# Firm-specific Exchange Rate Shocks and Employment Adjustment: Theory and Evidence*

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**Abstract**

This paper investigates the impact of exchange rate shocks on the employment of individual firms. We develop a theoretical model linking employment changes to exchange rate shocks in all of the firm's export destinations, import sources, and import-competing countries. Exchange rate changes affect employment through changing the cost of imported inputs, the local-currency denominated export price, and the degree of import competition in the domestic market. We test the predictions of the model using Chinese firm-level data. Effective exchange rate changes are constructed at the firm level on both export and import sides. We find evidence that exchange rate changes affect employment through changing the cost of imported inputs and the local-currency denominated export price, while there is weak evidence of the import competition effects. In general, the employment effects of exchange rate changes are small, but there is some degree of heterogeneity among firms with different degrees of internationalization.

**JEL**: E24, F16, F31

**Keywords**: exchange rate, employment, export, import

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# 1 Introduction

It is widely believed that exchange rate fluctuations have a fundamental impact on employment. Governments are usually reluctant to appreciate their currencies in fear of the potential negative impact on domestic jobs. These concerns beg the question of to what extent exchange rate fluctuations matter for employment, and how**?** In this paper, we address these questions by investigating the employment response to exchange rates of individual firms. We aim to accurately measure exchange rate shocks at the firm-level, explore the alternative mechanisms transmitting exchange rates shocks to employment changes, and quantify their relative importance.

We first develop a theoretical framework linking exchange rate shocks in multiple countries to firm-level employment changes. To highlight the transmission of exchange rate shocks to employment on both export and import sides, we build our theoretical model upon Amiti et al. (2014) which studies exchange rate pass-through accounting for both export and import behavior of firms. Whereas they study the response of prices to exchange rate shocks, we study the response of employment. Firms sell in the domestic market and potentially export to multiple destinations, additionally they source intermediate inputs domestically and potentially from multiple foreign countries. Within the domestic market, they also compete with firms from other countries. In such an environment, exchange rate shocks in all export destinations, import sources, and import-competing countries can affect the firm's labor demand. We derive a structural relationship linking firm-level employment changes with exchange rate shocks in all of the firm's related markets. Exchange rate shocks in different markets are aggregated at the firm-level based on firm's relatedness to these markets. Thus, the model provides a theoretical basis for linking firm-level employment changes with changes of firm-level effective exchange rates, on both input and output sides.

The model also distinguishes various mechanisms transmitting exchange rate shocks to employment changes. We show that exchange rate shocks affect employment through a "substitution effect" and a "scale effect". The substitution effect describes the employment changes stemming from the adjustment of factor composition for producing a fixed level of output, while the scale effect describes the employment changes due to changes in output given a fixed factor composition. The impact of exchange rate on output scale can be further broken down into three sub-channels: by changing the cost of importing intermediate inputs (the input cost channel), changing the local-currency price with a given producer-currency price (the export price channel), and changing the degree of import competition in the domestic market (the import competition channel). We also show that the impact through each channel depends on firms' external orientation, as reflected in firms' reliance on the export markets for sales and on the import markets for sourcing intermediate inputs.

We test the predictions of the model using a comprehensive matched data set of Chinese manufacturing firms during 2000-2006. A notable feature of the data is that it provides information of firm exports by destination and imports by source country. This allows us to construct effective exchange rates at the firm level that are strictly consistent with the theory. We construct firm-level effective exchange rate changes on both the export and import side. We also construct industry-level effective exchange rate changes that reflect the average exchange rate shocks pertaining to foreign countries that are competing within China's domestic market. Guided by theory, we interact these effective exchange rate changes with measures of firms' external orientation and investigate their relationships with employment growth. The variation across firms in both external orientation and effective exchange rate shocks are used to identify the impact of exchange rates on employment through different transmission channels. We also incorporate labor adjustment costs in order to quantitatively match the predictions of the theory with the data.

We find that employment growth responds to exchange rate changes in the direction predicted by the theory. Appreciations against export destinations are associated with reductions in employment, while appreciations against import source countries are associated with employment increases. There is weak evidence that appreciations reduce employment through intensifying the import competition in the domestic market. We also find supportive evidence of the theory prediction that the elasticities of employment to exchange rate changes increase with demand elasticity. Economically, the impact of exchange rate changes on employment is generally small. For a firm with average level of external orientation, a 10 percent effective appreciation is associated with a 0.85 percent employment reduction. However, the impact differ across firms with different degrees of external orientation. For a firm that neither exports nor imports, a 10 percent appreciation is associated with an employment reduction of 0.27 percent, while for the most internationalized firm, the associated impact is an employment reduction of 2 percent.

This paper is related to the abundant literature on the impact of exchange rate fluctuations on employment. Earlier works empirically investigate the exchange-employment relationship at the country or industry level.[1] Investigations at the firm level have only recently started to emerge. Nucci and Pozzolo (2010) studied the response of net employment to exchange rate fluctuations using Italian firm-level data. Ekholm et al. (2012) investigated the employment response of Norwegian manufacturing firms to the real appreciation of the Norwegian Krone in the early 2000s. Our study contributes to this emerging literature in two aspects. The first contribution is theoretical. We develop a full-fledged model to describe the various mechanisms transmitting exchange rate shocks to firm-level employment changes. Although the model is in its spirit similar to the model sketched out by Nucci

[1] See Branson and Love (1986, 1987); Revenga (1992); Burgess and Knetter, (1998); Goldberg and Tracy (2000); and Campa and Goldberg (2001) on exchange rate variations and net employment. See Gourinchas ( 1999); Klein et al. (2003) on exchange rate variations and gross job flows. Hua (2007) investigates the impact of real exchange rate on the manufacturing employment in China.

and Pozzolo (2010), it is distinct in two respects. First, we allow firms to export to multiple destinations and import from multiple source countries, so that the distribution of exports and imports across trading partners matters for exchange rate shocks. This provides a theoretical justification for the use of effective exchange rate changes that vary from firm to firm in the empirical analysis. In contrast, Nucci and Pozzolo (2010) assumes a hypothetical unified export market and import source. Second, our model is more "structural" in the sense that we connect differences in employment responses to exchange rates with the structural parameters in our model, such as demand elasticities, exchange rate pass-through, and labor adjustment costs. This allows us to quantitatively contrast the model with the data, given reasonable values of these structural parameters. The second contribution of our paper is empirical. We construct theory-consistent firm-specific effective exchange rate changes to measure the exchange rate shocks related to each firm. Compared with earlier works using effective exchange rate measures at more aggregate levels, our approach provides another source of cross-firm variation other than external orientation to identify the impact of exchange rate shocks.

Our paper is also related to the literature on the measurement of effective exchange rates. The traditional effective exchange rate is a piece of macroeconomic data which is computed with price and trade flow series at the national level.[2] However, the aggregate effective exchange rate does not effectively capture changes in industry competitive conditions induced by moves in specific bilateral exchange rates (Goldberg, 2004). Therefore, the industry-level studies on the real economic impact of exchange rate movements have generally adopted "industry-specific effective exchange rates" that are constructed using industry level trade weights.[3] In regard to micro level studies using firm-level data, however, the use of firm-specific effective exchange rates becomes necessary because the industry-specific effective exchange rates fail to account for the substantial heterogeneity of firms' trade distribution across export destinations and import source countries. When the investigation is at the firm-level, regressing employment against effective exchange rates constructed at more aggregate levels amounts to a measurement error in the independent variable, thus potentially leads to an attenuation bias. To the best of our knowledge, our study is the first to construct such firm-specific effective exchange rates and apply them to investigate the impact of exchange rate movements on firms. We show that using the firm-specific effective exchange rate measures leads to estimation results that are closer to the theoretical predictions, and increases the precision of the estimation.

One limitation of our study is that we are not able to assess the impact of exchange rate shocks on aggregate manufacturing employment (or unemployment). Our model assumes a frictionless labor market, so jobs only reallocate across firms with different exchange rate exposure without impacting aggregate employment. Assessing

[2] See Chinn (2006) for a review of the construction methods and applications of the aggregate effective exchange rates.
[3] See Revenga (1992), Goldberg et al.(1999), Campa and Goldberg (2001), Goldberg (2004).

the impact of exchange rate shocks on aggregate employment would require a model featuring labor market frictions, which is beyond the scope of this paper. Our analysis is better suited to uncover how exchange rate shocks affect employment through alternative transmission mechanisms. We believe this is a key step towards understanding the impact of exchange rate shocks on aggregate employment.

The rest of the paper is structured as follows. Section 2 develops the theoretical framework linking firms' employment changes to exchange rate shocks. Section 3 describes the empirical strategy. Section 4 describes the data and construction of variables. Section 5 presents the baseline estimation results and conducts robustness checks. Section 6 further discusses the role of demand elasticity on affecting the sensitivity of employment to exchange rates and the asymmetric response of employment to exchange rate appreciations and depreciations. The last section concludes.

## 2 Theory

In this section we develop a theoretical framework linking firm-level employment changes to exchange rate changes in a multi-country setting. This theory is designed to serve two purposes. First, it characterizes how exchange rate changes affect firm employment through different transmission mechanisms. Second, the model provides a theoretical foundation for our empirical exercise and provides guidance on the construction of variables that are used in the empirical analysis to identify the impact of exchange rate changes.

Our theoretical framework is built upon Amiti et al. (2014), which extends the oligopolistic competition model of Atkeson and Burstein (2008) by accounting for the importing behavior of firms. We consider a firm that sells products to multiple countries (both domestic and foreign), and imports intermediate inputs from multiple sources (both domestic and foreign). We first derive firm's labor demand function, which is equal to equilibrium employment given a perfectly elastic labor supply. We show that exchange rate changes affect employment through a substitution effect and a scale effect. Next, we separately investigate the magnitude of each effect, with a particular focus on the impact of exchange rates on the scale of production. We show that changes in bilateral exchange rate affect the level of production, thus employment, through three channels: by changing the costs of imported inputs, the export prices in the destination country's currency, as well as the degree of import competition in the domestic market. Finally, by aggregating the impact of bilateral exchange rates across a firm's export destinations, import sources, and import-competing countries within the domestic market, we derive a structural relationship between employment changes and effective exchange rate shocks reflecting different transmission mechanisms.

One important simplifying assumption we make throughout the model is that we take the exporting and importing status of firms as exogenous. That is, we do not model the decision of entry and exit into the export and import market, neither do we model the choice of export and import partners. Although we realize that there is a large literature on the endogenous decision of firms to enter and exit the export/import market, and on the selection of trade partners[4], incorporating the details of such selection mechanisms will not change the structural relationship between exchange rates and employment derived from the present model. Thus we abstract away these complications.

## 2.1 Demand

Consider a firm $i$ located in country $n$, producing a differentiated good in a given sector and supplying it to destination market $k$.[5] Consumers has a CES-form utility over varieties. The resulting demand function is given by

$$q_{ink} = p_{ink}^{-\sigma} P_k^{\sigma-\eta} D_k \tag{1}$$

where $q_{ink}$ is the quantity demanded and $p_{ink}$ is the firm's price denominated in the currency of the destination country. $D_k$ is the aggregate demand shifter in country $k$ which the firm takes as exogenous. $\sigma$ is the elasticity of substitution across firms within a sector, and $\eta$ is the cross-sector elasticity of substitution. We assume the within-sector elasticity of substitution is larger than the cross-sector elasticity of substitution, i.e. $\sigma > \eta$. The associated price index in destination country $k$ is defined as $P_k = (\sum\limits_n \sum\limits_{i \in \Omega_{nk}} p_{ink}^{1-\sigma})^{\frac{1}{1-\sigma}}$, where $\Omega_{nk}$ is the set of firms in country $n$ having sales in country $k$.

Let $e_{nk}$ denote the nominal exchange rate between country $n$ and $k$ (expressed as units of country $k$'s currency per unit of country $n$'s currency. i.e. an increase in $e_{nk}$ implies an appreciation of country $n$'s currency against country $k$'s), the price denominated in the local currency of country $k$ can be expressed as $p_{ink} = p_{ink}^* e_{nk}$, where $p_{ink}^*$ is the price denominated in the home currency of country $n$ (throughout the theory section, we use $*$ to denote variables that are denominated in the home currency). The associated price index can be rewritten as

$$P_k = [\sum_n \sum_{i \in \Omega_{nk}} (p_{ink}^* e_{nk})^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{2}$$

As in Atkeson and Burstein (2008), we assume firms act as Bertrand competitors. With this market structure and the CES demand system, the demand elasticity of firm $i$ in market $k$ is related to the firm's market share in country $k$.

$$\sigma_{ink} = \sigma(1 - S_{ink}) + \eta S_{ink} \tag{3}$$

[4] see for example, Bernard and Jensen (1999), Melitz (2003), Eaton et al. (2011)

[5] We refer to country $n$ as the home country in most of our theoretical analysis.

where $S_{ink} = \frac{p_{ink} q_{ink}}{P_k D_k}$ is the market share of firm $i$ in country $k$. Given $\sigma > \eta$, demand elasticity is decreasing in market share $S_{ink}$.

## 2.2 Production

Output ($Y$) is produced using labor ($L$) and intermediate inputs ($X$) according to a Cobb-Douglas production function

$$Y_{in} = \Omega_{in} L_{in}^{(1-\phi)} X_{in}^{\phi} \tag{4}$$

where $\Omega_{in}$ represents firm-level productivity and $\phi$ is a parameter measuring the share of intermediate inputs in firm expenditure and is common to all firms within a sector.

Intermediate inputs consist of a bundle of intermediate goods indexed by $j \in [0, 1]$ and are aggregated according to a Cobb-Douglas technology

$$X_{in} = \exp\{\int_0^1 \gamma_j \log X_{in,j} dj\} \tag{5}$$

where $\gamma_j$ measures the importance of intermediate good $j$ in the production process, with $\int_0^1 \gamma_j dj = 1$.

Each variety of intermediate good can be sourced from the home country and/or a set of foreign countries.

$$X_{in,j} = (Z_{inj}^{\frac{\varepsilon}{1+\varepsilon}} + \sum_{k \neq n} M_{inkj}^{\frac{\varepsilon}{1+\varepsilon}})^{\frac{1+\varepsilon}{\varepsilon}} \tag{6}$$

Where $Z_{inj}$ is the quantity of domestic intermediate input $j$ and $M_{inkj}$ is the quantity of input $j$ imported from country $k$. The elasticity of substitution between inputs sourced from different countries is governed by $1 + \varepsilon > 1$. Because domestic and imported inputs are imperfect substitutes, production is possible even without any imported inputs. On the other hand, imported intermediate inputs are useful due to the love-of-variety feature of the technology.

We assume a perfectly competitive labor market. The market wage rate is denoted by $W_n^*$, which the firm takes as given. The price of domestic intermediate inputs is denoted by $V_{nj}^*$, and the price of foreign inputs in the home currency is denoted by $(U_{nkj}/e_{nk})$, where $U_{nkj}$ is the foreign-currency denominated price of input $j$ imported from country $k$. We take the domestic input price as exogenously given, and allow the foreign input price $U_{nkj}$ to change with exchange rates.[6]

[6] The main predictions of the model will not change qualitatively if we also allow domestic input prices to be affected by exchange rates.

The firm minimizes total costs given by $W_n^* L_{in} + \int_0^1 V_{nj}^* Z_{inj} dj + \int_{J_{0,i}} (\sum_k (U_{nkj}/e_{nk}) M_{inkj}) dj$ subject to technology constraint (4) to (6), where $J_{0,i}$ is the optimal number of input variety for firm $i$, which is taken as given in our model.[7] Solving this problem yields the firm's conditional factor demand for labor and intermediate inputs, as well as the total cost ($TC_{in}^*$) as a function of factor prices, exchange rates and output.

### 2.3 Equilibrium relationships

Given the total cost function derived above, a firm solves the following profit-maximization problem:

$$\max_{Y_{in}, \{p_{ink}^*, q_{ink}\}} \{ \sum_{k \in Ki} p_{ink}^* q_{ink} - TC_{in}^* \} \tag{7}$$

Taking first order condition with respect to $p_{ink}^*$ gives the following optimal price rule:

$$p_{ink}^* = \mu_{ink} MC_{in}^* \tag{8}$$

where $MC_{in}^*$ is the home-currency denominated marginal cost derived from the total cost function ($TC_{in}^*$). $\mu_{ink} = \frac{\sigma_{ink}}{\sigma_{ink}-1}$ is the markup, which is determined by demand elasticity defined in Equation (3). This price setting further pins down firm's quantity sold to each market and thus total output $Y_{in}$, given all sectoral level variables. Factor demand of labor and intermediate inputs can then be derived as a function of wages, intermediate input prices and exchange rates by plugging $Y_{in}$ into the conditional factor demand equations.

### 2.4 Elasticity of employment to exchange rates

The Cobb-Douglas form of production implies that labor costs are a constant share of total costs. This implies the following labor demand function:

$$L_{in} = \frac{(1-\phi) MC_{in}^* Y_{in}}{W_n^*} \tag{9}$$

where $Y_{in}$ and $MC_{in}^*$ are in equilibrium functions of exogenous variables such as exchange rates, wage rates and input prices. We assume that firms face a perfectly elastic labor supply. Thus the equilibrium employment is also equal to $L_{in}$.

Taking wages as exogenous, the elasticity of employment with respect to bilateral exchange rates is given by:

[7] $J_{0,i}$ can be endogenized by assuming that firms face a fixed cost of sourcing each variety, so that firms trade off the benefit of higher productivity(due to the love-of-variety nature of the prodution function) and the fixed cost of adding one input variety. Incorporating this decision will not alter the predictions of the present model.

$$\frac{\partial \ln L_{in}}{\partial \ln e_{nk}} = \frac{\partial \ln MC^*_{in}}{\partial \ln e_{nk}} + \frac{\partial \ln Y_{in}}{\partial \ln e_{nk}} \tag{10}$$

Equation (10) decomposes the elasticity of employment to exchange rates into two components. The first component, $\frac{\partial \ln MC^*_{in}}{\partial \ln e_{nk}}$, characterizes the substitution between labor and imported inputs induced by exchange rate changes, given a fixed total output, which we refer to as the substitution effect. The second term, $\frac{\partial \ln Y_{in}}{\partial \ln e_{nk}}$, characterizes the impact of exchange rates on labor through changes of total output, given a fixed factor composition, which we refer to as the scale effect. Proposition 1 summarizes the substitution effect.

**Proposition 1** ***Substitution effect.*** *The exchange-rate-induced substitution effect, measured by the elasticity of marginal cost with respect to bilateral exchange rate $e_{nk}$, $\frac{\partial \ln MC^*_{in}}{\partial \ln e_{nk}}$, is related to the firm's fraction of total costs spent on imported intermediates from country k ($\varphi_{ink}$), adjusted by the exchange rate pass-through into imported input prices ($\eta^{IM}_{ink}$).*[8]

$$\frac{\partial \ln MC^*_{in}}{\partial \ln e_{nk}} = -\eta^{IM}_{ink}\varphi_{ink} \tag{11}$$

**Proof:** see the Theoretical Appendix.

Normally the pass-through rate $\eta^{IM}_{ink}$ lies between [0,1]. From Equation (11), an appreciation of the home currency (increase in $e_{nk}$) reduces labor demand through the substitution effect. When the home currency appreciates, imported inputs become cheaper relative to labor, inducing firms to use more intermediate inputs and less labor. The percentage change of labor is higher for firms whose initial input structure is more skewed towards imported materials. We refer to $\varphi_{ink}$ as firm $i$'s *import intensity* of inputs from country $k$. Also, the substitution effect is larger if changes in $e_{nk}$ have a larger effect on the price of imported inputs denominated in home currency (implied by a larger $\eta^{IM}_{ink}$). If the home-currency price of imported inputs does not respond to exchange rates, employment will not respond either.[9]

Next we investigate the scale effect, $\frac{\partial \ln Y_{in}}{\partial \ln e_{nk}}$. Since firms (potentially) sell to multiple destinations, changes in exchange rate $e_{nk}$ affect output by affecting product demand in both domestic and international markets. In order to highlight the different mechanisms driving the changes in total output, we rewrite $\frac{\partial \ln Y_{in}}{\partial \ln e_{nk}}$ as the

[8] Mathematically, $\varphi_{ink} = (\int_{J_{0,i}} (U_{nkj}/e_{nk})M_{inkj}dj)/TC^*_{in}$, and $\eta^{IM}_{ink} = -\frac{d \ln \frac{\overline{U}_{nk}}{e_{nk}}}{d \ln e_{nk}}$

[9] Note that our expression of $\frac{\partial \ln MC^*_{in}}{\partial \ln e_{nk}}$ is slightly different from Amiti et al. (2014). We explictly write out the term $\eta^{IM}_{ink}$ in order to highlight its potential effect in reducing the impact of exchange rates on employment through the import cost channel.

weighted average of three components that respectively reflect the impact of bilateral exchange rate on quantity sold; in the domestic market, in the export destination country $k$ (directly pertinent to bilateral exchange rate $e_{nk}$), and in all "third countries" denoted by $c$.

$$\frac{\partial \ln Y_{in}}{\partial \ln e_{nk}} = s_{inn}\frac{\partial \ln q_{inn}}{\partial \ln e_{nk}} + s_{ink}\frac{\partial \ln q_{ink}}{\partial \ln e_{nk}} + \sum_{c \notin \{n,k\}} s_{inc}\frac{\partial \ln q_{inc}}{\partial \ln e_{nk}} \tag{12}$$

where $s_{inv}$ ($v \in \{n, k, c\}$) is the (quantity-based) share of sales to market $v$ over total sales.[10]

Generally, changes in bilateral exchange rates can affect quantity demanded in each market through several channels. First, exchange rate changes affect the firm's export price denominated in the destination's local-currency, either through changing the costs of imported inputs, changing the competitive stance in the destination market, or changing the difference between the local-currency and producer-currency denominated export price. Second, exchange rates shift the demand curve faced by the firm by changing the price index in the firm's destination markets. These channels are summarized in the following proposition on the scale effect.

**Proposition 2** ***Scale effect.*** *The exchange-rate-induced scale effect, measured by the elasticity of firm-level output to bilateral exchange rate $e_{nk}$, is related to the firm's import intensity from country k ($\varphi_{ink}$), share of exports to country k over total sales ($s_{ink}$), and the interaction between the firm's share of domestic sales($s_{inn}$) and the import penetration ratio of country k ($M_{kn}$).*[11]

$$\frac{\partial \ln Y_{in}}{\partial \ln e_{nk}} = \alpha_{ink}\varphi_{ink} - \beta_{ink}s_{ink} - \gamma_{nk}s_{inn}M_{kn} \tag{13}$$

where $\alpha_{ink}$, $\beta_{ink}, \gamma_{nk} \ > 0$ are functions of elasticities of substitution, the elasticity of markup to price, as well as the exchange rate pass-through into the prices of final goods and intermediate inputs .[12]

**Proof:** see the Theoretical Appendix

The three terms in Equation (13) reflect different channels transmitting exchange rate shocks to employment by changing the scale of production. (1) The first term captures the impact of exchange rate changes on output

[10] Mathematically, $s_{inv} = \frac{q_{inv}}{\sum\limits_{v} q_{inv}}$

[11] The import penetration ratio $M_{kn}$ is the aggregate market share of firms from country $k$ in market $n$. Mathmatically, $M_{kn} = \sum\limits_{i \in \Omega_{kn}} S_{ikn}$, where $\Omega_{kn}$ denotes the set of firms from $k$ exporting to country $n$.

[12] Specifically, $\alpha_{in} = \sigma\frac{\eta^{IM}_{ink}}{1+\overline{\Gamma}_{in}}$ , $\beta_{ink} = \sigma\widetilde{\eta}^{e_{nk}}_{ink}$, $\gamma_{nk} = (\sigma - \eta)\overline{\eta}^{e_{nk}}_{kn}$, where $\overline{\Gamma}_{in}$ is the cross-market average of the elasticity of markup to prices. $\widetilde{\eta}^{e_{nk}}_{ink}$ is the exchange rate pass-through after purging the impact of imported intermediate inputs. $\overline{\eta}^{e_{nk}}_{kn}$ is the cross-firm average of the exchange rate pass-through into the price denominated in country n's currency.

through changing the cost of imported inputs (*the import cost channel*). Note that it is positive. An appreciation of the home currency against the currency of country $k$ lowers the home-currency price of inputs imported from country $k$, which further drives down a firm's marginal cost and lead to output expansion. The more the firm relies on imported inputs from country $k$ (as reflected by a larger $\varphi_{ink}$), the larger is the output expansion. (2) The second term captures the impact of exchange rate shocks on output by changing the local-currency export price in the destination market $k$ (*the export price channel).* It is negative. Given the home-currency export price, an appreciation of the home currency raises the export price denominated in the export destination's local currency, leading to contractions in output. The impact is larger for firms that are more reliant on exports in market $k$ (as reflected by a larger $s_{ink}$). (3) The third term captures the impact of $e_{nk}$ on output through changing the level of import competition in the domestic market (*the import competition channel*). It is also negative. An appreciation of the home currency reduces the home-currency price of exporters from country $k$, driving down the price index in the home market and thus reducing the output of domestic firms. The impact is larger if a higher proportion of the domestic market has been occupied by exporters from country $k$ (as reflected by a larger $M_{kn}$), and if the firm has a higher orientation towards the domestic market (as reflected by a larger $s_{inn}$).

Combining the substitution effect in Equation (11) and the scale effect in Equation (13) leads to the following proposition on the elasticity of employment to bilateral exchange rate $e_{nk}$:

**Proposition 3** *The elasticity of employment to bilateral exchange rate $e_{nk}$ can be written as a function of import intensity from country $k$ ($\varphi_{ink}$), the share of exports to country $k$ over total sales ($s_{ink}$), and the interaction between firm's share of domestic sales ($s_{inn}$) and the import penetration ratio of country $k$ ($M_{kn}$).*

$$\frac{\partial \ln L_{in}}{\partial \ln e_{nk}} = (\alpha_{ink} - \eta_{ink}^{IM})\varphi_{ink} - \beta_{ink}s_{ink} - \gamma_{nk}s_{inn}M_{kn} \tag{14}$$

where $\alpha_{ink}$, $\beta_{ink}, \gamma_{nk}$ $> 0$ are defined in Proposition 2.

**Proof:** Combining Equation (11) and (13)

Equation (14) combines the substitution effect and the scale effect in Proposition 1 and 2. The interpretations of the export share term and the import penetration term are identical to Proposition 2. One thing to note is the sign of the import intensity term. Without further restrictions on the values of structural parameters in the model, the sign of this term is generally ambiguous given that $\alpha_{in} > 0$ and $\eta_{ink}^{IM} > 0$. Intuitively, an appreciation of the home currency reduces the home-currency price of intermediate inputs. This has two offsetting effects on labor. On the one hand, given a fixed output, firms will substitute imported inputs for labor, reducing labor demand. On the other hand, the output expansion resulting from the fall in marginal cost will push up labor demand. The net impact will depend on the relative magnitude of the substitution effect and the scale effect.

The solutions for $\alpha_{ink}$, $\beta_{ink}, \gamma_{nk}$ respectively reveal the structural determinants of the relationship between employment and import intensity, export share, and import penetration ratio. Specifically,

$$\alpha_{ink} = \eta_{ink}^{IM} \frac{\sigma}{1 + \overline{\Gamma}_{in}} \tag{15}$$

$$\beta_{ink} = \sigma \widetilde{\eta}_{ink}^{e_{nk}} \tag{16}$$

$$\gamma_{nk} = (\sigma - \eta) \overline{\eta}_{kn}^{e_{nk}} \tag{17}$$

where $\eta_{ink}^{IM}$ is the exchange rate pass-through into imported input prices, $\overline{\Gamma}_{in}$ is the elasticity of markup to prices[13], $\widetilde{\eta}_{ink}^{e_{nk}}$ is the exchange rate pass-through into firm $i$'s price to market $k$ (in country $k$'s currency), after purging the impact of imported intermediate inputs, and $\overline{\eta}_{kn}^{e_{nk}}$ is the exchange rate pass-through into country $k$ exporters' price to country $n$ (in country $n$'s currency).[14]

Generally, the elasticity of employment to exchange rate shocks are related to two factors: the demand elasticity (which in the CES demand system is also the elasticity of substitution) and the pass-through rates. A higher demand elasticity and a higher pass-through implies higher response of employment to exchange rate shocks. A point to note is the coefficient for the export price channel in Equation (14). The relevant pass-through here is the pass-through rate *after purging the impact of imported intermediate inputs ($\widetilde{\eta}_{ink}^{e_{nk}}$)*. This is because part of the exchange rate pass-through arises from the impact of the exchange rate on the imported inputs costs (see proof of the exchange rate pass-through in the Theoretical Appendix), and this part of pass-through is already captured by the import intensity term in Equation (14).

## 2.5 Linking employment to firm-specific effective exchange rates

Once we have the elasticity of employment to each bilateral exchange rate, we can derive a relationship between firm-level employment changes and exchange rate shocks in all of the firm's related markets. According to Equation (9), a firm's employment changes can be expressed as a function of exchange rates in all of its export destinations, import sources, and impor-competing countries, which we denote by vector $\mathbf{e}_n$, as well as other

[13]Precisely, $\overline{\Gamma}_{in}$ is some average of the elasticity of markup to prices across firm i's related markets. We denote the average with a bar. See the Theoretical Appendix for details.

[14]Precisely, it is some average across all firms in country $k$ exporting to country $n$.

exogenous variables such as wages and intermediate input prices. i.e. $L_{in} = L_{in}(\mathbf{e}_n, w, V^*, U)$. Log linearize and aggregate across all the related markets, we can express the log changes of employment as:

$$\begin{aligned}\Delta \ln L_{in} &= (\alpha_{in} - \overline{\eta}_{in}^{IM})(\sum_k \varphi_{ink} \Delta \ln e_{nk}) - \beta_{in}(\sum_k s_{ink} \Delta \ln e_{nk}) \\ &\quad - \gamma_n s_{inn}(\sum_k M_{kn} \Delta \ln e_{nk}) + \mathbf{\Gamma Z}_n \end{aligned} \tag{18}$$

where $\alpha_{in}$, $\beta_{in}$ and $\gamma_n$ are respectively some cross-country average of $\alpha_{ink}$, $\beta_{ink}$ and $\gamma_{nk}$ defined in Proposition 2, $\overline{\eta}_{in}^{IM}$ is some cross-country average of $\overline{\eta}_{ink}^{IM}$.[15] $\mathbf{\Gamma Z}_n = \Gamma_w \Delta \ln W_n^* + \Gamma_u \Delta \ln V^*$ denotes the impact of exogenous changes of wages and input prices on employment.

In order to better illustrate the intuition behind this result, note that we can rewrite the firm-country level export (import) intensity as the product of firm-level export (import) intensity and firm-country level export (import) share. Thus, we can express the relation in Equation (18) in terms of effective exchange rates. Let us rewrite Equation (18) as follows:

$$\begin{aligned}\Delta \ln L_{in} &= (\alpha_{in} - \overline{\eta}_{in}^{IM})\varphi_{in} \Delta IMFEER - \beta_{in}\chi_{in} \Delta EXFEER \\ &\quad - \gamma_n(1 - \chi_{in}) \Delta IMPEER + \mathbf{\Gamma Z}_n \end{aligned} \tag{19}$$

with

$$\Delta IMFEER = \sum_k \omega_{ink}^M \Delta \ln e_{nk} \tag{20}$$

$$\Delta EXFEER = \sum_k \omega_{ink}^X \Delta \ln e_{nk} \tag{21}$$

$$\Delta IMPEER = \sum_k M_{kn} \Delta \ln e_{nk} \tag{22}$$

where $\varphi_{in}$ and $\chi_{in}$ are firm-level import and export intensity, and $\omega_{ink}^M$ ($\omega_{ink}^X$) is the share of imports from

[15] Specifically, $\beta_{in}$ satisfies $\beta_{in}(\sum_k s_{ink} \Delta \ln e_{nk}) = \sum_k \beta_{ink} s_{ink} \Delta \ln e_{nk}$, and $\gamma_n$ satisfies $\gamma_n(\sum_k M_{kn} \Delta \ln e_{nk}) = \sum_k \gamma_{nk} M_{kn} \Delta \ln e_{nk}$,

(exports to) country $k$ over total imports (exports).[16] $M_{kn}$ is the import penetration ratio of country $k$ in country $n$. Thus, Equation (19) links firm-level employment changes to three measures of effective exchange rate shocks using different trade shares as weights: the imported-weighted effective exchange rates ($\Delta IMFEER$), export-weighted effective exchange rates ($\Delta EXFEER$), and import-penetration exchange rates ($\Delta IMPEER$).

The first three terms in Equation (19) respectively reflect the impact of exchange rate changes on employment through the import cost channel, export price channel and the import competition channel. The magnitude of each channel will depend on the external orientation of the firm, as reflected in its import and export intensity, $\varphi_{in}$ and $\chi_{in}$.

One innovative result that distinguishes Equation (19) from those in Nucci and Pozzolo (2010) is that $\Delta IMFEER$ and $\Delta EXFEER$ are firm-specific. Because firms are different in the distribution of their imports and exports across trading partners, the effective exchange rate shocks related to each firm should be different. These effective exchange rate measures at the firm level are constructed in our empirical analysis.

## 2.6 Labor adjustment costs

Our previous analysis rests on the assumption that labor can be fully and costlessly adjusted. However, at the heart of the labor literature is that labor adjustment is slow and subject to substantial costs (Nickell, 1986; Hamermesh and Pfann, 1996). Incorporating labor adjustment costs into our model will not change the direction of the previously discussed transmission channels, yet it is important to quantitatively match the predictions of the theory with the estimates of employment sensitivity to exchange rates in our data. Proposition 3 shows that the sensitivity of employment to exchange rates will be determined by the demand elasticity and the exchange rate pass-through. Given that the conventional estimate of demand elasticity is around 4-10 (Broda and Weinstein, 2006), and of the exchange rate pass-through around 0.2-0.6 (Campa and Goldberg, 2005; Burstein and Gopinath, 2014), the sensitivity of employment to exchange rates as predicted by the model will be much larger than our benchmark estimates, most of which mostly fall into the range of 0.3-0.5. We believe this reflects the intrinsic nature of a slow labor adjustment caused by the costs of hiring and firing workers.

Following Campa and Goldberg (2001) and Nickell (1986), we assume labor adjustment costs are a quadratic function of changes in labor: $c(\Delta L_{in}) = w\frac{b}{2}\Delta L_{in}^2$.[17] The parameter $b$ reflects the degree of labor adjustment

[16] Mathematically, $\varphi_{in} = \sum_{k\neq n}\varphi_{ink}$, $\chi_{in} = \sum_{k\neq n} s_{ink}$, $\omega_{ink}^M = (\int_{J_{0,i}} (U_{nkj}/e_{nk})M_{inkj}dj)/(\sum_{k\neq n}\int_{J_{0,i}} (U_{nkj}/e_{nk})M_{inkj}dj)$, $\omega_{ink}^X = \frac{p_{ink}^* q_{ink}}{\sum_{k\neq n} p_{ink}^* q_{ink}}$

[17] We adopt this type of adjustment costs mainly because of its simplicity and its adequacy in delivering the message that adjustment costs reduce the response of labor to current shocks. This message will hold if we consider other forms of adjustment costs, such as fixed costs and asymmetric costs for firing and hiring workers.

costs. When such dynamic adjustment costs are present, reaction of current employment will not only depend on the current exchange rate shocks, but also the expected value of future exchange rate shocks. To facilitate empirical implementation, we follow Campa and Goldberg (2001) and assume that exchange rates follow a random walk, so that the current exchange rate is the best predictor of future exchange rates. Under this assumption, the actual level of employment can be written as a function of the lagged level of employment and the optimal level of current employment in the absence of adjustment costs, that is,

$$\ln L_{int} = \mu \ln L_{int-1} + (1-\mu) \ln \widetilde{L}_{int} \tag{23}$$

where $\widetilde{L}_{int}$ is the level of employment in the absence of adjustment costs expressed in Equation (19). $\mu \in [0,1]$ is an increasing function of labor adjustment costs $b$, so a larger $\mu$ implies larger adjustment costs and smaller responses of current employment to shocks. Taking first difference of Equation (23) and substituting in the expression of $\widetilde{L}_{int}$ in Equation (19), we get the final expression of the actual changes of employment when adjustment costs are present.

$$\begin{aligned} \Delta \ln L_{int} &= \mu \Delta \ln L_{in,t-1} + \beta_{1,in}\varphi_{in}\Delta IMFEER + \beta_{2,in}\chi_{in}\Delta EXFEER \\ &\quad + \beta_{3,n}(1-\chi_{in})\Delta IMPEER + \widetilde{\mathbf{\Gamma}}\mathbf{Z}_n \end{aligned} \tag{24}$$

with $\beta_{1,in} = (1-\mu)[(\alpha_{in} - \overline{\eta}_{in}^{IM})$, $\beta_{2,in} = -(1-\mu)\beta_{in} < 0$ and $\beta_{3,in} = -(1-\mu)\gamma_n < 0$, and $\widetilde{\mathbf{\Gamma}} = (1-\mu)\mathbf{\Gamma}$.[18]

This is the main equation to be estimated in the subsequent empirical analysis.

### 2.7 Calibration

According to Equation (24), the coefficients $\beta_1$,$\beta_2$, $\beta_3$ can be written as functions of the structural parameters in the model. By assigning reasonable values to the parameters, we can predict from the model a sensible value for $\beta_1$,$\beta_2$, $\beta_3$ which can be contrasted against our estimates in the empirical analysis.

The parameters required to recover $\beta_1$~$\beta_3$ are: the elasticities of substitution within-sector($\sigma$) and cross-sector($\eta$), the pass-through rate of Chinese exports purged of the effects of imported input costs ($\widetilde{\eta}_n^e$), the pass-through rate of Chinese imports of final goods ($\overline{\eta}_n^e$), the pass-through rate into imported input price ($\overline{\eta}_{in}^{IM}$),

[18] One thing to note is that these parameters are derived under the assumption that all exchange rate shocks are permanent. As noted in Campa and Goldberg (2001), the parameters before these exchange rate terms are increasing in the degree of permanence of the shock. If exchange rate shocks are transitory, the employment response will be a fraction of the employment adjustment arising from a permanent exchange rate shock.

the elasticity of markup to prices ($\Gamma_{inn}$), as well as the labor adjustment costs ($\mu$). For most of the parameters, we will assign two sets of values, one delivering small $\beta_1$~$\beta_3$, and another delivering large $\beta_1$~$\beta_3$. By changing the value of parameters one at a time, we can track the change of coefficients and get a sense of the sensitivity of the coefficients to different parameters.

For within-sector elasticity of substitution, our conservative choice (referring to the parameter value that delivers small coefficients) is 4, which is close to the median of the import demand elasticities for China estimated in Broda, Greenfield and Weinstein (2006). The liberal choice (referring to the parameter value that delivers large coefficients) is 7, which is close to the mean elasticity for China in Imbs and Mejean (2010). There are much fewer estimates for cross-sector elasticity. We take the value of 1 following Atkeson and Burstein (2008).

For exchange rate pass-through rates, we need to assign values to the pass-through rate of Chinese imports of final goods ($\overline{\eta}_n^e$), the pass-through rate into imported input price($\overline{\eta}_{in}^{IM}$), and the pass-through rate of Chinese exports purged of the effects of imported input costs ($\widetilde{\eta}_n^e$). For $\overline{\eta}_n^e$, ideally we would need the data for the exchange rate pass-through into retail price of imported final goods. Unfortunately, to our knowledge the estimates for this are unavailable. As an alternative, we use the exchange rate pass-through into import prices at the dock as our liberal value and the exchange rate pass-through into CPI of tradeables as our conservative value. The actual value of $\overline{\eta}_n^e$ may well be lower than the exchange rate pass-through into import prices at the dock because of the presence of local distribution costs, but higher than the pass-through into CPI because CPI includes the price of domestic good and services which are less sensitive to exchange rate changes. We choose a liberal value of 0.64, which is the point estimate of pass-through into import prices for China in Shu and Su (2009). The choice of the conservative value is 0.2, which is close to the median for the long-run exchange rate pass-through into CPI for eight countries as reported in Burstein and Gopinath (2014).[19] For $\overline{\eta}_{in}^{IM}$, we are not aware of any studies that specifically investigate the exchange rate pass-through into price of intermediate inputs. However, considering that the local distribution costs are likely to be lower for intermediate inputs than for final goods (Burstein and Gopinath,2014), we take a slightly higher pass-through rate than $\overline{\eta}_n^e$. We chose 0.7 as the liberal value and 0.25 as the conservative value.

For the value of exchange rate pass-through for China exports purged of the effects of imported input costs ($\widetilde{\eta}_n^e$), we chose a liberal value of 0.66 and a conservative value of 0.22 based on the following considerations. First, like $\overline{\eta}_n^e$, we rely on pass-through into import prices for the liberal approach and pass-through into consumer price for the conservative approach. For pass-through into import prices, we take the value of 0.6 in Campa and Goldberg (2005) for OECD countries considering that most of China's exports are directed to these countries.

[19] We realize that the passthrough into CPI is likely to be somewhat lower than the passthrough into the retail price of imported goods because CPI includes the price of domestic good and services which are less sensitive to exchange rate changes.

For the pass-through into consumer price, we take 0.2 from Burstein and Gopinath (2014). Second, we need to recover the pass-through rate from which the impact of imported inputs has been removed. Our calculation is based on Amiti et al. (2014), which shows that lowering the import intensity from the highest quartile to the lowest quartile raises the pass-through rate by about 10% (from 0.85 to 0.93).[20] Multiplying the original pass-through rate by (1+10%) we get the liberal value of 0.66 and a conservative value of 0.22.

For the elasticity of markup to prices, $\Gamma_{inn}$, we take a liberal value of 0.0015 and a conservative value of 0.0017. The reason is that in our model which is based on Atkeson and Burstein (2008), the elasticity of markup to prices is an increasing function of market share.[21] In our ASIF data, the average market share of a firm in a 4-digit CIC industry is around 0.002. Given the values of $\sigma$ and $\eta$ for the corresponding approach we can get the value for $\Gamma_{inn}$. Note that the two different values for $\Gamma_{inn}$ are very similar, so they make little difference to the results.

For the labor adjustment costs parameter $\mu$, we choose 0.47 as the liberal value and 0.69 as the conservative value. Both numbers are obtained from Arellano and Bond (1991) which estimates a dynamic employment equation derived from a model with labor adjustment costs, using alternative specifications.

Table 1 summarizes the choice of parameter values, and reports the corresponding value of $\beta_1$~$\beta_3$ implied by the theory. Moving from Column (1) to (4), we change the value of labor adjustment costs, the pass-through rates, and the demand elasticity from conservative to liberal one at a time. In Column (1), the theory implies that the coefficients before the imported input term ($\beta_1$), export term ($\beta_2$) and the import competition term ($\beta_3$) are respectively 0.23, -0.27 and -0.19 for the most conservative parameters values (low demand elasticity, low pass-through, high adjustment costs). Column (2) lowers the labor adjustment costs, keeping other parameters unchanged. The coefficients increased in magnitude to 0.40, -0.47, and -0.32 for $\beta_1$~$\beta_3$, respectively. Column (3) raises the pass-through rates. The choice of the pass-through rates have a large impact on the coefficients. The coefficients almost tripled as we move from the conservative to the liberal pass-through rates. Finally, Column (4) raises the within-sector elasticity of substitution, and the coefficients almost double compared with Column (3). Comined together, the demand elasticity, the pass-through rates and the labor adjustment costs explain a vast amount of the sensivitiy of employment to exchange rates.

One thing to note is the coefficient before the imported input term, $\beta_1$. The theory showed that the sign of this coefficient is generally ambiguous, depending on the relative magnitude of the substitution effect and the scale effect. However, given conventional values of the structural parameters in the model, $\beta_1$ is positive in all of our parameter value experiments. In other words, the scale effect always dominates the substitution effect.

[20] see Column (3) of Table (A1) in Amiti et al.(2014)

[21] specifically, $\Gamma_{inn} = \frac{S_{inn}}{(\frac{\sigma}{\sigma-\eta} - S_{inn})(1 - \frac{\sigma-\eta}{\sigma-1} S_{inn})}$

This is because the scale effect is magnified by the demand elasticity and is thus usually large in number than the substitution effect.

Before closing the theoretical section, some words of caution are needed. In our empirical analysis, we generally find a small sensitivity of employment to exchange rate changes, with the coefficients before the exchange rate terms lying between 0.3-0.5. In our calibration exercise, we attribute this small sensitivity to the low degree of exchange rate pass-through and to a low demand elasticity. However, it should be noted that some alternative explanations also exist. For instance, in the current model we assumed that all exchange rate shocks are permanent. If the exchange rate shocks involve some transitory component, the theory-predicted employment sensitivity will only be a fraction of what we have obtained. Another assumption of the model is that the labor adjustment costs took a quardratic form, so we can capture it in our regression with a lagged employment term. However, in reality there may also exist other types of labor adjustment costs (e.g. the fixed costs) that can not be completely captured by the lagged employment term. A theory incorporating these additional adjustment costs may generate a smaller employment sensitivity to exchange rates than what we have.

# 3 Empirical Strategy

The main equation we are going to estimate is Equation (24). We specify an empirical counterpart of Equation (24) at the firm-level as follows:

$$\begin{aligned} \Delta \ln L_{it} \quad = \quad & \beta_0 + \beta_1 \varphi_{i,t-1} \Delta IMFEER_{it} + \beta_2 \chi_{i,t-1} \Delta EXFEER_{it} \\ & + \beta_3 (1 - \chi_{i,t-1}) \Delta IMPEER_{jt} + \beta_4 \Delta \ln L_{i,t-1} + \beta_5 \Delta \ln W_{it} + \nu_j + \lambda_t + \varepsilon_{it} \end{aligned} \tag{25}$$

Where $\varphi_{i,t-1}$ and $\chi_{i,t-1}$ are respectively firm-level import intensity and export intensity, lagged for one period to avoid potential endogeneity.[22] $\Delta IMFEER_{it}$, $\Delta EXFEER_{it}$, are respectively the changes of import-weighted effective exchange rate and export-weighted effective exchange rate, both of which are firm-specific. $\Delta IMPEER_{jt}$ is the change of import-penetration-weighted effective exchange rate constructed at the industry level. Lagged changes in log employment ($\Delta \ln L_{i,t-1}$) and changes in log wages are included according to Equation (24). In our theory, intermediate input prices are considered to be exogenous variables. However, if these variables are also affected by exchange rates through general equilibrium effects and are correlated with employment growth, omitting them in the regression will bias our estimates. To address this concern, we include

[22] We also experiment with making $\varphi$ and $\chi$ time-invariant. The results are reported in the robustness section.

year fixed effects ($\lambda_t$) to capture the possible general-equilibrium relationship between domestic input prices and exchange rates. Lastly, we include a full set of 4-digit CIC industry dummies ($v_j$) to absorb the industry-specific trends in employment changes and to ensure that our identification is based on cross-firm variations within narrowly defined industries. In some specifications we will experiment with including more demanding fixed effects, such as industry-year fixed effects and firm fixed effects.

The regression Equation (25) is a structural relationship emerging from the theoretical model in Section 2. The coefficients $\beta_1$, $\beta_2$ and $\beta_3$ capture the impact of exchange rates on employment through the input cost channel ($\beta_1$), export price channel ($\beta_2$) and import competition channel ($\beta_3$). In theory, these coefficients can vary by firm, but our approach can been seen as estimating a weighted average of the corresponding effects across firms. According to the theory, the sign of $\beta_1$ is generally ambiguous. However, given reasonable values of the model's structural parameters, we expect it to be positive (see the calibration section). $\beta_2$ and $\beta_3$ are expected to be negative. In addition, the absolute value of $\beta_1$-$\beta_3$ should be increasing in demand elasticity, the pass-through rate (for final goods and imported inputs), and decreasing in labor adjustment costs. We will explore some of these heterogeneity across sectors in Section 5.

Regarding the identification strategy, the coefficients of $\beta_1$ and $\beta_2$ are identified from the cross-firm variations in two dimensions. The first dimension is the cross-firm variation in external orientation, which is reflected by the import intensity ($\varphi$) and export intensity ($\chi$). The second dimension is the cross-firm variation in effective exchange rates, which further stemmed from the cross-firm variations in the distribution of trade over trading partners, as well as the cross-country variation in exchange rate movements. Previous studies such as Nucci and Pozzolo (2010) exploited the first variation but ignored the second. $\beta_3$ is identified from cross-firm variation in domestic orientation $(1-\chi)$ and industry-time variation in import penetration effective exchange rates.

Since our regressors include a lagged dependent variable, it is necessary to estimate Equation (25) by generalized methods of moments (GMM). As GMM-type instruments we selected the lagged value of employment in levels dated period t-2 and earlier. Hansen test of over-identifying restrictions and the test for second-order serial correlation are performed to ensure that the selection of instruments is appropriate.

# 4 Data and summary statistics

## 4.1 Data

**Firm-level data.** Our firm-level data comes from the Annual Survey of Industrial Firms conducted by the National Bureau of Statistics of China during 2000-2006. This data set includes all State Owned Enterprises (SOE) and those Non-State Owned Enterprises with annual sales of RMB five million (or equivalently, about

$650,000) or more. Compared with the full firm census data in 2004, the ASIF data covers 72% of the industrial workforce and 90% of output. The data provides detailed information on firm's identification, ownership, industry classification, and around 80 balance sheet variables. Variables of particular use in our paper include number of employees, total wage bills, total sales, domestic sales and profit.

**Trade data.** The second data source is the transaction-level trade data from China's General Administration of Customs during 2000-2006. The data covers the universe of China's exporters and importers. Export and import values are reported at the firm-level by product (HS 8-digit) and by destination or source country. The original data is recorded monthly, but we aggregate it to the annual level in order to match with the ASIF. This data set allows us to calculate firm-level exports by destination and imports by source country, which will be used to construct firm-specific effective exchange rates.

**Match the two data sets.** We match the ASIF data with the customs trade data using firm name, telephone number and zip code. The merged data sets account for 54% of China's total exports and 50% of total imports over this period (see Appendix for a detailed description of the matching procedures).

**Exchange rate and price index data.** Nominal exchange rate data is obtained from International Financial Statistics (IFS) for 175 of China's trading partner countries during 2000-2006. We also extract the consumer price index data in Penn World Tables 7.0 in order to construct real exchange rates.

**Sample.** We dropped observations if they meet any of the following criterion: (1) reporting missing or negative for any of the following variables: total sales, total revenue, total employment, capital, intermediate inputs. (2) less than 8 employees. (3) total export value or import value in the customs data is larger than total sales in ASIF. (4) in non-manufacturing sectors. We also dropped all state-owned-enterprises considering that the firing and hiring decisions of SOEs are highly restricted by central planning.[23] The filtered sample includes 254,559 observations for 66,289 firms, accounting for 85% of observations in the unfiltered merged data. We report the summary of the sample in Table A1 in the Appendix. A point of note is that since our matching is based on firm rather than firm-year, we have the employment record of the matched firms for all years they are active in ASIF, including the years before they enter the export (import) market and the years after they quit exporting (importing). This is important for two reasons. First, our theory applies regardless of whether changes of exports and imports occur at the extensive margin or intensive margin, thus it is necessary to include both margins in our empirical analysis. Second, even when firms neither export nor import, their employment can still be affected by exchange rate changes through the import competition channel. In all the regressions, we set firm export and import value to zero for years no trade transaction is recorded in the customs data.[24]

[23] In the robustness section we also consider the sample with SOEs. There is little changes in results because SOE only account for 3% of firms in our matched sample.

[24] Theoretically, we should also include firms with no trade transactions throughout the sample period (i.e. the unmatched firms)

## 4.2 Construction of variables

Fundamental to our empirical analysis is the construction of effective exchange rate changes and export and import intensity.

Following Equation (20) and (21), we construct the export-weighted and import-weighted effective exchange rates at the firm level, using export ($EX_{ik,t-1}$) and import ($IM_{ik,t-1}$) values by firm-country in the customs data, and bilateral real exchange rate changes ($\Delta \ln e_{kt}$) from IFS:[25]

$$\Delta EXFEER_{it} = \sum_k (EX_{ik,t-1} / \sum_k EX_{ik,t-1}) \Delta \ln e_{kt} \tag{26}$$

$$\Delta IMFEER_{it} = \sum_k (IM_{ik,t-1} / \sum_k IM_{ik,t-1}) \Delta \ln e_{kt} \tag{27}$$

where all trade variables are lagged for one period to avoid potential endogeneity.

Another effective exchange rate variable is the change of import-penetration weighted effective exchange rate, which is constructed following Equation (22) for each industry $j$.

$$\Delta IMPEER_{jt} = \sum_k \left( \frac{IM_{jk,t-1}}{DOMSALE_{jt-1} + \sum_k IM_{jk,t-1}} \right) \Delta \ln e_{kt} \tag{28}$$

$IM_{jk,t-1}$ is China's aggregate import value from country $k$ in industry $j$(CIC 4-digit), which we obtain from the full customs data.[26] $DOMSALE_{jt-1}$ is total domestic sales, which are aggregated from firm level to industry level based on the full ASIF data. Thus $\frac{IM_{jk,t-1}}{DOMSALE_{jt-1}+\sum_k IM_{jk,t-1}}$ is the import penetration ratio from country k in China's domestic market.[27]

The other two key variables are export intensity ($\chi_{i,t-1}$) and import intensity ($\varphi_{i,t-1}$), which are constructed by dividing total exports and import value from the customs data by total sales in ASIF for each firm.[28] Like

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because the employment of these firms can also be affected by exchange rates through the import competition channel. Practically, however, treating all unmatched firms as non-trading firms is associated with some risk. First, since we merge the ASIF and the customs data based on firm name, zip code and telephone number, imperfect matching is possible. Thus, we can not guarantee that the unmatched firms are necessarily non-exporters or non-importers. Second, firms may export or import through trade intermediaries. These indirect exporters (importers) will not be matched because they have no transaction records in the customs data. If we assume that the probability of switching trade mode (direct/indirect) is low, by restricting the sample to firms that have directly traded at least once in our sample period, we can ensure that the exporting and importing status in our sample is precise.

[25] The main reason of using real exchange rates for the benchmark regressions is to facilitate comparison with the existing studies like Campa and Goldberg (2001) and Nucci and Pozzolo (2010), which examined the response of employment to real exchange rate changes. Results using nominal exchange rates are qualitatively similar. During our sample period, the real and nominal effective exchange rate changes (at the aggregate level) has a high correlation of 0.89.

[26] To map HS to CIC, we use a concordance between HS 6-digit and CIC 4-digit. The concordance takes into account the revision of HS code in 2002 and the revision of CIC in 2003.

[27] Note that the weights don't sum to one because we don't include domestic sales in the numerator. However, adding the domestic sales back will not change the results because exchange rate changes ($\Delta \ln e_{kt}$) are always zero for RMB against itself.

[28] value of exports and imports in the original customs data are donominated in the U.S. dollar while sales in ASIF are in yuan. We convert them to the same currency using the yearly dollar-RMB exchange rates.

the effective exchange rate measures, we also lag these variables for one period to alleviate endogeneity.

$$\chi_{i,t-1} = \frac{\sum_k EX_{ik,t-1}}{SALES_{i,t-1}} \tag{29}$$

$$\varphi_{i,t-1} = \frac{\sum_k IM_{ik,t-1}}{SALES_{i,t-1}} \tag{30}$$

### 4.3 Summary statistics

Table 2 reports the summary statistics of the key variables. Firms in our sample exhibit considerable variations in external orientation. On the one hand, there are firms that have no connections to both the export and import markets. The 5th percentile of the export intensity and import intensity distribution are both zero. On the other hand, some firms are highly reliant on foreign markets for sales and for sourcing inputs. The firms at the 95th percentile of the export intensity and import intensity distribution exports 94% of its total output and imports 60% of its input. This suggests that the impact of a given exchange rate shock can have substantial variation across firms. Another source of variation we explore for identification is the variation of export-weighted and import-weighted effective exchange rate changes. In Table 2, the coefficient of variation for the export-weighted effective exchange rate changes is 15 (0.91/0.06), and that for the import-weighted effective exchange rate changes is 23 (0.92/0.04), suggesting substantial variability.

One feature of these firm-specific effective exchange rates is that they exhibit a higher degree of variation across firms than the effective exchange rates constructed at more aggregate levels. To show this, Column (1) to (3) in Table 3 reports the mean and the standard deviation of the export-weighted effective exchange rate changes constructed at the firm level, industry level, and aggregate (country) level, respectively.[29] Although the mean of the effective exchange rates at various aggregation levels show highly consistent movements[30], they differ considerably in their variation across firms. The standard deviation for firm-specific effective exchange rate changes are normally 2-3 times larger than the industry-specific effective exchange rate changes, while the aggregate effective exchange rate changes exhibit no cross-firm variation at all.

The differences in the variation of effective exchange rate changes across aggregation levels are ultimately reflected in the variation of firms' exchange rate exposure on the export and the import side. We define export (import) exchange rate exposure as the product of the firm's export (import) intensity and export-weighted (import-weighted) effective exchange rate changes, i.e. $\chi_{i,t-1}\Delta EXFEER_{it}$ ($\varphi_{i,t-1}\Delta IMFEER_{it}$). Figure 1

[29] Results for import-weighted effective exchange rate changes are qualitatively similar.

[30] except one year(2005) in which the firm-level effective exchange rate increased but the aggregate exchange rate decreased.

plots the distribution of exchange rate exposure constructed using firm-specific, industry-specific and aggregate effective exchange rate changes in 2006. It is clear that the exchange rate exposure constructed using firm-specific effective exchange rate changes exhibit larger variations than the one constructed using industry-specific effective exchange rate changes, which is yet more variable than the one constructed using aggregate-level effective exchange rate changes. This ranking holds well for exchange rate exposure on both the export and import side. Since the variation of the export and import intensity are identical across aggregation levels, the differences in the variation of exchange rate exposure purely stemmed from the differences in the variation of the effective exchange rate changes. In sum, the firm-specific effective exchange rates provide more cross-firm variations which could be utilized to identify the impact of exchange rate changes in our firm-level investigation.

Figure 2 reports the firm's exchange rate exposure through the import competition channel. A large variation across firms is evident. One source of this variation comes from the difference of firm's reliance on domestic sales $(1-\chi_{i,t-1})$, and the other source comes from the changes in the import-penetration weighted effective exchange rates across industry and over time. According to Table 2, the import-penetration weighted effective exchange rate changes also exhibit a high degree of variability, with a variation coefficient of 10.

# 5 Results

## 5.1 Baseline results

Table 4 reports the estimation results of Equation (25). We start with an OLS regression without including the lagged difference of log employment in Column (1). We include industry and year fixed effects. We get a coefficient of -0.33 for the export term, and 0.23 for the import term, both of which are significant at 1% level. The coefficient before the import penetration term also has the expected sign, but is insignificant. In Column (2), we add the lagged difference of log employment and estimated the equation by GMM.[31] The coefficient before the export term increase to -0.42 and the coefficient before the import term increase to 0.33. The coefficient before the import penetration term increases to -0.21 and becomes marginally significant. Lagged employment growth has a coefficient of 0.49. In Column (3), we replaced the industry and year fixed effects with the more demanding industry-year fixed effects. This specification accounts for the possibility that the impact of exchange rate on wages and input prices resulting from the general equilibrium effects are industry-specific, for instance, due to industry-specific factor market frictions. In Column (4), we included even more demanding firm fixed effects to absorb other possible firm-specific trends in employment growth. The results are qualitatively similar, with

[31] Note that the sample size shrinks a bit because once the lagged log difference of employment is included, the sample is restricted to firms that have at least three years of consecutive data.

the magnitude of the coefficient slightly larger for the specification with firm fixed effects. In sum, the results are consistent with the predicitons of the model. Appreciation of the home currency increases firm employment by lowering the costs of imported inputs, and reduces employment by raising the local-currency export price as well as by intensifying the import competition in the domestic market. The magnitude of the coefficients are also sensible. Comparing the point estimate of each coefficient with its corresponding theory-predicted value as reported in Table 1, it can be seen that all the coefficients of interest fit into the range suggested by the theory. The estimates are closest to the values in Column (2) of Table 1, where we assigned a demand elasticity of 4, a labor adjustment costs of 0.47 (which is also similar to the estimate of $\mu$ in our data), and pass-through rates of around 0.2-0.25.

How large is the employment response to exchange rates implied by these estimates? We assess this by assuming that the RMB appreciated against all other currencies by 10%. This corresponds to a 10% increase for the export-weighted effective exchange rates and import-weighted effective exchange rates, and a 1.3% increase for the import-penetration weighted effective exchange rates.[32] We feed in the point estimates of the coefficients before the three exchange rate exposure terms in our preferred specification in Column (2) of Table 4, and conduct a back-of-envelope calculation. According to Equation (24), the resulting employment response is dependent on firm's external orientation as reflected in export and import intensity. First, consider a firm with average level of external orientation. We set the export intensity at 0.24 and import intensity at 0.11 (corresponding to the sample average of the export intensity and import intensity distribution). For this hypothetical firm with average degree of external orientation, a 10% effective appreciation of the RMB is associated with an employment reduction of 0.85%. Decomposing this net employment change into subcomponents reflecting different channels of transmission, employment increases by 0.36% due to cheaper imported inputs, decreases by 1% due to higher local-currency export price, and decreases by 0.21% due to intensified import competition. So the export price channel contributes most to the employment reduction, but is partially offset by the increases in employment through the import cost channel.

Second, we investigate the employment response of a less internationalized firm. Export and import intensity are both set at 0 (corresponding respectively to the 5th percentiles of the export intensity and import intensity distributions). For this firm, that neither exports nor imports, the entire effect of exchange rate changes on employment is through the import competition channel. A 10% appreciation of the home currency is associated

[32] According to Equation (28), if all bilateral exchange rates increase by 10%, the import-penetration-weighted effective exchange rates will increase by 10%$\times$ (the combined import penetration ratio of all foreign countries), i.e. $\frac{\sum_k IM_{jk,t-1}}{DOMSALE_{jt-1}+\sum_k IM_{jk,t-1}}$. The median of the combined import penetration ratio across industry-year in our data is 0.13.

with an employment reduction of 0.27%. Thus, for firms that have no connections to the international markets, the impact of exchange rates is small.

Finally, consider a firm with high degrees of internationalization. We set export intensity at 0.94 and import intensity at 0.6 (corresponding respectively to the 95th percentiles of the export intensity and import intensity distributions). A 10% appreciation reduces the firm's employment level by 2%. Employment increases by 1.97% through the import cost channel, decreases by -3.95% through the export price channel, and a negligible -0.02% change through the import competition channel. Thus, for a highly internationalized firm, exchange rates can have a sizable impact on their employment.

It is useful at this moment to compare our results with those in the existing literature. Qualitatively, our estimation results generally verified the results in the existing literature on the export channel and the import costs channel. Nucci and Pozzolo (2010) found the responses of employment appreciations against export trade partners are associated with employment reductions, and appreciations against import partners are associated with employment increases, a result similar to ours. On the import competition side, Nucci and Pozzolo (2010) and Ekholm et al. (2010) found the impact through the import competition channel is significant. The evidence for the import competition channel in our study is somewhat weaker.

Quantitatively, the baseline results suggest that for the hypothetical firm with an average degree of external orientation, a 10% effective appreciation of the RMB is associated with an employment reduction of 0.85%. For comparison, Nucci and Pozzolo (2010) found that a 10% effective appreciation is associated with a net employment reduction of 0.5% for a hypothetical firm exhibiting median value of international exposure. Ekholm et al. (2010) found that the 20% real appreciation of the Krone is associated with a 1.2% - 1.6% change in employment growth. In Campa and Goldberg (2001), the average effect is not significantly different from zero. Thus our estimates confirm the quantitative findings in the existing empirical literature that the impact of exchange rates on employment is small on average.

We also calculate the predicted employment response of firms trading with different countries that experienced different exchange rate shocks. We consider three of China's major trading partners that experienced starkly exchange rate movements in our sample period: U.S., Japan, and Germany. During 2000 to 2005 (a period in which China pegged the RMB to the US dollar), the real exchange rate of the RMB against the US dollars depreciated by a slight 0.24% due to relative price changes. At the same time, the RMB depreciated by 8.96% against the Japanese Yen while appreciated by 24.4% against the Euro. This implies that the employment response of firms trading with these different countries can have substantial variation. To show this, we fix the firm's export intensity and import intensity at our sample average, and feed in the estimates of Column (2) of

Table 4, as well as the actual change of the bilateral exchange rate against these countries. For a firm that only exports to and imports from the US, its employment will increase only slightly by 0.02% due to exchange rate movements. In the meantime, a typical firm which only exports to and imports from Germany will have a predicted employment reduction of 2.11%. Finally, for a firm that only exports to and imports from Japan, employment will increase by 0.77%. In summary, the predicted employment response will exhibit considerable variation if we take into account the heterogeneity of firms in terms of their distribution of trade across countries.

## 5.2 Robustness checks

We conduct a series of checks to ensure that our baseline results are robust to an alternative weighting scheme, the inclusion of additional controls, allowing for exchange rates to have dynamic effects, and the selection of subsamples.

**Weights.** In the baseline specification all trade weights in the effective exchange rate measures are lagged for one period to avoid potential endogeneity. As an alternative, we make all the trade shares time-invariant by taking their year-average during 2000-2006. The results in Column (1) of Table 5 suggest that using time-invariant weights does not qualitatively change the results. The magnitude of coeficients are slightly smaller than the baseline results.

**Additional controls.** We follow Nucci and Pozzolo (2010) and include the first difference of log sales and firm markup as additional controls. A theoretical justification for including these variables is that they capture the impact of other firm-specific and time-varying idiosyncratic shocks that we do not explicitly consider in the model. We constructed measures of firm-level markup as in Keller and Yeaple (2009)[33]. The results in Column (2) of Table 5 suggests that for the export and import terms, the baseline results still hold qualitatively, but the coefficient before the import penetration term becomes insignificant. As expected, sales growth is positively correlated with growth in employment. Changes in markup has little effect.

**Lagged exchange rates.** In theory, the exchange rate pass-through can be quite different in the short-, medium- and long- run, leading to different employment responses to exchange rate at different time horizons. The use of annual data in our study can shed light on the medium- and long-run effect of exchange rates on employment. As the literature typically investigates exchange rate pass-through in a time window of two years, we add one period lag to the three effective exchange rate changes to capture the potential long-run effect of exchange rates on employment. The result is reported in Column (3) of Table 5. The coefficients before the current exchange rate changes are very similar to the baseline. Lagged export- and import- weighted exchange

[33]Specifically, markup is defined as sales over sales minus profit, $markup_{it} = \frac{sales_{it}}{sales_{it} - profit_{it}}$

rate changes also have an impact on employment in the direction predicted by the theory, but the magnitude is only 1/4 of the current exchange rate changes. The coefficient before import-penetration weighted exchange rate is positive and not statistically significant. Therefore, the effect of a permanent change of exchange rate on employment will in the long run (two years) increase by 25% via the export and import channel than the medium run (one year).

**Firms with different trade status.** Our theoretical model applies to exporters and importers, as well as firms that neither export nor import. For the former, exchange rate changes affect employment through all the channels highlighted in the theoretical section. For the latter, only the import competition channel is at work. We run the regression separately for the two groups of firms to check whether both groups are affected by exchange rate changes as predicted by the model. Column (4) of Table 5 reports the results for observations with positive exports and imports. The import cost channel and the export price channel still have a significant impact, while the impact through import competition is not significant. Column (6) restricts the sample to observations with neither exports nor imports. Note that for this subsample we can no longer include the export interaction nor the import interaction term because export intensity and import intensity exhibits no cross-firm variation. The coefficient before the import-competition term is identified by the variation of the import-penetration weighted effective exchange rate changes across industry-year. The results suggest an insignificant impact through import penetration, but the direction of the coefficient is consistent with the theory's prediction.

**Including state-owned enterprises.** We dropped all state owned firms in the baseline regression in order to ensure that our empirical results can be extrapolated to other countries. In Column (6) of Table 5 we add back these SOEs. It can be seen that including SOEs causes few changes to the results.

## 5.3 Results using effective exchange rates at more aggregate levels

One methodological innovation in our empirical analysis is that we construct effective exchange rate changes at the firm level to measure the exchange rates shocks pertaining to individual firms. In contrast, the existing studies on the topic usually use effective exchange rates constructed at more aggregate levels, such as industry-specific effective exchange rates or country-level effective exchange rates. As we showed in the theory section, a theory-consistent measure of the exchange rate shocks pertaining to each firm is the firm-specific effective exchange rate changes. Using exchange rate changes at more aggregate levels as a proxy can potentially lead to an attenuation bias as they fail to take into account the firm's distribution of trade across trade partners. Moreover, the use of firm-level effective exchange rate changes provides one additional source of cross-firm variation and thus has the potential benefit of increasing the precision of the estimation.

In order to empirically assess how the firm-level effective exchange rates perform compared with their aggregate counterparts in terms of consistency and precision in firm-level investigations, we redo the baseline regression but now replace the firm-level effective exchange rate changes (for both export-weighted and import-weighted) with their aggregate counterparts.[34] The results are reported in Table 6. In Column (1), we used industry-specific effective exchange rate changes at CIC 4-digit level so that effective exchange rate changes are now identical to all firms within an industry.[35] Using the industry-specific effective exchange rates, we still find a significant impact of exchange rates on employment through the export price channel and a marginally significant effect through the import competition channel, in the direction predicted by the theory. However, the estimate for the import cost channel has a sign that is opposite to the theoretical predictions, and is not significant. Thus, compared with industry-specific effective exchange rates, the results using firm-level effective exchange rates are more consistent with the theory and are more precisely estimated. In Column (2) we use country-level effective exchange rate changes as reported in IFS to replace the firm-level export-weighted and import-weighted effective exchange rate changes. The results are similar to those obtained using industry-specific effective exchange rates, with the coefficient before the import cost term having the opposite sign to the theory predictions, and is insignificant. Moreover, the standard errors of the coefficients before the export and import terms are consistently larger than those obtained in our baseline results using firm-level effective exchange rates and the results in Column (1) using industry-level effective exchange rates. This also suggests that using effective exchange rates at more disaggregate levels can help improve the precision of the estimation.

It should be noted that using effective exchange rate changes at the aggregate level, Nucci and Pozzolo (2010) found that both the coefficient before the export and import terms have signs as predicted by our theory. One possible reason why using the aggregate level effective exchange rates works well in their study but not in ours is that the inconsistency resulted from the use of aggregate level effective exchange rate is likely to be more severe in countries like China where the distributions of trading partners vary widely across firms. Another possible reason is that the RMB was pegged to the dollar through much of this sample period and that the aggregate RER does not vary too much (See Table 3). Thus, using aggregate effective exchange rates is possibly more problematic in our current context than the other contexts where the aggregate exchange rate does vary.

[34] The import-penetration weighted effective exchange rates is still at the industry level.

[35] To construct industry-specific effective exchange rate changes, we use the log difference of the relevant bilateral real exchange rate of China's trading partners, and trade partner weightsd defined by the lagged share of each partner countries in the total export or import value of each individual CIC 4-digit industry. We use the HS-CIC concordance to map trade values in the customs data at HS 6-digit level to CIC 4-digit level.

# 6 Further Discussions

## 6.1 Industry heterogeneity: the role of demand elasticity

We also investigate whether the sensitivity of employment to exchange rates are heterogeneous across industries in some systematic way. According to the theory, the sensitivity of employment to exchange rates is related to demand elasticity, the exchange rate pass-through, and the labor adjustment costs. Here we focus on the role of demand elasticity because the data for demand elasticity at industry level are readily obtainable.

According to the theory, the sensitivity of employment to exchange rates is increasing in demand elasticity. A higher demand elasticity amplifies the response of output to price changes and thus makes employment more responsive to exchange rate changes through the scale effect. We check this theory prediction by exploring the relationship between industry-level demand elasticity and industry-level sensitivity of employment to exchange rates. We divide all manufacturing industries into three groups (a low elasticity group, a medium elasticity group and a high elasticity group) with equal number of industries according to the trade elasticity estimates in Broda, Greenfield and Weinstein (2006).[36][37] We run the baseline regression for each group of industries.

Column (1) to (3) of Table 7 reports the results for low elasticity industries, medium elasticity industries and high elasticity industries, respectively. The results are highly consistent with the theory predictions: the sensitivity of employment to exchange rates increases as we move from low to medium to high elasticity industries. The senstivitity for the high elasticity group is approximately 2 to 3 times larger than those for the low elasticity group, depending on the specific transmission channel. We do not expect the difference of estimates across elasticity groups to exactly match the difference of elasticity because sectors can also differ in the other factors determining the sensitivity of employment to exchange rates, such as labor adjustment costs and pass-through rate. However, the theoretical prediction that the sensitivity of employment to exchange rates is increasing in demand elasticity is born out very well in the data.

## 6.2 Asymmetric response to appreciations and depreciations

We also explore whether the response of employment to exchange rates are asymmetric for appreciations and depreciations. Asymmetric responses to appreciations and depreciations may arise because of different labor adjustment costs of hiring and firing workers. Empirical estimates in the labor literature generally suggest that adjustment costs are higher for firing workers than for hiring workers (Pfann and Palm, 1993; Abowd and

[36] The data in Broda, Greenfield and Weinstein (2006) is for 3-digit HS products. We use a HS-CIC concordance to map them to CIC 4-digit industries.

[37] The median of elasticity for the low elasticity group, medium elasticity group and high elasticity group is 2.45, 3.38 and 7.04, respectively.

Kramarz, 2003). An implication of this is that the sensitivity of employment to exchange rates should be larger when the exchange rate changes lead to employment expansions (job creation) than employment contractions (job destruction). For example, consider the import cost channel. An appreciation of the home currency increases labor demand while a depreciation reduces labor demand. Since it is more costly to reduce than to increase labor, employment should be more responsive to exchange rate appreciations than to exchange rate depreciations. This implies a larger impact of the import cost effect ($\beta_1$) in appreciations than in depreciations. By the same token, the impact of the export price effect ($\beta_2$) should be larger in depreciations than in appreciations. Also, the import competition effect ($\beta_3$) should be larger in depreciations than in appreciations.

In order to check whether these predictions are born out in the data, we divide the sample into an "appreciation group" and a "depreciation group", based on the direction of their effective exchange rate changes. Since our main equation includes three measures of effective exchange rate changes, which may have different signs for the same year, we need to choose a criteria for an observation to be included in the appreciation group or depreciation group. Our preferred criteria is as follows. An observation is included in the appreciation (depreciation) group if at least one of the three effective exchange rate change measures suggests an appreciation (depreciation), and none of the three effective exchange rate measures suggests a depreciation (appreciation). For example, if the export-weighted effective exchange rate change is positive, and the import-weighted effective exchange rate change is zero (e.g. for a firm that never imports), we will include this observation in the appreciation group. This criteria allows us to include observations that only export or import, or observations that neither export nor import (in which case only the import-penetration weighted exchange rate suggests appreciation or depreciation).[38]

We run the baseline regression for the appreciation group and the depreciation group separately. The results in Table 8 provide strong support for the asymmetric response to appreciations and depreciations, in the expected way. The coefficient before the export term is larger in depreciations, suggesting that, through the export price channel depreciations have a larger impact on labor than appreciations. In contrast, appreciations have a larger impact on labor than depreciations through the import cost channel. Also, depreciations have a larger employment impact than appreciations through the import competition channel. In sum, all the evidence is consistent with the hypothesis that employment is more responsive to exchange rates when the exchange rate changes lead to employment expansions as opposed to employment contractions, due to higher adjustment costs of firing than hiring workers.[39]

[38] An alternative approach is to include observations with appreciations for all of the three effective exchange rate measures. However, adopting this approach will restrict the sample to observations that both export and import. This substantially reduces the sample size.

[39] Consistent with the hypothesis of higher adjustment costs of firing workers, Moser et al. (2010) found that the employment in the German manfacturing sector responded to real exchange rate changes mainly through job creation rather than job destruction.

# 7 Conclusion

This paper investigates how exchange rate shocks affect the employment of individual firms. We develop a theoretical model linking firm employment changes to exchange rate shocks in the firm's export destinations, import sources, and import-competing countries. The model provides a theoretical foudation of firm-specific effective exchange rate changes on both the output and input side. The model also shed lights on the various mechanisms transmitting exchange rate shocks to employment changes. Exchange rate shocks affect employment by changing the cost of imported inputs, the export price denominated in the local-currency, and the competitive stance in the domestic market, with the magnitude of each transmission channel depending on a firm's external orientation. The predictions of the model are tested using comprehensive matched Chinese firm-level data combining employment with trade information. Effective exchange rates are constructed at the firm level on both export and import sides. We find evidence that both qualitatively and quantitatively supports the theory's predictions . Effective appreciations against export destinations are associated with reductions in employment, while effective appreciations against import source countries are associated with increases in employment. There is weak evidence that exchange rates affect employment by changing the competitive stance in the domestic market. In general, the impact of exchange rate shocks on employment is small, but there is some degree of heterogeneity among firms with different degrees of internationalization.

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# 8 Appendix (online only)

## 8.1 Theoretical Appendix

### 8.1.1 Proof of Proposition 1 (the substitution effect)

For brevity, we drop the firm identifier $i$ and the home country identifier $n$. Firms minimize total cost given by

$$W^*L + \int_0^1 V_j^* Z_j dj + \int_{J_{0,i}} (\sum_k e_k U_{kj} M_{kj}) dj \tag{A1}$$

subject to (4)-(6). Let $\lambda, \psi, \zeta$ denote the lagrangian multiplier of Equation (4)-(6), respectively. The first order conditions are respectively:

$$\begin{aligned} W^* &= (1-\phi)\lambda Y/L \\ \psi &= \lambda\phi Y/X \\ \zeta &= \psi\gamma_j X/X_j && j \in [0,1] \\ V_j^* &= \zeta(X_j/Z_j)^{\frac{1}{1+\varepsilon}} && j \in [0,1] \\ U_{kj}/e_k &= \zeta(X_j/M_{kj})^{\frac{1}{1+\varepsilon}} && j \in J_0,\ k \neq n \end{aligned}$$

substitue and rearrange we can rewrite as

$$\begin{aligned} W^*L &= (1-\phi)\lambda Y \\ V_j^* X_j &= \lambda\phi\gamma_j Y(X_j/Z_j)^{\frac{1}{1+\varepsilon}} && j \in [0,1] \\ \frac{U_{kj}}{e_k V_j^* Z_j} &= (\frac{U_{kj}}{e_k V_j^*})^{-\varepsilon} && j \in J_0,\ k \neq n \end{aligned}$$

Combining the last expression with (6) we can get $X_j = Z_j[1 + \sum_k (\frac{U_{kj}}{e_k V_{nj}^*})^{-\varepsilon}]^{\frac{1+\varepsilon}{\varepsilon}}$ for $j \in J_0$

Marginal cost of the firm can be solved as

$$MC^* = \lambda = \frac{1}{\Omega}(\frac{\exp\{\int_0^1 \gamma_j \ln(\frac{V_j^*}{\gamma_j})dj\}}{\phi \exp\{\int_{J_0} \gamma_j \ln b_j dj\}})^{\phi}(\frac{W^*}{1-\phi})^{1-\phi} = \frac{C^*}{B^{\phi}\Omega} \tag{A2}$$

where

$$C^* = (\frac{\exp\{\int_0^1 \gamma_j \ln(\frac{V_j^*}{\gamma_j})dj\}}{\phi})^{\phi}(\frac{W^*}{1-\phi})^{1-\phi}$$

$$B = \exp\{\int_{J_0} \gamma_j \ln b_j dj\} \tag{A3}$$

with

$$b_j = [1 + \sum_k (\frac{U_{kj}}{e_{nk}V_{nj}^*})^{-\varepsilon}]^{\frac{1}{\varepsilon}} \tag{A4}$$

import intensity from country $k$ is equal to

$$\varphi_k = \frac{\int_{J_0}(U_{kj}/e_k)M_{kj}dj}{\lambda Y} = \phi\int_{J_0}\gamma_j(\frac{(\frac{U_{kj}}{e_k V_j^*})^{-\varepsilon}}{1+\sum_k(\frac{U_{kj}}{e_k V_j^*})^{-\varepsilon}})dj \tag{A5}$$

where we used the first order conditions to substitute $(U_{kj}/e_k)M_{kj}$ as an expression of $\lambda Y$.

The elasticity of marginal cost with respect to bilateral exchange rate $e_{nk}$ can be shown as

$$\frac{\partial \ln MC^*}{\partial \ln e_k} = \frac{\partial \ln \lambda}{\partial \ln B}\frac{\partial \ln B}{\partial \ln e_k} = -\phi\int_{J_0}\gamma_j\frac{\partial \ln b_j}{\partial \ln e_k}dj \tag{A6}$$

Substituting in the expression of $b_j$ in Equation (A4), we get

$$\frac{\partial \ln MC^*}{\partial \ln e_k} = \phi\eta_{ink}^{IM}\int_{J_0}\gamma_j(\frac{(\frac{U_{kj}}{e_k V_j^*})^{-\varepsilon}}{1+\sum_k(\frac{U_{kj}}{e_k V_j^*})^{-\varepsilon}})dj \tag{A7}$$

where $\eta_{ink}^{IM} = -\frac{\partial(U_{kj}/e_k)}{\partial e_k} > 0$ is the passthrough rate of exchange rates into home-currency based price of imported inputs.

.

Combining (A5) and (A7) yields Equation (11) in the main text.

### 8.1.2 Proof of passthrough rate

**Passthrough of $e_{nk}$ to $p_{ink}$** Start with the expression for local-currency based price.

$$p_{ink} = (\mu_{ink} MC^*_{in}) e_{nk} \tag{A8}$$

totally differentiate to get

$$d \ln p_{ink} = d \ln \mu_{ink} + d \ln MC^*_{in} + d \ln e_{nk} \tag{A9}$$

Changes in markups can be expressed as

$$d \ln \mu_{ink} = -\Gamma_{ink}(d \ln p_{ink} - d \ln P_k) \tag{A10}$$

where $\Gamma_{ink}$ is the elasticity of markup with respect to prices, $\frac{\partial \ln \mu_{ink}}{\partial \ln p_{ink}}$

Using the expression of marginal cost in Equation (A2), changes in marginal cost is equal to

$$d \ln MC^*_{in} = d \ln \frac{C^*}{\Omega_i} - \phi d \ln B_i \tag{A11}$$

where $\phi d \ln B_i = \phi \int\limits_{J_{i,0}} (\gamma_j d \ln b_j) dj$

Substituting the expression of $b_j$ in Equation (A4) to get

$$d \ln b_j = -\sum_k \gamma_j \left( \frac{(\frac{U_{kj}}{V^*_{nj} e_{nk}})^{-\varepsilon}}{1 + \sum\limits_k (\frac{U_{kj}}{V^*_{nj} e_{nk}})^{-\varepsilon}} \right) d \ln \left( \frac{U_{jk}}{V^*_j e_{nk}} \right) \tag{A12}$$

Thus,

$$\begin{aligned} \phi d \ln B_i &= \phi \int\limits_{J_{i,0}} (\gamma_j d \ln b_j) dj \\ &= -\sum_k (\varphi_{ink} d \frac{\overline{U}_k}{\overline{V}^* e_{nk}}) - \phi \sum_k [\int\limits_{J_{i,0}} \gamma_j ( \frac{(\frac{U_{kj}}{V^*_{nj} e_{nk}})^{-\varepsilon}}{1 + \sum\limits_k (\frac{U_{kj}}{V^*_{nj} e_{nk}})^{-\varepsilon}} )(d \ln \frac{U_{jk}}{\overline{U}_k} - d \ln \frac{V^*_j}{\overline{V}^*}) dj] \end{aligned}$$

substitute this into the expression of $d \ln MC^*_{in}$ we get

$$d\ln MC^*_{in} = \sum_k \varphi_{ink} d\ln \frac{\overline{U}_k}{\overline{V}^* e_{nk}} + d\ln \frac{C^*}{\Omega_i} + \epsilon_i^{MC} \tag{A13}$$

where $\epsilon_i^{MC} = \phi \sum_k [\int_{J_{i,0}} \gamma_j (\frac{(\frac{U_{kj}}{V^*_{nj} e_{nk}})^{-\varepsilon}}{1+\sum_k (\frac{U_{kj}}{V^*_{nj} e_{nk}})^{-\varepsilon}})(d\ln \frac{U_{jk}}{\overline{U}_k} - d\ln \frac{V^*_j}{\overline{V}^*})dj - d\ln \frac{\Omega_i}{\Omega}$.

Inserting Equation (A13) in to Equation (A9) and rearrange terms we get

$$d\ln p_{ink} = \frac{1}{1+\Gamma_{nk}} d\ln e_{nk} + \sum_k \frac{1}{1+\Gamma_{nk}} \varphi_{ink} d\ln \frac{\overline{U_k}}{\overline{V}^* e_{nk}} + \frac{1}{1+\Gamma_{nk}} \epsilon_{ink} \tag{A15}$$

where $\epsilon_{ink} = \epsilon_i^{MC} + \Gamma_{ink} d\ln P_k + d\ln \frac{C^*}{\Omega_i}$ , $\Gamma_{nk}$ is the elasticity of markups to prices evaluated at some average exporter to country k.

Divide by $d\ln e_{nk}$, we get the exchange rate elasticity of local-currency based import price

$$\frac{d\ln p_{ink}}{d\ln e_{nk}} = -\gamma_{ink}\varphi_{ink} + \widetilde{\eta_{ink}^{e_{nk}}} \tag{A16}$$

where $\gamma_{ink} = \frac{1}{1+\Gamma_{nk}} \eta_{ink}^{IM}$ , where $\eta_{ink}^{IM} = -\frac{d\ln \frac{\overline{U}_k}{e_{nk}}}{d\ln e_{nk}} > 0$ is the exchange rate passthrough into the price of imported intermediate inputs. $\widetilde{\eta_{ink}^{e_{nk}}} = \frac{1}{1+\Gamma_{nk}}(1 + \frac{d\epsilon_{ink}}{de_{nk}})$ is the passthrough rate *after purging the impact of imported intermediate inputs.*

**Passthrough of $e_{nk}$ to $p_{inn}$** Analagous to Equation (A14), the differential of log $p_{inn}$ can be exressed as

$$d\ln p_{inn} = -\Gamma_{inn}(d\ln p_{inn} - d\ln P_n) + \sum_k \varphi_{ink} d\ln \frac{\overline{U}_k}{\overline{V}^* e_{nk}} + d\ln \frac{C^*}{\Omega_i} + \epsilon_i^{MC} \tag{A17}$$

Rearrange and divide by $d\ln e_{nk}$ to get

$$\frac{d\ln p_{inn}}{d\ln e_{nk}} = -\frac{1}{1+\Gamma_{inn}} \eta_{ink}^{IM} \varphi_{ink} + \widetilde{\eta_{inn}^{e_{nk}}} \tag{A18}$$

where $\widetilde{\eta_{inn}^{e_{nk}}} = \frac{1}{1+\Gamma_{nk}} \frac{d\epsilon_{inn}}{de_{nk}}$ and $\epsilon_{inn}$ is defined analogously as $\epsilon_{ink}$.

**Passthrough of $e_{nk}$ to $p_{inc}$** For the elasticity of $p_{inc}$ $(c \neq n, k)$ with respect to $e_{nk}$,

$$d\ln p_{inc} = -\Gamma_{inc}(d\ln p_{inc} - d\ln P_c) + \sum_k \varphi_{ink} d\ln \frac{\overline{U}_k}{\overline{V}^* e_{nk}} + d\ln \frac{C^*}{\Omega_i} + \epsilon_i^{MC} \tag{A19}$$

Combine and rearrange terms to get

$$d\ln p_{inc} = \frac{\Gamma_{inc}}{1+\Gamma_{inc}} d\ln P_c + \frac{1}{1+\Gamma_{inc}}\left(\sum_k \varphi_{ink} d\ln \frac{\overline{U}_k}{\overline{V}^* e_{nk}} + d\ln \frac{C^*}{\Omega_i} + \epsilon_i^{MC}\right) \tag{A20}$$

assume $\frac{d\ln P_c}{d\ln e_{nk}} = 0$ and divide by $d\ln e_{nk}$ to get

$$\frac{d\ln p_{inc}}{d\ln e_{nk}} = -\frac{1}{1+\Gamma_{inc}} \eta_{ink}^{IM} \varphi_{ink} \tag{A21}$$

### 8.1.3 Proof of Proposition 2 (the scale effect)

Start by decomposing the exchanage rate elasticity of total output into weighted average of the exchange rate elasticity of sales in the home country, the export destination k directly pertaining to $e_{nk}$, and all "third countries":

$$\frac{\partial \ln Y_{in}}{\partial \ln e_{nk}} = s_{inn} \frac{\partial \ln q_{inn}}{\partial \ln e_{nk}} + s_{ink} \frac{\partial \ln q_{ink}}{\partial \ln e_{nk}} + \sum_{c \notin \{n,k\}} s_{inc} \frac{\partial \ln q_{inc}}{\partial \ln e_{nk}} \tag{A22}$$

where $s_{inv} = \frac{q_{inv}}{\sum_a q_{ina}}$ $(v \in \{n, k, c\})$ is the (quantity-based) share of sales to market $v$ over total sales.

**Exchange rate elasticity of sales in third countries** From (1), $q_{inc} = p_{inc}^{-\sigma} P_c^{\sigma-\eta} D_c$. Taking $D_c$ as given, we can get

$$\frac{\partial \ln q_{inc}}{\partial \ln e_{nk}} = -\sigma \frac{\partial \ln p_{inc}}{\partial \ln e_{nk}} + (\sigma - \eta) \frac{\partial \ln P_c}{\partial \ln e_{nk}} \tag{A23}$$

**Assumption:** exchange rate between two countries does not affect the competitive stance in the third countries, i.e.$\frac{\partial \ln P_c}{\partial \ln e_{nk}} = 0$.

Combining this assumption with the passthrough equation (A21) to get

$$\frac{\partial \ln q_{inc}}{\partial \ln e_{nk}} = \eta_{ink}^{IM} \frac{\sigma}{1+\Gamma_{inc}} \varphi_{ink} \tag{A24}$$

**Exchange rate elasticity of sales in export destination k.** Using the demand function in Equation (1) to get

$$\frac{\partial \ln q_{ink}}{\partial \ln e_{nk}} = -\sigma \frac{\partial \ln p_{ink}}{\partial \ln e_{nk}} + (\sigma - \eta) \frac{\partial \ln P_k}{\partial \ln e_{nk}} \tag{A25}$$

Combining passthrough Equation (A16) to get

$$\frac{\partial \ln q_{ink}}{\partial \ln e_{nk}} == -\sigma(\widetilde{\eta_{ink}^{e_{nk}}} - \gamma_{ink}\varphi_{ink}) + (\sigma - \eta) \frac{\partial \ln P_k}{\partial \ln e_{nk}} \tag{A26}$$

**Exchange rate elasticity of sales in domestic market**

$$\begin{aligned} \frac{\partial \ln q_{inn}}{\partial \ln e_{nk}} &= -\sigma \frac{\partial \ln p_{inn}}{\partial \ln e_{nk}} + (\sigma - \eta) \frac{\partial \ln P_n}{\partial \ln e_{nk}} \qquad \text{(A27)} \\ &= -\sigma \frac{\partial \ln p_{inn}}{\partial \ln e_{nk}} + (\sigma - \eta) \, [\sum_{i \in \Omega_{nn}} \frac{\partial \ln P_n}{\partial \ln p_{ikn}} (\frac{\partial \ln p_{ikn}}{\partial \ln e_{nk}}) + \widetilde{M}_{nn} + \widetilde{M}_{cn}] \\ &= -\sigma \frac{\partial \ln p_{inn}}{\partial \ln e_{nk}} + (\sigma - \eta) [\sum_{i \in \Omega_{kn}} S_{ikn} \eta_{ikn}^{e_{nk}} + \widetilde{M}_{nn} + \widetilde{M}_{cn}] \end{aligned}$$

where $\widetilde{M}_{nn} = \sum_{i \in \Omega_{nn}} \frac{\partial \ln P_n}{\partial \ln p_{inn}} (\frac{\partial \ln p_{inn}}{\partial \ln e_{nk}})$ and $\widetilde{M}_{cn} = \sum_{i \in \Omega_{cn}} \frac{\partial \ln P_n}{\partial \ln p_{icn}} (\frac{\partial \ln p_{icn}}{\partial \ln e_{nk}})$ are the aggregate domestic market share of domestic firms and third country exporters (adjusted by passthrough rate). To arrive at the last equality, we used the result $\frac{\partial \ln P_n}{\partial \ln p_{ikn}} = S_{ikn}$ for the CES demand system.

Substituing the expression of $\frac{\partial \ln p_{inn}}{\partial \ln e_{nk}}$ in Equation (A18), we get

$$\frac{\partial \ln q_{inn}}{\partial \ln e_{nk}} = \sigma(\frac{1}{1 + \Gamma_{inn}} \varphi_{ink} - \widetilde{\eta_{inn}^{e_{nk}}}) + (\sigma - \eta) \overline{\eta}_{kn}^{e_{nk}} M_{kn} + (\sigma - \eta)(\widetilde{M}_{nn} + \widetilde{M}_{cn}) \tag{A28}$$

where $\overline{\eta}_{kn}^{e_{nk}}$ is some average passthrough rate that satisfies $\sum_{i \in \Omega_{kn}} S_{ikn} \eta_{ikn}^{e_{nk}} = \overline{\eta}_{kn}^{e_{nk}} M_{kn}$. $M_{kn} = \sum_{i \in \Omega_{kn}} S_{ikn}$ is the aggregate market share of country $k$ firms in market $n$, i.e. the import penetration ratio of country $k$ firms in market $n$.

**Combining all terms** Using the expression of $\frac{\partial \ln Y_{in}}{\partial \ln e_{nk}}$ in Equation (A22), and substituting in the expression of $\frac{\partial \ln q_{inn}}{\partial \ln e_{nk}}$, $\frac{\partial \ln q_{ink}}{\partial \ln e_{nk}}$ and $\frac{\partial \ln q_{ink}}{\partial \ln e_{nk}}$ in (A24), (A26), (A28)

$$\frac{\partial \ln Y_{in}}{\partial \ln e_{nk}} = \Psi_{in} \varphi_{ink} + \Theta_{ink} s_{ink} + \Phi_{nk} s_{inn} M_{kn} + \varepsilon_{in} \tag{A29}$$

where

$$\Psi_{in} = \sigma\eta^{IM}_{ink}(\frac{1}{1+\Gamma_{inc}}s_{inn} + \frac{1}{1+\Gamma_{ink}}s_{ink} + \sum_{c\notin\{n,k\}}\frac{1}{1+\Gamma_{inc}}s_{inc}) > 0,$$

$$\Theta_{ink} = [-\sigma\widetilde{\eta}^{e_{nk}}_{ink} + (\sigma-\eta)\frac{\partial \ln P_k}{\partial \ln e_{nk}}] < 0,$$

$$\Phi = (\sigma-\eta)\overline{\eta}^{e_{nk}}_{kn} > 0,$$

$$\varepsilon_{in} = (\sigma-\eta)s_{inn}(\widetilde{M}_{kn} + \widetilde{M}_{cn}) - \sigma\widetilde{\eta}^{e_{nk}}_{inn}$$

In order to facilitate our empirical analysis, we make the following assumptions to simplify Equation (A29).

**Assumptions:**

(1) There exists some average $\overline{\Gamma}_{in}$ that satisfies

$$\overline{\Gamma}_{in} = \frac{1}{1+\Gamma_{inc}}s_{inn} + \frac{1}{1+\Gamma_{ink}}s_{ink} + \sum_{c\notin\{n,k\}}\frac{1}{1+\Gamma_{inc}}s_{inc}$$

(2) The following interaction terms are close to zero: $s_{inn}\widetilde{M}_{kn}$, $s_{inn}\widetilde{M}_{cn}$, $s_{ink}(\frac{\partial \ln P_k}{\partial \ln e_{nk}})$, $s_{inn}\widetilde{\eta}^{e_{nk}}_{inn}$

With these assumptions, Equation (A29) is reduced to

$$\frac{\partial \ln Y_{in}}{\partial \ln e_{nk}} = \alpha_{in}\varphi_{ink} - \beta_{ink}s_{ink} - \gamma_{nk}s_{inn}M_{kn} \tag{A30}$$

where $\alpha_{in} = \frac{\sigma\eta^{IM}_{ink}}{1+\overline{\Gamma}_{in}}$ , $\beta_{ink} = \sigma\widetilde{\eta}^{e_{nk}}_{ink}$, $\gamma_{nk} = (\sigma-\eta)\overline{\eta}^{e_{nk}}_{kn}$
which is Equation (13) in the main text.

## 8.2 Data Appendix

### 8.2.1 Matching customs data with ASIF

Although both the customs data and the ASIF report firm codes, they come from different administrative systems and have no common elements. Thus we construct a concordance matching the firm code in the customs data (which we will call "id_customs") with the firm code the ASIF (which we will call "id_asif"). We use firm name as the main matching variable and use zip code and telephone number as a supplement. The detailed matching procedure are described as below.

**Match by name.** A straightforward way of matching is to match a id_customs-year observation with a id_asif if they have exactly the same name for the same year. However, the issue with this approach is that sometimes firm names recorded in the two data sets can be slightly different, and in each data set, the name for the same firm might also be slightly changing over time. This may arise because of typos, inaccurate recordings by the administrative staff, and other reasons. For example, a firm may report its name in the customs data as "Beijing ABC Steel Company" in year 2001 and "Beijing ABC Steel Co.Ltd" in year 2002, while in the ASIF, they report the opposite. In this case, no observations will be matched if the matching is based on firm name and year.

To address this issue, we adopt an alternative way of matching. The basic idea is that we do the match based on all names that are ever used by the firm in the two data sets. More precisely, an id_customs will be matched to an id_asif as long as one of the names ever used by this id_customs is also ever used by the id_asif. In our previous example, since "Beijing ABC Steel Company" appeared in the customs data in year 2001 and in ASIF in year 2002, firm codes pertaining to this name will be matched. In other words, we exhaust all combinations of id_customs and id_asif if one of the names pertaining to the id_customs were ever used by the id_asif. This approach allows us more flexibility in the variation of firm names due to typos or inaccurate recordings.

**Match by zip code and telephone number.** The rationale for this matching criteria is that telephone number is unique within a region. We match two firm codes if they have identical zip code and the last seven digits of the telephone number. Using the last seven digits of the telephone number is based on several considerations. First, telephone numbers are reported in different formats in the two data sets. Area codes are included at the beginning of each telephone number in the customs data, but not in ASIF. Taking the last seven digits makes the formats in the two data sets comparable. Second, during the sample period, some large cities changed their telephone numbers from seven to eight digits by adding one digit before the original seven-digit number. As a result, the reported telephone number for the same firm may change over time. Taking the last seven digits solves this problem. We dropped the zip codes and telephone numbers that are inconsistent with China's regulations(e.g. they have only one digit, or contain non-numerical symbols). Finally, similar to the matching by name, we also exhaust all combinations of id_customs and id_asif if one of the zip-telephone pertaining to the id_customs was ever used by the id_asif.

Table 1 Parameter values and implied regression coefficients

| | (1) low elasticity low pass-through high adjustment costs | (2) low elasticity low pass-through low adjustment costs | (3) low elasticity high pass-through low adjustment costs | (4) high elasticity high pass-through low adjustment costs |
|---|---|---|---|---|
| **Parameters** | | | | |
| $\sigma$ | 4 | 4 | 4 | 7 |
| $\eta$ | 1 | 1 | 1 | 1 |
| $\overline{\eta}_n^e$ | 0.2 | 0.2 | 0.64 | 0.64 |
| $\overline{\eta}_{in}^{IM}$ | 0.25 | 0.25 | 0.7 | 0.7 |
| $\widetilde{\eta}_n^e$ | 0.22 | 0.22 | 0.66 | 0.66 |
| $\Gamma_{inn}$ | 0.0017 | 0.0017 | 0.0017 | 0.0015 |
| $\mu$ | 0.69 | 0.47 | 0.47 | 0.47 |
| **Implied coefficients** | | | | |
| $\beta_1$ | 0.232 | 0.397 | 1.113 | 2.222 |
| $\beta_2$ | -0.273 | -0.466 | -1.399 | -2.449 |
| $\beta_3$ | -0.186 | -0.318 | -1.357 | -2.035 |

Note: $\sigma$: the elasticities of substitution within-sector; $\eta$: the elasticities of substitution across-sector; $\overline{\eta}_n^e$: the pass-through rate of imports of final goods; $\overline{\eta}_{in}^{IM}$: the pass-through rate into imported input price; $\widetilde{\eta}_n^e$: the pass-through rate of Chinese exports purged of the effects of imported input costs; $\Gamma_{inn}$: the elasticity of markup to prices; $\mu$ : labor adjustment costs.

Table 2 Summary Statistics

| Variable | Mean | Sd. | 5th pctl. | 95th pctl. |
|---|---|---|---|---|
| $\Delta$ ln(# employees) | 0.040 | 0.362 | -0.470 | 0.616 |
| Export intensity | 0.243 | 0.323 | 0 | 0.937 |
| Import intensity | 0.115 | 0.204 | 0 | 0.607 |
| $\Delta EXFEER$ | -0.006 | 0.091 | -0.152 | 0.105 |
| $\Delta IMFEER$ | -0.004 | 0.092 | -0.156 | 0.152 |
| $\Delta IMPEER$ | -0.002 | 0.021 | -0.036 | 0.024 |
| $\Delta$ ln(wage per worker) | 0.107 | 0.532 | -0.633 | 0.909 |
| $\Delta$ ln(sales) | 0.131 | 0.482 | -0.570 | 0.834 |
| $\Delta$markup | -0.001 | 1.036 | -0.145 | 0.140 |

Note: Export-weighted firm effective exchange rate changes ($\Delta EXFEER$) and import-weighted firm effective exchange rate changes ($\Delta IMFEER$) are respectively calculated according to Equation (26) and (27). Import-penetration-weighted effective exchange rate changes ($\Delta IMPEER$) are constructed according to Equation (28) at 4-digit CIC industry level. Markup= $\frac{sales}{sales-profit}$

Table 3 Mean and standard deviation of effective exchange rates at different aggregation levels

| | (1) | (2) | (3) |
|---|---|---|---|
| Type of EER | Firm-specific | Industry-specific | Aggregate |
| 2001 | .1563 | .1436 | 0.0430 |
| | (.2028) | (.0501) | - |
| 2002 | -.0338 | -.0302 | -0.0231 |
| | (.1435) | (.0647) | - |
| 2003 | -.1195 | -.1156 | -0.0656 |
| | (.1168) | (.0382) | - |
| 2004 | -.0686 | -.0663 | -0.0269 |
| | (.0696) | (.0238) | - |
| 2005 | .0037 | .0063 | -0.0054 |
| | (.0659) | (.0181) | - |
| 2006 | .0300 | .0285 | 0.0157 |
| | (.0660) | (.0185) | - |

Note: Column (1)-(3) respectively report the mean and standard deviation of the firm-specific effective exchange rate changes, industry-specific effective exchange rate changes, and aggregate effective exchange rate changes across firms in the matched data. Industry-specific effective exchange rate changes are constructed at the CIC 4-digit industry level. Aggregate effective exchange rate data is obtained from IFS. Standard deviation in parenthesis.

Table 4 Baseline estimation results

| Dep variable: $\Delta \ln L_{it}$ | (1) OLS | (2) GMM | (3) GMM | (4) GMM |
|---|---|---|---|---|
| $\varphi_{i,t-1} \times \Delta IMFEER_{it}$ | 0.230*** | 0.328*** | 0.344*** | 0.336*** |
| | (0.042) | (0.050) | (0.062) | (0.056) |
| $\chi_{i,t-1} \times \Delta EXFEER_{it}$ | -0.333*** | -0.423*** | -0.421*** | -0.504*** |
| | (0.032) | (0.038) | (0.042) | (0.042) |
| $(1-\chi_{i,t-1}) \times \Delta IMPEER_{jt}$ | -0.055 | -0.211* | -0.056 | -0.323** |
| | (0.088) | (0.117) | (0.163) | (0.129) |
| $\Delta \ln L_{i,t-1}$ | | 0.487*** | 0.485*** | 0.307*** |
| | | (0.018) | (0.017) | (0.053) |
| $\Delta \ln W_{it}$ | -0.215*** | -0.259*** | -0.259*** | -0.240*** |
| | (0.002) | (0.005) | (0.003) | (0.008) |
| Industry FE | Yes | Yes | | |
| Year FE | Yes | Yes | | Yes |
| Industry-year FE | | | Yes | |
| Firm-FE | | | | Yes |
| Hansen-p | | 0.228 | 0.309 | 0.237 |
| AR(2)-p | | 0.379 | 0.342 | 0.174 |
| Observations | 148,890 | 107,828 | 107,828 | 107,828 |

Note: $\Delta \ln L_{it}$: log changes of number of workers. $\chi$: export intensity, $\varphi$ : import intensity. $\Delta EXFEER$, $\Delta IMFEER$ and $\Delta IMPEER$ are respectively export-weighted, import-weighted and import-penetration weighted exchange rate changes defined by Equation (26) to (28). $\Delta \ln W_{it}$ : log difference of wage per worker. Column (1)-(2) include 4-digit CIC industry fixed effects and year fixed effects. Column (3) include industry-year fixed effects. Column (4) include firm fixed effects and year fixed effects. Column (2)-(4) are estimated using generalized methods of moments. Lagged employment levels dated period t-2 and earlier are used as instruments for $\Delta \ln L_{i,t-1}$. Robust standard errors in parenthesis. *, ** and *** correspond to 10%, 5% and 1% significance levels respectively.

Table 5 Robustness checks

| Dep variable: $\Delta \ln L_{it}$ | (1) time-invariant weights | (2) add control variables | (3) add lagged exchange rates | (4) obs. w/ positive exp. & imp. | (5) obs. w/ zero exp. & imp. | (6) including SOEs |
|---|---|---|---|---|---|---|
| $\varphi_{i,t-1} \times \Delta IMFEER_{it}$ | 0.285*** | 0.378*** | 0.301*** | 0.350*** | | 0.297*** |
| | (0.052) | (0.047) | (0.052) | (0.063) | | (0.051) |
| $\chi_{i,t-1} \times \Delta EXFEER_{it}$ | -0.350*** | -0.320*** | -0.453*** | -0.364*** | | -0.425*** |
| | (0.036) | (0.036) | (0.040) | (0.045) | | (0.038) |
| $(1-\chi_{i,t-1}) \times \Delta IMPEER_{jt}$ | -0.079* | 0.004 | -0.219* | -0.126 | -0.238 | -0.109 |
| | (0.042) | (0.109) | (0.123) | (0.192) | (0.252) | (0.115) |
| $\Delta$ lnL$_{i,t-1}$ | 0.474*** | 0.420*** | 0.489*** | 0.501*** | 0.516*** | 0.511*** |
| | (0.017) | (0.017) | (0.018) | (0.029) | (0.035) | (0.017) |
| $\Delta$ lnW$_{it}$ | -0.259*** | -0.273*** | -0.258*** | -0.243*** | -0.277*** | -0.265*** |
| | (0.005) | (0.004) | (0.005) | (0.008) | (0.010) | (0.005) |
| $\Delta$ lnSales$_{it}$ | | 0.214*** | | | | |
| | | (0.004) | | | | |
| $\Delta Markup_{it}$ | | -0.001 | | | | |
| | | (0.001) | | | | |
| $\varphi_{i,t-2} \times \Delta IMFEER_{it-1}$ | | | 0.086* | | | |
| | | | (0.050) | | | |
| $\chi_{i,t-2} \times \Delta EXFEER_{it-1}$ | | | -0.113*** | | | |
| | | | (0.044) | | | |
| $(1-\chi_{i,t-2}) \times \Delta IMPEER_{jt-1}$ | | | 0.015 | | | |
| | | | (0.104) | | | |
| Industry FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Hansen-p | 0.176 | 0.103 | 0.352 | 0.148 | 0.140 | 0.144 |
| AR(2)-p | 0.181 | 0.934 | 0.518 | 0.114 | 0.413 | 0.373 |
| Observations | 113,013 | 107,761 | 103,917 | 39,370 | 22,446 | 111,728 |

Note: Column (1) uses year-average of export shares, import shares and import penetration ratios to construct time-invariant weights of effective exchange rate changes. Export and import intensity are also made time-invariant by taking year-averages. Column (2) includes log difference of sales ($\Delta \ln Sales_{it}$) and changes in markup ($\Delta Markup_{it}$) as additional regressors. Column (3) adds one-year lags of the effective exchange rate changes, interacted with 2-period lagged export and import intensity. Column (4) restricts the sample to observations with positive exports and imports. Column (5) restricts the sample to observations with no exports nor imports. Column (6) includes state owned enterprises (SOEs). All columns are estimated using generalized methods of moments. Lagged employment levels dated period t-2 and earlier are used as instruments for $\Delta \ln L_{i,t-1}$. All regressions include 4-digit CIC industry fixed effects and year fixed effects. Robust standard errors in parenthesis. *, ** and *** correspond to 10%, 5% and 1% significance levels respectively.

Table 6 Results using effective exchange rates at more aggregate levels

| Dep variable: $\Delta \ln L_{it}$ | (1) industry-level exchange rate | (2) aggregate-level exchange rate |
|---|---|---|
| $\varphi_{i,t-1} \times \Delta Industry\_IMEER_{jt}$ | -0.041 | |
| | (0.075) | |
| $\chi_{i,t-1} \times \Delta Industry\_EXEER_{jt}$ | -0.334*** | |
| | (0.057) | |
| $\varphi_{i,t-1} \times \Delta Aggregate\_EER_{t}$ | | -0.019 |
| | | (0.153) |
| $\chi_{i,t-1} \times \Delta Aggregate\_EER_{t}$ | | -0.649*** |
| | | (0.115) |
| $(1-\chi_{i,t-1}) \times \Delta IMPEER_{jt}$ | -0.206* | -0.207* |
| | (0.119) | (0.116) |
| $\Delta \ln L_{i,t-1}$ | 0.495*** | 0.479*** |
| | (0.018) | (0.017) |
| $\Delta \ln W_{it}$ | -0.258*** | -0.259*** |
| | (0.005) | (0.005) |
| Industry FE | Yes | Yes |
| Year FE | Yes | Yes |
| Hansen-p | 0.034 | 0.051 |
| AR(2)-p | 0.142 | 0.071 |
| Observations | 102,634 | 112,925 |

Note: $\Delta Industry\_EXEER_{jt}$ and $\Delta Industry\_IMEER_{jt}$ are respectively export-weighted and import-weighted effective exchange rate changes constructed at 4-digit CIC industry level. $\Delta Aggregate\_EER_{t}$ is aggregate effective exchange rate changes from IFS. All columns are estimated using generalized methods of moments. Lagged employment levels dated period t-2 and earlier are used as instruments for $\Delta \ln L_{i,t-1}$. All regressions include 4-digit CIC industry fixed effects and year fixed effects. Robust standard errors in parenthesis. *, ** and *** correspond to 10%, 5% and 1% significance levels respectively.

Table 7 Sensitivity of employment to exchange rates across industries with different demand elasticities

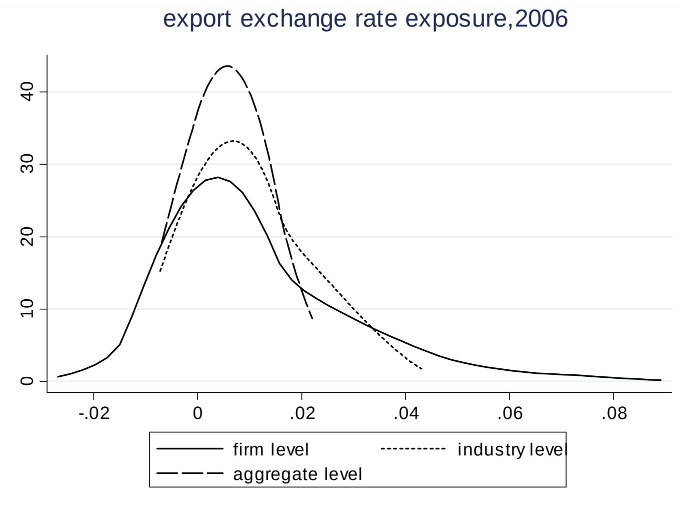
| Dep variable: $\Delta \ln L_{it}$ | (1) low-elasticity industries | (2) medium-elasticity industries | (3) high-elasticity industries |
|---|---|---|---|
| $\varphi_{i,t-1} \times \Delta IMFEER_{it}$ | 0.218** | 0.304*** | 0.611*** |
| | (0.099) | (0.090) | (0.078) |
| $\chi_{i,t-1} \times \Delta EXFEER_{it}$ | -0.308*** | -0.391*** | -0.680*** |
| | (0.076) | (0.059) | (0.062) |
| $(1-\chi_{i,t-1}) \times \Delta IMPEER_{jt}$ | -0.044 | -0.226 | -0.433** |
| | (0.221) | (0.210) | (0.195) |
| $\Delta \ln L_{i,t-1}$ | 0.525*** | 0.469*** | 0.525*** |
| | (0.036) | (0.029) | (0.031) |
| $\Delta \ln W_{it}$ | -0.257*** | -0.254*** | -0.264*** |
| | (0.010) | (0.008) | (0.008) |
| Industry FE | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes |
| Hansen-p | 0.647 | 0.416 | 0.318 |
| AR(2)-p | 0.589 | 0.600 | 0.210 |
| Observations | 25,434 | 35,956 | 36,735 |

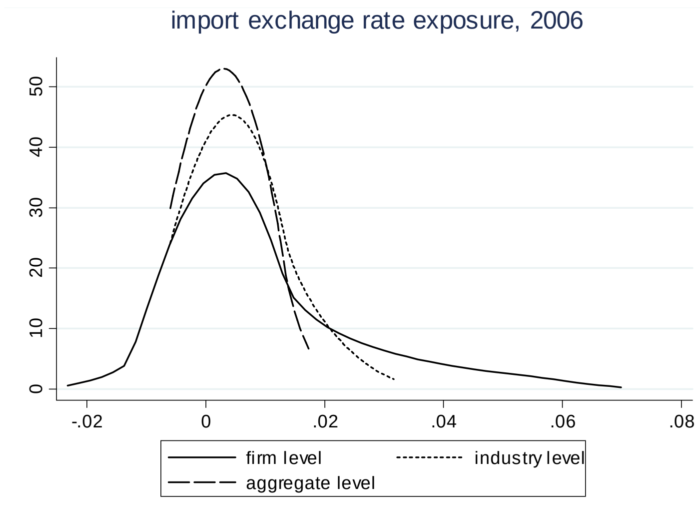
Note: Column (1)-(3) respectively reports regression results for low demand elasticity industries, medium demand elasticity industries, and high demand elasticity industries. Industries are split into three groups with equal number of industries based on the trade elasticity for China reported in Broda, Greenfield and Weinstein (2006). The median elasticity for low, medium and high elasticity group are 2.45, 3.38 and 7.04, respectively. All columns are estimated using generalized methods of moments. Lagged employment levels dated period t-2 and earlier are used as instruments for $\Delta \ln L_{i,t-1}$. All regressions include 4-digit CIC industry fixed effects and year fixed effects. Robust standard errors in parenthesis. *, ** and *** correspond to 10%, 5% and 1% significance levels respectively.

Table 8 Asymmetric response to appreciations and depreciations

| Dep variable: $\Delta \ln L_{it}$ | (1) appreciation | (2) depreciation |
|---|---|---|
| $\varphi_{i,t-1} \times \Delta IMFEER_{it}$ | 0.730*** | 0.153* |
| | (0.090) | (0.088) |
| $\chi_{i,t-1} \times \Delta EXFEER_{it}$ | -0.275*** | -0.534*** |
| | (0.076) | (0.060) |
| $(1-\chi_{i,t-1}) \times \Delta IMPEER_{jt}$ | 0.150 | -0.420** |
| | (0.403) | (0.188) |
| $\Delta \ln L_{i,t-1}$ | 0.412*** | 0.626*** |
| | (0.030) | (0.029) |
| $\Delta \ln W_{it}$ | -0.273*** | -0.258*** |
| | (0.008) | (0.007) |
| Industry FE | Yes | Yes |
| Year FE | Yes | Yes |
| Hansen-p | 0.247 | 0.229 |
| AR(2)-p | 0.585 | 0.150 |
| Observations | 35,339 | 44,168 |

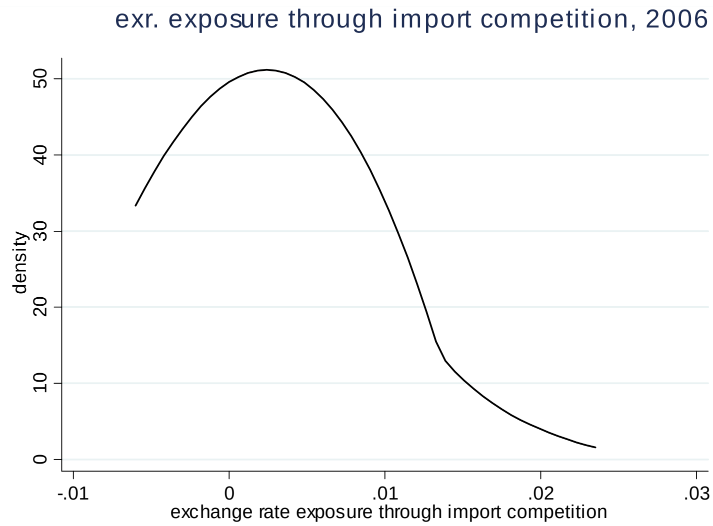
Note: Column (1) and (2) respectively report the regression results for the appreciation group and depreciation group. An observation is included in the appreciation (depreciation) group if at least one of the three effective exchange rate change measures suggests an appreciation (depreciation), and none of the three effective exchange rate measures suggests a depreciation (appreciation). All columns are estimated using generalized methods of moments. Lagged employment levels dated period t-2 and earlier are used as instruments for $\Delta \ln L_{i,t-1}$. All regressions include 4-digit CIC industry fixed effects and year fixed effects. Robust standard errors in parenthesis. *, ** and *** correspond to 10%, 5% and 1% significance levels respectively.




Note: Export exchange rate exposure equals the product of export intensity and export-weighted effective exchange rate changes ($\chi_{i,t-1} \times \Delta EXFEER_{it}$). Import exchange rate exposure equals the product of import intensity and import-weighted effective exchange rate changes ($\varphi_{i,t-1} \times \Delta IMFEER_{it}$). "firm-level", "industry level", and "aggregate level" refers to the aggregation level of the effective exchange rate changes used to construct the exposure. bandwith=0.007 for export and 0.006 for import. All variables are trimmed at 5%.

Figure 1 Distribution of export and import exchange rate exposure using effective exchange rates at various aggregation levels




Note: Exchange rate exposure through import competition equals the product of the import-penetration-weighted effective exchange rate changes at the industry level and the share of domestic sales over total sales at the firm level, $(1 - \chi_{i,t-1}) \times \Delta IMPEER_{jt}$. The exposure is trimmed at 5%.

Figure 2 Distribution of exchange rate exposure through import competition

Table A1 Number of firms

| Year | ASIF (1) | Customs (2) | Matched (3) | Filtered (4) |
|---|---|---|---|---|
| 2000 | 162,883 | 82,063 | 25,212 | 18,930 |
| 2001 | 169,031 | 89,660 | 30,797 | 24,058 |
| 2002 | 181,557 | 104,245 | 35,257 | 28,476 |
| 2003 | 196,222 | 124,299 | 39,303 | 34,113 |
| 2004 | 276,474 | 153,779 | 55,242 | 48,563 |
| 2005 | 271,835 | 179,665 | 54,748 | 48,815 |
| 2006 | 301,961 | 208,425 | 58,042 | 51,604 |

Note: Column (1) reports number of firms in ASIF data. Column (2) report number of firms in the full customs data. Column (3) report number of firm in the ASIF-customs matched data. Column (4) report number of firms in the ASIF-customs matched data after dropping firms with one of the following features: (1) report missing or negative for any of the following variables: total sales, total revenue, total employment, capital, intermediate inputs. (2) less than 8 employees. (3) total export value or import value in the customs data is larger than total sales in ASIF. (4) in non-manufacturing sectors. (5) state-owned enterprises.