北京大学中国经济研究中心
China Center for Economic Research
讨论稿系列
Working Paper Series

E2018018 **2018-08-02**

Exchange Rate and Domestic Value Added in Processing Exports: Evidence from Chinese Firms

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1st Aug 2018

This paper studies the effect of the exchange rate on the domestic value-added ratios of processing exports via two channels: substitution and markup. First, home currency depreciation leads to an increase in domestic value-added ratios through affecting each firm's imported and domestic intermediate inputs (the substitution channel). Second, home currency depreciation improves exporters' profitability and results in higher domestic value-added ratios of processing firms (the markup channel), as exports become more competitive with depreciation. Using Chinese firm-level production data and product-level trade transaction data, our corresponding empirical analysis finds that processing firms' domestic value-added ratios increase significantly through the two channels in response to firm-level nominal effective exchange rate depreciation. The markup channel contributes almost 39 percent of the variation in domestic value-added ratios in response to changes in the exchange rate.

Keywords: Exchange Rate, Markups, Domestic Value-added Ratios
JEL: F14 F31 O11

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1 Introduction

As a worldwide manufacturing base and processing hub, China today plays a key role in global value chains, with dramatically increasing exports and imports (Feenstra and Wei 2010). Two stylized facts indicate that domestic contents in exports has been rising obviously in China, even though production processes become more and more fragmented. First, China's average growth rate of exports of intermediate inputs was about 24 percent from 1970 to 2011, however, its average growth rate of imports of intermediate inputs was only about 13 percent (UNIDO 2013). The difference between these two indicators suggests that China's domestic intermediate inputs have contributed to a significant part of its exports. Second, processing trade, which is often combined with low-skilled, low value-added tasks, takes up 55 percent to one third of China's exports since its accession to the World Trade Organization (WTO). Intriguingly, the difference between the shares of China's processing exports and imports enlarged gradually during 2006—11, which implies an increase in domestic components embodied in processing exports.

[Insert Figure 1 Here]

The entire increase in the domestic value added in exports was caused by processing exports rather than ordinary exports (Koopman et al. 2012, 2014; Kee and Tang 2016). According to Kee and Tang (2016), the domestic value-added ratios (DVARs) of processing exports increased by nine percentage points on average from 2000 to 2007. By contrast, the DVARs of ordinary exports decreased by about 2 percentage points. Moreover, there is obvious heterogeneity among the DVARs of various sectors.[2] Therefore, it is necessary to separate processing exporters from ordinary ones, regarding its special characteristics, including low value added per capita, capital-labor ratio, and productivity (Dai et al. 2016; Yu 2015); high dependence on foreign capital (Fernandes and Tang 2012); and production volatility (Bergin et al. 2009). Processing trade is also a significant cause of bilateral trade imbalance, wage inequality (Ho et al. 2005), and other overall economic performance(Wang and Yu 2012).

With increasing appreciation pressure from the accumulated trade surplus, China government stated that China would adopt a managed floating exchange rate regime in July 2005. After that, Chinese exporters were faced with a much more fluctuating exchange rate.[3] In prices and volumes, exporters' responses to changes in the exchange rate are heterogeneous (Berman et al. 2012). These responses will be further different in the country where processing trade is pervasive. However, there is little evidence linking pricing to market to exporters' behavior in the context of value-added.

[2] For instance, the DVARs for the wood pulp sector at the 2-digit Chinese Standard Industrial Classification (CIC) code 10 and the precious metal sector at CIC code 14 increased by more than 20 percent. However, the DVARs for the stone, plaster, and cement (CIC code 13) and base metals (CIC code 15) industries have fluctuated and increased at a slightly lower rate.

[3] On the one side, the renminbi (RMB) appreciated significantly against the U.S. dollar and Japanese yen during July 2005 to July 2007; on the other side, the RMB depreciated significantly against the Euro, pound sterling and Australian dollar during December 2005 to October 2007.

In this paper we investigate the response of exports to exchange rate movements from the perspective of value added, by studying exporters' decisions on firm-level factor allocation and exported goods pricing. We use data on processing exporters to examine the response of domestic value added in exports to exchange rate changes. On the one side, the change in the exchange rate regime in 2005 offers a quasi-natural experiment to identify this influence. On the other side, we could have a much accurate measure of firm-level domestic value-added in processing exports, as entire imports of these special enterprises are used for the production of exports.

First, we construct a theoretical model with two types of intermediate inputs and derive a structural function of domestic value added in exports in terms of price markups and relative prices of imported materials. We find two implications. On the one hand, home currency depreciation generates intra-firm reallocation, using more domestic intermediate inputs instead of imported ones, given that foreign materials become more expensive. Thus, the depreciation leads to an increase in DVARs, which is called the *substitution effect*. On the other hand, home currency depreciation also brings about inter-firm reallocation through forcing low efficiency enterprises to get out of the market and encouraging incumbent exporters to increase price markups. This results in increasing profits and higher DVARs. We denote the second channel as the *markup effect*. Both effects lead to an increase in the DVARs of exports with home currency depreciation.

Second, we use China's industrial enterprise production data from the National Bureau of Statistics and product-level trade transaction data from the General Administration of Customs to test our theoretical expectations. We find that processing firms' DVARs increase significantly through these two channels in response to firm-level nominal effective exchange rate depreciation. Moreover, the markup channel contributes almost 39 percent to the variation in DVARs in response to exchange rate changes.

Our paper provides three contributions to the literature. Firstly, we provide a heterogeneous framework with multiple-inputs to study the overall effects and mechanisms of exchange rate movements on DVARs. This helps us understand the responses of DVARs deeply and precisely, from the perspective of import and export linkages. Among the theoretical studies of vertical fragmentation, Feenstra and Hanson (1997) and Feenstra (2010) developed the outsourcing theory for commodities. Yi (2003) tested the propagation effects of tariff reductions, when adding vertical fragmentation to a dynamic Dornbusch-Fischer-Samuelson Ricardian international trade framework. Grossman and Rossi-Hansberg (2008, 2012) extend the outsourcing theory to a generalized model for commodity and services outsourcing. Costinot et al. (2013) and Antràs and Chor (2013) developed a theory of global supply chains from the perspective of sequential production. Our model is inspired by Kee and Tang (2016) and Rodriguez-Lopez (2011), for one thing, substitution among domestic and foreign materials is taken account of in production technology; for another, we consider preference with variable elasticity of substitution and stress the markup channel through which the exchange rate affects DVARs.

Secondly, we re-study the response of DVARs to exchange rate movement with data on heterogeneous firms. Our study is close to that of Kee and Tang (2016), who provide an approach to estimate firm-level DVARs of processing trade, then aggregate them to industry-level, and find that the influence of RMB exchange rate changes on processing firms' DVARs is ignorable, due to its economically insignificant influence on domestic input varieties. However, we provide significant evidences with China's firm-level DVARs and weighted exchange rate data. Our findings prove the importance of the heterogeneity in domestic value-added and exchange rate exposure.

We estimate firm-level DVARs of each exporter. This method works much better for processing exporters, given that these enterprises are forbidden to serve the domestic market and all imports are required to be used for processing exports only. Another approach to estimate DVARs is using input-output tables. Hummels et al. (2001) documented the use of imported inputs in exports as vertical specialization. Johnson and Noguera (2012) generalized their work through assuming that a country's exports could be partly absorbed at home. Koopman et al. (2012, 2014) further showed that any approach failed to distinguish processing trade from ordinary trade would lead to overestimation of the DVARs in countries where processing trade is pervasive. However, this could only yield industry-level DVARs.

We construct firm-level effective exchange rate. Studies regarding the impact of exchange rate movements generally adopted effective exchange rates weighted by industry-level trade values (Campa and Goldberg 2001; Goldberg, 2004). However, industry-specific effective exchange rates can not capture the substantial heterogeneity of firms' trade distributions across countries (Dai and Xu 2017). Typically, there are two types of processing regimes, processing with assembly trade and processing with imported materials. Pure assembly firms sign contracts with foreign firms and earn fees to cover the cost of labor, so exchange rate changes may only have a small effect on them. However, the second type of processing firms could source their imported materials worldwide and are faced with more exchange rate risks. Thus, the use of firm-specific effective exchange rates becomes necessary. We use effective exchange rates weighted by trade share in the first year when a firm appears in our sample (hereafter we refer to this as "trade share," "import share," or "export share"), as firms may change export destinations or import sources in response to exchange rate changes.

Papers on exchange rate changes and international trade usually focus on the disconnected relationship between the exchange rate and prices of imports (Campa and Goldberg 2005; Devereux and Engel 2002; Gopinath and Rigobon 2008; Gron and Swenson 1996; Rodriguez-Lopez 2011). For example, Rodriguez-Lopez (2011) found that low exchange rate pass-through to firm- and aggregate-level import prices coexist with large movements in trade flows in a sticky-wage model. Further, a few papers link pricing to market to exporters' characteristics. For instance, Berman et al. (2012) find that exchange rate depreciation leads incumbents to raise price markups. In particular, firms with high productivity would experience a significant increase in price markups with slightly increasing export value. On the RMB exchange rate, Thorbecke and Smith (2010), Whalley and Wang (2011) showed the appreciation of the RMB after 2005 strengthened trade deficit pressure and decreased exports.

Finally, we provide significant firm-level evidences for the substitution and markup effects through which exchange rate changes affect DVARs. On the one hand, depreciation leads to substitution among domestic and foreign materials as the former becomes much cheaper in RMB against the latter. On the other hand, DVARs of incumbents rise as compared with the average productivity of exporters they became more competitive and increased their price markups, with the currency depreciation. However, there is little evidence linking pricing to market to exporters' behavior in the context of value-added. We estimate exporters' price markups to distinguish these two channels. The markup effect contributes almost 39 percent of the variation in domestic value-added ratios in response to changes in the exchange rate.

The remainder of the paper is organized as follows. Section 2 presents a partial equilibrium model of the exchange rate and DVARs. Section 3 describes our econometric specification, data, and key measures. Section 4 introduces empirical evidence for the theoretical implications and conduct related robustness checks. Section 5 concludes.

2 Model

In this section, we outline a model with two countries, one sector, and two intermediate inputs under a heterogeneous framework to guide our empirical analysis. We use this model to derive the firm-level implications for how the domestic value added of exports responds to exchange rate changes.

The model delivers two key results. First, from the perspective of input sourcing, home currency depreciation leads domestic firms to replace imported intermediates with domestic inputs, because the cost, insurance, and freight (c.i.f.) prices of imports in terms of domestic currency increase. Second, from the perspective of export pricing, home currency depreciation induces some firms, whose productivity was lower than the initial cutoff point for exporters, to begin to export. The average productivity for exporting firms falls and incumbent exporters increase their price markup. That is, the home currency depreciation weakens domestic demand for imported inputs and strengthens the price advantage of incumbent exporters. The two channels lead to an increase in the DVARs of exports.

Our model is a combination and extension of the models of Rodriguez-Lopez (2011) and Kee and Tang (2016). The former paper studies the disconnection between the exchange rate and import prices under a heterogeneous framework with endogenous markup. The latter paper offers an estimation of the firm-level domestic value added in exports. We combine and extend these two frameworks and address two channels through which the exchange rate could affect the domestic value added in exports. In the remainder of this section, we introduce preference and derive demand for differentiated products. Then we present the production sector and obtain access to the domestic value added in exports. Finally, we show how the exchange rate influences the domestic value added of exports. As most parts of our model refer to the home country, analogous expressions with superscript asterisks hold for foreign agents.

2.1 Demand

The representative consumer's preference for final goods is based on a continuum-of-goods version of the translog expenditure function (Bergin and Feenstra 2000; Feenstra 2003)[4],

$$lnE = lnU + a + \frac{1}{N}\int_{i\in\Delta} lnp_i di + \frac{\gamma}{2N}\int_{i\in\Delta}\int_{j\in\Delta} lnp_i(lnp_{jt} - lnp_i)djdi \quad (1)$$

where Δ is the set of the continuum of differentiated goods that are available and consumed by the home country. N is the total number of goods included in Δ. E is the minimum expenditure to realize utility U. p_i is the price of differential good i. γ is the parameter measuring the degree of substitution among differentiated goods and is assumed to be positive. [5] In addition, the larger is γ, the higher is the elasticity of substitution. Finally, a represents all other variety-invariant parts of expenditure. The preference of the foreign representative consumer is analogous.

With the expenditure function, we can obtain the demand for variety i based on Shephard's lemma. Taking the derivative of equation (1) against $\ln p_i$, we obtain the expenditure share of variety i. That is, $s_i = \gamma \ln(\frac{\hat{p}}{p_i})$, where $\hat{p} = e^{\frac{1}{N\gamma}+\overline{\ln(p)}}$, $\overline{\ln(p)} = \frac{1}{N}\int_{j\in\Delta} lnp_j dj$. $\hat{p}$ is the maximum price in terms of the home currency that a firm can set for the home market. Then the demand for variety i equals,

$$q_i = \gamma \ln(\frac{\hat{p}}{p_i})\frac{I}{p_i} \quad (2)$$

where I is total consumption expenditure in terms of the home currency. Given optimal utility U^*, I is equivalent to $E(U^*)$.[6]

2.2 Production

There is a continuum of firms, and each only produces a different variety. All products are sold in a monopolistic competition market. To start the production of a variety, a firm must pay a sunk entry cost. However, we ignore fixed cost in this model, as with variable elasticity of substitution, we can use the zero markup condition to pin down the cutoff productivity levels. Only after entry, firms draw a productive efficiency from the Pareto distribution, whose cumulative distribution function is $G(\varphi) = 1 - (\varphi)^{\theta}$. Production here requires three inputs, labor, capital, and composite intermediate materials. The aggregated intermediate bundle is a constant elasticity of substitution (CES) aggregation of domestic and imported materials. [7] Home and Foreign markets are segmented. Materials can move across the border, but capital and labor cannot. To simplify the expression, we usually omit the subscript for variety. Consider a Cobb-Douglas production function,

$$y = \varphi k^{\alpha^k} l^{\alpha^l} m^{\alpha^m}, \alpha^k + \alpha^l + \alpha^m = 1 \quad (3)$$

where y is the quantity of a variety produced by a specific firm. φ is the firm's productive efficiency. l, k and m are labor, capital, and composite intermediate materials, respectively. α^l, α^k and α^m are the corresponding expenditure shares for

[4] We use a translog expenditure function because, on the one side, it is much more flexible, and, on the other side, we want to study the effect of the exchange rate on DVARs with variable substitution elasticity.

[5] When γ is negative, differentiated goods are complementary rather than substitutes.

[6] More details on the derivation of the equation can be found in appendix A.

[7] It is straightforward to extend this model to the case with a variety of domestic and imported intermediate goods.

each input against total cost. [8] The composite of intermediate materials is a CES aggregation of domestic and imported materials, where the elasticity of substitution between the domestic intermediate input m^D and the imported input m^I is assumed to be σ.

$$m = [(m^D)^{\frac{\sigma-1}{\sigma}} + (m^I)^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}, \sigma > 1 \tag{4}$$

Cost Minimization. Firms use a two-stage strategy to minimize their cost. First, given the objective quantity, a firm chooses an optimal combination of labor, capital, and composite intermediate materials to minimize cost. Second, given the optimal demand for the composite intermediate bundle, the firm decides its usage of domestic and imported materials. The optimal results from this method are exactly the same as those from cost minimization against labor, capital, and domestic and imported intermediate materials. So, the minimum cost function is

$$c = \frac{y}{\varphi}(\frac{r}{\alpha^k})^{\alpha^k}(\frac{w}{\alpha^l})^{\alpha^l}(\frac{p^M}{\alpha^m})^{\alpha^m} \tag{5}$$

The marginal cost function is

$$mc = \frac{\Psi}{\varphi}, \Psi = (\frac{r}{\alpha^k})^{\alpha^k}(\frac{w}{\alpha^l})^{\alpha^l}(\frac{p^M}{\alpha^m})^{\alpha^m} \tag{6}$$

where w is the wage; r is the capital rental rate; and p^M is the price of the composite intermediate inputs. Therefore, marginal cost is a function of the input prices vector (r, w, p^M) and its productive efficiency, φ. Assume firms take input prices as given, Ψ is constant and marginal cost is an inverse function of the firm's productive efficiency.

Then the firm decides its usage of domestic and imported materials, given the optimal demand for composite intermediate materials. That is,

$$\mathrm{Min} p^{DM}m^D + p^{IM}m^I, \mathrm{s.t.} [(m^D)^{\frac{\sigma-1}{\sigma}} + (m^I)^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}} \leq m \tag{7}$$

where p^{DM} and p^{IM} are the prices of domestic and imported intermediate materials in terms of local currency, respectively. According to equation (7), we obtain the price index for the composite intermediate bundle, which is $p^M = [(p^{DM})^{1-\sigma} + (p^{IM})^{1-\sigma})]^{\frac{1}{1-\sigma}}$. In addition, firms' expenditure on these two materials satisfies

$$\frac{p^{IM}m^I}{p^M m} = \frac{1}{1+(\frac{p^{IM}}{p^{DM}})^{\sigma-1}} \tag{8}$$

Therefore, when imported materials become more expensive compared with domestic ones, the expenditure share on imported materials decreases nonlinearly.

Profit Maximization. With the demand equation (2) and marginal cost function (6), the price of variety i is given by

$$p = [1 + \ln(\frac{\hat{p}}{p})]mc \tag{9}$$

We use the Lambert W-function [9] to solve equation (9) and obtain the explicit solution of p. To prevent confusion between the symbols for the Lambert W-function and the

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[8] $\frac{rk}{c} = \alpha^k, \frac{wl}{c} = \alpha^l, \frac{p^M m}{c} = \alpha^m$.

[9] The Lambert W-function is the inverse function of the function $x = We^W$. See Corless et al. (1996) for more details.

wage rate, we use Ω to denote it later. With some algebra, the explicit solution for the price is

$$p = \Omega(e\frac{\hat{p}}{mc})mc \tag{10}$$

Let μ be the price markup over marginal cost. Then

$$\mu = \Omega(e\frac{\hat{p}}{mc}) - 1 \tag{11}$$

$\Omega = \Omega(x)$ is a concave function in terms of x, with $\Omega'(x) > 0$, $\Omega''(x) < 0$, $\Omega(0) = 0$ and $\Omega(e) = 1$. These characteristics will be used in the next section .

Zero Cut-off Markup Condition. Similar to Melitz (2003), the marginal firm gets zero profit in this model. Under a typical Melitz framework, fixed cost is assumed to pin down the cutoff productivity. However, here we use the zero cutoff markup condition to ascertain the marginal productivity for each market. That is, the cutoff firm sets zero markup and gets zero profits. Let cutoff productivities for the domestic and export markets be $\varphi^r = inf\{\varphi : \mu^r(\varphi) > 0\},\ r \in \{D, X\}$ separately. When markup is zero, the firm sets its price to be the maximum price that it could set at the market. This yields the cut-off productivity

$$\varphi^D = \frac{\Psi}{\hat{p}}, \varphi^X = \frac{\tau\Psi}{\varepsilon\hat{p}^*} \tag{12}$$

where τ is the iceberg cost for the transportation of one unit of the product to the foreign market. ε is the exchange rate in terms of direct quotation, that is, one unit of foreign currency equals ε units of home currency. $\hat{p}^*$ is the maximum price that a firm can get in the foreign market. Combining equations (11) with (12), we get a clearer expression for the markup:

$$\mu^r(\varphi) = \Omega(\frac{\varphi}{\varphi^r}e) - 1, r \in \{D, X\} \tag{13}$$

To solve the cutoff productivities, we still need the free-entry condition. However, as the goal of this paper is to study the influence of the exchange rate on the domestic value added of exports, there is no need to present detailed solutions. Rodriguez-Lopez (2011) shows the details on how to get these cutoff points and the effect of the exchange rate on the critical productivity. Thus, we apply their finding that when the exchange rate depreciates the cutoff productivity for exporters falls. [10]

2.3 Domestic Value Added in Exports

In this section, we use the framework discussed above to analyze how domestic value added in exports responds to exchange rate changes. First, the domestic value added of outputs, denoted DVA_i , is defined as the part of value from the domestic country rather than foreign suppliers:

$$DVA = py - p^{IM}m^I, DVAR = 1 - \frac{p^{IM}m^I}{py}$$

where $DVAR$ is the domestic value-added ratio. Combining equations (5)-(6), (8)-(9) and (11), yields a clearer expression to disentangle the potential determinants of DVARs:

[10] Although we have three types of inputs in our model, the basic finding of Rodriguez-Lopez (2011) still holds, as input prices are exogenous for firms here.

$$DVAR = 1 - \frac{\alpha^m}{1+\mu}\frac{1}{1+(\frac{p^{IM}}{p^{DM}})^{\sigma-1}} = 1 - \frac{\alpha^m}{1+\mu}(\frac{p^{IM}}{p^M})^{1-\sigma} \quad (14)$$

Equation (14) shows that changes in the DVARs of outputs come from two aspects. On the one side, when inputs from a foreign country become expensive, firms will substitute domestic intermediate materials for imported ones. One the other side, an increase in the price markup will lead to a higher DVAR, as the firm gets more profits with larger market power (denoted $\frac{p-mc}{p}$). Therefore, the DVARs of outputs increase.

In the rest of this subsection, we focus on the response of DVARs of exports to exchange rate depreciation. First, we replace the c.i.f. price of imported inputs in equation (14) with a function of the free on board (f.o.b.) price, iceberg cost, and exchange rate. Let $p^{IM} = \varepsilon\tau^* p^{XF*}$, where p^{XF*} is the f.o.b. price of foreign intermediate materials. Then the DVAR for exporter is

$$DVAR^X = 1 - \frac{\alpha^m}{1+\mu^X}(\frac{\tau^*\varepsilon p^{XF*}}{p^M})^{1-\sigma} \quad (15)$$

where μ^X is the price markup for a firm at export market. Then take the derivative of DVAR against exchange rate.

$$\frac{\partial DVAR^X}{\partial \varepsilon} = \underbrace{\frac{\alpha^m}{1+\mu^X}\frac{(\frac{\tau^* p^{XF*}}{p^{DM}})^{\sigma-1}\varepsilon^{\sigma-2}}{[1+(\frac{\tau^*\varepsilon p^{XF*}}{p^{DM}})^{\sigma-1}]^2}}_{\text{Substitution Effect}} + \underbrace{\frac{\partial DVAR}{\partial \mu^X(\varphi)}\frac{\partial \mu^X(\varphi)}{\partial \varepsilon}}_{\text{Markup Effect}} \quad (16)$$

The first term in equation (16) reflects the influence of the exchange rate on DVARs through affecting the allocation of domestic and foreign intermediate inputs. We denote it as the substitution effect, which is undoubtedly positive. Moreover, the second term in equation (16) is denoted as the markup effect, which shows the impact of the exchange rate on DVARs through its influence on export pricing.

To identify the overall effect of the exchange rate on the DVARs, we need to figure out the relationship between the exchange rate and price markup. However, given the productive efficiency, the response of the markup to the exchange rate change only depends on how the cutoff productivity responds to this shock (see equation (11)). When the domestic currency depreciates, home exporters can export more goods and obtain more revenue as their products become cheaper and more competitive in terms of foreign currency. And some firms that previously could not participate in the foreign market will export now. Therefore, the average productive efficiency of exporters declines.[11] Incumbents have an incentive to improve the price markup in pursuit of greater profits, as their productivity is much higher than the average level. Therefore, an increase in the exchange rate leads to an increase in the price markup:

$$\frac{\partial \mu^X(\varphi)}{\partial \varepsilon} = -[\frac{\varphi}{(\varphi^X)^2}e]\frac{\partial \Omega(x)}{\partial x}, \frac{\partial \varphi^X}{\partial \varepsilon} > 0$$

Intuitively, a larger markup means higher profits. Therefore, the DVARs will also increase, which means that the markup effect is also positive.

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[11] Rodriguez-Lopez (2011) verifies this result in partial and general equilibrium. Although we have three inputs here, this finding still holds, as input prices are regarded as given for firms. Berman et al. (2012) show similar results.

In a summary, home currency depreciation causes rising DVARs of exports through these two channels. On the one side, home currency depreciation results in imported materials becoming more expensive, which causes firms to use more domestic intermediate inputs and less imported ones. On the other side, home currency depreciation makes it possible for some firms that initially were not exporting to participate in the foreign market, thus lowering the average productivity of exporters and encouraging incumbents to enhance their price markups. On the whole, the DVARs of exports increase.

3 Empirical Specification, Data, and Measures

In this section, we introduce the empirical specification, data, and measures. First, we focus on how to set the empirical specification with the implications from the theoretical model. Second, we briefly describe the data. Third, we present measures for some key variables.

3.1 Empirical Specification

Taking logarithms on the both sides of equation (15) in the theoretical section,

$$\ln(1 - DVAR^X) = \ln(\alpha^m) - \ln(1 + \mu^X) - (\sigma - 1) \times \ln(\tau^*) - (\sigma - 1) \times \ln(\varepsilon) - (\sigma - 1) \times \ln(\frac{p^{XF*}}{p^M})$$

A depreciation of the domestic currency (an increase in ε) will bring about an increase in the DVARs of exports through an increase in the use of domestic intermediate inputs and an augmented price markup. Hence, we start by estimating the following specification at the firm level to clarify the total effect of the exchange rate on the domestic value added in exports.

$$\ln(FVAR_{it}^X) \equiv \ln(1 - DVAR_{it}^X) = \beta_0 + \beta_1 \ln(\varepsilon_{it}) + \beta_2 \mathbf{X_{it}} + \alpha_i + \gamma_t + \zeta_{it} \quad (17)$$

where $FVAR_{it}^X$ is defined as the foreign value-added ratio (FVAR) of variety i in year t, which is identically equivalent to one minus the DVAR. ε_{it} represents the firm-level exchange rate. A firm may produce a series of products and serve several foreign markets. However, we do not have enough disaggregated data to estimate the firm-product-destination-level domestic value added of exports. Instead, we estimate the DVAR at the firm level and aggregate the exchange rate from the firm-destination level to the firm level and obtain the nominal exchange rate weighted by trade share for each firm. X_{it} represents other firm-level covariates. α_i and γ_t are firm-specific and year-specific fixed effects, respectively. ζ_{it} reflects idiosyncratic shock. β_1 is the elasticity of $FVAR_{it}^X$ against ε_{it}, and it is expected to be negative. In the next section, we will go back to the two mechanisms in detail and provide additional evidence.

We derive the response of the DVARs to the exchange rate from a regression of the FVAR. The dependent variable in the baseline regression (17) is $FVAR_{it}^X$ rather than $DVAR_{it}^X$. To estimate the elasticity of $DVAR_{it}^X$ against the exchange rate, since $FVAR_{it}^X \equiv 1 - DVAR_{it}^X$, then $\Delta FVAR_{it}^X = -\Delta DVAR_{it}^X$ where $\Delta FVAR_{it}^X$ and $\Delta DVAR_{it}^X$ are the first-order differences of $FVAR_{it}^X$ and $DVAR_{it}^X$, respectively.

$$\frac{\Delta FVAR_{it}^{X}}{FVAR_{it}^{X}} = \frac{DVAR_{it}^{X}}{FVAR_{it}^{X}} \times \frac{-\Delta DVAR_{it}^{X}}{DVAR_{it}^{X}} \tag{18}$$

In equation (18) , the percentage change of $DVAR_{it}^{X}$ is a linear function of the percentage change of $FVAR_{it}^{X}$, where the slope is the ratio of $DVAR_{it}^{X}$ against $FVAR_{it}^{X}$.

3.2 Data

We focus on processing exporters in our empirical analysis when providing firm-level evidence for how DVARs respond to exchange rate changes. Here, processing firms refer to those with positive imports and exports under the processing regime.[12] Since 2000, processing trade has become increasingly prevalent in China. The General Administration of Customs of China regulates these processing exporters. They enjoy duty-free intermediate inputs and other preferential policies, but they cannot serve the domestic market. This means that the imported materials of processing firms are only used for exports. Then, it would be straightforward and reliable to estimate the DVARs for processing firms.

We mainly use two disaggregated types of Chinese micro data, product-level trade transaction data and firm-level production data. [13] The product-level trade transaction data (2000-09), which provide detailed information on trade transactions, are from China's General Administration of Customs. We use these data to distinguish processing exporters from non-processing ones, and to estimate the DVARs of processing firms and nominal effective exchange rate weighted by trade shares. The firm-level production data (2000-09) are from China's National Bureau of Statistics. These data include complete information on the three major accounting statements (i.e., balance sheet, profit and loss account, and cash flow statement) for all state-owned enterprises (SOEs) and non-SOEs whose annual sales exceed 5 million RMB. We use these data to find covariates that may affect the DVARs, such as firm size, ownership, and labor productivity.

We use some specific methods to match the two data sets, as their coding systems are completely different. First, we matched the two data sets by using each firm's Chinese name and year of founding. Second, we used zip codes and the last seven digits of phone numbers to merge the firms that could not be matched via the first method. [14] The matched data are non-balanced, including 37,993 processing firms and 94,424 observations whose DVARs are greater than 0 and less than 1. [15]

In addition, we use some country-level indicators from the World Bank World Development Indicators data set to build key independent variables, including exchange rate, money (M1), and money and quasi money (M2) in current local currency units from 2000 to 2009. Since a firm may export to several countries, we build a firm-level nominal effective exchange rate index that is weighted by trade shares. Similarly, we establish firm-level M1 and M2 growth rate indexes. We use these indexes as instruments for the

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[12] There are two types of processing trade, processing with assembly and processing with imported inputs.

[13] These data are widely used in studies on China. We only introduce them briefly. See Yu (2015) and Dai et al. (2016) for more details.

[14] See Yu (2015) for more details on matching.

[15] Almost one-third of the observations with negative DVARs are dropped in our baseline regression. We will check the robustness of the results with the full sample and discuss the possible reason for these negative DVARs later.

exchange rate to deal with endogeneity issues.

3.3 Measures of Key Variables

Based on Kee and Tang (2016), firm i's domestic value added in exports is given by

$$DVA_{it} = EXP_{it} - (IMP_{it} - \delta_{it}^{K} + \delta_{it}^{F})\frac{EXP_{it}}{P_{it}Y_{it}} \quad (19)$$

$$DVAR_{it} = 1 - \frac{IMP_{it} - \delta_{it}^{K} + \delta_{it}^{F}}{P_{it}Y_{it}} \quad (20)$$

where EXP_{it} is total exports. IMP_{it} represents total imports. δ_{it}^{K} is the value of imported capital goods. δ_{it}^{F} is the value of foreign contents embodied in domestic materials. Usually, IMP_{it} includes capital goods, which are used as production tools. Therefore, it is necessary to eliminate them from the imports. For processing firms, there are separate statistics for imports of capital goods. For δ_{it}^{F}, we use an industry-level indicator estimated by Wang et al. (2014) as a proxy. In addition, Kee and Tang (2016) use the ratio of exports to output to discount the imported materials, considering that part of the foreign inputs could be used to produce goods sold in the domestic market or exported under the ordinary trade regime. For pure processing, exports and output are equal. However, for hybrid exporters [16], they might use some imported processing materials for ordinary exports or even for sale in the domestic market. Thus, in the baseline regressions, we assume there is no illegal usage of processing imported materials. An alternative measure discounted by the ratio of processing exports to output will be considered in the robustness checks.

We estimate price markups for all processing firms based on the approaches of Ackerberg et al. (2006) and De Loecker and Warzynski (2012). With some algebra on profit maximization[17], we obtain an expression for the markup as a ratio of the output elasticity of labor over its ratio of expenditure to revenue. We could observe revenue shares directly in the micro data. However, we still need to estimate the production function to recover the output elasticity for each 2-digit CIC sector.

Taking logs of equation (3),

$$lnQ_{it} = \alpha^{l} lnl_{it} + \alpha^{k} lnk_{it} + \alpha^{m} lnm_{it} + ln\varphi_{it} + \vartheta_{it}$$

where lnQ_{it} is defined as observed log output of firm i at t in terms of quantity. ϑ_{it} is the measurement error between the real and observed log outputs.

First, we need to estimate the predicted output and measurement error. To avoid simultaneity and selection biases, we assume productivity is a function of investment inv_{it}, capital stock k_{it} and firm-level characteristics z_{it}, that is $ln\varphi_{it} = h(lninv_{it}, lnk_{it}, zit)$. Define

$$\phi_{it} = \alpha^{l} lnl_{it} + \alpha^{k} lnk_{it} + \alpha^{m} lnm_{it} + h(lninv_{it}, lnk_{it}, z_{it}) \quad (21)$$

, then $lnQ_{it} = \phi_{it}(lnl_{it}, lnk_{it}, lnm_{it}, z_{it}) + \vartheta_{it}$. We use a fourth-order polynomial function to fit $h(\cdot)$ and ordinary least squares (OLS) to estimate equation (??). The fitted value of $\hat{\phi}_{it}$ is taken as the predicted output. The residual ϑ_{it} is the fitted value for

[16] Hybrid exporters are engaged in processing and ordinary exporting simultaneously

[17] More details can be found in appendix C.

measurement error. We estimate real capital based on the perpetual inventory (stock) approach and observed depreciation data. The output and input deflators are from Brandt et al. (2012).

Second, we estimate the production function coefficients according to the law of motion for productivity:

$$\varphi_{it} = g_t(\varphi_{it-1}) + \xi_{it} \tag{22}$$

Given $\alpha^l, \alpha^k, \alpha^m$, it is straightforward to get productivity, $\varphi_{it} = \widehat{\phi_{it}} - \alpha^l lnl_{it} - \alpha^k lnk_{it} - \alpha^m lnm_{it}$. Through nonparametrically regressing φ_{it} on its lags, we obtain the fitted value of $\xi_{it}(\alpha)$, which shall be independent of lag labor and intermediate input. As capital stock in period t is determined in period $t-1$, it is uncorrelated with current $\xi_{it}(\alpha)$. So, we have three moments to back out these coefficients.

$$E\left(\xi_{it}\begin{pmatrix} l_{it-1} \\ m_{it-1} \\ k_{it} \end{pmatrix}\right) = 0 \tag{23}$$

Third, we use the standard generalized method of moments to get estimations for all the alphas, $\alpha_l, \alpha_m, \alpha_k$. With the estimated measurement error, observed output value, and total labor income in hand, a robust estimation equation for the price markup is

$$\widehat{1+\mu_{it}} = \widehat{\alpha^l} / \frac{w_t l_{it}}{p_t Q_{it}(\cdot)/e^{\vartheta_{it}}} \tag{24}$$

Next, we calculate the firm-level nominal effective exchange rate, following Dai and Xu (2017). To distinguish changes in the weights from variations in the bilateral exchange rate, we aggregate the exchange rate by the trade share in the year when the firm was first active in our sample.

$$NEER_{it} = e^{\sum_{c=1, c\neq h}^{N_c} \omega_{ict_0} \ln(NER_{ct})}, \text{where} \omega_{ict_0} = \frac{IM_{ict_0}}{\sum_{c=1, c\neq h}^{N_c} IM_{ict_0}} \text{and} \sum_{c=1, c\neq h}^{N_c} \omega_{ict_0} = 1 \tag{25}$$

where c is a country index and the total number of countries is N_c. h is the index for the home country (China). t_0 reflects the initial year when firm i became active in our sample. NER_{ct} is the bilateral nominal exchange rate. IM_{ict_0} represents firm i's import from country c at time t_0. In equation (25), we only calculate nominal effective exchange rate weighted by import share. we only calculate the nominal effective exchange rate weighted by import shares. It is straightforward to substitute imports with exports to obtain the nominal effective exchange rate aggregated by export shares.

3.4 Summary Statistics

The means of the key variables switched during 2005—09, compared with those in the full sample. First, the DVAR of processing exporters increased significantly after China's accession to the WTO: an increase of about 1.9 percentage points every year during 2000—09. The estimated DVARs of processing exporter here are a little bit higher than those in Kee and Tang (2016), who show that Chinese processing exports' DVAR increased from 0.46 in 2000 to 0.55 in 2007. Our estimation for 2000 is 0.49 and that for 2007 is 0.63. However, If we restrict our sample to pure processing firms only, the results are similar.

Second, after 2005, Chinese exporters were faced with a much more fluctuating exchange rate. The RMB appreciated significantly against the U.S. and depreciated against a few currencies simultaneously. Before 2005, even though the RMB was pegged to the dollar, exchange rates between the RMB and other currencies varied frequently. Thus, the firm-level nominal effective exchange rate was certainly not constant from 2000 to 2005. As shown in table 1, the mean for the RMB nominal effective exchange rate weighted by import shares during 2005−09 is a little larger than that for 2000−09. Taking into consideration that we use direct quotation, an increase in the nominal effective exchange rate means a depreciation of the RMB. However, during the same period, the firm-level exchange rate weighted by export shares was up-valued slightly. [18]

Third, there is an obvious decrease in the means of the price markups compared with the two periods before and after 2005. When estimating the price markup of an enterprise, we deflate output and material values with the corresponding output and input deflators from Brandt et al. (2012). [19] Once deflated output, intermediate inputs, capital stock, investment, and labor are in hand, we estimate the price markups based on the method described above.[20]

Fourth, we establish the price indexes for 424 3-digit CIC-level industries and observe an obvious increase in input deflators from 2000 to 2007. These prices indexes are used to show explicitly domestic value added in response to exchange rate movements through reallocating the usage of domestic and imported materials. We take the input deflator from Brandt et al. (2012) as a price index of domestic materials, considering that they only use data on Chinese enterprises to establish the index. we establish a price index for foreign intermediate inputs by aggregating the unit value for each traded good with import shares as weights.[21]. To make the price index for domestic materials comparable with that for imported ones, we divide the input deflator from Brandt et al. (2012) by 100.

Fifth, Chinese processing firms became larger and more efficient with an increase in labor productivity based on value added [22] and sales. The share of SOEs decreased from 0.03 to 0.004, and foreign-invested enterprises (FIEs) made up more than half of all processing firms. These findings are consistent with two events in China's economy during this period. On the one side, foreign countries invested in many processing firms in China.

[18] Although these two indicators have different tendencies in our sample for processing exporters, they co-move in the full sample for all importers and exporters.

[19] The output deflator for 1998−2003 is deduced from two output-value indicators; one is in current prices and the other is in constant prices. From 2004 to 2007, output values in constant prices are missing, so they use industry-level deflators from the National Bureau of Statistics. The input deflator is obtained through aggregating the output deflator with intermediate use shares from input-output tables as weights.

[20] Because we only have data on the growth rate of capital stock for 2000−06, the number of observations with price markups are much fewer than the total number of observations.

[21] The approach to establish this index is similar to using the firm-level exchange rate.

[22] The National Bureau of Statistics of China only provides data on value added during 2000 to 2007; afterward, the data are missing. We calculate labor productivity after 2007 by assuming that the ratio of value-added to sales in 2008 and 2009 equaled that in 2007.

On the other side, the share of SOEs in China fell dramatically after the SOE reform starting in the late 1990s. [23].

[Insert Table 1 Here]

4 Estimation Results

4.1 Baseline Results

4.1.1 Overall Effects of the Exchange Rate on DVARs

Table 2 presents the overall influence of exchange rate shocks on DVARs. The regressand is log FVAR and the core control variable is the firm-level nominal effective exchange rate weighted by import shares. Columns (1) and (2) first regress log FVAR on log effective exchange rate weighted by import share. The coefficient for the key variable is significantly negative under the econometric specifications, OLS and fixed effects, respectively. Column (3) controls for some key covariates, like labor productivity and firm size, and industry-level fixed effects at the 4-digit CIC level. To avoid potential endogeneity issues, we use lag log labor productivity and sales. The weighted exchange rate is still significantly negatively correlated with log FVAR. The results in column (4) are similar to those in column (3) except for considering firm-level fixed effects. Moreover, a firm with higher labor productivity tends to have a larger part of domestic value added. SOEs and FIEs tend to have higher FVARs than the others on average. This finding is natural for FIEs. But the reason for SOEs is that, on the one side, the share of SOEs in our sample is less than 5 percent on average; on the other side, SOEs often enjoy preferential policies and have been proven to be less productive.

All coefficients for the log weighted exchange rate are significantly negative in columns (5) to (7) and have approximately stable magnitudes. Labor productivity based on value added is used in columns (5) to (7), to avoid the overestimation of productivity for firms with a large number of intermediate inputs. Column (6) controls for the interactions between production efficiency and SOE or FIE dummies separately and classifies firms into three groups, exiting enterprises, new entrants, and incumbents. Column (7) loosens the restrictions on the regression specification and includes observations with negative DVARs. In column (6) and (7), log FVAR is negatively correlated with lag log labor productivity. Moreover, an increase in labor productivity for a non-FIE improves its DVAR. Exiting firms have lower FVARs on average and the opposite is true for new entrants. This may be because most processing firms are responsible for labor-intensive tasks in the production of foreign products, and only those that enjoy good connections with foreign partners can survive. Column (6) is regarded as our baseline

[23] See Hsieh and Song (2015) for more details about the SOE reform in China and its economic impacts.

results.

To explore the economic significance of the results, we discuss the response of DVAR to exchange rate changes. Based on equation (18), it is straightforward to derive the average percentage change in DVAR from the regression results on FVAR. To compare our findings with those of the literature and avoid the impact of the financial crisis, we focus on the widely used sample for 2000–06. We use medians of key variables during this period to estimate the ratio of FVAR to DVAR, that is $\overline{FVAR_{it}}/\overline{DVAR_{it}} = 0.46/0.54 \approx 0.85$. As $\Delta \mathrm{FVAR_{it}}/\mathrm{FVAR_{it}} = -0.034 \times \Delta\mathrm{NEER_{it}}/\mathrm{NEER_{it}}$, then a 10 percent increase in the weighted exchange rate will lead to a significant 0.29 percent ($0.034 \times 10\% \times 0.85 \approx 0.29\%$) increase in DVAR. Given that the median of the log nominal effective exchange rate weighted by import share increased by 64 percent from 2000 to 2006, then DVAR increases by 1.9 percent ($0.29\% \times 64\% \div 10\% \approx 1.9\%$) or 1.03 percentage points ($1.9\% \times 0.54 \times 100 \approx 1.03$) on average. In our sample, DVAR increases by about 14 percentage points from 2000 to 2006. Therefore, the exchange rate contributes about 7.4 percent of the variation in DVAR. If we use the estimation of DVAR in Kee and Tang (2016), then the exchange rate contributes about 17.2 percent of the variation in DVAR. Further, the effect of the exchange rate on FVAR is much closer to that of an increase in productivity. So, in general, our findings are economically significant.

[Insert Table 2 Here]

4.1.2 Mechanisms

In this subsection, we shed some light on the mechanisms through which processing exporters adjust their DVARs in response to exchange rate movements. As shown in equation (16), there are two influence channels, substitution and markup effects. The former means that the exchange rate affects processing exporters' allocation of domestic and foreign intermediate inputs through changing the relative prices of imported materials. The latter reflects that incumbent exporters increase the price markup with new competitive advantage from depreciation. To identify these two mechanisms, we use price markups estimated based on De Loecker and Warzynski (2012) and build a firm-level price index for imported materials. After that, we estimate a three-stage specification.

$$ln(1+\mu_{it}) = \theta_0 + \theta_1 ln(\varepsilon_{it}) + \theta_2 X_{it}^1 + \iota_i + \upsilon_t + \Phi_{it}$$
$$ln(\frac{p^{IM}}{p^{DM}})_{it} = \delta_0 + \delta_1 ln(\varepsilon_{it}) + \delta_2 X_{it}^2 + \eta_i + \kappa_t + \Lambda_{it} \quad (26)$$
$$ln(FVAR_{it}^X) = \rho_0 + \rho_1 ln(\widehat{1+\mu_{it-1}}) + \rho_2 ln(\widehat{\frac{p^{IM}}{p^{DM}}})_{it} + \rho_3 X_{it} + \alpha_i + \gamma_t + \zeta_{it}$$

First, we regress log markup on the exchange rate, and get the fitted value of the dependent variable. Second, we examine the elasticity of the relative price index of imported materials against exchange rate changes. Third, we substitute the fitted values of the lag log markup and log relative price index of imported materials into our benchmark specification, to deliver the elasticities of FVAR against the markup and relative price index of imported materials. The reason for using lag fitted values of log price markup in the third stage is to avoid simultaneity bias. For the relative prices of imported intermediate inputs, we use import shares to build this index to deal with this problem.

We make use of partially distinct covariates for each stage; otherwise, we cannot distinguish the two effects, because the fitted values in the third stage would be completely correlated with each other. Independent-variable matrices in each step are denoted X_{it}^1, X_{it}^2 and X_{it} respectively. Moreover, the controlled variables in the benchmark regression are considered common covariates of X_{it}^1, X_{it}^2 and X_{it}. In addition, X_{it} also controls for the expenditure share of materials, according to equation (15). We control for lag log productivity at the industry level when studying the response of the markup to exchange rate changes. [24] X_{it}^2 includes the average price index of imported materials at the 3-digit CIC level. We could identify these two effects through controlling the two distinct covariates.

Table 3 lists the regression results for the mechanisms. As shown in columns (1) and (3), the weighted exchange rate is significantly correlated with the markup and relative price index of materials. Substituting fitted values from columns (1) and (3) into equation (26), we find that both fitted values are significantly and negatively correlated with log FVAR, consistent with our theoretical implications. Based on columns (1), (3), and (5), a 10 percent increase in the weighted exchange rate index results in a 0.60 percent increase in the price markup, while the relative price index for imported intermediate goods increase by 0.56 percent. In the third stage, the coefficients for the two fitted values are -0.554 and -0.909. Therefore, when the RMB depreciates 10 percent, FVAR decreases by 0.33 ($0.60 \times 0.554 \approx 0.33$) percent through the markup channel and 0.51 ($0.56 \times 0.909 \approx 0.51$) percent through the substitution effect. Thus, the markup channel explains about 39 percent ($\frac{0.33}{0.33+0.51} \approx 0.39$) of the response of FVAR to exchange rate movements. Columns (2), (4), and (6) redo this three-stage regression with interaction terms and get analogous results.

[Insert Table 3 Here]

4.2 Robustness Checks

4.2.1 Alternative Measures of DVARs

In this subsection, we start by using alternative measures for DVAR to check the impact of potential measurement errors in the basic measure of the DVAR on the empirical results. In the baseline regressions, we assume that processing exporters strictly obey the rule that duty-free imported materials through the processing regime are only

[24] We take average firm-level productivity at the 4-digit CIC level as the industry-level indicator. According to the equation (11), the price markup is negatively correlated with industry-level productivity. To avoid the endogeneity issue, we use lags.

used for processing exports. We also eliminate observations on processing firms without any record of imported materials. Therefore, it is worthwhile to check what would happen if we loosened these restrictions.

In table 4, first we take a step toward including observations with zero processing imported materials. The estimation results are quite like those of the baseline results. Columns (2) and (3) redo the basic regression with alternative measures. We establish a new index, FVAR1, which assumes that, for hybrid firms, imported raw materials through the processing regime are evenly used for normal and processing exports according to the export value. Analogously, we build an FVAR2 index, assuming that these materials could be used in the production of domestic goods. [25] The weighted exchange rate is still significantly negatively correlated with the FVARs, except that the significance level in column (3) falls. The other coefficients in column (2) are almost the same as those in column (1). Columns (4) to (6) redo the baseline regression with the sample during the period 2000—07. The baseline results still hold.

[Insert Table 4 Here]

4.2.2 Alternative Measures of the Firm-Level Exchange Rate

Firm-level effective exchange rate weighted by current trade shares are faced with self-selection bias as enterprises have an incentive to import from the countries where their local currencies devalue against the RMB and the opposite is true for exports. In column (1) in table 5, the coefficient for the exchange rate weighted by current import share is insignificantly positive. Column (2) further controls for each firm's import share from the country whose local currency depreciates against the RMB. Interestingly, the coefficient for the exchange rate weighted by current import share becomes insignificantly negative. Meanwhile, the import share from the countries with depreciated currencies is negatively correlated with log FVAR. Therefore, it is necessary to use the exchange rate weighted by trade shares in the year when the firm was first active in our sample.

Compared with nominal indexes, the real effective exchange rate reflects the real competitive power of domestic goods, as it is not influenced by prices. Thus, in column (3), we replace the nominal effective exchange rate with the real one, which is defined as

$$REER_{it} = e^{\sum_{c=1, c\neq h}^{N_c} \omega_{ict_0} \ln(NER_{ct} \frac{CPI_{ct}}{CPI_t})} \tag{27}$$

where CPI_{ct} is the consumer price index of country c, CPI_t denotes the domestic consumer price index. Then $REER_{it}$ is firm i's real effective exchange rate weighted by import shares. In column (3) in table 5, the real effective exchange rate is also significantly and negatively correlated with FVAR.

Finally, we end this subsection by discussing an insight on the differences between the firm-level exchange rates weighted by import and export shares. Only exchange rate

[25] The incentive for hybrid firms to use imported materials under the normal trade regime, which are levied tariffs, is negligible, as they can be imported without duty through the processing channel.

indexes weighted by import shares have been listed in our main analysis so far. Here we also use exchange rate indexes weighted by export shares to revisit all the regressions in the paper. Surprisingly, we find that the relationship between this index and FVAR is always insignificantly different from zero. One possible reason for this finding could be that processing enterprises sign contracts with foreign partners before production and exporting, but most of them still enjoy flexibility on sourcing imported raw materials.[26] Therefore, log FVAR is more sensitive to exchange rate indexes weighted by import shares.

[Insert Table 5 Here]

4.2.3 Other Robustness Checks

Column (1)-(2) in table 6 check whether our findings are robust with a broad SOE indicator and an alternative measure of total factor productivity. Column (1) controls for the revised SOE indicator and industry-level output tariff. Here any firm with state-owned capital involved is regarded as an SOE. Our baseline findings still hold. Column (2) substitutes total factor productivity estimated with the Olley and Pakes (1996) semi-parametric method (denote TFP_OP) for labor productivity based on value added, to avoid simultaneity and selection biases. In column (2), an increase in the weighted exchange rate brings about a significant decrease in FVAR. The elasticity of FVAR against the exchange rate is a little bit larger than that in the benchmark results.

Column (3) in table 6 excludes sectors with large shares of imported capital goods. During 2000—06, China's Customs distinguished the importation of common products under the processing regime from capital goods. However, from 2007 to 2009, all trade transactions were only classified into two groups, normal and processing trade. So there may have been imported capital in import values during this period, which could result in a bias in our estimation of DVAR. So we deleted observations in sectors 36 and 37, large shares of imported capital goods. Column (3) in table 6 shows the regression results with the refined sample, where our benchmark findings still hold.

Column (4)-(5) in table 6 exclude indirect importers. Although China's Customs strictly regulates processing trade, indirect importation is still possible. That is, some processing firms may sell or buy duty-free imported materials, which would mean our regressions underestimate the DVARs of sellers and overestimate the DVARs of buyers. Referring to Kee and Tang (2016), we restrict processing firms' DVARs to be greater than their value-added ratios, defined as one minus the ratio of intermediate inputs to sales, and less than the 50th percentile of the net export ratios of normal exporters in the same industry at the 2-digit CIC level (column 4) or 3-digit CIC level (column 5). Both two coefficients for the weighted exchange rate are significantly negative.

Column (6) in table 6 consider the case with standard errors clustered at the 4-digit CIC level. The estimated coefficients are exactly the same as those in column (6) in table 2, but the standard errors enlarger a little bit. Column (7) in table 6 check the case

[26] Processing exports with imported materials accounted for about 77.5 percent of the total processing trade from 2000 to 2009.

with log DVAR as the dependent variable. The coefficient for the weighted exchange rate is close to our estimated elasticity of DVAR against the exchange rate based on equation (18).

[Insert Table 6 Here]

4.3 Robustness Checks for Mechanisms

In this subsection, we test the robustness of various mechanisms. We redo the three-stage regression in six cases, one by one. In general, our benchmark results for the mechanisms in table 3 still hold. Further, we find that the contribution of the markup effect is between 30.4 and 34.3 percent in columns (1) to (9) and (13) to (15) in table 7. When indirect importers are eliminated, the markup effect reaches up to 65.8 percent.

First, column(1)-(3) in panel A take into account an alternative measure for productivity, total factor productivity based on Olley and Pakes (1996). The weighted exchange rate is still positively correlated with the markup and relative price index for imported materials, although the latter is insignificant. The coefficient for the fitted lag log markup is significantly negative. The t-statistic of the coefficient for the fitted log relative price index is close to the critical value at the 10 percent significance level. Second, column (4)-(6) in panel A use an estimation for the markup based on OLS. As shown in panel A in table 7, all the findings in the benchmark checks hold. Third, column (7)-(9) in panel A add observations with negative DVARs to our regression sample. All the coefficients are consistent with the benchmark findings.

Fourth, column (10)-(12) in panel B exclude indirect importers and find that the coefficients for the weighted exchange rate are also positive but turn to insignificant. A possible reason for this may be the dramatic decrease in the size of the regression sample. Fifth, column (13)-(15) in panel B replace the nominal effective exchange rate index with the real one. All the coefficients for our key variables are similar to those in table 3. Sixth, column (16)-(18) exclude sectors with a large share of imported capital goods. All the findings hold except that the lag fitted value of log markup is negative but insignificantly correlated with log FVAR.

[Insert Table 7 Here]

4.4 Endogeneity Issue

Companies with higher domestic value added tend to be larger, more productive, with more exports, and exposed to a lot of foreign exchange risks. Thus, they have an incentive to lobby the government to seek preferential exchange rate policies. Therefore, although we use the nominal effective exchange rate weighted by import shares in the year when the firm was first active in the sample, our findings may still be subject to endogeneity problems. In this section, we take M1, M2, and their growth rates weighted by import shares as instruments for the firm-level nominal effective exchange rate. [27] According to relative purchasing power parity, the nominal exchange rate is closely related to the growth rate of the supply of money (M1 or M2). Further, the money supply for each country is controlled by governments and independent of Chinese firms' behavior. In addition, the growth rates of M1 and M2 are free from the effects of the unit of measure.

In table 8, we use panel instrumental variable regression to study the relationship between FVAR and the weighted exchange rate. In columns (1) to (4), all the coefficients for the weighted nominal effective exchange rate are significantly negative, with much larger magnitudes compared with the baseline results. Table 8 also reports the endogeneity test statistic, Kleibergen-Paap rank LM Chi2 statistic (under-identification test), Kleibergen-Paap rank Wald F statistic (weak identification test), and Hansen J statistic (over-identification test). The endogeneity test and the first-stage regression coefficients in columns (1) to (4) are significant. The Kleibergen-Paap rank LM Chi2 statistic is significantly larger than the critical value at the 1 percent significance level. So, the instruments and endogenous variable are significantly correlated, and there is no problem of insufficient identification. At the same time, the Kleibergen-Paap rank Wald F statistics in columns (1) to (4) are much larger than 10, the critical value given by Baum et al. (2007). Therefore, the regressions are also free from the weak instrument problem. Finally, all the regressions pass the over-identification test.

[Insert Table 8 Here]

5 Concluding Remarks

In this paper, we established a theoretical model of the exchange rate and domestic value added in exports through combining the models of Rodriguez-Lopez (2011) and Kee and Tang (2016). Our theoretical model implies that home currency depreciation improves processing firms' DVARs through two channels. The first channel is the substitution effect. That is, home currency depreciation encourages firms to use more domestic intermediate goods as foreign ones become relatively expensive. Then domestic value-added in exports increases. The second channel is the markup effect, which means incumbent exporters have an incentive to improve price markups with an increase in competitive advantage from the exchange rate depreciation. Thus, their DVARs increase due to growing profits. With a multiple-inputs framework, we understand the responses of DVARs deeply and precisely, from the perspective of import and export linkages.

Encouraged by the theoretical implications, we used Chinese firm-level production data and product-level trade transaction data to test our theoretical findings and found supportive evidence. An increase in the nominal effective exchange rate weighted by import shares (meaning a depreciation of the home currency) leads to a significant increase in the DVARs of processing exporters. We dismantled the overall

[27] In the same manner as in equation (25), firm-level M1, M2 and their the growth rates weighted by import shares are established.

effect into two parts. One depicts contributions from the substitution channel. The other shows explanations from the markup channel. We found that the latter effect contributes about 39 percent of the response of DVARs to exchange rate movements. Our paper provides robustness firm-level evidences for the responses of DVARs to exchange rate movements and various mechanisms.

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Table 1: Summary Statistics for Key Variables

Variable	2000-2009			2005-2009		
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
DVAR	94,424	0.58	0.29	49,907	0.62	0.28
FVAR	94,424	0.42	0.29	49,907	0.38	0.28
Price Markup †	36,737	1.35	1.73	12,447	1.09	1.50
Price Index for Imported Materials Weighted by Import Share in Initial Year ‡	51,748	0.65	0.52	23,158	0.65	0.49
Price Index for Domestic Materials at CIC 4-Digit ‡	3,392	1.10	0.18	1,272	1.22	0.24
Log Nominal Effective Exchange Rate Weighted by Import Share in Initial Year	131,344	1.19	1.94	72,763	1.24	2.04
Log Nominal Effective Exchange Rate Weighted by Export Share in Initial Year	144,593	2.12	2.64	81,063	2.07	2.60
Log Labor Productivity Based on Value added	64,204	3.89	1.44	31,772	4.15	1.43
State-Owned Enterprise (SOE) Indicator	133,052	0.03	0.18	70,564	0.004	0.07
Foreign-Invested Enterprise (FIE) Indicator	133,052	0.59	0.49	70,564	0.68	0.47
Log Sales	132,909	10.40	1.39	70,476	10.75	1.38

Source: Firm-level production data from the National Bureau of Statistics and product-level trade transaction data from China's General Administration of Customs.

Note: The table uses merged data obtained through combining firm-level production data and product-level trade transaction data. We set the reasonable domain for DVAR to be (0,1). The observations with reasonable DVAR are much fewer than the total number of observations in the full sample. † data on price markups from 2000 to 2006; ‡ data after 2007 are missing.

Table 2: Benchmark Estimation Results

Regressand: Log FVAR	Full Sample, 2000-2009						Including Negative DVAR
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log Nominal Effective Exchange Rate Weighted	-0.052***	-0.039***	-0.038***	-0.039***	-0.036***	-0.034***	-0.052***
by Import Share in Initial Year	(0.002)	(0.009)	(0.003)	(0.012)	(0.013)	(0.013)	(0.015)
Lag Log Labor Productivity			-0.119***	-0.012			
Based on Gross Output			(0.007)	(0.009)			
Lag Log Labor Productivity					0.001	-0.041***	-0.040***
Based on Value Added					(0.007)	(0.012)	(0.013)
Lag Log Labor Productivity Based						0.017	0.025
on Value Added × SOE Indicator						(0.025)	(0.027)
SOE Indicator			-0.263***	0.197***	0.137***	0.078	-0.001
			(0.063)	(0.027)	(0.037)	(0.089)	(0.104)
Lag Log Labor Productivity Based						0.059***	0.066***
on Value Added × FIE Indicator						(0.012)	(0.013)
FIE Indicator			0.029*	0.198***	0.136***	-0.081*	-0.114**
			(0.017)	(0.014)	(0.019)	(0.045)	(0.050)
Lag Log Sales			-0.008*	0.004	0.000	-0.005	-0.019**
			(0.005)	(0.006)	(0.008)	(0.008)	(0.009)
Exit Indicator						-0.054***	-0.061***
						(0.018)	(0.021)
Entry Indicator						0.060***	0.071***
						(0.019)	(0.023)
Constant	-1.053***	-0.969***	-0.572***	-1.194***	-1.170***	-0.969***	-0.264**
	(0.014)	(0.016)	(0.046)	(0.059)	(0.093)	(0.102)	(0.117)
Year-Specific Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Level-Specific Effects			Yes				
Firm-Level- Specific Effects		Yes		Yes	Yes	Yes	Yes
Observations	90,742	90,742	54,134	54,134	40,147	40,147	48,842
R-squared	0.040	0.062	0.142	0.056	0.060	0.062	0.042

Note: Robust standard errors are in parentheses. * p<0.10; ** p<0.05; *** p<0.01.

Table 3: Mechanisms for How DVARs Respond to Exchange Rate Movements

	Log Markup		Log $\frac{P_{IM}}{P_{DM}}$		Log FVAR		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log Nominal Effective Exchange Rate Weighted	0.060***	0.060***	0.056**	0.056**			-0.027*
by Import Share in Initial Year	(0.022)	(0.022)	(0.023)	(0.023)			(0.015)
Lag Fitted Value of					-0.554*	-0.380	
Log Markup					(0.315)	(0.280)	
Fitted Value of Log $\frac{P_{IM}}{P_{DM}}$					-0.909***	-0.833***	
					(0.319)	(0.323)	
Lag Fitted Value of Log Relative							
Price Index for Materials							
Log Expenditure share of					0.492	0.445	0.418
Materials at CIC 3-Digit Level					(0.523)	(0.525)	(0.306)
Lag Log Labor Productivity Based on	-0.016	-0.021					
Value-Added at CIC 4-Digit Level	(0.026)	(0.027)					
Log Relative Price Index for			0.168***	0.169***			
Materials at CIC 3-Digit Level			(0.031)	(0.031)			
Lag Log Labor Productivity	0.023*	0.032	-0.004	-0.004	-0.036***	-0.075***	-0.038**
Based on Value Added	(0.014)	(0.021)	(0.007)	(0.011)	(0.013)	(0.026)	(0.015)
Lag Log Labor Productivity Based on		-0.107**		-0.045		-0.026	0.000
Value Added × SOE Indicator		(0.043)		(0.042)		(0.047)	(0.036)
SOE Indicator	-0.042	0.358**	0.119	0.290	0.295***	0.384**	0.165
	(0.070)	(0.176)	(0.078)	(0.194)	(0.076)	(0.180)	(0.123)
Lag Log Labor Productivity Based on		-0.006		-0.000		0.054*	0.047***
Value Added × FIE Indicator		(0.020)		(0.011)		(0.029)	(0.016)
FIE Indicator	0.052	0.076	0.050***	0.051	0.197***	-0.001	-0.027
	(0.035)	(0.082)	(0.018)	(0.044)	(0.049)	(0.105)	(0.057)
Lag Log Sales	-0.005	-0.006	0.012	0.012	-0.008	-0.014	-0.001
	(0.018)	(0.018)	(0.008)	(0.008)	(0.020)	(0.021)	(0.009)
Exit Indicator	-0.009	-0.008		0.005	-0.095***	-0.090***	-0.091***
	(0.031)	(0.031)		(0.019)	(0.035)	(0.035)	(0.024)
Entry Indicator	-0.174	-0.170		-0.033	-0.096	-0.134	0.093
	(0.129)	(0.129)		(0.055)	(0.122)	(0.123)	(0.072)
Constant	-0.084	-0.085	-0.750***	-0.748***	-1.493***	-1.214***	-0.824***
	(0.235)	(0.236)	(0.110)	(0.120)	(0.429)	(0.463)	(0.143)
Observations	10,841	10,841	17,093	17,093	8,079	8,079	24,994
R-squared	0.071	0.072	0.074	0.074	0.030	0.031	0.061

Note: All columns control for year- and firm-level specific effects. Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 4: Alternative Measures of DVARs

	2000-2009				2000-2007	
	Log FVAR_adj	Log FVAR1	Log FVAR2	Log FVAR	Log FVAR1	Log FVAR2
	(1)	(2)	(3)	(4)	(5)	(6)
Log Nominal Effective Exchange Rate Weighted	-0.034***	-0.037***	-0.038**	-0.040**	-0.045***	-0.050**
by Import Share in Initial Year	(0.013)	(0.012)	(0.019)	(0.016)	(0.016)	(0.024)
Lag Log Labor Productivity	-0.041***	-0.045***	-0.049*	-0.041***	-0.043***	-0.027
Based on Value Added	(0.012)	(0.011)	(0.027)	(0.012)	(0.012)	(0.031)
Lag Log Labor Productivity Based	0.017	0.029	0.005	0.028	0.039	-0.005
on Value Added × SOE Indicator	(0.025)	(0.024)	(0.157)	(0.026)	(0.025)	(0.199)
SOE Indicator	0.078	0.041	-0.481	0.028	0.001	-0.675
	(0.089)	(0.086)	(0.764)	(0.091)	(0.089)	(0.928)
Lag Log Labor Productivity Based	0.059***	0.063***	0.034	0.053***	0.055***	0.013
on Value Added × FIE Indicator	(0.012)	(0.012)	(0.028)	(0.013)	(0.013)	(0.031)
FIE Indicator	-0.081*	-0.095**	-0.952***	-0.062	-0.067	-0.964***
	(0.045)	(0.044)	(0.094)	(0.048)	(0.047)	(0.102)
Lag Log Sales	-0.005	-0.005	0.001	-0.008	-0.008	0.009
	(0.008)	(0.008)	(0.011)	(0.009)	(0.009)	(0.014)
Exit Indicator	-0.054***	-0.052***	-0.016	-0.069***	-0.065***	-0.038
	(0.018)	(0.017)	(0.023)	(0.018)	(0.017)	(0.024)
Entry Indicator	0.060***	0.063***	0.074***	0.046**	0.052***	0.057**
	(0.019)	(0.019)	(0.025)	(0.020)	(0.019)	(0.027)
Constant	-0.969***	-1.040***	-0.563***	-0.969***	-1.044***	-0.656***
	(0.102)	(0.100)	(0.162)	(0.116)	(0.113)	(0.189)
Year-Specific Effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Level-Specific Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	40,147	40,147	30,899	30,506	30,506	22,564
R-squared	0.062	0.073	0.121	0.035	0.043	0.091

Note: FVAR_adj, one minus the share of foreign value added embodied in domestic intermediate inputs, if there is no record of imports. FVAR1, for hybrid firms, imported raw materials through the processing regime are evenly used for normal and processing exports according to the export value. FVAR2, for hybrid firms, imported raw materials through the processing regime are evenly used for exports and domestic consumption. Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 5: Alternative Measures of the Firm-Level Exchange Rate

Regressand: Log FVAR	(1)	(2)	(3)
Log Nominal Effective Exchange Rate Weighted	0.145	-0.006	
by Import Share in Current Year	(0.092)	(0.099)	
Import Share from Country Whose		-0.098***	
Local Currency Depreciates against RMB		(0.021)	
Log Real Effective Exchange Rate Weighted			-0.031**
by Import Share in Initial Year			(0.013)
Lag Log Labor Productivity	-0.041***	-0.039***	-0.041***
Based on Value Added	(0.012)	(0.012)	(0.012)
Lag Log Labor Productivity Based on	0.016	0.015	0.017
Value Added × SOE Indicator	(0.025)	(0.025)	(0.025)
SOE Indicator	0.082	0.087	0.078
	(0.089)	(0.089)	(0.089)
Lag Log Labor Productivity Based	0.059***	0.058***	0.059***
on Value Added × FIE Indicator	(0.012)	(0.012)	(0.012)
FIE Indicator	-0.082*	-0.079*	-0.081*
	(0.045)	(0.045)	(0.045)
Lag Log Sales	-0.004	-0.003	-0.005
	(0.008)	(0.008)	(0.008)
Exit Indicator	-0.055***	-0.053***	-0.055***
	(0.018)	(0.018)	(0.018)
Entry Indicator	0.060***	0.059***	0.060***
	(0.019)	(0.019)	(0.019)
Constant	-0.925***	-0.883***	-0.964***
	(0.101)	(0.102)	(0.102)
Year-Specific Effects	Yes	Yes	Yes
Firm-Level-Specific Effects	Yes	Yes	Yes
Observations	40,146	40,146	40,147
R-squared	0.062	0.063	0.062

Note:Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 6: Other Robustness Checks

	Log FVAR						
	Broad SOEs and Control for Tariff	TFP_OP	Excluding Sectors with a Lot of Imported Capital	Excluding Indirect Importers		Standard Errors Clustered at 4-digit CIC Level	Log DVAR
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log Nominal Effective Exchange Rate Weighted	-0.043*	-0.049**	-0.032**	-0.023**	-0.020*	-0.034**	0.018*
by Import Share in Initial Year	(0.025)	(0.021)	(0.013)	(0.011)	(0.011)	(0.015)	(0.009)
Lag Log Productivity Efficiency	-0.054**	0.024	-0.033**	-0.016**	-0.013*	-0.041**	0.005
	(0.022)	(0.027)	(0.016)	(0.007)	(0.007)	(0.016)	(0.008)
Industry-Level Output Duty	0.064						
	(0.216)						
Lag Log Productivity	0.023	-0.033	0.019	-0.008	-0.000	0.017	0.024
Efficiency × SOE Indicator	(0.042)	(0.040)	(0.029)	(0.013)	(0.013)	(0.029)	(0.018)
SOE Indicator	0.079	-0.158	0.145	0.129**	0.112**	0.078	-0.089
	(0.149)	(0.276)	(0.109)	(0.052)	(0.053)	(0.071)	(0.068)
Lag Log Productivity	0.064***	-0.044**	0.053***	0.009	0.002	0.059***	-0.007
Efficiency × FIE Indicator	(0.023)	(0.021)	(0.016)	(0.007)	(0.008)	(0.021)	(0.009)
FIE Indicator	-0.024	-0.183	0.012	-0.001	0.016	-0.081*	0.010
	(0.086)	(0.151)	(0.063)	(0.028)	(0.030)	(0.047)	(0.034)
Lag Log Sales	0.002	0.002	-0.010	-0.003	-0.002	-0.005	0.006
	(0.016)	(0.014)	(0.008)	(0.005)	(0.006)	(0.012)	(0.006)
Exit Indicator	-0.075***	-0.072***	-0.051***	-0.016	-0.007	-0.054***	0.050***
	(0.028)	(0.023)	(0.019)	(0.011)	(0.013)	(0.020)	(0.014)
Entry Indicator	0.118	0.030	0.063***	0.007	-0.000	0.060***	-0.042***
	(0.096)	(0.025)	(0.020)	(0.012)	(0.014)	(0.020)	(0.014)
Constant	-1.118***	-1.063***	-1.028***	-0.643***	-0.670***	-0.969***	-0.979***
	(0.210)	(0.216)	(0.116)	(0.065)	(0.072)	(0.145)	(0.080)
Year-Specific Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Level-Specific Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,309	19,901	36,377	22,359	22,319	40,147	40,147
R-squared	0.020	0.037	0.065	0.216	0.198	0.062	0.058

Note: Except in column (2), the variable productivity efficiency in the table refers to the labor productivity based on value added without any special notification. TFP_OP, total factor productivity estimated with the Olley and Pakes (1996) semi-parametric method. Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 7: Robustness Checks for the Mechanisms

Panel A:

	TFP_OP			Alternative Measures for Markups			Including Observations with Negative DVARs		
	Log Markup	Log $\frac{P_{IM}}{P_{DM}}$	Log FVAR	Log Markup	Log $\frac{P_{IM}}{P_{DM}}$	Log FVAR	Log Markup	Log $\frac{P_{IM}}{P_{DM}}$	Log FVAR
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log NEER Weighted by Import Share in Initial Year	0.077***	0.041		0.033**	0.056**		0.049**	0.077***	
	(3.073)	(1.171)		(2.316)	(2.408)		(2.210)	(3.467)	
Lag Fitted Value of Log Markup			-0.199*			-0.611*			-0.543
			(-1.657)			(-1.670)			(-1.557)
The Fitted Value of Log $\frac{P\_IM}{P\_DM}$			-0.784			-0.825**			-0.662**
			(-1.484)			(-2.554)			(-2.187)
Observations	9,366	12,702	4,979	10,844	17,093	8,079	13,644	21,061	8,079
R-squared	0.101	0.075	0.033	0.030	0.074	0.031	0.073	0.072	0.030

Panel B:

	Excluding Indirect Importers			Real Effective Exchange Rate			Excluding Sectors with a Lot of Imported Capital		
	Log Markup	Log $\frac{P_{IM}}{P_{DM}}$	Log FVAR	Log Markup	Log $\frac{P_{IM}}{P_{DM}}$	Log FVAR	Log Markup	Log $\frac{P_{IM}}{P_{DM}}$	Log FVAR
	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Log NEER Weighted by Import Share in Initial Year	0.044	0.030					0.050**	0.049**	
	(1.423)	(0.916)					(2.069)	(2.099)	
Log REER Weighted by Import Share in Initial Year				0.060***	0.055**				
				(2.717)	(2.322)				
Lag Fitted Value of Log Markup			-0.379*			-0.382			-0.070
			(-1.899)			(-1.368)			(-0.257)
Fitted Value of Log $\frac{P\_IM}{P\_DM}$			-0.289*			-0.851***			-0.742**
			(-1.890)			(-2.602)			(-2.153)
Observations	5,645	9,339	4,438	10,841	17,093	8,079	9,743	15,465	7,593
R-squared	0.032	0.089	0.093	0.072	0.074	0.031	0.078	0.077	0.029

Note: NEER and REER are abbreviations for nominal and real effective exchange rate. TFP_OP, total factor productivity estimated with the Olley and Pakes (1996) semi-parametric method. T-statistics are in parentheses. * p<0.10; ** p<0.05; *** p<0.01.

Table 8: IV Estimations

Regressand: Log FVAR	(1)	(2)	(3)	(4)
Log Nominal Effective Exchange Rate Weighted	-0.177***	-0.488***	-0.562***	-0.487***
by Import Share in Initial Year	(0.035)	(0.141)	(0.205)	(0.133)
Lag Log Labor Productivity Based on Value Added	-0.041***	-0.047***	-0.053***	-0.043***
	(0.011)	(0.014)	(0.013)	(0.013)
Lag Log Labor Productivity Based	0.021	0.033	0.029	0.032
on Value Added × SOE Indicator	(0.025)	(0.027)	(0.027)	(0.026)
SOE Indicator	0.067	-0.022	0.006	0.005
	(0.092)	(0.097)	(0.100)	(0.097)
Lag Log Labor Productivity Based	0.057***	0.063***	0.067***	0.058***
on Value Added × FIE Indicator	(0.012)	(0.014)	(0.014)	(0.013)
FIE Indicator	-0.074*	-0.109**	-0.127**	-0.084*
	(0.044)	(0.052)	(0.050)	(0.050)
Lag Log Sales	-0.006	-0.002	-0.007	-0.009
	(0.007)	(0.009)	(0.008)	(0.008)
Exit Indicator	-0.052***	-0.065***	-0.060***	-0.065***
	(0.017)	(0.021)	(0.020)	(0.020)
Entry Indicator	0.057***	0.065***	0.057***	0.069***
	(0.019)	(0.023)	(0.021)	(0.021)
Year-Specific Effects	Yes	Yes	Yes	Yes
Firm-Level-Specific Effects	Yes	Yes	Yes	Yes
Observations	32,291	23,178	25,610	26,200
Centered R-squared	0.057	0.027	0.010	0.025
First Stage				
IV1: Log M1 Weighted by Import	-0.170***			
Share in Initial Year	(0.010)			
IV2: Log M2 Weighted by Import	0.134***			
Share in Initial Year	(0.009)			
IV3: Log M1 Growth Rate Weighted		-0.021***	-0.031***	
by Import Share in Initial Year		(0.004)	(0.005)	
IV4: Log M2 Growth Rate Weighted		-0.048***		-0.066***
by Import Share in Initial Year		(0.008)		(0.009)
Endogeneity Test	20.9***	12.9***	7.88***	14.4***
Kleibergen-Paap rank LM Chi2	270***	51.2***	43.4***	53.0***
Kleibergen-Paap rank Wald F	220	27.3	44.7	56.7
Hansen J	1.98	0.182	-	-

Note: Robust standard errors are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

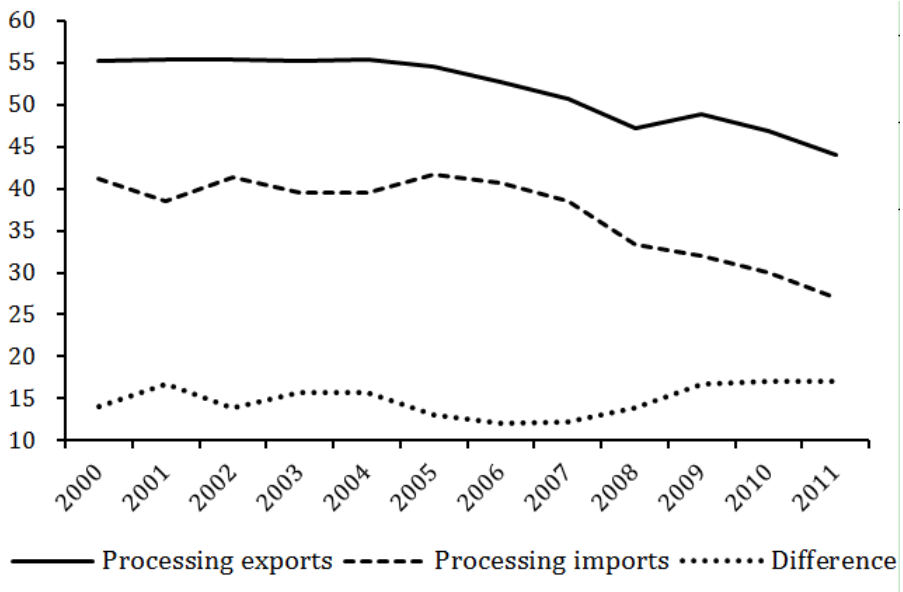

Figure 1: Shares of Processing Imports and Exports in China

Source: General Administration of Customs of China.

Note: The share of processing exports at t is equal to the ratio of processing export (import) values to total export (import) values. Here, processing trade is defined as processing with assembly or processing with imported materials.

Appendix A: Theoretical Derivation

A.1 Demand Side

According to equation (1), representative consumer's preference for final goods is from a continuum-of-goods version of the translog expenditure function.

$$lnE_t = lnU_t + a_t + \frac{1}{N_t}\int_{i\in\Delta_t} lnp_{it}di + \frac{\gamma}{2N_t}\int_{i\in\Delta_t}\int_{j\in\Delta_t} lnp_{it}(lnp_{jt} - lnp_{it})djdi$$

Then, the expenditure share of product i at time t is,

$$s_{it} = \frac{\partial \ln(E_t)}{\partial \ln(p_{it})} = \gamma \ln\frac{e^{\frac{1}{N_t\gamma}+\overline{\ln(pt)}}}{p_{it}} = \gamma\ln(\frac{\hat{p}_t}{p_{it}})$$

where $\overline{\ln(p_t)} = \frac{1}{N_t}\int_{j\in\Delta_t} lnp_{jt}dj$, $\widehat{p_t} = e^{\frac{1}{N_t\gamma}+\overline{\ln(p_t)}}$. $\widehat{p_t}$ is the maximum Home-currency price that a firm can set at Home market.

Then the demand of representative consumer for product i is

$$q_{it} = \frac{s_{it}I_t}{p_{it}} = \gamma\ln(\frac{\hat{p}_t}{p_{it}})\frac{I_t}{p_{it}}$$

A.2 Supply Side

The input prices vector $(r_t, w_t, p_t^{DM}, p_t^{XM})$ includes rental rate, wage rate, the price of domestic intermediate input and the price of imported intermediate input in terms of Home currency at time t. Analogous expressions are used for the representative Foreign household, except associated with superscript asterisks, such as r_t^*, w_t^*, p_t^{DM*}, p_t^{XM*}.

Each firm maximizes their profit at time t,

$$\underset{l_{it}, k_{it}, m_{it}}{Max}\; y_{it} - w_t l_{it} - r_t k_{it} - p_t^M m_{it}$$

$$\underset{l_{it}, k_{it}, m_{it}^D, m_{it}^I}{Max}\; y_{it} - w_t l_{it} - r_t k_{it} - p_t^{DM} m_{it}^D - p_t^{IM} m_{it}^I$$

These two maximum propositions are equivalent. Combining these two with the production function of intermediate input, the price index of intermediate input is

$$p_t^M = [(p_t^{DM})^{1-\sigma} + (p_t^{IM})^{1-\sigma})]^{\frac{1}{1-\sigma}}$$

Simultaneously, each firm minimizes their cost at time t,

$$\underset{l_{it}, k_{it}, m_{it}}{Max} w_t l_{it} + r_t k_{it} + p_t^M m_{it}, s.t. \varphi_{it} k_{it}^{\alpha_k} l_{it}^{\alpha_l} m_{it}^{\alpha_m} \geq y_{it}$$

Then the optimum cost function of firm i at time t is

$$c_{it} = \frac{y_{it}}{\varphi_{it}} (\frac{r_t}{\alpha_k})^{\alpha_k} (\frac{w_t}{\alpha_l})^{\alpha_l} (\frac{p_t^M}{\alpha_m})^{\alpha_m}$$

And its marginal cost is

$$mc_{it} = \frac{\Psi}{\varphi_{it}}$$

where $\Psi = \frac{r_t}{\alpha_k})^{\alpha_k} (\frac{w_t}{\alpha_l})^{\alpha_l} (\frac{p_t^M}{\alpha_m})^{\alpha_m}$, which is a constant independent on a single firm's production strategy.

$$p_{it} = (1 + \mu_{it}) mc_{it} = (1 + \mu_{it}) \frac{\Psi}{\varphi_{it}}$$

$$p_{it} y_{it} = (1 + \mu_{it}) \frac{\Psi y_{it}}{\varphi_{it}} = (1 + \mu_{it}) c_{it}$$

So,

$$\frac{p_t^M m_{it}}{c_{it}} = \alpha_m$$

$$\frac{p_t^{IM} m_{it}^I}{p_{it} y_{it}} = \frac{p_t^{IM} m_{it}^I}{(1+\mu_{it}) c_{it}} = \frac{p_t^{IM} m_{it}^I}{p_t^M m_{it}} \frac{p_t^M m_{it}}{(1+\mu_{it}) c_{it}} = \frac{\alpha_m}{(1+\mu_{it})} \frac{p_t^{IM} m_{it}^I}{p_t^M m_{it}}$$

Firm i minimizes its cost on intermediate input, given the optimum quantity of intermediate input solved from the profit maximization principle. That is,

$$\underset{m_{it}^D, m_{it}^I}{Max}\, p_t^{DM} m_{it}^D + p_t^{IM} m_{it}^I, s.t. [(m_{it}^D)^{\frac{\sigma-1}{\sigma}} + (m_{it}^I)^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}} \geq m_{it}$$

From this, we get

$$\frac{p_t^{IM} m_{it}^I}{p_t^M m_{it}} = \frac{1}{1+(\frac{p_t^{IM}}{p_t^{DM}})^{\sigma-1}}$$

Then

$$DVAR_{it} = 1 - \frac{p_t^{IM} m_{it}^I}{p_{it} y_{it}} = 1 - \frac{\alpha_m}{1+\mu_{it}} \frac{1}{(\frac{p_t^{IM}}{p_t^{DM}})^{\sigma-1}}$$

Therefore the optimum price strategy[28] of firm i at time t is

$$p_{it} = argMax\{p_{it} q_{it} - c_{it}\}$$

And the first order condition of firms' profit maximization principle is

$$p_{it} = \frac{mc_{it}}{1+\frac{\partial p_{it} q_{it}}{\partial q_{it} p_{it}}} = \frac{mc_{it}}{1+\frac{1}{\eta_{it}}}$$

where $\eta_{it} = \frac{\partial q_{it}}{\partial p_{it}} \frac{p_{it}}{q_{it}}$ is the price elasticity of demand.

[28] We ignore fixed costs, which are constant and should not influence firms' optimal price strategy.

As $q_{it} = \gamma \ln(\frac{\hat{p}_t}{p_{it}}) \frac{I_t}{p_{it}}$, take the logarithm form of this equation,

$$\ln(q_{it}) = \ln(\gamma) + \ln[\ln(\frac{\hat{p}_t}{p_{it}})] + \ln(I_t) - \ln(p_{it})$$

So,

$$\eta_{it} = \frac{\partial q_{it}}{\partial p_{it}} \frac{p_{it}}{q_{it}} = \frac{-1}{\ln(\frac{\hat{p}_t}{p_{it}})} - 1$$

$$p_{it} = [1 + \ln(\frac{\hat{p}_t}{p_{it}})] mc_{it}$$

where $\widehat{p_t} = e^{\frac{1}{N_t \gamma} + \overline{\ln(pt)}}$. We can get the analytic solution of p_{it}, through using Lambert W function . To distinguish Lambert W function and wage rate, we use Ω to represent Lambert W function[29]. Ω is a concave function in terms of x, with $\Omega(x) > 0$, $\Omega(x) < 0$, $\Omega(0) = 0$ and $\Omega(e) = 1$.

$$\frac{p_{it}}{mc_{it}} = 1 + \ln(\frac{\hat{p}_t}{p_{it}}) = \ln(e \frac{\hat{p}_t}{p_{it}})$$

$$\frac{p_{it}}{mc_{it}} e^{\frac{p_{it}}{mc_{it}}} = e \frac{\hat{p}_t}{mc_{it}}$$

So

$$p_{it} = \Omega(e \frac{\hat{p}_t}{mc_{it}}) mc_{it}$$

$$\mu_{it} = \Omega(e \frac{\hat{p}_t}{mc_{it}}) - 1$$

Let τ represent the iceberg of domestic firms export to Foreign market. ε is the domestic price needed for one unit Foreign currency. I^* is the consumption expenditure of Foreign representative consumers in terms of Foreign currency. Then the Home-

[29] See Corless et al. (1996) for more details about the Lambert W function.

currency domestic price $p_{it}^{D}(\varphi_{it})$ and the Foreign-currency export price $p_{it}^{X}(\varphi_{it})$ of Home good i is shown in the following equation, which is a function of the markup and firms' marginal cost. In addition, the Foreign-currency export price is still a function of iceberg cost τ and exchange rate ε. Analogously, we can deduce the expressions for firm i's domestic markup $\mu_{it}^{D}(\varphi_{it})$, Foreign-currency export price markup $\mu_{it}^{X}(\varphi_{it})$, domestic quantity $y_{it}^{D}(\varphi_{it})$, export quantity $y_{it}^{X}(\varphi_{it})$, domestic profit $\pi_{it}^{D}(\varphi_{it})$ and export profit $\pi_{it}^{X}(\varphi_{it})$, with productivity φ_{it} at time t.

$$
\begin{aligned}
p_{it}^{D}(\varphi_{it}) &= [1+\mu_{it}^{D}(\varphi_{it})]\frac{\Psi_t}{\varphi_{it}} & p_{it}^{X}(\varphi_{it}) &= [1+\mu_{it}^{X}(\varphi_{it})]\frac{\tau\Psi_t}{\varepsilon\varphi_{it}} \\
\mu_{it}^{D}(\varphi_{it}) &= \Omega(e\frac{\varphi_{it}\hat{p}_t}{\Psi_t})-1 & \mu_{it}^{X}(\varphi_{it}) &= \Omega(e\frac{\varepsilon\varphi_{it}\hat{p}_t^{*}}{\tau\Psi_t})-1 \\
y_{it}^{D}(\varphi_{it}) &= \frac{\mu_{it}^{D}(\varphi_{it})}{1+\mu_{it}^{D}(\varphi_{it})}\frac{\gamma I\varphi_{it}}{\Psi_t} & y_{it}^{X}(\varphi_{it}) &= \frac{\mu_{it}^{X}(\varphi_{it})}{1+\mu_{it}^{X}(\varphi_{it})}\frac{\varepsilon\gamma I^{*}\varphi_{it}}{\tau\Psi_t} \\
\pi_{it}^{D}(\varphi_{it}) &= \frac{[\mu_{it}^{D}(\varphi_{it})]^2}{1+\mu_{it}^{D}(\varphi_{it})}\gamma I & \pi_{it}^{X}(\varphi_{it}) &= \frac{[\mu_{it}^{X}(\varphi_{it})]^2}{1+\mu_{it}^{X}(\varphi_{it})}\gamma I^{*}
\end{aligned}
$$

Then, the similar variables of Foreign firm i with productivity φ_{it} are expressed with superscript asterisks. Those are

$$
\begin{aligned}
p_{it}^{D*}(\varphi_{it}^{*}) &= [1+\mu_{it}^{D*}(\varphi_{it}^{*})]\frac{\Psi_t^{*}}{\varphi_{it}^{*}} & p_{it}^{X*}(\varphi_{it}^{*}) &= [1+\mu_{it}^{X*}(\varphi_{it}^{*})]\frac{\varepsilon\tau^{*}\Psi_t^{*}}{\varphi_{it}^{*}} \\
\mu_{it}^{D*}(\varphi_{it}^{*}) &= \Omega(e\frac{\varphi_{it}^{*}\hat{p}_t^{*}}{\Psi_t^{*}})-1 & \mu_{it}^{X*}(\varphi_{it}^{*}) &= \Omega(e\frac{\varphi_{it}^{*}\hat{p}_t^{*}}{\varepsilon\tau^{*}\Psi_t^{*}})-1 \\
y_{it}^{D*}(\varphi_{it}^{*}) &= \frac{\mu_{it}^{D*}(\varphi_{it}^{*})}{1+\mu_{it}^{D*}(\varphi_{it}^{*})}\frac{\gamma^{*}I^{*}\varphi_{it}^{*}}{\Psi_t^{*}} & y_{it}^{X*}(\varphi_{it}^{*}) &= \frac{\mu_{it}^{X*}(\varphi_{it}^{*})}{1+\mu_{it}^{X*}(\varphi_{it}^{*})}\frac{\gamma^{*}I^{*}\varphi_{it}^{*}}{\varepsilon\tau^{*}\Psi_t^{*}} \\
\pi_{it}^{D*}(\varphi_{it}^{*}) &= \frac{[\mu_{it}^{D*}(\varphi_{it}^{*})]^2}{1+\mu_{it}^{D*}(\varphi_{it}^{*})}\gamma^{*}I^{*} & \pi_{it}^{X*}(\varphi_{it}^{*}) &= \frac{[\mu_{it}^{X*}(\varphi_{it}^{*})]^2}{1+\mu_{it}^{X*}(\varphi_{it}^{*})}\gamma^{*}I
\end{aligned}
$$

Due to $\varphi_r = inf\{\varphi_{it}: \mu_{it}^{r}(\varphi_{it}) > 0\}$, $\varphi_r^{*} = inf\{\varphi_{it}: \mu_{it}^{r*}(\varphi_{it}) > 0\}$, $r \in \{D, X\}$, the cut-off exporter gets zero price markup and its price should be equal to the upper bound price of the destination market.

$$
\varphi_D = \frac{\Psi_t}{\hat{p}_t}, \varphi_X = \frac{\tau\Psi_t}{\varepsilon\hat{p}_t^{*}}, \varphi_D^{*} = \frac{\Psi_t^{*}}{\hat{p}_t^{*}}, \varphi_X^{*} = \frac{\varepsilon\tau^{*}\Psi_t^{*}}{\hat{p}_t}
$$

So

$$
\mu_{it}^{r}(\varphi_{it}) = \Omega(\frac{\varphi_{it}}{\varphi_r}e) - 1, r \in \{D, X\}
$$

$$
\mu_{it}^{r*}(\varphi_{it}) = \Omega(\frac{\varphi_{it}}{\varphi_r^{*}}e) - 1, r \in \{D, X\}
$$

The equilibrium value of φ_D, φ_X, φ_D^*, φ_X^* are got form the free entry condition, which means firms can enter and exit freely in long run term and marginal firm's expected revenue in the future should be equal to its entry cost. More details about the derivation of φ_D, φ_X, φ_D^*, φ_X^* can be found in Rodriguez-Lopez (2011). In this paper, we cite the basic result of Rodriguez-Lopez (2011) $\frac{\partial \varphi_X}{\partial \varepsilon} < 0$ directly. What's more, the equations above imply that the Home-currency import price (c.i.f) of a Foreign good i is a function of firm i's marginal cost, iceberg cost, exchange rate and export price markup. That is

$$p_{it}^{X*}(\varphi_{it}^*) = [1 + \mu_{it}^{X*}(\varphi_{it}^*)] \frac{\varepsilon\tau^*\Psi_t^*}{\varphi_{it}^*}$$

Define $p_{it}^{IM} = \varepsilon\tau^* p_{it}^{XF*}(\varphi_{it})$. As pure processing firms export all its final goods, so $\mu_{it} = \mu_{it}^X(\varphi_{it})$, $p_{it} = p_{it}^X(\varphi_{it})$, $y_{it} = y_{it}^X(\varphi_{it})$. Ignoring the heterogeneity within domestic (imported) intermediate inputs, then

$$DVAR_{it}^{pe_{it}=1} = 1 - \frac{\alpha_m}{1+\mu_{it}^X} \frac{1}{1+(\frac{\tau^*\varepsilon p_{it}^{XF*}}{p_t^{DM}})^{\sigma-1}}$$

Appendix B: Matching Production and Trade Data Sets

B.1 Data and Matching Method

Before merge firm-level and product-level date, we delete the observations that, 1) any of industrial sales, revenue, employment, fixed asset, export value and import value are negative or missing; 2) the total employment are less than eight; 3) export value are larger than its industrial sales.

Two methods are used to match these two data sets. First, we match the two data sets by using each firm's Chinese name and year. The year variable is very necessary, as some firms may change their Chinese names across years and newcomers may use these firms' original names. Second, we use zip code and the last seven digits of the firm's phone number to identify it, as firms should have different and unique phone numbers within a postal district.

B.2 Comparison

As we mainly focus on processing firms' export and import, we list the information of the merged data on four industrial sectors' processing export and import share in table B1. And all other statistic information about the merged data can be found in Yu (2015). In table B2 and B3, we compare the processing export share, processing import share and processing firms' DVARs in the merged data with those in the trade data.

Table B1: Processing Export and Import Share in the Trade and Merged Data from 2000 to 2009 (%)

Year	Trade Data		Merged Data	
	Processing Export	Processing Import	Processing Export	Processing Import
	55.2	41.1	71.0	61.0
	55.3	38.5	65.5	53.7
	55.3	41.4	53.9	52.9
	55.2	39.5	62.4	53.8
	55.3	39.5	61.0	55.6
	54.6	41.6	58.1	55.8
	52.7	40.6	59.6	53.1
	50.7	38.5	49.4	41.7
	47.3	33.4	52.4	48.9
	48.8	32.1	57.7	45.3

Source: Product-level trade transaction data from the China's Customs.

Notes: the share of processing export at $t = \frac{\sum_{k=1}\sum_i EX_{ikt}}{\sum_k \sum_i EX_{ikt}}$, the share of processing import at $t = \frac{\sum_{k=1}\sum_i IM_{ikt}}{\sum_k \sum_i IM_{ikt}}$. EX_{ikt} is the export value of firm i at time t with trade transaction mode k ; IM_{ikt} is the import value of firm i at time t with trade transaction mode k ; k is a dummy variable and equal to 1, when the code of trade transaction mode is equal to 14 (processing with assembly) or 15 (processing with imported materials).

Table B2: Nominal and Real Effective Exchange Rate Weighted by the Initial-year Import and Export Share

	All Firms		Processing Firms	
	Mean	S.D.	Mean	S.D.
NEER weighted by the birth-year import share	2.15	2.99	1.05	1.70
NEER weighted by the birth-year export share	2.20	2.76	2.38	2.79
REER weighted by the birth-year import share	2.18	3.04	1.06	1.72
REER weighted by the birth-year export share	2.22	2.80	2.40	2.83

Notes: NEER stands for nominal effective exchange rate. REER stands for real effective exchange rate.

Appendix C: Price Markup

We use the method based on De Loecker and Warzynski (2012) to estimate price markups for processing exporters. Each firm minimize its production cost in period t, consider the following Lagrangian function,

$$L(l_{it}, m_{it}, k_{it}, \lambda_{it}) = w_t l_{it} + p_t^M m_{it} + r_t k_{it} + \lambda_{it}(y_{it} - y_{it}(\cdot)) \quad (28)$$

where λ_{it} is the Lagrange multiplier. $y_{it}(\cdot)$ represents production function. Additionally, meanings of other indicators are the same as those in our model. Thus from the first order condition with respect to l_{it}, we yield

$$\frac{\partial y_{it}(\cdot)}{\partial l_{it}} \frac{l_{it}}{y_{it}(\cdot)} = \frac{1}{\lambda_{it}} \frac{w_t l_{it}}{y_{it(\cdot)}} \quad (29)$$

According to Envelope theorem, it is straightforward to show that $\lambda_{it} = \partial L / \partial y_{it}$. That is, the Lagrange multiplier is exactly equal to marginal cost given objective quantity. Combine this with equation (29),

$$\frac{\partial y_{it}(\cdot)}{\partial l_{it}} \frac{l_{it}}{y_{it}(\cdot)} = \frac{p_t}{\lambda_{it}} \frac{w_t l_{it}}{p_t y_{it(\cdot)}} = (1 + \mu_{it}) \frac{w_t l_{it}}{p_t y_{it(\cdot)}} \quad (30)$$

Therefore, price markup is equal to the ratio between the elasticity of output against labor and the expenditure share of labor.

$$1 + \mu_{it} = \frac{\frac{\partial y_{it}(\cdot)}{\partial l_{it}} \frac{l_{it}}{y_{it}(\cdot)}}{\frac{w_t l_{it}}{p_t y_{it(\cdot)}}} = \frac{\alpha_l}{\frac{w_t l_{it}}{p_t Q_{it}(\cdot)/e^{\vartheta_{it}}}} \quad (31)$$

Once we obtain all estimations for production coefficients, it is natural to show that a estimation for price markup is $\widehat{1 + \mu_{it}} = \frac{\widehat{\alpha_l}}{\frac{w_t l_{it}}{p_t Q_{it}(\cdot)/e^{\widehat{\vartheta_{it}}}}}$.