \gamma_j dj} \cdot \exp \left\{ \phi \int_H \gamma_j \log a_j dj \right\} \\
&\geq \left( \frac{\varphi_{i'}}{\varphi_i} \right)^{1+b\phi \int_{J_i^{M*}} \gamma_j dj} \\
&> \frac{\varphi_{i'}}{\varphi_i}
\end{aligned} \tag{43}$$

The first inequality holds with equality when  $H = \emptyset$  and holds strictly otherwise. The second inequality holds strictly because we assume that  $\varphi_{i'} > \varphi_i \geq \varphi_{nm}$ , which results in a non-empty set  $J_i^{M*}$ .

For firm  $i$  with productivity lower than the no-import cutoff,  $\varphi_i < \varphi_{nm}$ , its TFP is:

$$\begin{aligned}
TFP_i &= \frac{y_i}{L_i^{1-\phi} \exp \left\{ \phi \left( \int_0^1 \gamma_j \log Z_{ij} dj \right) \right\}} \\
&= \varphi_i
\end{aligned} \tag{44}$$

Since it does not import any foreign inputs, there is no productivity enhancing effect from imported inputs. Hence, its TFP is the same as its baseline productivity parameter,  $\varphi_i$ . It is then trivial to show that the TFP ratio between two firms that are both below the cutoff is  $\frac{TFP_{i'}}{TFP_i} = \frac{\varphi_{i'}}{\varphi_i}$ .

Trade liberalization increases firm-level TFP through the expansion of the set of imported inputs. Again suppose this trade liberalization induces a reduction in no-import cutoff from  $\varphi_{nm}$  to  $\varphi_{nm'}$ , as in the first case in proposition 1. First, consider a firm with productivity

$\varphi_i \geq \varphi_{nm}$ . Before trade liberalization, its optimal set of imported inputs is  $J_i^{M*}$ . It expands to  $J_i^{M*'}$  with  $H$  being the difference between the two sets. Then the expansion in the optimal set of imported inputs induced by trade liberalization increases its TFP by a factor:

$$\frac{TFP'_i}{TFP_i} = \varphi_i^{b\phi \int_H \gamma_j dj} \cdot \exp \left\{ \phi \int_H \gamma_j \log a_j dj \right\} \geq 1$$

Equality holds only when  $H = \emptyset$ .

For a firm with productivity  $\varphi_i \in [\varphi_{nm'}, \varphi_{nm})$ , its TFP increases by a factor:

$$\frac{TFP'_i}{TFP_i} = \varphi_i^{b\phi \int_{J_i^{M*'}} \gamma_j dj} \cdot \exp \left\{ \phi \int_{J_i^{M*'}} \gamma_j \log a_j dj \right\} > 1$$

because its set of imported inputs expands from null set to  $J_i^{M*'} \supset \emptyset$ . And further,  $J_i^{M*'}$  is weakly increasing in  $\varphi_i$  for such a firm by proposition 2. So for a newly importing firm, the increase in TFP is increasing in its baseline productivity.

Trivially, for a firm that never imports, there are no TFP gains from trade liberalization.

However, it is not straightforward to compare the increase in TFP of two arbitrary firms, either both are existing importers,  $\varphi_i, \varphi_{i'} \geq \varphi_{nm}$ , or one is a new importer while the other is an existing importer,  $\varphi_{nm'} \leq \varphi_i < \varphi_{nm}, \varphi_{i'} \geq \varphi_{nm}$ ). That depends on the expansion of the set of imported inputs induced by trade liberalization, and on the parameter  $b$ , which governs the degree of differential efficiency among firms in using foreign inputs. In general, a more productive firm has smaller room to expand its set of imported inputs. However, this constraint can be alleviated by a large  $b$  - that is, it is also much more efficient in using the higher quality foreign inputs.

## 7 Empirical Results

### 7.1 First Stage

Since a firm’s decision to import foreign inputs is endogenous, we adopt the fixed effects 2SLS model to estimate the effects of the differential change in import intensity of firms on their productivity and average wage. More specifically, we use the input tariff reductions following China’s accession to the WTO as an instrument for firm import behavior, following [Goldberg et al. \(2010\)](#). Another concern is that the trade reform itself is endogenous in the sense that less efficient industries lobby for higher trade protection. [Branstetter and Lardy \(2006\)](#) discuss the motive for China’s leadership to agree to the conditions required for its WTO accession. They conclude that, “In short, China’s top political leadership made extensive commitments to the WTO in order to advance their domestic reform agenda.” China joined the WTO to speed up the domestic reforms and facilitate the transition into a market economy. The input tariff reductions are unlikely due to the protection pressure from interest groups in less efficient industries.

To examine the effects of tariff reductions on firm import behavior, we have to consider the set of intermediate inputs that a firm may actually import. We construct an industry-level input tariff at the 4-digit Chinese Industry Classification (CIC) level to avoid endogeneity bias following [Amiti and Konings \(2007\)](#), [Goldberg et al. \(2010\)](#) and [Ge et al. \(2011\)](#). We construct an output tariff by taking a simple average of the HS 8-digit codes within each 4-digit CIC code. The difficulty is that our sample period covers a revision of CIC system in 2003 and a major reclassification of the international HS 6-digit codes in 2002. First, we follow [Brandt et al. \(2012\)](#) to create a concordance of standardized 4-digit CIC codes

consistent before and after 2003. Then we construct a link of 6-digit HS codes before and after 2002. We further construct a crosswalk between standardized 6-digit HS codes and standardized CIC codes based on [Brandt et al. \(2012\)](#). With these links in place, we assign each 8-digit HS product to the 6-digit HS code it belongs to, and then connect this 6-digit HS code with the corresponding 4-digit CIC code, for each year. Next, for each 4-digit industry, we compute an input tariff as a weighted average of the output tariff, where the weights are the cost shares of one industry in the production of a good in another based on the Input-Output Table. We drop output tariff of the industry that a firm belongs to from this calculation to remove the direct effects of output tariffs on wages. Finally, we interact the industry-level input tariff with a firm’s baseline productivity to study their heterogeneous responses. We use the firm-level TFP measured in 1998 to proxy for it, which is independent of a firm’s future import choices.

The first-stage regression that we run is the following:

$$\begin{aligned}
Import_{ft} = & \alpha_0 + \alpha_1 InputTariff_{it} * Productivity_{f,1998} + \alpha_2 InputTariff_{it} \\
& + Z_{f,t-1}\lambda + D_f + D_t + v_{ft}
\end{aligned} \tag{45}$$

where  $Import_{ft}$  is measured by the total number of newly imported varieties (or products).  $Z$  includes firm age, last year’s log revenue and last year’s export status.  $D_t$  is a set of year dummies that control for possible variation in the macroeconomic environment over time;  $D_f$  is included to control for unobservable individual effects of the firm that could be correlated with its import behavior. We use robust standard errors that are clustered at the firm level.

Table [XIII](#) reports the regression results at the variety (product-country of origin pair)

Table XIII: First Stage

	<i>Total Variety<sub>ft</sub></i>
<i>InputTariff<sub>it</sub> * Prod<sub>f,1998</sub></i>	-0.118** [0.052]
<i>InputTariff<sub>it</sub></i>	-0.145** [0.067]
<i>Export Status<sub>ft-1</sub></i>	1.102*** [0.351]
<i>log(Industrial Sale<sub>ft-1</sub>)</i>	2.293*** [0.367]
<i>log(Age<sub>ft</sub>)</i>	-1.067* [0.592]
<i>Year FE</i>	yes
* $p < 0.1$ ; ** $p < 0.05$ ; *** $p < 0.01$ ;	

level. We find that the total number of varieties that are newly imported goes up as a result of tariff reductions. The coefficient of *InputTariff<sub>it</sub> \* Productivity<sub>f,1998</sub>* is also statistically significant and negative, which suggests that a firm with higher baseline productivity increases its imported inputs by more in response to tariff reductions. The total number of newly imported varieties is also higher for a firm that is bigger, younger and exports. We also look at the corresponding regression at the product level and the results are very similar.

## 7.2 Second Stage

Next, we look in the data to see how the expansion of the external margin of imported inputs affects firm-level TFP and average wage.

The second-stage regression that we run is the following:

$$\begin{aligned}
Y_{ft} = & \alpha_0 + \alpha_1 \widehat{import}_{ft} * Productivity_{f,1998} + \alpha_2 \widehat{import}_{ft} \\
& + Z_{f,t-1} \lambda + D_f + D_t + v_{ft}
\end{aligned} \tag{46}$$

where  $Y_{ft}$  is firm-level TFP and its log average wage. Standard errors are robust to heteroscedasticity and clustered at the firm level.

Table XIV reports the regression results of TFP measured by Levinsohn-Petrin method and firm log average wage. We use TFP measured by Olley-Pakes method as a robustness check and the two regressions lead to very similar results. Note that imported inputs increase firm productivity and average wage a firm pays to its workers. Since a firm with higher baseline productivity increases its imported inputs by more, its productivity goes up by more as well as its average wage. As discussed in the section of model implications, each unit of newly imported inputs also increases measured TFP and average wage of a more productive firm by more, and this prediction is supported by the statistically significant and positive coefficient of  $\widehat{import}_{ft} * Prod_{f,1998}$  in each of the regressions. Firm productivity and average wage are also higher if a firm is bigger, younger and exports.

Table XIV: Second Stage

	$TFP_{ft}$	$\log(Wage_{ft})$
$\widehat{import}_{ft} * Prod_{f,1998}$	0.01 <sup>**</sup> [0.004]	0.004 <sup>**</sup> [0.002]
$\widehat{import}_{ft}$	0.054 <sup>***</sup> [0.018]	0.016 <sup>**</sup> [0.007]
$Export\ Status_{ft-1}$	0.009 [0.031]	0.009 [0.014]
$\log(Industrial\ Sale_{ft-1})$	0.308 <sup>***</sup> [0.042]	0.028 [0.018]
$\log(Age_{ft})$	-0.108 <sup>**</sup> [0.045]	-0.025 [0.019]
$Year\ FE$	yes	yes
* $p < 0.1$ ; ** $p < 0.05$ ; *** $p < 0.01$ ;		

## 8 Conclusion and Future Work

In this chapter, we develop a partial equilibrium, heterogeneous firm model with endogenous imported inputs and labor quality choice and establish a link between an improvement in firm performance and the use of imported inputs. The model further predicts that firms that upgrade their intermediate inputs also upgrade their labor quality, resulting in higher wages. Combining Chinese Annual Survey of Industrial Firms and Chinese Customs Data, we are able to test our model's predictions in the data, and we find considerable support.

There are some issues that we have not yet addressed and are left as future work. First, we wish to empirically test the output quality upgrading hypothesis proposed in [Broda and Weinstein \(2006\)](#). Second, we want to extend our model to accommodate variable markups and then empirically test the model's prediction about firm markup distribution. Third, we would also like to look into firm ownership structure more carefully so that we can say more about the mechanism that generates the link between firms profits and wage inequality that is observed in the data.



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