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Firm-specific exchange rate shocks and employment adjustment: Evidence from China[☆]

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ABSTRACT

This paper examines how exchange rate shocks affect intra-industry labor reallocation across firms. Using comprehensive Chinese firm-level data, we examine the employment response to exchange rates of firms that are heterogeneous along two dimensions: external orientation and trading partner distribution. Firm-specific effective exchange rates are constructed to accurately measure exchange rate shocks pertinent to individual firms. We find that exchange rate movements induce significant labor reallocation across firms with different degrees of external orientation and with different trading partners. Trading partner distribution is as important as external orientation in explaining firms' heterogeneous employment response to exchange rates. Compared with effective exchange rate measures at more aggregate levels, using firm-specific effective exchange rates generates estimation results more consistent with theory and substantially increases the estimated impact of exchange rates on intra-industry job reallocation.

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1. Introduction

In open economies, exchange rate changes are often considered to be an important shock that affects the labor market. Most previous studies have used industry or country-level data to study the impact of such changes on employment.[1] However, the evidence on how exchange-rate changes induce labor reallocation across firms within an industry is limited. Understanding this question has important implications because recent trade literature has consistently showed that an economy's exposure to an international environment may induce reallocation of resources at the firm-level,[2] and many studies in labor economics reveal that the majority of job reallocation occurs within narrowly defined industries.[3]

To address this issue, we use comprehensive Chinese firm-level data to examine how exchange rate shocks induce intra-industry labor reallocation across firms. A methodological contribution of our study is that we construct effective exchange rates at the firm level to measure the overall exchange rate shocks faced by each firm. The idea behind these firm-specific effective exchange rates is intuitive: since firms trade with different countries whose exchange rates move differently, the effective exchange rate shocks vary by firm. Using this new effective exchange rate measure has two benefits: (1) It enables us to examine cross-firm job reallocation along two dimensions: firms' external orientations and their specific exposures to exchange-rate shocks. The latter is particularly novel in the literature since it captures the fact that firms trading with different countries may experience different exchange rate movements. (2) Using firm-specific effective exchange rates increases consistency and precision of the estimation, and facilitates the identification of the alternative transmission channels underlying the relationship between exchange rates and employment.

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1 See Revenga (1992), Campa and Goldberg (2001), and Klein et al. (2003).

2 See Melitz (2003) and Pavcnik (2002).

3 See Davis and Haltiwanger (1999), Haltiwanger et al. (2014), and Faggio and Konings (2003).

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To guide our empirical analysis, we develop a simple model to rationalize firm-specific effective exchange rate measures and to explain the transmission channels behind the exchange-rate-employment relationship. Next, we empirically construct firm-specific exchange-rate measures exploiting the richness of our data which reports exports by destination and imports by source country for each firm. Guided by theory, we interact these effective exchange rate measures with firms' external orientation measures to investigate the relationships between exchange-rate changes and employment growth. Moreover, to examine how firm-specific effective exchange rates affect our understanding of the impact of exchange rates on job reallocation, we compare the estimated impacts of exchange rates on employment using firm-specific, industry-specific and aggregate effective exchange rates.

Our estimates verify that exchange rates induce significant cross-firm labor reallocation along the aforementioned two dimensions. First, home currency appreciations reduce the relative employment growth in firms more reliant on exports, and increase the relative employment growth in firms more reliant on imported intermediate inputs. Second, exchange rate changes also induce reallocation across firms with different export destinations and import source countries because they face different effective exchange rate shocks. We further show that trading partner distribution is as important as external orientation in explaining firms' heterogeneous employment responses to exchange-rate movements. Finally, compared with effective exchange-rate measures constructed at more aggregate levels, using firm-specific effective exchange rates generates estimation results that are more precise and closer to theoretical predictions, and increases the predicted cross-firm variation of exchange-rate-induced employment changes by around 40%.

An important feature of our identification strategy needs to be emphasized. We identify the impact of exchange rate changes by exploiting firms' cross-section variation in export intensity, import intensity, and firm-specific effective exchange rates. As such, our estimates can only be interpreted as the exchange rates' effects on relative employment growth across firms. The potential economy-wide general equilibrium relationship between exchange rates and other aggregate level variables is captured by the time-fixed effects. In other words, we cannot infer the absolute employment effects of exchange rate changes from the coefficients because the effects common across firms are absorbed by the time-fixed effects. However, despite this limitation, our identification strategy still sheds light on firms' heterogeneous responses to exchange rate changes, and is particularly helpful for the understanding of how the employment effects of exchange rate changes vary with firm characteristics, that is, firms' external orientations and trading partner distributions.

This study contributes to the abundant literature regarding the impact of exchange rate fluctuations on employment. Earlier studies empirically investigate the exchange-rate-employment relationship at the country or industry level.[4] Investigations at the firm level have only emerged in recent years. 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 Norwegian Krone's real appreciation in the early 2000s. These studies investigated the impact of exchange rates in firms that are heterogeneous in their external orientation. In this study, we consider not only firms' external orientations, but also firms' heterogeneity in terms of the effective exchange rate shocks. We show that considering this second heterogeneity significantly increases the estimated impacts of exchange rate fluctuations on cross-firm labor reallocation.

Our study also contributes to the literature regarding the measurement of effective exchange rates. The traditional effective exchange rate is a piece of macroeconomic data, which is computed using price and trade flow series at the national level.[5] However, the aggregate effective exchange rate does not effectively capture changes in industry-level competitive conditions induced by specific bilateral exchange rate movements (Goldberg, 2004). Thus, industry-level studies regarding the impact of exchange rate movements have generally adopted industry-specific effective exchange rates that are constructed using industry-level trade weights.[6] For micro-level studies using firm-level data, however, the use of firm-specific effective exchange rates becomes necessary because industry-specific effective exchange rates fail to consider the substantial heterogeneity of firms' trade distributions across export destinations and import source countries. To the best of our knowledge, our study is the first to construct firm-specific effective exchange rates and use them to investigate the impact of exchange rate movements on firms.

The remainder of this paper is organized as follows. Section 2 proposes a theoretical model linking firm-specific effective exchange rate shocks to employment changes. Section 3 describes the empirical strategy. Section 4 introduces the data and conducts preliminary analyses. Section 5 presents the baseline results, conducts robustness checks, and compares the results of firm, industry, and aggregate effective exchange rates. Section 6 discusses the alternative dimensions of firm heterogeneity emphasized in the existing literature. The last section concludes.

2. Theory

We develop a theoretical framework linking firm-level employment changes to exchange rate changes in all of the firm's related markets. 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 lays out a theoretical foundation for our empirical exercise and provides guidance on constructing the variables used in the empirical analysis. We present the detailed mathematical treatment of the model in Appendix A.1. In this section we describe the basic setup of the model and present the main model predictions to be used in the subsequent empirical analysis.

We consider an economy composed of many countries. Demand for each variety takes the constant elasticity of substitution (CES) form.[7] Production combines labor and intermediate inputs according to a Cobb–Douglas technology. Intermediate inputs can be either domestically sourced or imported from foreign countries. Domestic and imported inputs are imperfect substitutes, combined using a CES aggregator. A firm can sell the final outputs to the domestic market, and potentially export them to many foreign countries. We allow for a flexible market structure, so markups can respond to exchange rates in flexible ways.[8]

We will proceed our theoretical exposition in two steps. First, we derive a firm's employment elasticity with respect to the bilateral

[4] 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), and 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.

[5] See Chinn (2006) for a review of the construction methods and applications of the aggregate effective exchange rates.

[6] See Revenga (1992), Goldberg et al. (1999), Campa and Goldberg (2001); and Goldberg (2004).

[7] Note that using the CES demand does not preclude variable markups. See, for example, Atkeson and Burstein (2008) and Dornbusch (1987).

[8] Different models yield different results regarding the markup adjustments to exchange rates and the heterogeneity of such adjustments across firms. See, for example, Atkeson and Burstein (2008) and Berman et al. (2012). Burstein and Gopinath (2014) provide an excellent review. We get back to this issue in Section 6.

exchange rate (e.g. RMB against the US dollar). We explain the three key mechanisms through which bilateral exchange rates affect firm employment. Second, we link firm employment with firm-specific effective exchange rates, and derive the theoretical equation for the empirical analysis.

Denote firm by i, the producer's country by n, and the export destination or import source country by 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, that is, an increase in e_{nk} implies the appreciation of country n′s currency against country k′s. Proposition 1 summarizes the elasticity of a firm's employment, L_{in}, with respect to bilateral exchange rate e_{nk} .

Proposition 1. *The elasticity of employment L_{in} with respect to bilateral exchange rate e_{nk} is a function of a firm's (1) share of inputs imported from country k over total costs, which we call "import intensity" from country k (φ_{ink}), (2) the share of exports to country k over total sales (χ_{ink}), and (3) the interaction between a firm's share of domestic sales over total sales (χ_{inn}) and the import penetration ratio of country k (M_{kn}).*

$$\frac{\partial \ln L_{in}}{\partial \ln e_{nk}} = \left(\alpha_{nk} - \eta^M_{nk}\right)\varphi_{ink} - \beta_{nk}\chi_{ink} - \gamma_{nk}\chi_{inn}M_{kn} + \lambda_{nk} \quad (1)$$

where $\eta^M_{nk} > 0$ is the exchange rate pass-through (ERPT) into the relative price of imported inputs to domestic inputs.[9] $\alpha_{nk}, \beta_{nk}, \gamma_{nk} > 0$ are functions of demand elasticity, ERPT into the prices of final goods, and ERPT into domestic and imported input prices.[10] λ_{nk} is the equilibrium relationship between domestic costs and exchange rates, which we will expound upon in Proposition 2.

The three terms in the above equation reflect the three distinct channels that shape the response of a firm's employment to bilateral exchange rate changes. These channels are explained as follows:

(1) *Import cost channel:* the first term, $(\alpha_{nk} - \eta^M_{nk})\varphi_{ink}$, captures the impact of exchange rate changes on employment by changing the cost of imported inputs. This effect is stronger for firms that are more reliant on imported inputs from country k, as reflected in a larger import intensity, φ_{ink}. Note that the sign of this effect is generally ambiguous without further assumptions about the functional forms and parameter values of the model. This is because an appreciation in the home currency has two offsetting effects on employment. On the one hand, as foreign inputs become cheaper firms may substitute foreign inputs for labor, reducing labor demand (substitution effect). On the other hand, the cost reduction induced by cheaper foreign inputs will increase the firm's output, thus increasing labor demand (scale effect). However, with the Cobb–Douglas technology and conventional estimates for demand elasticity, we expect the net effect to be positive.[11]

(2) *Export price channel:*the second term captures the impact of exchange rate shocks on employment by changing the local-currency export price. Given the home-currency export price, an appreciation of the home currency raises the export price denominated in the export destination's local currency, reducing output and labor demand. The impact is larger for firms that are more reliant on exports in market k, as reflected by a larger export share χ_{ink}.

(3) *Import competition channel:*the third term captures the impact of exchange rates on employment by changing the level of import competition in the domestic market. 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 reducing the labor demand in 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 import penetration ratio M_{kn}, and if the firm has a higher orientation towards the domestic market, as reflected by a larger χ_{inn}.

2.1. Linking employment to firm-specific effective exchange rates

Using the employment elasticity to each bilateral exchange rate, we can aggregate across markets to derive the relationship between firm-level employment growth and exchange rate shocks of a firm's export destinations, import sources countries, and import competing countries. This relationship is summarized in Proposition 2.

Proposition 2. *A firm's employment growth can be expressed as functions of the firm's overall export intensity (χ_{in}), import intensity (φ_{in}), and three sets of effective exchange rate changes: imported-weighted effective exchange rates (ΔIMFEER), export-weighted effective exchange rates (ΔEXFEER), and import-penetration exchange rates (ΔIMPEER).*

$$\Delta \ln L_{in} = (\alpha_n - \bar{\eta}^M_n)\varphi_{in}\Delta IMFEER - \beta_n\chi_{in}\Delta EXFEER - \gamma_n(1-\chi_{in})\Delta IMPEER + \lambda_n \quad (2)$$

with

$$\Delta IMFEER = \sum_k \omega^M_{ink}\Delta \ln e_{nk} \quad (3)$$

$$\Delta EXFEER = \sum_k \omega^X_{ink}\Delta \ln e_{nk} \quad (4)$$

$$\Delta IMPEER = \sum_k M_{kn}\Delta \ln e_{nk} \quad (5)$$

where ω^M_{ink} (ω^X_{ink}) is the share of imports from (exports to) country k in the firm's total imports (exports). M_{kn} is the import penetration ratio of country k in country n.

Several remarks are in order. First, the intuition behind Proposition 2 is the same as Proposition 1. The first three terms in Eq. (2) reflect the impact of exchange rate changes on employment through the import cost, export price, and import competition channels, respectively. Second, when we consider all related markets of a firm, the magnitude of each channel depends on the firm's overall export intensity and import intensity, in contrast to Eq. (1) where each channel's magnitude depends on the export intensity and import intensity with respect to a particular country k. Third, both the export-weighted effective exchange rates (Δ*EXFEER*) and the import-weighted effective exchange rates (Δ*IMFEER*) are firm-specific. Since firms differ in their imports and exports distribution across trading partners, the effective exchange rate shocks pertinent

[9] We allow the prices of both imported and domestic inputs to vary with exchange rates. We assume that an appreciation lowers the price of imported inputs (in home currency) relative to domestic inputs.

[10] See Appendix A.1 for details. Note that the magnitudes of these coefficients are dependent on the specific general equilibrium environment of the model. In our empirical analysis, we estimate these coefficients by exploiting the cross-firm variations in the responses to shocks. However, these estimates are not suitable for undertaking counterfactuals across general equilibrium environments, since the coefficients change with the detailed general equilibrium environment of the model.

[11] Under the Cobb–Douglas technology where the elasticity of substitution between labor and materials is 1, $\alpha_{nk} - \eta^M_{nk} = (\sigma - 1)\eta^M_{nk}$., where σ is demand elasticity. The conventional estimates of the demand elasticity in the existing literature are normally 4–10 (Broda and Weinstein, 2006; Broda et al., 2006; Imbs and Mejean, 2010). Therefore, the net effect is positive.

to each firm are different. We will construct these firm-level effective exchange rates in our empirical analysis.

The last term on the right hand side of Eq. (2), λ_n, captures the equilibrium relationship between domestic factor prices (wages and domestic input price) and the exchange rates of all China's trading partner countries. Note that in a general equilibrium model, exchange rates and factor prices are both determined by exogenous shocks that hit the economy (e.g. productivity, preference or monetary shocks). Thus, we do not interpret λ_n as the partial equilibrium response of wages and input prices to exchange rates. In contrast, it represents the comovement between exchange rates and factor prices determined in general equilibrium. The magnitude of λ_n will depend on the detailed general equilibrium environment of the model and the underlying sources of exchange rate movements. However, the important point is that λ_n is common across all firms within a country, so it will be canceled out when comparing the employment response across firms. In our empirical analysis, we will identify the coefficients of interest by exploiting cross-firm variations in the export intensity, import intensity, and firm-specific effective exchange rates, controlling for time-fixed effects to capture the economy-wide equilibrium relationship between aggregate variables and exchange rates. Because of this methodology, the effects identified in our subsequent empirical work should be interpreted as relative effects, not the absolute response of a firm's employment to exchange rates.

3. Empirical strategy

The main equation we estimate is Eq. (2). We specify an empirical counterpart of Eq. (2) at the firm level as follows:

$$\Delta \ln L_{it} = \beta_0 + \beta_1 \varphi_{i,t-1} \Delta IMFEER_{it} + \beta_2 \chi_{i,t-1} \Delta EXFEER_{it} + \beta_3 (1-\chi_{i,t-1}) \Delta IMPEER_{jt} + \nu_j + \eta_t + \varepsilon_{it} \tag{6}$$

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.[12] $\Delta IMFEER_{it}$, $\Delta EXFEER_{it}$, are changes in the import-weighted effective exchange rate and export-weighted effective exchange rate respectively, both of which are firm-specific. $\Delta IMPEER_{jt}$ is the change in import-penetration-weighted effective exchange rate constructed at the industry level. We include 4-digit industry fixed effects (ν_j) to absorb the industry-specific trends of employment growth. Importantly, the employment response to exchange rates depends on the economy-wide equilibrium relationship between domestic factor prices and exchange rates (λ_n in Eq. (2)). We control for this relationship by including year fixed effects (η_t). In an alternative specification, we replace the industry and year fixed effects with industry-year fixed effects (ν_{jt}). This specification allows for the possibility that the equilibrium relationship between domestic factor prices and exchange rates is industry-specific, which may be the case if labor market frictions prohibit workers from moving freely across industries, or industries differ in their intermediate input composition.

The coefficients of interest are β_1, β_2 and β_3 . They capture the impact of exchange rates on employment through the input cost channel (β_1), export price channel (β_2) and import competition channel (β_3). We expect β_1 to be positive, and β_2 and β_3 to be negative.

Regarding the identification strategy, the coefficients of β_1 and β_2 are identified from cross-firm variations in two dimensions. The first dimension is the cross-firm variation in external orientation, which is reflected by the import intensity (φ) and export intensity (χ). The second dimension is the cross-firm variation in effective exchange rates, which stemmed from the cross-firm variations in the distribution of trade across trading partners, and the cross-country variation in exchange rate movements. Previous studies such as Nucci and Pozzolo (2010) exploited the first variation but ignored the second. β_3 is identified from cross-firm variation in domestic orientation $(1-\chi)$ and industry-time variation in import penetration effective exchange rates.

Several econometric issues are in order. First, for consistency, which requires that the error term ε_{it} is uncorrelated with the independent variables, we make the assumption as in Amiti et al. (2014) that a firm's idiosyncratic shock (relative to the average) does not vary systematically with exchange rates. This nevertheless allows for aggregate variables, such as exchange rates and cost indexes, to have arbitrary correlation. This correlation is captured by the year fixed effects. Second, the pairwise correlation between the three exchange rate exposure terms are all below 0.3, so multicollinearity issues are unlikely despite exchange rates entering the equation three times.[13] Actually, compared with using industry-specific exchange rates, our approach has the advantage of alleviating multicollinearity because we exploit the rich variations in firms' trading partner distribution.

4. Data and summary statistics

4.1. Data

4.1.1. Firm-level data

Firm-level data are obtained from the Annual Survey of Industrial Firms (ASIF) conducted by the National Bureau of Statistics of China during 2000–2006. This dataset includes all State Owned Enterprises (SOEs) and Non-State Owned Enterprises with annual sales of RMB five million (about \$650,000) or more. Compared with the firm census data in 2004, the ASIF data cover 72% of the industrial workforce and 90% of the output. The data provide detailed information regarding firms' identification, ownership, industry classification, and around 80 balance sheet variables. The variables used in this study include number of employees, total wage bills, total sales, domestic sales, and profit.

4.1.2. Trade data

Transaction-level trade data are obtained from China's General Administration of Customs during 2000–2006. The data cover 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 are recorded monthly, but we aggregate it to the annual level to match the ASIF data. This dataset 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.

4.1.3. Match the two datasets

We match the ASIF data with the customs trade data using firm name, telephone number and zip code. The merged dataset accounts for 54% of China's total exports and 50% of total imports over this period (see Appendix A.2.1 for a detailed description of the matching procedures).

4.1.4. Exchange rate and price index data

Nominal exchange rate data are obtained from the International Financial Statistics (IFS) for 175 of China's trading partners during

[12] We also experiment with making φ and χ time-invariant. The results are reported in the Robustness checks section.

[13] The correlation is 0.28 for $\varphi_{i,t-1}\Delta IMFEER_{it}$ and $\chi_{i,t-1}\Delta EXFEER_{it}$, 0.11 for $\chi_{i,t-1}\Delta EXFEER_{it}$ and $(1-\chi_{i,t-1})\Delta IMPEER_{jt}$, and 0.19 for $\varphi_{i,t-1}\Delta IMFEER_{it}$ and $(1-\chi_{i,t-1})\Delta IMPEER_{jt}$.

Table 1
Share of firms by its top export destination and import source country.

	Export		Import	
	2001	2006	2001	2006
United States	0.25	0.26	0.10	0.11
Euro zone	0.10	0.12	0.14	0.14
Japan	0.25	0.17	0.30	0.26
Korea	0.06	0.07	0.18	0.16
Others	0.33	0.38	0.28	0.33

2000–2006. We also extract the consumer price index data from Penn World Tables 7.0 in order to construct real exchange rates.

4.1.5. Sample

We exclude observations if they meet any of the following criterion: (1) reported missing or negative for any of the following variables: total sales, total revenue, total employment, capital, or intermediate inputs; (2) have less than 8 employees; (3) total export value or import value in the customs data is larger than total sales in ASIF data; (4) operate in non-manufacturing sectors. We also exclude all SOEs considering that firing and hiring decisions in SOEs are highly restricted by central planning. The filtered sample includes 254,559 observations for 66,289 firms, accounting for 85% of observations in the unfiltered merged data. We present 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 the ASIF data, 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 in exports and imports occur at the extensive 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 when no trade transaction is recorded in the customs data.[14]

4.2. Motivating evidence

Our use of the firm-specific effective exchange rates is motivated by two features of the Chinese data. First, export destinations and import source countries are widely heterogeneous across firms. Second, the movements of the RMB exchange rate against China's major trading partners are widely different. We describe these features as follows.

Table 1 shows that Chinese firms are heterogeneous in terms of export destinations and import source countries. We calculate the share of firms by their top export destination and import source country. For expositional purposes, we report the share for China's top 4 trading partners: the United States, Euro Zone, Japan, Korea, as well as other countries as a whole. According to Table 1, the distribution of Chinese firms' export destinations is broad. There is a significant proportion of firms exporting to each of China's top four trade partners. Moreover, around one third of firms mainly export to other countries. The choice of major import source countries shows a similar pattern.

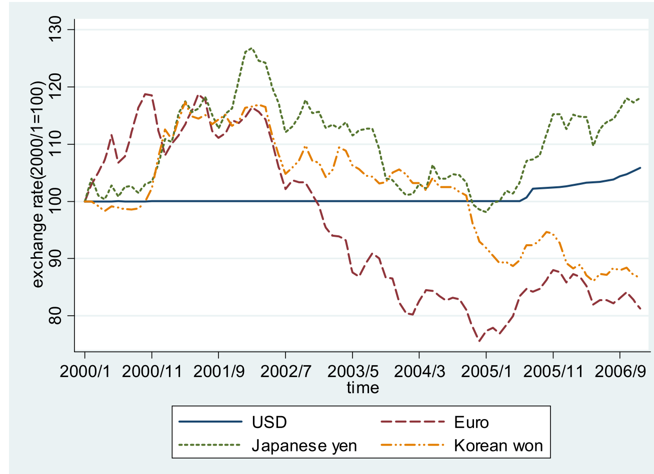

Fig. 1. Exchange rate against RMB for US dollar, Euro, Yen and Won, 2000–2006.

Fig. 1 shows that the movements of the RMB exchange rate against China's major trading partners are vastly different. We draw the bilateral exchange rate of the RMB against the US dollar, Euro, Japanese Yen, and the Korean Won. The real exchange rate against the U.S. dollar changed very slightly in 2000-2004 (due to the nominal pegging of the RMB to US dollars), followed by a small appreciation around 5% in the next two years. The Euro and the Korean Won experienced an overall appreciation of around 20% against the RMB during the sample period, whereas the Japanese Yen experienced an overall depreciation of around 15%.

All in all, this historical period has seen vast heterogeneity in firms' choices of trading partners and their exposure to differential exchange rate movements. Accordingly, we need a firm-level measure of effective exchange rate changes to capture this cross-firm variation. We now construct firm-specific effective exchange rates and other variables.

4.3. Construction of variables

Following Eqs. (3) and (4), 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:[15]

$$\Delta EXFEER_{it} = \sum_k \left(EX_{ik,t-1} \Big/ \sum_k EX_{ik,t-1} \right) \Delta \ln e_{kt} \tag{7}$$

$$\Delta IMFEER_{it} = \sum_k \left(IM_{ik,t-1} \Big/ \sum_k IM_{ik,t-1} \right) \Delta \ln e_{kt} \tag{8}$$

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

[14] Theoretically, we should also include firms with no trade transactions throughout the sample period (i.e. the unmatched firms) because these firms' employment can also be affected by exchange rates through the import competition channel. Practically, however, treating all unmatched firms as non-trading firms comes at a cost. First, since we merge the ASIF and the customs data based on firm name, zip code and telephone number, imperfect matching may occur. Thus, we cannot 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.

[15] 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) have a high correlation of 0.89.

Table 2
Summary statistics.

Variable	Mean	Sd.	5th pctl.	95th pctl.
Δln (# employees)	0.040	0.362	−0.470	0 .616
Export intensity	0.243	0.323	0	0.937
Import intensity	0.121	0.215	0	0.646
Δ*EXFEER*	−0.006	0.091	−0.152	0.105
Δ*IMFEER*	−0.004	0.092	−0.156	0.152
Δ*IMPEER*	−0.002	0.021	−0.036	0.024
Δln (sales)	0.131	0.482	−0.570	0.834
Δ markup	−0.001	1.036	−0.145	0.140

Note: Export intensity and import intensity are calculated according to Eqs. (10) and (11). Export-weighted firm effective exchange rate changes (Δ*EXFEER*) and import-weighted firm effective exchange rate change (Δ*IMFEER*) are respectively calculated according to Eqs. (7) and (8). Import-penetration-weighted effective exchange rate change (Δ*IMPEER*) is constructed according to Eq. (9) at 4-digit CIC industry level. Markup= $\frac{sales}{sales-profit}$.

Another effective exchange rate variable is the change of import-penetration weighted effective exchange rate, which is constructed following Eq. (5) for each industry *j*.

$$\Delta IMPEER_{jt} = \sum_k \left(\frac{IM_{jk,t-1}}{DOMSALE_{jt-1} + \sum_k IM_{jk,t-1}} \right) \Delta \ln e_{kt} \tag{9}$$

$IM_{jk,t-1}$ is China's aggregate import value from country k in industry j (CIC 4-digit), which we obtain from the full customs data.[16] $DOMSALE_{jt-1}$ 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.[17]

The other two key variables are export intensity ($\chi_{i,t-1}$) and import intensity ($\varphi_{i,t-1}$). We construct export intensity as total exports over total sales ($SALES_{i,t-1}$), and import intensity as total imports over total costs, where total costs ($TC_{i,t-1}$) comprise a firm's total wage bill and total material cost.[18] We also lag these variables for one year to alleviate endogeneity. In equations:

$$\chi_{i,t-1} = \frac{\sum_k EX_{ik,t-1}}{SALES_{i,t-1}} \tag{10}$$

$$\varphi_{i,t-1} = \frac{\sum_k IM_{ik,t-1}}{TC_{i,t-1}} \tag{11}$$

4.4. Summary statistics

Table 2 reports the summary statistics of the key variables. Firms in our sample exhibit considerable variations in export and import intensity. Some firms have no connections to both the export and import markets. The 5th percentile of the export intensity and import intensity distribution are both zero. However, 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 export 94% of its total output and import 65% of its input. This suggests that the impact of a given exchange rate shock can vary substantially across firms. Another source of variation we explore for identification is the variation of export-weighted and import-weighted effective exchange rate changes. According to Table 2, the coefficient of variation for the export-weighted effective exchange rate changes is 15 (0.091 / 0.006), and that for the import-weighted effective exchange rate changes is 23 (0.092 / 0.004), suggesting substantial variability.

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	0.1563	0.1436	0.0430
	(0.2028)	(0.0501)	–
2002	−0.0338	−0.0302	−0.0231
	(0.1435)	(0.0647)	–
2003	−0.1195	−0.1156	−0.0656
	(0.1168)	(0.0382)	–
2004	−0.0686	−0.0663	−0.0269
	(0.0696)	(0.0238)	–
2005	0.0037	0.0063	−0.0054
	(0.0659)	(0.0181)	–
2006	0.0300	0.0285	0.0157
	(0.0660)	(0.0185)	–

Note: Columns (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.

An important 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 demonstrate this, 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.[19] Although the average movement of the exchange rates constructed at various aggregation levels seems to look very similar [20], they differ considerably in their cross-firm variation. The standard deviation for firm-specific effective exchange rate changes is 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, that is, $\chi_{i,t-1}\Delta EXFEER_{it}(\varphi_{i,t-1}\Delta IMFEER_{it})$. Fig. 2 plots the distribution of exchange rate exposure constructed using firm-specific, industry-specific and aggregate effective exchange rate changes in 2006. There is a strong pattern that the exchange rate exposure constructed using firm-specific effective exchange rate changes exhibits larger variations than the one constructed using industry-specific effective exchange rate changes, which is more variable than the one constructed using aggregate-level effective exchange rate changes. Such ranking holds well for exchange rate exposure on both the export

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

17 Note that the weights do not sum to one because we do not include domestic sales in the numerator. However, adding the domestic sales back will not change the results because exchange rate changes (Δlne_{kt}) are always zero for the RMB against itself.

18 The value of exports and imports are obtained from the customs data, while total sales, total wage bill, and total material costs are obtained from the ASIF data. The value of exports and imports in the original customs data is denominated in the U.S. dollar while sales, wage bills and material costs data in the ASIF data are in RMB. We convert them to the same currency using the yearly dollar-RMB exchange rates.

19 Results for import-weighted effective exchange rate changes are qualitatively similar and is available upon request.

20 Except one year (2005) in which the firm-level effective exchange rate increased but the aggregate exchange rate decreased.

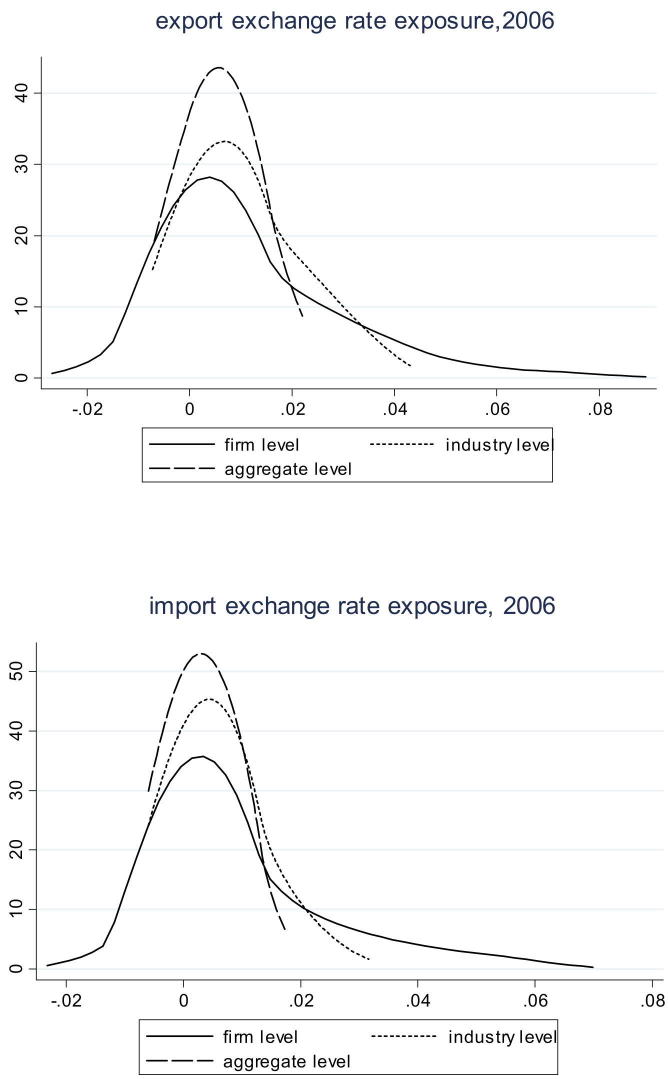

Fig. 2. Distribution of export and import exchange rate exposure using effective exchange rates at various aggregation levels. Note: Export exchange rate exposure equals the product of export intensity and export-weighted effective exchange rate changes ($\chi_{i,t-1} \times \Delta EXFEER_{it}$). Import 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%.

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 stem from the differences in the variation of the effective exchange rate changes. In sum, firm-specific effective exchange rates provide more cross-firm variations which can be utilized to identify the impact of exchange rate changes in our firm-level investigation.

5. Results

5.1. Baseline results

Table 4 reports the OLS estimation results of Eq. (6). We start by including the two terms that incorporate the firm-specific effective exchange rates, $\varphi_{i,t-1}\Delta IMFEER_{it}$ and $\chi_{i,t-1}\Delta EXFEER_{it}$. In Column (1), we include industry fixed effects plus year fixed effects. We obtain a coefficient of −0.32 for the export term, and 0.16 for the import term, both of which are significant at the 1% level. In Column (2), we replace the industry fixed effects and year fixed effects with more demanding industry–year fixed effects. The coefficients only changed slightly. These results confirm the first two key mechanisms of our model: appreciation of the home currency promotes firm employment growth by lowering the costs of imported inputs, and lowers employment growth by raising the local-currency export price. In Columns (3) and (4), we include the import competition term $(1-\chi_{i,t-1})\Delta IMPEER_{jt}$. The coefficient is negative but not statistically significant. This is, to some extent, consistent with the theory that an appreciation reduces employment by intensifying the import competition in the domestic market.[21]

Table 4
Baseline estimation results.

Dep variable: $\Delta \ln L_{it}$	(1)	(2)	(3)	(4)
$\varphi_{i,t-1} \times \Delta IMFEER_{it}$	0.156***	0.211***	0.155***	0.208***
	(0.043)	(0.045)	(0.043)	(0.045)
$\chi_{i,t-1} \times \Delta EXFEER_{it}$	−0.318***	−0.323***	−0.322***	−0.326***
	(0.034)	(0.035)	(0.034)	(0.035)
$(1-\chi_{i,t-1}) \times \Delta IMPEER_{jt}$			−0.092**	−0.122*
			(0.093)	(0.126)
Industry FE	Yes	No	Yes	No
Year FE	Yes	No	Yes	No
Industry-year FE	No	Yes	No	Yes
Observations	148,912	148,912	148,912	148,912
R-squared	0.010	0.025	0.010	0.025

Note: This table reports the OLS estimation results of Eq. (6). ΔlnL_{it} : log changes of number of workers. χ : export intensity, φ: import intensity. $\Delta EXFEER$, $\Delta IMFEER$ and $\Delta IMPEER$ are respectively export-weighted, import-weighted and import-penetration weighted exchange rate changes calculated according to Eqs. (7) to (9). Columns (1) and (3) include 4-digit CIC industry fixed effects and year fixed effects. Columns (2) and (4) industry-year fixed effects. Robust standard errors in parenthesis.
* Corresponds to 10% significance level.
** Corresponds to 5% significance level.
*** Corresponds to 1% significance level.

5.2. The impact of exchange rates on job reallocation

Our estimates have immediate implications for the impact of exchange rates on job reallocation across firms. To show this, we quantify firms' heterogeneous employment adjustment in response to exchange rates along two dimensions: external orientation and trading partner distributions, and compare their relative importance.

We calculate the fitted value of employment growth for each firm and year as follows:

$$\Delta \ln \widehat{L}_{it} = \widehat{\beta}_1 \varphi_{i,t-1} \Delta IMFEER_{it} + \widehat{\beta}_2 \chi_{i,t-1} \Delta EXFEER_{it} + \widehat{\beta}_3 (1-\chi_{i,t-1}) \Delta IMPEER_{jt} \quad (12)$$

where $\widehat{\beta}_1$ to $\widehat{\beta}_3$ are estimates in Column (4) of Table 4.[22] We then examine how this predicted employment growth varies across firms with different characteristics. An important note is that this predicted employment growth should not be interpreted as the absolute response of firm employment to exchange rate movements. The reason is that, as shown in Eq. (2), the absolute employment response to exchange rates depends on the equilibrium relationship between

[21] We also check whether the sensitivity of employment to exchange rates is related to the demand elasticity as predicted by the theory. According to our theory, the sensitivity of employment to exchange rates increases with demand elasticity. We check this 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 (low elasticity, medium elasticity, and high elasticity) according to trade elasticity estimates obtained from Broda et al. (2006). The results reported in Table A2 in the Appendix indeed show that employment sensitivity to exchange rates is higher in high demand elasticity industries.

[22] For the coefficients that are not statistically significant, we still impute their point estimates as reported in the table.

Table 5a
Predicted employment growth (%) by export and import intensity bins, year 2006.

Exp./imp.	Low	Medium	High
Low	−0.05	−0.01	0.36
Medium	−0.13	−0.20	0.18
High	−0.47	−1.06	−0.72

Note: From top to bottom: low, medium and high export intensity firms. From left to right: low, medium and high import intensity firms. Low, med, high export (import) intensity firms are split according to the 50 and 75 percentile of the export (import) intensity distribution. Predicted employment changes at firm level are calculated according to Eq. (12). The mean value of each bin is reported.

Table 5b
Predicted employment growth (%) by top export destination and import source country, year 2006.

Destination./source	Japan	United States	Euro zone	Korea
Japan	−0.86	−0.88	−0.90	−1.34
United States	−0.12	−0.30	−0.33	−0.48
Euro zone	−0.05	−0.27	−0.25	−0.40
Korea	0.26	0.15	0.14	0.13

Note: Countries are sorted according to the exchange rate changes of their currency against the RMB. The RMB depreciates more against the destination (source country)'s currency as we move from top to bottom (left to right) of the table. Predicted employment changes at firm level are calculated according to Eq. (12). The mean value of each bin is reported.

exchange rates and domestic factor prices, λ_n, which is absorbed by the time fixed effects along with other macro shocks. However, since λ_n is common across all firms and will be canceled out when comparing one firm with another, it is informative to examine how the predicted employment growth varies across firms with different characteristics. In other words, by examining the *difference* in the predicted employment growth across firms, we can infer how exchange rate changes affect the *relative* employment growth across firms with different characteristics. We view this as evidence that labor reallocate across firms as consequences of exchange rate shocks.

5.2.1. Reallocation across firms with different external orientation

We split all the firms into low, medium, and high export intensity firms and low, medium, and high import intensity firms, so altogether we have 9 bins of firms with different export and import intensities.[23] In Table 5a, we report the mean predicted employment growth of each bin. For expositional purposes, we report the result for year 2006, when RMB effectively appreciated against other currencies by 1.6%. Table 5a shows that the employment impact of the exchange rate shocks varies widely across firms with different export and import intensity. As firms became more dependent on exports, the impact of the appreciation becomes more negative, while for firms more dependent on imports, the effect becomes more positive.[24] Quantitatively, for firms with medium import intensity, the appreciation reduces the employment growth of the high export intensity firms by 1.05% (1.06% − 0.01%) *relative to* the low export intensity firms. Alternatively, for firms with medium export intensity, the appreciation raises the employment growth of the high import intensity firms by 0.31% (0.13% + 0.18%) relative to the low import intensity firms.

5.2.2. Reallocation across firms with different trading partners

Exchange rate shocks not only induce job reallocation across firms with different export and import intensities, but also across firms with different trading partners. In Table 5b, we report the average predicted employment growth by firms' top export destination and import source countries in 2006, taking China's top four trading partners: the United States, Japan, the Euro Zone, and Korea as an example. The RMB exchange rate varied significantly against the currencies of these countries in 2006, with the largest appreciation against Japanese Yen and a largest depreciation against Korean won (Fig. 1). In Table 5b, we sort China's export destinations according to the magnitude of their bilateral exchange rate depreciation against the RMB, that is, the Yen has experienced the largest depreciation against the RMB, so Japan is reported at the top of the table; the Korean Won has experienced the largest appreciation against the RMB so Korea is reported at the bottom. Similarly, for import source country, Japan is situated at the leftmost while Korea situated rightmost in Table 5b.

Table 5b reveals that employment response varies significantly across firms with different export destinations and import source countries. A larger RMB appreciation against the currency of the firm's major export destination (from top to bottom of the table) is associated with a larger employment decline (or a slower employment growth), whereas a larger RMB appreciation against the currency of the firm's major import source country (from left to right of the table) is associated with a larger employment growth (or a slower employment decline). The predicted employment growth of firms most negatively affected by the appreciation (exporting to Japan and importing from Korea) is 1.6% lower than the firms most positively affected (exporting to Korea and importing from Japan).

5.2.3. Quantifying the contribution of external orientation and trading partner distribution

Next, we quantitatively assess the relative importance of the previous two factors, that is, external orientation and the trading partner distribution, in determining firm's employment response to the exchange rate. We remove the cross-firm variations in export (import) intensity and firm-specific effective exchange rates individually, and investigate how eliminating the variation of each factor affects the variation of predicted employment growth across firms. Specifically, we conduct the following two exercise: (1) Fix all firms' export and import intensities at their industry mean and allows the firm-specific effective exchange rates to vary across firms, then predict the employment growth according to Eq. (12), and calculate its standard deviation for each industry and year. This provides us with a measure of the variability of employment response to exchange rates if all firms in an industry have the same export and import intensities.[25] In other words, it measures the variability of employment response which stems solely from the variation of firm's heterogeneity in the trading partner distribution (reflected in their effective exchange rate shocks). (2) Fix the firm-specific effective exchange rates at its industry mean and allow the export and import intensity to vary. The associated standard deviation of the predicted employment growth measures the variability of employment response which stems solely from the variation of export and

[23] The bins are divided according to the 50th and 75th percentile of export intensity and import intensity distributions. The average export and import intensities of each bin are reported in Table A4 in the Appendix.

[24] Note that there appears to be some exceptions to this pattern. For example, for firms with medium export intensity, the predicted employment growth actually decreased when import intensity increases from low to medium. There are two reasons for this. (1) Even for firms in the same export intensity bin, the value of their export intensity can still be different across import intensity bins. For example, in Table A4, the average export intensity for firms with high export intensity and medium import intensity are 4% higher than that of firms with high export intensity and low import intensity. So the positive employment effect through the import cost channel can be offset by the negative employment effects through the export price channel. (2) Firms in different bins may experience different exchange rate movements.

[25] Some other measures, such as gross job reallocation rates and excess job reallocation rates, are often used in the literature to measure job reallocation at industry level (Davis and Haltiwanger, 1999). However, these measures are not suitable for our analysis because they require information on whether exchange rates induced job creation or job destruction for a particular firm, and therefore requires information of the absolute impacts of exchange rates on employment. As mentioned in Section 4.2, this is something we cannot infer from our estimates.

Table 6
Standard deviation of predicted employment growth.

	(1)	(2)	(3)	(4)	(5)
	Std. of $\Delta \ln \hat{L}_{it}$			Contribution (%)	
Year	Main	Fix exp.& imp. intensity	Fix FEER	FEER	Exp. & imp. intensity
2001	0.0099	0.0042	0.0055	42.31	55.33
2002	0.0059	0.0028	0.0018	46.27	30.48
2003	0.0099	0.0048	0.0047	47.82	46.96
2004	0.0078	0.0035	0.0034	44.66	43.28
2005	0.0060	0.0034	0.0012	56.90	19.38
2006	0.0070	0.0037	0.0021	52.50	30.52
Average	0.0078	0.0037	0.0031	48.41	37.66

Note: Columns (1)–(3) report the standard deviation of the predicted employment changes, averaged across all industries for each year. In Column (1), $\Delta \ln \widehat{L}_{it} = \widehat{\beta}_1 \varphi_{i,t-1} \Delta IMFEER_{it} + \widehat{\beta}_2 \chi_{i,t-1} \Delta EXFEER_{it} + \widehat{\beta}_3 (1-\chi_{i,t-1}) \Delta IMPEER_{jt}$. In Column (2), export intensity($\chi_{i,t-1}$) and import intensity($\varphi_{i,t-1}$)are set to the mean value for all firms within an 4-digit industry and year. In Column (3), firm-specific effective exchange rates ($\Delta IMFEER_{it}$and $\Delta EXFEER_{it}$) are set to their mean value for all firms within an 4-digit industry and year. Columns (4) and (5) report the contribution of firm-specific effective exchange rates and export&import intensity in explaining the variation of the total predicted employment growth. Specifically, (4) = (2)/(1), and (5) = (3)/(1).

import intensities, assuming that firms have identical trading partner distribution. Finally, we compare the two standard deviations to quantify the relative importance of each factor in explaining firm's heterogeneous employment response to exchange rates.

Table 6 presents the decomposition results. Column (1) reports the standard deviation of the predicted employment growth for the baseline, where we allow both export–import intensity and the firm-specific effective exchange rates to vary across firms.[26] Column (2) fixed export and import intensities, Column (3) fixed firm-specific effective exchange rates. The last two columns report the contribution of each component. Overall, the contribution of the firm-specific effective exchange rates is comparable with that of the export and import intensities: the firm-specific effective exchange rate changes accounts for 48% of the total variation in predicted employment growth, while export and import intensities accounts for 37%.[27] Therefore, the decomposition results suggest that trading partner choice is as important as external orientation in shaping the cross-firm job reallocation in response to exchange rate shocks.

5.3. Robustness checks

We conduct a series of checks to ensure that our baseline results are robust to alternative weighing schemes, the inclusion of additional controls, allowing for exchange rates to have dynamic effects, the selection of subsamples, and the incorporation of labor adjustment costs.

5.3.1. 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 7 suggest that using time-invariant weights does not qualitatively change the baseline results.

5.3.2. Additional controls

We follow Nucci and Pozzolo (2010) and include the first difference in firm's log sales and 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)[28]. The results in Column (2) of Table 7 are qualitatively similar to the baseline. As expected, sales growth is positively correlated with employment growth. Changes in markup have little effect.

5.3.3. Lagged exchange rates

ERPT can be quite different in the short-, medium- and long-term, leading to different employment responses to exchange rates 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. Since the existing literature typically investigates ERPT within a time window of two years, we add one period lag to the three effective exchange rate changes to capture the potential long-term effects of exchange rates on employment. The result is reported in Column (3) of Table 7. The coefficients before the current exchange rate changes are very similar to the baseline. Lagged export- and import- weighted exchange rate changes also have the expected sign, but the magnitude is smaller. The coefficient before import-penetration weighted exchange rate changes is still not statistically significant.

5.3.4. 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 as 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 7 reports the results for observations with strictly positive exports and imports. The results are qualitatively similar to the baseline. Column (5) restricts the sample to firms that neither export nor import. Note that for this subsample we can no longer include the export interaction term or the import interaction term because export and import intensities exhibit no cross-firm variation. The coefficient before the import-competition term is identified by variations in firms' domestic orientation, and the variation of the import-penetration weighted effective exchange rate changes across industry-year. The results suggest that import penetration has a insignificant impact, but the direction of the coefficient is consistent with the theory's prediction.

5.3.5. Including labor adjustment costs

Labor literature has documented that employment adjustment is slow and subject to substantial costs (Hamermesh and Pfann, 1996; Nickell, 1986). To capture these labor adjustment costs, we follow Campa and Goldberg (2001) and include a lagged term for the firm's employment growth ($\Delta \ln L_{i,t-1}$). This specification is justified theoretically if we assume that labor adjustment costs take a quadratic form, and exchange rate shocks follow a random walk. Since our regressors include a lagged dependent variable, it is necessary to estimate Eq. (6) by generalized methods of moments (GMM). We selected the lagged value of employment in levels dated period $t-2$ and earlier as GMM-type instruments. The Hansen test for over-identifying restrictions and the test for second-order serial correlation are performed to ensure that the selection of instruments is appropriate. The results in Column (6) of Table 7 shows a positive coefficient of 0.49 before the lagged employment growth, suggesting that labor adjustment costs is present. Nevertheless, our baseline

[26] We report the mean value across all industries for each year.

[27] Note that the contributions do not sum to 1, with the rest contributed by the correlation between firms' external orientation and firm-specific effective exchange rates.

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

Table 7
Robustness checks.

Dep variable: $\Delta\ln L_{it}$	(1) Time-invariant weights	(2) Add control variables	(3) Add lagged exchange rates	(4) Positive exp./imp.	(5) Zero exp.&imp.	(6) Including adj. cost
$\varphi_{i,t-1} \times \Delta IMFEER_{it}$	0.144***	0.189***	0.202***	0.173***		0.227***
	(0.046)	(0.041)	(0.055)	(0.043)		(0.053)
$\chi_{i,t-1} \times \Delta EXFEER_{it}$	−0.277***	−0.242***	−0.402***	−0.341***		−0.431***
	(0.033)	(0.033)	(0.040)	(0.034)		(0.041)
$(1-\chi_{i,t-1}) \times \Delta IMPEER_{jt}$	0.008	0.031	−0.176	−0.128	−0.081	−0.144
	(0.032)	(0.089)	(0.116)	(0.111)	(0.180)	(0.123)
$\Delta \text{lnSales}_{it}$		0.210***				
		(0.002)				
$\Delta Markup_{it}$		−0.001				
		(0.001)				
$\varphi_{i,t-2} \times \Delta IMFEER_{it-1}$			0.082*			
			(0.049)			
$\chi_{i,t-2} \times \Delta EXFEER_{it-1}$			−0.082**			
			(0.040)			
$(1-\chi_{i,t-2}) \times \Delta IMPEER_{jt-1}$			−0.025			
			(0.093)			
$\Delta \text{lnL}_{i,t-1}$						0.494***
						(0.019)
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	148,907	148,780	107,301	113,861	35,051	107,884
R-squared	0.010	0.089	0.012	0.011	0.023	–
Hansen-p						0.980

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 ($\Delta lnSales_{it}$) 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 lagged employment growth. Columns (1)–(5) are estimated by ordinary least squares, and Column (6) by generalized methods of moments (GMM). For Column (6), lagged employment levels dated period $t-2$ and earlier are used as instruments for $\Delta lnL_{i,t-1}$. All regressions include industry-year fixed effects. Robust standard errors in parenthesis.
* Corresponds to 10% significance level.
** Corresponds to 5% significance level.
*** Corresponds to 1% significance level.

results on the impact of exchange rates on employment still hold qualitatively.[29]

5.4. Comparison with more aggregate effective exchange rate measures

5.4.1. Comparison of regression results

A methodological contribution of 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, existing studies on the topic usually use effective exchange rates constructed at more aggregate levels such as industry-specific or country-level effective exchange rates. In firm-level studies, using these aggregate level exchange rates to proxy for the exchange rate shocks faced by a firm can potentially lead to an attenuation bias because aggregate exchange rates fail to consider the firm's trade distribution across trading partners. Moreover, the use of firm-level effective exchange rate changes provides an additional source of cross-firm variation and can thus enhance the precision of estimation.

To empirically assess the performance of firm-level versus industry and aggregate exchange rate, we repeat the baseline regression using all three measures. The results are reported in Table 8. In the first two columns, we used industry-specific effective exchange rate changes at the CIC 4-digit level so that effective exchange rate changes are now identical for all firms within an industry.[30] Column (1) includes industry fixed effects and year fixed effects, and Column (2) includes industry-year fixed effects. We find a significant impact of exchange rates on employment through the export price channel and an insignificant effect through the import competition channel, as predicted by the theory. However, the estimate for the import cost channel has a positive sign and is only marginally significant. In Columns (3) and (4), we use country-level effective exchange rate changes 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 a positive sign, and is insignificant when we control for the more demanding industry-year fixed effects.

The main difference between using firm-specific effective exchange rates and more aggregate effective exchange rates is the reverse sign of the import cost effect. There are two reasons why we believe the results using firm-specific effective exchange rates are more plausible. First, as we mentioned in the Theory section, under Cobb–Douglas technology and conventional demand elasticity estimates, we expect the scale effects to outweigh the substitution effects. Second, using firm-specific effective exchange rates has the advantage that the export-weighted and import-weighted effective exchange rates are less correlated, and thus their effects are more likely to be identified separately. To see this, Table 10 reports the

[29] We also explore whether the employment response to exchange rates are asymmetric for appreciations and depreciations. Asymmetric responses to appreciations and depreciations may arise because of different labor adjustment costs involved in hiring and firing workers. Empirical estimates in the labor literature generally suggest that adjustment costs are higher for firing workers than for hiring workers (Abowd and Kramarz, 2003; Pfann and Palm, 1993). The results reported in Table A3 of the Appendix suggests that employment sensitivity to exchange rates are indeed consistent with the view that the labor adjustment costs are larger when cutting employment. Specifically, we find that employment sensitivity to exchange rates is larger when the exchange rate movements lead to employment expansions than employment contractions.

[30] 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 weights defined by the lagged share of each partner country 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 from the HS 6-digit level to the CIC 4-digit level.

Table 8
Results using effective exchange rates at more aggregate levels.

Dep variable: $\Delta \ln L_{it}$	(1) Industry REER	(2) Industry REER	(3) Aggregate REER	(4) Aggregate REER
$\varphi_{i,t-1} \times \Delta Industry\_IMEER_{jt}$	−0.125**	−0.094*		
	(0.056)	(0.060)		
$\chi_{i,t-1} \times \Delta Industry\_EXEER_{jt}$	−0.286***	−0.309***		
	(0.046)	(0.048)		
$\varphi_{i,t-1} \times \Delta Aggregate\_EER_t$			−0.359***	−0.218
			(0.135)	(0.141)
$\chi_{i,t-1} \times \Delta Aggregate\_EER_t$			−0.685***	−0.691***
			(0.109)	(0.112)
$(1-\chi_{i,t-1}) \times \Delta IMPEER_{jt}$	−0.098	−0.190	−0.108	−0.203
	(0.096)	(0.129)	(0.096)	(0.129)
Industry FE	Yes	No	Yes	No
Year FE	Yes	No	Yes	No
Industry-year FE	No	Yes	No	Yes
Observations	135,436	135,436	135,436	135,436
R-squared	0.010	0.023	0.010	0.023

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. Columns (1) and (3) include 4-digit CIC industry fixed effects and year fixed effects. Columns (2) and (4) include industry-year fixed effects. Robust standard errors in parenthesis.
* Corresponds to 10% significance level.
** Corresponds to 5% significance level.
*** Corresponds to 1% significance level.

correlation between export-weighted and imported-weighted effective exchange rates in our data. For firm-specific effective exchange rates the correlation is 0.24. However, for industry-specific effective exchange rates the correlation is as high as 0.84. This is appropriate because for a particular firm it is more likely that the export destinations are different from the countries from which they source inputs. At the industry level, export destinations and import source countries are expected to have a greater overlap because of the prevalence of intra-industry trade. When the correlation between export-weighted and imported-weighted exchange rates is high, it becomes more difficult to disentangle the effects of the import and export channel.

In addition to obtaining more sensible coefficients before the import cost term, using firm-specific effective exchange rates also significantly enhances the precision of estimation: the standard errors of the coefficients before the export and import terms using the aggregate-level exchange rate measure (0.14 for import term and 0.11 for the export term) are consistently larger than those using the firm-specific measure (0.04 for the import term and 0.03 for the export term).[31]

Table 9a
Standard deviation of predicted employment growth: comparison of firm, industry and aggregate exchange rates.

REER measures:	(1) Firm REER	(2) Industry REER	(3) Aggregate REER
2001	1.10	1.01	0.74
2002	0.67	0.36	0.42
2003	1.11	0.95	1.33
2004	0.91	0.56	0.57
2005	0.71	0.14	0.13
2006	0.79	0.28	0.34
Year average	0.88	0.55	0.59

Note: this table reports the employment-weighted average of the industry-level standard deviation of predicted employment changes, calculated with different exchange rate measures. For expositional purposes we multiply the standard deviation by 100. The predicted employment changes of each firm is calculated according to Eq. (12). Predicted employment changes in Column (1) to Column (3) is calculated based on estimates of Column (4) of Table 4; Column (2) of Table 8 and Column (4) of Table 8, respectively. Standard deviation is calculated for each industry and year and industry employment weights are used to aggregate them up to the year level.

Table 9b
Variation of employment growth explained by exchange rate changes: comparison of firm, industry and aggregate exchange rates.

REER measures:	(1) Firm REER	(2) Industry REER	(3) Aggregate REER
2001	0.027	0.025	0.018
2002	0.020	0.010	0.012
2003	0.034	0.029	0.040
2004	0.022	0.014	0.014
2005	0.021	0.004	0.004
2006	0.025	0.009	0.011
Year average	0.025	0.015	0.017

Note: this table reports the proportion of employment growth variation explained by exchange rate changes, for firm, industry, and aggregate effective exchange rates. Proportion of employment variation explained by exchange rates is defined as the ratio between the standard deviation of predicted employment growth and the standard deviation of the actual employment growth. See text for details. The predicted employment growth of each firm is calculated following Eq. (12). Predicted employment changes in Column (1) to Column (3) is calculated based on estimates of Column (4) of Table 4; Column (2) of Table 8 and Column (4) of Table 8, respectively. Standard deviation is calculated for each industry and year and industry employment weights are used to aggregate them up to the year level.

Table 10
Correlation between export and import weighted effective exchange rate changes.

Year	Firm REER	Industry REER
2001	0.15	0.86
2002	0.10	0.97
2003	0.22	0.85
2004	0.21	0.90
2005	0.37	0.68
2006	0.40	0.77
Year average	0.24	0.84

Note: this table reports the correlation between export-weighted and import-weighted effective exchange rate changes by year. The first column reports the correlation for firm-specific effective exchange rate, and the second column for industry-specific effective exchange rates.

5.4.2. Comparison of the overall impact of exchange rates on employment

To compare the overall industry-level variation of exchange-rate-induced-employment growth for firm, industry, and aggregate level exchange rates, we calculate the predicted employment growth using three different effective exchange rate measures and derive their standard deviation for each industry and year.[32]To quantify the contribution of exchange rates to the overall heterogeneity in firms' employment growth, we calculate the standard deviation ratio of the predicted and actual employment growth.

Tables 9a and 9b report the standard deviation of predicted employment growth and the contribution of exchange rates to the

[31] Using aggregate effective exchange rate changes, Nucci and Pozzolo (2010) found that both the coefficient before the export and import terms have signs as predicted by our theory. A possible reason why using aggregate effective exchange rates works well in their study but not in ours is that the inconsistency resulting from the use of aggregate effective exchange rate is likely to be more severe in countries like China where trading partner distributions vary widely across firms. Another possible reason is that the RMB was pegged to the dollar for most of this sample period and that the aggregate effective exchange rate 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.

[32] Predicted employment growth for each firm based on firm-specific, industry-specific, and aggregate effective exchange rate respectively, is calculated using the estimates in Column (4) of Table 4, Column (2) of Table 8 and Column (4) of Table 8.

Table 11
TFP and employment adjustment to exchange rates.

Dep variable: $\Delta \ln L_{it}$	(1)	(2)	(3)	(4)
$\varphi_{i,t-1} \times \Delta IMFEER_{it}$	0.179***	0.226***	0.176***	0.223***
	(0.042)	(0.044)	(0.042)	(0.044)
$(1-\chi_{i,t-1}) \times \Delta IMPEER_{jt}$	−0.006**	−0.088*	−0.006	−0.087
	(0.101)	(0.144)	(0.101)	(0.144)
$\chi_{i,t-1} \times \Delta EXFEER_{it}$	−0.243***	−0.261***	−0.318***	−0.305***
	(0.045)	(0.046)	(0.043)	(0.044)
$TFP_{i,t-1}$	0.034***	0.035***		
	(0.001)	(0.001)		
$\chi_{i,t-1} \times \Delta EXFEER_{it} \times TFP_{i,t-1}$	0.052	0.032		
	(0.039)	(0.039)		
$TFP\_medium_{i,t-1}$			0.032***	0.032***
			(0.002)	(0.002)
$TFP\_high_{i,t-1}$			0.074***	0.075***
			(0.003)	(0.003)
$\chi_{i,t-1} \times \Delta EXFEER_{it} \times TFP\_med$			0.074	0.043
			(0.068)	(0.069)
$\chi_{i,t-1} \times \Delta EXFEER_{it} \times TFP\_high$			0.077	0 .038
			(0.085)	(0.086)
Industry FE	Yes	No	Yes	No
Year FE	Yes	No	Yes	No
Industry-year FE	No	Yes	No	Yes
Observations	124,124	124,124	124,124	124,124
R-squared	0.018	0.035	0.018	0.034

Note: This table reports the OLS estimation results of Eq. (6), with TFP and the interaction between TFP and export exchange rate exposure as additional variables. ΔlnL_{it}: log changes of number of workers. χ : export intensity, φ : import intensity. $\Delta EXFEER$, $\Delta IMFEER$ and $\Delta IMPEER$ are respectively export-weighted, import-weighted and import-penetration weighted exchange rate changes calculated according to Eqs. (7) to (9). *TFP* is total factor productivity estimated using Ackerberg et al. (2015) method. TFP_medium=1 if firm's TFP lies between the 50th and 75th percentile of the TFP distribution. TFP_high = 1 if firm's TFP is above the 75th percentile of the TFP distribution. Columns (1) and (3) include 4-digit CIC industry fixed effects and year fixed effects. Columns (2) and (4) industry-year fixed effects. Robust standard errors in parenthesis.
* Corresponds to 10% significance level.
** Corresponds to 5% significance level.
*** Corresponds to 1% significance level.

overall variation of firm's employment growth respectively.[33]The results indicate that using firm-specific effective exchange rates substantially increases the contribution of exchange rates to the cross-firm heterogeneity of employment growth: on average, the within-industry standard deviation of employment growth predicted by firm-specific effective exchange rates is 38% ((0.88 − 0.55)/0.88) larger than that predicted by industry-specific effective exchange rate and 33% ((0.88 − 0.59)/0.88) larger than that predicted by aggregate effective exchange rate.[34] Table 9b also shows that, when firm-specific effective exchange rates are used, exchange rate changes can explain 2.5% of the cross-firm variation of employment growth.

6. Discussion: alternative dimension of firm heterogeneity

In our previous analysis, firms' heterogeneous employment response to exchange rates depends on their external orientation and trading partner distribution. However, previous research also highlights the other source of heterogeneity: the capability to adjust markup in the presence of exchange rate shock. Berman et al. (2012) show that in three standard models of variable markup, firms with higher total factor productivity (TFP) have higher markup elasticity, leading to lower ERPT into export prices and smaller size response to exchange rates. In this section, we discuss how the heterogeneity as emphasized in Berman et al. (2012) affects firm's price and employment adjustment to exchange rates in the Chinese data. In particular, we examine how price and employment adjustment differ across firms with different TFPs.

To prelude our analysis of the employment effects, in Appendix A.2.2 we estimate the elasticity of export prices (in the producer currency) to exchange rates.[35,36] The results show that the ERPT into export price is indeed lower for firms with a higher TFP, but the magnitude of the difference is minimal. Despite a very high average pass-through rate of 97%, a standard deviation increase in TFP reduces the ERPT by only 0.9 percentage point. The ERPT of the firm at the 90th percentile of the TFP distribution is only 2 percentage points lower than the firm at the 10th percentile (ERPT is 98% for the former and 96% for the latter).[37]

Similarly, firms' employment responses to exchange rates also tend to show little heterogeneity along the markup elasticity dimension. Here we consider the heterogeneity of employment response through the export channel.[38] To do so, we augment the baseline equation (6) by including firms' TFP and an interaction between TFP and the export exchange rate exposure term ($\chi_{i,t-1} \times \Delta EXFEER_{it} \times TFP_{i,t-1}$). Table 11 reports the results. Columns (1) and (2) include the continuous TFP measure, with a different set of fixed effects in

[33] Since we have many industries, Tables 9a and 9b report the employment-weighted average across industries for each year.

[34] The predicted variation using aggregate effective exchange rates is slightly larger than that using industry-specific effective exchange rates, due to the larger estimated coefficient.

[35] Ideally, we should examine the price response to exchange rates in each of the firms' destination markets including the domestic market. Since domestic price is not available in our data, we only examine the response of export prices.

[36] We regress the log change of export prices for a firm-product-country-year against the change of log bilateral exchange rate, firms' log TFP, and the interaction term between exchange rate change and TFP. We estimate TFP using the Ackerberg et al. (2015) method. Similar results are obtained if we estimate TFP using the Olley and Pakes (1996) method.

[37] These estimates are consistent with a recent paper by Li et al. (2015) using the Chinese data.

[38] We focus on the export channel because our price regression considers the heterogeneity of ERPT into export prices.

each column. In both columns, the coefficient before the interaction term is positive as predicted by the theory, but insignificant. In Columns (3) and (4) we split the sample into three bins according to the 50th and 75th percentile of the TFP distribution and include the TFP dummies and the interaction between the TFP dummies and export exposure. The results are similar: the employment response to exchange rates does not change significantly with TFP.

In sum, in the Chinese context, although we find some evidence of the Berman et al. (2012) type heterogeneity in the ERPT, the effect is quantitatively small so that the heterogeneity does not affect the employment response to exchange rates. One possible explanation for the difference between our results and Berman et al. (2012) is that China has a tremendous manufacturing sector, with a vast number of firms fiercely competing in each industry. As such, most firms are well approximated by the monopolistic competition model of constant markups and have negligible market power. Perhaps in an economy with a relatively smaller manufacturing sector, the role of markup elasticity will be more pronounced.

7. Conclusion

This paper investigates how exchange rate shocks induce intra-industry labor reallocation across firms. We constructed firm-specific effective exchange rates to accurately measure the overall exchange rate shocks pertinent to each firm. Using this new exchange rate measure, we find significant job reallocation across firms with different external orientation and with different trading partner distribution. In explaining the heterogeneous employment response to exchange rates across firms, the role of firm-specific effective exchange rates is as significant as the role of external orientation. Compared with effective exchange rate measures at more aggregate levels, using firm-specific effective exchange rates generates estimation results that are more consistent with theory, and substantially increases the estimated heterogeneity of the impact of exchange rates on employment.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jinteco.2017.05.004.

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