Real Exchange Rate Movements and Allocation Efficiency: Evidence from China

Risheng Mao, Yan Wu, and Linhui Yu

Abstract: This paper investigates the linkage between real exchange rate movements and allocation efficiency, as measured by the markup dispersion in industries. We first develops a theoretical framework to comprehensively characterize the impacts of exchange rate changes on markup dispersion. Our empirical analysis hinges on Chinese firm level data and the real exchange rate of RMB during 1998-2007. Four major findings are derived from this study: First, markup dispersion is significantly affected by real effective exchange rate (REER) changes at narrowly-defined industry level; specifically, an appreciation (depreciation) in REER significantly reduces (expands) the markup dispersion across firms in the same industry. Second, the impacts of REER movements on markup dispersion are closely associated with the trade dependence of manufacturing industries. Third, REER movements impact allocation efficiency through both the intensive and extensive margins; specifically, an appreciation of REER will increase the markup dispersion of incumbent firms through the export dependence channel but will also substantially reduce markup dispersion by accelerating their exit and entry rate through the import dependence and import competition channels, and the latter effect dominates the former effect. Fourth, REER changes have asymmetric impacts on the markup dispersion in industries, and the allocative effect of REER is greater when it depreciates than appreciates.

Key Words: real effective exchange rate; trade dependence; allocative efficiency; markup dispersion
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1.Introduction

In recent years, there is increasing interest of economic researchers to identify the impact of exchange rate movement on economic activities at micro levels. Existing studies have well documented the firms' responses to exchange rate movement in terms of price, volume, scope, wage, employment, productivity, markup, etc. (e.g., Knetter, 1993; Goldberg and Knetter, 1997; Atkeson and Burstein, 2008; Gopinath and Itskhoki, 2010; Berman *et al.*, 2012; Amiti *et al.,* 2014; Li *et al.*, 2015; etc.) These studies have found differential impacts of exchange rates on behaviors of firms, especially depending on to what extent firms get involved in international trade. Actually, if exchange rate movement is large and persistent, the consequences can be huge and even comparable to tariff changes (Feenstra, 1989). In this sense, an appreciation in the home currency may be viewed as an increase in the tariff of an export destination country. Consequently, currency appreciation will intensify intra-industry competition and force out the less productive firms. As a result, movements in the exchange rate would cause intra-industry reallocations and impact allocation efficiency—similar to the well-known intra-industry effects of international trade (Melitz, 2003).

Given the possibly huge effect of exchange rate movement on intra-industry resource allocation, few studies so far have carefully examined this issue. In this paper, we attempt to establish a linkage between industry-level real effective exchange rate (REER) and intra-industry allocation efficiency. To measure the degree of allocation efficiency within an industry, we employ the markup dispersion of firms in this industry. Generally, firms with higher markups employ resources at less than optimal levels, and firms with lower markups produces more than optimal level (Lu and Yu, 2015), thus first-best efficiency is achieved when markups are the same across products in each industry (Robinson, 1934). To characterize how exchange rate movement affects the markup dispersion of industries that involve in international trade, we develop a partial equilibrium model and derive that export dependence (export to sales ratio), import dependence (import input ratio, namely the ratio of imported inputs to total intermediate inputs) and import competition (import penetration ratio) are three major channels through which industry-specific REER impacts markup dispersion of the industry.

Our empirical analysis hinges on a large panel of Chinese manufacturing firms over the period of 1998-2007, during which there was a highly volatile real exchange rate for the RMB (Chinese currency). We recovered quantity-based firm markup following De Loecker and Warzynski (2012). Since material inputs in our data are revenue-based instead of in physical terms, we refer to De Loecker *et al*. (2016) to solve the omitted input prices bias in production function estimation.[1] With estimated firm markups, we

[1] As pointed out by De Loecker (2014), the price index at industry level is not appropriate to eliminate estimation bias using revenue-based production function due to the price changes at firm level is clearly inconsistent with price changes at the aggregated industry level. Actually, the importance of physical output in estimating production function has also been emphasized by earlier studies (Eslava et al., 2013; Foster et al., 2008; Hsieh and Klenow, 2009).

are able to calculate for each narrowly-defined industry (four-digit CIC) the dispersion of firm markups at yearly basis. The REER is constructed at the same industry level as markup dispersion following the trade weighted method developed by Goldberg (2004). Specifically, we combine the PPI based bilateral real exchange rate with bilateral trade flows in over 400 manufacturing industries between China and other 41 economies and thus obtain the time-varying and industry-specific trade weighed REER. Using the merged data of REER and markup dispersions, we are able to conduct an in-depth and comprehensive investigation of the intra-industry allocation effect caused by exchange rate movements. In particular, we examine the three channels through which firm markup (and thus markup distribution) can be influenced by exchange rate fluctuation, i.e., export dependence, import dependence and import competition (Campa and Goldberg, 2001, 2005, 2010; Ekholm *et al.*, 2012). In addition, the following two aspects discussed in the literature are also examined. First, the impact of exchange rate movement on incumbent firms (intensive margin) and entry and exit of firms (extensive margin), which is emphasized in the literature (Epifani and Gancia, 2011; Peters, 2013; Tomlin, 2014). Second, the asymmetric effects of exchange rate movement on firm markup adjustment as a result of heterogenous pricing to market (PTM) behaviors of firms under depreciation and appreciation (Marston, 1990; Kasa, 1992; Kanas, 1997; Knetter, 1994; Koutmos and Martin, 2003; Fang, *et al.*, 2009).

Our baseline regression results show that an appreciation (or depreciation) of the real exchange rate will significantly reduce (or expand) the markup dispersion within manufacturing industries; and further analysis indicates that real exchange rate changes impact markup dispersion through all three proposed channels and at both intensive and extensive margins. More specifically, an appreciation (or depreciation) of the real exchange rate of the RMB will reduce (or expand) the markup dispersion mainly through the import dependence and import competition channel; And this effect, however, only works for entry and exit firms (extensive margin) in terms of a positive association between both import dependence and import competition and the turnover of an industry. In contrast, export dependence channel plays little role in affecting the impact of real exchange rate on markup dispersion of an industry. Interestingly, our subsample analysis shows that an appreciation (or depreciation) of the real exchange rate of the RMB can expand (or reduce) the markup dispersion among incumbent firms (intensive margin) through the export dependence channel.[2] In sum, despite the positive correlation of exchange rate movement and markup dispersions for incumbent firms (intensive margin) through export dependence channels, the overall negative relationship between exchange rate valuation and markup dispersions is dominated by entry and exit of firms (extensive margin) through the import channels (including

[2] De Loecker and Warzynski (2012) shows that export firms have a higher markup, implying that an appreciation in the exchange rate will drive down the markup gap between export and non-export firms, especially in those industries with high exposure to international trade. Our empirical evidence contradicts to theirs because the average markup of Chinese export firms is significantly lower than that of non-export firms, as indicated in previous studies using the same Chinese firm-level data (Lu, et al., 2010; Dai et al., 2016). Thus, the gap in markups between exporter and non-exporters will be further widened in case of an appreciation in the exchange rate.

import competition and import dependence). This implies that, on average, the impacts of real exchange rate movements are more pronounced at the extensive margin than at the intensive margin. Additionally, we find asymmetric impacts of real exchange rate movements on the markup dispersion of firms during appreciation and depreciation. Specifically, real exchange rate has much greater and pronounced impacts on markup dispersion in the period when currency is deprecating than that of appreciating.

China provides an ideal research context for us to examine the effects of exchange rate movements on allocation efficiency. Firstly, China has the largest manufacturing industry, which includes almost all of the different manufacturing sectors. Secondly, China is also one of most important players in both exporting and importing in the global market. This feature allows us to fully explore how exchange rate movements affect and link with allocation efficiency, from both export and import perspectives. In addition, China's exchange rate policies have been substantially adjusted over the past decade; From January. 2001 to July 2005, the real effective exchange rate of Chinese Renminbi (RMB) consistently depreciated more than 14.5%; however, since the reform of the RMB exchange rate regime on July 21, 2005, the real effective exchange rate of RMB appreciated more than 55% by the end of 2015. Such policy background thus provides us sufficient variations in exchange rate during our examination period.

Our study has several novel features. First, our proxies for exchange rate movements are at the four-digit industrial level instead of at national aggregate level, which allows us to capture larger and more precise variations in the exchange rates. More importantly, our identification strategy hinges upon such precisely defined industries. Specifically, industrial-level movements in exchange rates are more likely to be independent of firm-specific characteristics, i.e., their movements mainly occur as responses to exchange rate movements at national level or changes in industrial-specific trading patterns. Therefore, industry-specific REER should be exogenous to firm-level markups and thus markup dispersions at industry-level.

Second, we focus on the distribution of firm markups. The new generation of trade theories proposed by Krugman (1979), Eaton and Kotum (2002), Melitz (2003), Bernard *et al.* (2003) all assume that a firm's markup is invariable; therefore, they are not suitable for fully understanding the trade welfare generated by the pro-competitive effects of a decline in trade costs. A large number of previous studies primarily measure misallocations in view of productivity dispersion or distribution (Restuccia and Rogerson, 2008; Midrigan and Xu, 2010; Syverson, 2004; Hsieh and Klenow, 2009; Alfaro *et al.*, 2008; Moll, 2014); as productivity usually measures the cost of a firm, it is obviously less advantageous/comprehensive than markup which can capture both price and cost of a firm. For this reason, increasing numbers of studies emphasize the importance of variable markup assumptions in trade models for clarifying the welfare effects of trade liberalization (Melitz and Ottaviano, 2008; De Blas and Russ, 2015; Edmond *et al.*, 2011; Peters, 2013; Holmes *et al.*, 2014; Opp *et al.,* 2014; Feenstra, 2014).[3] Therefore, in order to precisely evaluate the link between exchange rate

[3] For example, trade liberalization could lower the prices of domestic goods through import competition, which

movement and allocation efficiency, it is critical to employ the markup dispersion instead of markup level or productivity dispersion.

Third, we investigate the impacts of real exchange rate changes on allocation efficiency at the extensive and intensive margins. In so doing, we not only elaborate on the mechanism of the impacts of exchange rate movements but also identify the different magnitudes of the impacts of exchange rate changes at both the intensive and extensive margins. We investigate whether or not a firm's entry and exit could play an even more important role in impacting the markup dispersion of firms (Epifani and Gancia, 2011; Peters, 2013).

Our study contributes to several different strands of the literature. In recent years, firm heterogeneity has been introduced into trade theories. A few studies have investigated the welfare and allocation effects associated with trade shocks, including movements in exchange rates (e.g, Tomlin and Fung, 2015). Our work further extends these studies by evaluating intra-industry reallocation effects of real effective exchange rate movements by investigating the distribution of firm markups in narrowly-defined manufacturing industries.

Our work is also related to studies that examine how exchange rate movements affect various behaviors of firms involving in international trade (see Amiti *et al.*, 2014 for a review of literature). Especially, Li *et al*. (2015) show that the export RMB price response to RMB exchange rate movements is very small, while the volume response is moderate. Our finding suggests that effects on the entry-exit channel are more pronounced. We also find that the import channels of exchange rate movements also plays an important role in affecting allocation efficiency by increasing the firm turnover rate within specific industries. Another strand of literature that are closely related to our work is about the movement of exchange rates and industrial structuring and economic growth (See Ekholm *et al.*, 2012; Habib *et al.*, 2017 for a review of literature). For example, Rodrik (2008) and provide evidence that the undervaluation of a currency stimulates economic growth, particularly for developing countries. In contrast, Kappler *et al.* (2012) find that currency appreciation has little impact on overall GDP—because appreciation decreases net exports but increases domestic demand. The relatively low and inflexible exchange rate of China's currency was believed to have contributed to the rapid economic growth in China but may have hurt its trade partners' economies (Aghion *et al.*, 2009). Our study thus provides a more comprehensive understanding of the impacts of exchange rate policies.

The remainder of this paper is arranged as follows. Section 2 develops a theoretical model. Section 3 describe the data and variables. Section 4 introduces the baseline empirical models and presents estimation results. Section 5 discusses and empirically test the mechanism through which markup dispersion is affected by exchange rate.

would promote allocation efficiency. On the other hand, trade liberalization could also lead to a decline in import costs for inputs and an increase in markups, particularly for firms with high import dependency for inputs. Therefore, trade liberalization could further expand the markup dispersion among firms, thereby increasing the degree of misallocation. (Epifani and Gancia, 2011; De Loecker et al., 2016; Weinberger, 2015).

Section 6 examines the important impacts of exchange rate on markup distribution from two additional channels, and section 7 concludes.

2. Theoretical model

In this section, we formally characterize the impact of exchange rate movement on firm markups (therefore markup dispersion) by relying on a partial equilibrium theoretical framework. Our models are used to show that exchange rate movements have different impacts on the markup of firms participating in foreign trade and those that do not, which can account for the markup dispersion across firms within the same industry.

We assume the profit function of a trade firm in the manufacturing industry is

$$\pi(e) = \max_{\substack{q^d, q^x, q^m \\ L, Z, I}} \left\{ \begin{array}{c} p^d(e, q^d) * q^d + \dfrac{p^x(e, q^x)}{e} * q^x - w * L \\ -r * Z - \dfrac{s(e)}{e} * I \end{array} \right\}, \tag{1}$$

and the Cobb-Douglas production function for the firm is

$$q^d + q^x = Q = AL^{\alpha} Z^{\beta} I^{1-\alpha-\beta}, \tag{2}$$

where q^d and q^x denote the firm's sales in domestic market and export market, respectively. p is selling price of product, which is different in domestic market and export markets. p^x, selling price in export market, is a function of exchange rate e and export sales q^x. L and Z represents labor inputs and non-labor inputs from the domestic market, respectively; and I is imported inputs. w is the wage rate for employment, r is the factor price of input Z, and $s(e)$ is the price of imported inputs which is also affected by exchange rate. As e represents the real exchange rate for the host country against foreign countries, an increase (decrease) in e means appreciation (depreciation) of the real exchange rate. The total production of the firm is Q, including its domestic sales q^d and export sales q^x. To solve the profit maximization problem of equation (1) at a given amount of total production Q, we derive the first-order conditions of equation (1) for q^d and q^x as

$$\frac{\partial \pi(e)}{\partial q^d} = \frac{\partial p^d(e, p^d)}{\partial q^d} * q^d + p^d - \lambda = 0, \tag{3}$$

$$\frac{\partial \pi(e)}{\partial q^x} = \frac{1}{e}\left(\frac{\partial p^x(e, p^x)}{\partial q^x} * q^x + p^x \right) - \lambda = 0. \tag{4}$$

Thus, the markup of the firm, λ, is

$$\lambda = p^d\left(1 + \frac{1}{\eta^d}\right) = \frac{p^x}{e}\left(1 + \frac{1}{\eta^x}\right) \tag{5}$$

where η^d and η^d represent the demand elasticity of selling price in domestic market and foreign market, respectively. As shown in equation (5), the firm markup λ depends on both demand elasticity and selling prices. The first-order conditions for solving the optimal demand of factor inputs are

$$\frac{\partial \pi(e)}{\partial L} = -w + \lambda \frac{\partial Q}{\partial L} = 0 \tag{6}$$

$$\frac{\partial \pi(e)}{\partial Z} = -r + \lambda \frac{\partial Q}{\partial Z} = 0 \tag{7}$$

$$\frac{\partial \pi(e)}{\partial I} = -\frac{s(e)}{e} + \lambda \frac{\partial Q}{\partial I} = 0 \tag{8}$$

Combining the Euler theorem with the first-order conditions for solving the input demands, we can derive the optimal demand for labor

$$L = \frac{Q}{w}\left\{ p^d\left(1+\frac{1}{\eta^d}\right)(1-\theta) + \frac{p^x}{e}\left(1+\frac{1}{\eta^x}\right)\theta - \gamma\beta\left(\frac{\partial Q}{\partial Z}\right)^{-1} - \frac{s}{e}(1-\alpha-\beta)\left(\frac{\partial Q}{\partial I}\right)^{-1} \right\} \tag{9}$$

In equation (9), θ represents the ratio of export demand to total sales; therefore, the elasticity of labor demand to exchange rate is

$$\frac{\partial L}{\partial e}\frac{e}{L} = \frac{Q}{wL}\left(\begin{array}{c} p^d\left(1+\frac{1}{\eta^d}\right)\eta^{d,e} + \theta\left[\frac{p^x}{e}\left(1+\frac{1}{\eta^x}\right)(\eta^{x,e}-1) - p^d\left(1+\frac{1}{\eta^d}\right)\eta^{d,e}\right] \\ +\frac{s}{e}(1-\alpha-\beta)\left(\frac{\partial Q}{\partial I}\right)^{-1}(1-\eta^{s,e}) \end{array} \right) \tag{10}$$

Combined with equations (5), (8), and (10), the labor demand elasticity of exchange rate is reduced to

$$\frac{\partial L}{\partial e}\frac{e}{L} = \frac{1}{\alpha\lambda}\left(\eta^{d,e} + \theta\left(\eta^{x,e} - \eta^{d,e} - 1\right) + (1-\alpha-\beta)(1-\eta^{s,e})\right) \tag{11}$$

where λ is the markup of the firm. As indicated by previous studies (Dornbusch,1987; Campa and Goldberg, 1995, 1999, 2001), the pass-through of exchange rate movements to domestic prices, export prices and import input prices are all proportional to the import penetration rates of firms or industries; therefore, the multiplier used for the ratios, including $\theta(\eta^{x,e} - \eta^{d,e})$ and $(1-\alpha-\beta)\eta^{s,e}$ in equation (11) are both minimal values or approximately equal to zero. Hence, the labor demand elasticity of exchange rate can be further reduced to the following

$$\frac{\partial L}{\partial e}\frac{e}{L} = \frac{1}{\alpha\lambda}\left(\eta^{d,e} - \theta + (1-\alpha-\beta)\right) \tag{12}$$

In alignment with the existing studies, the pass-through of exchange rate changes to domestic sale prices crucially depends on the import penetration rate, that is, $\eta^{d,e} \propto c_0 M$; where M is the import penetration ratio for firms or industries, and c_0 is the coefficient for the import penetration ratio. Equation (12) can be expressed as follows

$$\frac{\partial L}{\partial e}\frac{e}{L}=\frac{1}{\alpha\lambda}\left(c_0 M-\theta+(1-\alpha-\beta)\right) \tag{13}$$

With equations (9), (10) and (13), we can derive the reduced expression of labor demand and exchange rate changes

$$\widehat{L^D}=\alpha_0+\alpha_1\widehat{Q}+\alpha_2\widehat{w}+\frac{1}{\lambda}\{\alpha_3\theta+\alpha_4(1-\alpha-\beta)+\alpha_5 M\}\hat{e} \tag{14}$$

To construct the link between markup and exchange rate changes, we also need to introduce the labor supply equation to solve for the labor market equilibrium. In alignment with prior studies (Klein *et al.*, 2003; Campa and Goldberg, 2001), the labor supply equation is specified as follows

$$L^S=\left(\frac{w}{P}\right)^{\vartheta} Q \tag{15}$$

where P represents the aggregate level of consumer prices, and ϑ is the coefficient of the elasticity of labor supply to wage rates.

Under the perfect labor market assumption, $\widehat{L^D}=\widehat{L^S}$, the link between markup and real exchange rate changes is reduced to

$$\lambda=\beta_0+\beta_1\widehat{P}+\{\beta_2\theta+\beta_3(1-\alpha-\beta)+\beta_4 M\}\hat{e}+\beta_5\lambda\widehat{Q}+\beta_6\lambda\widehat{w} \tag{16}$$

where β_0 to β_6 are the coefficients for the variables in equation (16).

By following the same logic as above, we can also derive the optimal demand for non-labor inputs (Z) and imported inputs (I). The elasticities of the demand for inputs Z and I to exchange rate changes are

$$\frac{\partial Z}{\partial e}\frac{e}{Z}=\frac{1}{\beta\lambda}\left(\eta^{d,e}-\theta+(1-\alpha-\beta)\right) \tag{17}$$

$$\frac{\partial I}{\partial e}\frac{e}{I}=\frac{1}{(1-\alpha-\beta)\lambda}\left(\rho_0 M-\theta\right) \tag{18}$$

The equations for the optimal demand for inputs Z and I are solved as follows,

$$\widehat{Z^D}=\alpha_0+\alpha_1\widehat{Q}+\alpha_2\hat{r}+\frac{1}{\lambda}\{\alpha_3\theta+\alpha_4(1-\alpha-\beta)+\alpha_5 M\}\hat{e} \tag{19}$$

$$\widehat{I^D}=\chi_0+\chi_1\widehat{Q}+\chi_2\widehat{\left(\frac{s}{e}\right)}+\frac{1}{\lambda}\{\chi_3\theta+\chi_4 M\}\hat{e} \tag{20}$$

The supply functions for non-labor inputs follows the same form as labor input, as follows

$$Z^S=\left(\frac{r}{P}\right)^{\upsilon} Q \qquad I^S=\left(\frac{s}{eP}\right)^{\sigma} Q$$

Under the assumption of a perfect market for non-labor inputs Z and imported inputs I, i.e., $\widehat{Z^D}=\widehat{Z^S};\widehat{I^D}=\widehat{I^S}$, we can also establish the link between markup and exchange rate changes using the following two different equations:

$$\lambda = \delta_o + \delta_1 \widehat{P} + \left\{ \delta_2 \theta + \delta_3 (1 - \alpha - \beta) + \delta_4 M \right\} \hat{e} + \delta_5 \lambda \widehat{Q} + \delta_6 \lambda \hat{r} \tag{21}$$

$$\lambda = \varphi_o + \varphi_1 \widehat{P} + \left\{ \varphi_2 \theta + \varphi_3 M \right\} \hat{e} + \varphi_5 \lambda \widehat{Q} + \varphi_6 \lambda \widehat{\left(\frac{s}{e} \right)} \tag{22}$$

Combining the system equations (16), (21) and (22), we can drop some variables ($\widehat{Q}; \widehat{\left(\frac{s}{e} \right)}; \widehat{w}$) and derive the reduced equation that describes the relationship between markup and exchange rate changes as follows

$$\lambda = \psi_o + \psi_1 \widehat{P} + \left\{ \psi_2 \theta + \psi_3 (1 - \alpha - \beta) + \psi_4 M \right\} \hat{e} + \psi_5 \lambda \hat{r} \tag{23}$$

It makes sense that the price of non-labor inputs obtained from the domestic market and the aggregate level of consumer prices are both invariant across firms; therefore, these two variables have a constant value at the firm level. Thus, equation (23) can be further reduced to

$$\lambda = \phi_o + \left\{ \phi_1 \theta + \phi_2 (1 - \alpha - \beta) + \phi_3 M \right\} \hat{e} \tag{24}$$

In equation (24), it is clear that the exchange rate movements impact the markup of a typical trade firm through three main channels: export dependence (export ratio θ), import dependence (import input ratio 1-α-β), and import competition (import penetration ratio M). This result is similar to previous studies focusing on the impacts of exchange rate movements on employment and investments (Campa and Goldberg, 2001, 2005, 2010). The above equation also implies that the impacts of exchange rate movements on markup dispersion are also associated with variations in the level of trade dependence of firms within industries (Ekholm *et al*., 2012).

To clarify the impacts of real exchange rate movements on the markup dispersion of firms within industries, the markup dispersion of firms is measured by the weighted sum of the markup deviation of every firm within industry i, that is,

$$Dispersion\lambda_i = \sum_{j=1}^{n} \alpha_{ij} * \left| \lambda_{ij} - \overline{\lambda}_i \right| \tag{25}$$

The subset of firms with a markup that is higher than the average markup within industry i is defined as $S+$, and the subset of firms with a markup that is lower than the average markup within the industry is defined as $S-$. Therefore, equation (25) can be written as

$$\begin{aligned} Dispersion\lambda_i &= \sum_{j=1, j \in S+}^{n+} \alpha_{ij} * \left(\lambda_{ij} - \overline{\lambda}_i \right) + \sum_{j=1, j \in S-}^{n-} \alpha_{ij} * \left(\overline{\lambda}_i - \lambda_{ij} \right) \\ &= \sum_{j=1, j \in S+}^{n+} \alpha_{ij} * \lambda_{ij} - \sum_{j=1, j \in S-}^{n-} \alpha_{ij} * \lambda_{ij} + \overline{\lambda}_i * \left(\sum_{j=1, j \in S-}^{n-} \alpha_{ij} - \sum_{j=1, j \in S+}^{n+} \alpha_{ij} \right) \end{aligned} \tag{26}$$

Combined with equation (24), the markup dispersion within industry i is

$$\begin{aligned} Dispersion\lambda_i &= \phi_0 \sum_{j=1, j \in S+}^{n+} \alpha_{ij} + \sum_{j=1, j \in S+}^{n+} \alpha_{ij} \left\{ \phi_1 \theta_{ij} + \phi_2 (1 - \alpha - \beta)_{ij} + \phi_3 M_i \right\} \hat{e} \\ &- \phi_0 \sum_{j=1, j \in S-}^{n-} \alpha_{ij} - \sum_{j=1, j \in S-}^{n-} \alpha_{ij} \left\{ \phi_1 \theta_{ij} + \phi_2 (1 - \alpha - \beta)_{ij} + \phi_3 M_i \right\} \hat{e} + \overline{\lambda}_i k \end{aligned} \tag{27}$$

where $k=\left(\sum_{j=1,j\in s-}^{n-}\alpha_{ij}-\sum_{j=1,j\in s+}^{n+}\alpha_{ij}\right)$ in equation (27) can be reduced to

$$Dispersion\lambda_i=c_0+\left\{c_1\theta_i^{+}+c_2\theta_i^{-}+c_3\left(1-\alpha-\beta\right)_i^{+}+c_4\left(1-\alpha-\beta\right)_i^{-}-\phi_3kM_i\right\}\hat{e}+\overline{\lambda_i}k \quad (28)$$

$$c_0=\phi_0\left(\sum_{j=1,j\in s+}^{n+}\alpha_{ij}-\sum_{j=1,j\in s-}^{n-}\alpha_{ij}\right),\ \theta_i^{+}=\sum_{j=1,j\in s+}^{n+}\alpha_{ij}V_{ij};\theta_i^{-}=\sum_{j=1,j\in s-}^{n-}\alpha_{ij}V_{ij},$$

$$\left(1-\alpha-\beta\right)_i^{+}=\sum_{j=1,j\in s+}^{n+}\alpha_{ij}\left(1-\alpha-\beta\right)_{ij};\left(1-\alpha-\beta\right)_i^{-}=\sum_{j=1,j\in s-}^{n-}\alpha_{ij}\left(1-\alpha-\beta\right)_{ij}$$

where $\overline{\lambda_i}$ is the average markup of all firms within industry i, which can be expressed as equation (29) according to equation (24)

$$\overline{\lambda_i}=\overline{\phi_0}+\left\{\overline{\phi_1}\overline{\theta_i}+\overline{\phi_2}\overline{\left(1-\alpha-\beta\right)_i}+\overline{\phi_3}M_i\right\}\hat{e} \quad (29)$$

By combining equations (28) and (29), the markup dispersion equation can be further reduced to

$$Dispersion\lambda_i=d_0+\left\{\begin{matrix}d_1\theta_i^{+}+d_2\theta_i^{-}+d_3\overline{\theta_i}+d_4(1-\alpha-\beta)_i^{+}+\\ d_5(1-\alpha-\beta)_i^{-}+d_6\overline{(1-\alpha-\beta)_i}+d_7M_i\end{matrix}\right\}\hat{e} \quad (30)$$

It makes sense that the linear combination of the trade dependence of subset firms is proportional to overall trade dependence within the same industries, which are as follows

$$\begin{aligned}&d_1\theta_i^{+}+d_2\theta_i^{-}+d_3\overline{\theta_i}\propto k_1\theta_i\\&d_4(1-\alpha-\beta)_i^{+}+d_5(1-\alpha-\beta)_i^{-}+d_6\overline{(1-\alpha-\beta)_i}\propto k_2\left(1-\alpha-\beta\right)_i\end{aligned}$$

Therefore, the link between markup dispersion and exchange rate movements can finally expressed as

$$Dispersion\lambda_i=k_0+\left\{k_1\theta_i+k_2\left(1-\alpha-\beta\right)_i+k_3M_i\right\}\hat{e} \quad (31)$$

Thus, it is obvious from the above equation (31) that the impacts of the exchange rate movements on markup dispersion within an industry are also highly affected by the degree of trade involvement of the whole industry, including export dependence, import dependence and the import penetration ratio of the industry. The reason for this is that trade dependence generally illustrates the distribution of trade and non-trade firms in an industry, and the markup dispersion within that industry is also mainly generated by the differences in the impact of exchange rate movements on the markup of trade firms and non-trade firms.

3. Data and variables

3.1 Data

Panel data on industrial firms. The main dataset used in this study was obtained from the Annual Survey of Industrial Firms (ASIF), conducted by the National Bureau of Statistics of China for 1998–2007. This dataset covers all the state-owned enterprises and above-scale (annual sales higher than 5 Million RMB or approximately 827,000 USD) non-state-owned enterprises in China. The number of firms in this dataset ranges from 140,000+ in 1998 to 313,000+ in 2007. The manufacturing firms in our sample are distributed among 28 two-digit (164 three-digit and 464 four-digit) manufacturing industries and across China's 31 provinces (including 4 municipalities).[4] The dataset includes detailed firm information, including industry affiliation, firm location, and all the operations and performance data from the accounting statements, such as output, intermediate materials, employment, book value and the net value of fixed assets, etc. We strictly follow the procedure of Brandt *et al.* (2012) to clean up the data.[5] This dataset has also proved to be reasonably accurate and reliable due to the strict double-checking procedures used for data collection (Cai and Liu, 2009). Accordingly, it has been widely used by economic researchers in recent years, e.g., Lu *et al.* (2010); Brandt *et al.* (2012); Lu and Yu (2015); and Brandt *et al.* (2017).[6] We use the information provided in this dataset to estimate the production function, recover firm markups (and total factor productivity), calculate various indices and construct industry-level controls by aggregating firm-level information to the industry level, which allows us to conduct an in-depth analysis.

Panel data on product-level production of industrial firms. The literature has noted the importance of estimating a quantity-based production function for solving the estimation bias caused by an estimation based on a revenue-based production function (Eslava *et al.,* 2013; Foster *et al.*, 2008; Hsieh and Klenow, 2009). A crucial step in calculating firm markup involves the estimation of a production function, which requires determining the firm-level output in physical terms. As this information is not provided by the ASIF, we obtain this information from another large panel data set on the product-level production of industrial firms compiled by the National Bureau of Statistics of China, which is available only for the year 2000–2006. This dataset

[4] we exclude the tobacco industry from our analysis because (i) there are few observations, and (ii) this is a monopoly industry, which is protected by the government.

[5] During our sample period, some Chinese cities changed their region codes due to either an adjustment in their administrative territories or coding updates. Using the 1999 National Standards (promulgated at the end of 1998 and called GB/T 2260-1999) as the benchmark codes, we convert the region codes of all the firms to the benchmark to achieve consistency in the regional codes throughout the sample period. Meanwhile, a new classification system for industry codes (GB/T 4754-2002) was adopted in 2003 that replaced the old classification system (GB/T 4754-1994), which had been used from 1995 to 2002. To achieve consistency in the industry codes for the whole sample period (1998–2007), we convert the old industry codes used for the 1998–2002 data to the new classification system. For other procedures used to clean the data, we strictly follow Brandt et al. (2012).

[6] One drawback of this dataset is that it covers all the SOEs but only covers non-SOEs with annual sales of 5 million RMB (Chinese currency) or more. Hence, it is possible that both the overall degree of markup dispersion and the effect of exchange rate fluctuations on markup dispersion are underestimated, as this is a relatively more homogeneous sample due to data truncation.

contains information on all the products (defined at the five-digit HS level) produced by the firms in ASIF data, including output quantity. As the product-level data and the ASIF data use the same firm identifier, we can easily combine these two datasets.

Product-level custom transaction data. To construct industry-specific trade related measures, we need product-level information on imports, exports and imported inputs. This information is obtained from the Chinese Import and Export data issued by the Customs (2000-2015). We match each eight-digit HS code with a unique four-digit Chinese Industrial Classification (CIC, GB/T 4754-2002) code. The concordance table is obtained from the National Bureau of Statistics of China (Lu and Yu, 2015).

Other data. To construct industry-specific real effective exchange rates (REER), we must obtain the value of the exports and imports that are exchanged between China and its trading partners in narrowly defined industries. We obtain bilateral trade information for 1998-2007 from the COMTRADE database compiled by the United Nations. The monthly and annual producer price index (PPI) and the nominal exchange rate for China and 41 other economies are available from the International Financial Statistics (IFS) compiled by the IMF. We then construct the REER based on the bilateral trade volume between China and 41 economies and the PPI index over the period of 1996 to 2014. The bilateral trade volume between China and 41 other economies accounts for more than 85% to 90% of the trade volume between China and all other economies from 1996 to 2014, which is highly representative of foreign competition and the dependence of China's manufacturing firms on the global market.

3.2 Key variables and descriptive statistics

Estimation of firm markups

We follow the method of De Loecker and Warzynski (2012) to estimate firm markup. The key to this estimation method is to precisely estimate the output elasticity of inputs without adjustment costs. We assume that the production function of firm i at time t has the following general form

$$Q_{it} = Q_{it}(L_{it}, K_{it}, M_{it}, \omega_{it}) \tag{E1}$$

where L_{it}, K_{it}, M_{it} denote the physical inputs of labor, capital and intermediate materials, respectively, and ω_{it} represents firm-specific productivity. To derive the markup equation, we assume that the production function $Q_{it}(\cdot)$ is continuous and twice-differentiable with respect to all of its arguments. Consider the following cost-minimization problem for firm i at time t:

$$\min w_{it}L_{it} + r_{it}K_{it} + s_{it}M_{it} \tag{E2}$$

$$\text{subjected to: } Q_{it}(L_{it}, K_{it}, M_{it}, \omega_{it}) \geq \overline{Q}_{it}$$

where w_{it}, r_{it}, s_{it} represent the wage rate, the rental prices of capital, and the prices of intermediate materials, respectively. $\overline{Q}_{it}$ represents the minimum level of firm output. Therefore, the Lagrangian function of the firm's cost optimization problem can be written as

$$L(L_{it}, K_{it}, M_{it}, \omega_{it}, \delta_{it}) = w_{it}L_{it} + r_{it}K_{it} + s_{it}M + \delta_{it}(\overline{Q}_{it} - Q_{it}) \tag{E3}$$

For the reason discussed in Lu and Yu (2015), labor in the Chinese context is not freely chosen due to considerable adjustment costs, and capital is often considered to be a dynamic input; thus, we employ intermediate materials, which is free of any adjustment costs to recover markup. Specifically, we solve for the first-order condition for intermediate materials as follows.

$$\frac{\partial L_{it}}{\partial M_{it}} = s_{it} - \delta_{ti}\frac{\partial Q_{it}}{\partial M_{it}} = 0 \tag{E4}$$

By rearranging equation (4) and then multiplying M_{it}/Q_{it} to both sides of the equation, we derive the following equation:

$$\frac{\partial Q_{it}}{\partial M_{it}}\frac{M_{it}}{Q_{it}} = \frac{1}{\delta_{it}}\frac{s_{it}M_{it}}{Q_{it}} = \frac{P_{it}}{\delta_{it}}\frac{s_{it}M_{it}}{P_{it}Q_{it}} \tag{E5}$$

where P_{it} is the price of the final product. Note that the marginal cost of production is equivalent to δ_{it} for a given level of output, i.e. $\partial L/\partial Q_{it} = \delta_{it}$. Therefore, the markup, which is defined as $\mu_{it} = P_{it}/\delta_{it}$, can be easily derived from equation (E5) as

$$\mu_{it} = \theta_{it}^{m}\left(\alpha_{it}^{m}\right)^{-1} \tag{E6}$$

where $\theta_{it}^{m} = \left(\partial Q_{it}/\partial M_{it}\right) * \left(M_{it}/Q_{it}\right)$ is the output elasticity of intermediate materials, and $\alpha_{it}^{m} = \left(s_{it}M_{it}\right)/\left(P_{it}Q_{it}\right)$ is the share of expenditures for intermediate materials over total sales. As the information on expenditures for intermediate materials and total sales is available in the data, α_{it}^{m} can be readily calculated. However, to obtain the output elasticity of intermediate materials θ_{it}^{m}, we need to estimate the production function Q_{it} of firm i at time t.

We adopt the control function approach developed by Ackerberg *et al.* (2015) to control for unobserved productivity shocks in production function estimation. To ensure that there is sufficient flexibility of the output elasticity of the inputs for each individual firm, we employ a translog specification of the production function, i.e.,

$$\begin{aligned} q_{it} = {} & \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \beta_{ll} l_{it}^2 + \beta_{kk} k_{it}^2 + \beta_{mm} m_{it}^2 \\ & + \beta_{lk} l_{it} k_{it} + \beta_{km} k_{it} m_{it} + \beta_{lm} l_{it} m_{it} \\ & + \beta_{lkm} l_{it} k_{it} m_{it} + \omega_{it} + \varepsilon_{it}, \end{aligned} \tag{E7}$$

where the lowercase letters represent the logarithm of the uppercase letters; β_i is parameters to be estimated; ω_{it} is firm-specific productivity; and ε_{it} is an i.i.d error term.

We estimate the translog production function (E7) separately for each two-digit manufacturing industry. Once the estimates of β_i is obtained, the output elasticity of the materials can be calculated as $\theta_{it}^{m} = \hat{\beta}_m + 2\hat{\beta}_{mm} m_{it} + \hat{\beta}_{km} k_{it} + \hat{\beta}_{lm} l_{it} + \hat{\beta}_{lkm} l_{it} k_{it}$. Then, firm markup can be obtained using equation (E6).

Several practical details in estimation of production are worth noting here. First, to estimate equation (E7), we combine the ASIF data with the product-level data with physical outputs of firms. By doing so, we are able to solve the omitted price bias on the output side of the production function. For the input side, our data include the number of employees at each firm for each year, thus allowing us to measure the physical input of labor. However, capital k_{it} is measured by the net value of fixed assets, and the intermediate materials variable m_{it} is measured as the total value of intermediate materials; both are used in value terms. To back out the physical inputs of k_{it} and m_{it}, we deflate these values with the price indices provided by Brandt *et al.* (2012). As this practice still leaves the firm-specific omitted input price issue unsolved, we follow De Loecker *et al.* (2016) and correct this omitted input price bias using a control function approach, i.e., we control for the omitted firm-specific input prices by adding the output prices, market shares, and exporter status as well as their interaction terms with the deflated inputs in the production function estimation.

Second, we use only single-product firms to estimate the production function because we aim to calculate the markup aggregated at firm level. The disaggregated markup at the firm-product level is not essential for our analysis; therefore, we align with De Loecker, *et al*. (2016) and assume that multi-product firms use the same technology as single-product firms in the same industry.

Lastly, to control for demand and supply shocks, we also include output prices, five-digit product dummies, city dummies, product market shares, exporter status, industry-level input and output tariffs in the production function estimation (De Loecker, 2011). For the details of estimation of quantity-based production function and firm markups, see Lu and Yu (2015).

Estimated markups and measurement of markup dispersion

Figure 1 shows the average markup for every two-digit Chinese manufacturing industry from 1998 to 2007. This figure indicates that the average markup of most manufacturing industries is greater than 1, which aligns with our expectations. Certain industries, including chemical fiber manufacturing, paper machine printing, pharmaceutical manufacturing, computer and communications equipment manufacturing, plastics and rubber manufacturing, and transportation equipment, have higher markups (i.e., higher than 1.3) than others, indicating that they have relatively higher market power or profitability. These industries also require a high level of capital or technology inputs. Conversely, industries, such as food processing, textiles and garment manufacturing, wood processing and art crafts and others, have average markups lower than 1, indicating that these industries are more competitive and less profitable than others. Clearly, these industries have high labor intensity and to some extent are highly dependent on foreign demand (export).

Figure 1 Average Markup for Chinese Manufactuing Industries, 1998-2007

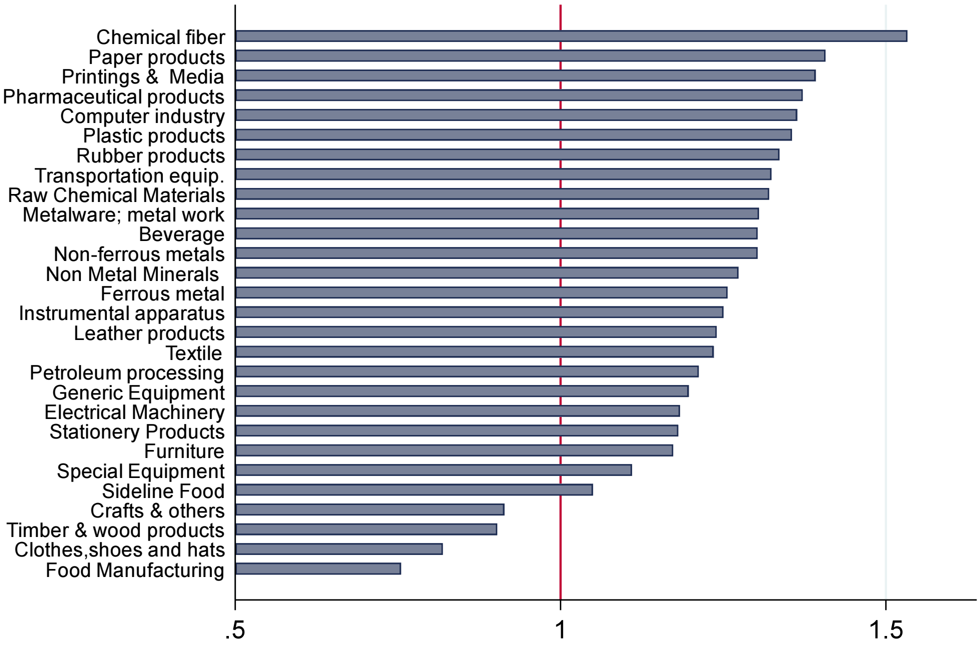

Figure 2 shows the average markups of Chinese exporters and non-exporters in manufacturing industries from 1998-2007. Clearly, the average markups of Chinese exporters are lower than those of non-exporters. Although this finding contradicts the theoretical prediction that exporters usually outperform non-exporters because there is a productivity threshold for firms to enter export market (Melitz, 2003), it is consistent with other recent empirical findings on international trade that use Chinese data (Lu *et al.*, 2010; Dai *et al.*, 2016).[7] This information is important because it motivates us to treat Chinese exporters and non-exporters differently in this study due to their heterogeneity in markups. Figure 2 also indicates that after China's accession from the WTO (in 2001), the gap in the markups between Chinese exporters and non-exporters has shrunk.

This study employs three methods, including the Theil entropy index (Theil), the Gini coefficient (GINI), and the coefficient of variation (COV) to measure the degree of markup dispersion in each industry. While the Theil index is used in our baseline regressions, the other two indices are used as robustness checks. The formula for calculating markup dispersion using the Theil index can be expressed as:

$$Theil_{it} = \frac{1}{n_{it}} \sum_{f=1}^{n} \frac{y_{fit}}{\bar{y}_{it}} \log\left(\frac{y_{fit}}{\bar{y}_{it}}\right)$$

[7] Empirical studies using data from developed countries also support this theory, for example, De Loecker and Warzynski (2012).

where i and t denote industry and year, respectively. n is the number of firms within the industry, y_{fit} is the estimated markup of firm f, and $\bar{y}_{it}$ is the average markup of industry i in year t.

Meanwhile, we also experiment with two other dispersion measures in the robustness checks. The GINI is frequently used, and the COV is defined as the ratio of the standard deviation to the mean (i.e., $CV_{it} = \sqrt{V_{it}} / \bar{y}_{it}$, where V_{it} is the standard deviation of the firm markups in industry i for year t).

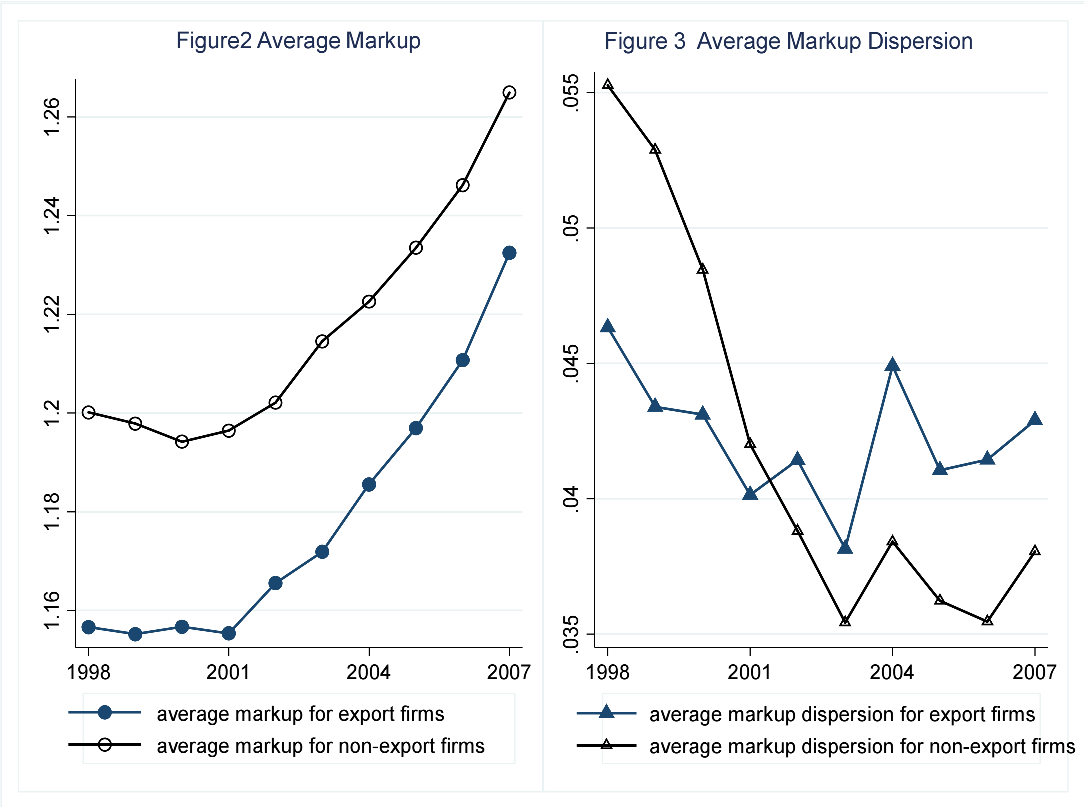

Figure 3 shows the markup dispersion (using the Theil index) of Chinese exporters and non-exporters in manufacturing industries from 1998-2007. The results indicate that the markup dispersion of exporters and non-exporters both declined before 2003, and this trend changed when their markup dispersion became staggered after 2003. This change is very likely caused by the intensified market competition in the manufacturing industries, which drive down firm markups and decreases the markup dispersion in an industry. In addition, the markup dispersion of non-exporters was higher than exporters before 2001, but it dropped significantly below that of exporters after 2001, which may imply that China's accession to the WTO in 2001 further decreased the markup dispersion of non-exporters compared to that of exporters.

Industry-specific real effective exchange rate (REER)

To investigate the impacts of exchange rate movement on the markup dispersion for firms in a specific industry, it is essential to obtain the REER of each industry. We calculate the REER for each four-digit manufacturing industry using the trade-weighted approach by following Goldberg (2004). Specifically, we first construct the bilateral real exchange rate index of the RMB between China and its main 41 trading partners. Then, we use the geometric weighting method to construct a three category industry-specific real exchange rate for manufacturing industries, i.e., the export-weighted REER index ($REERX_{it}$), the import weighted REER index ($REERM_{it}$) and the total trade-weighted exchange rate index ($REER_{it}$). The following equation shows the method for constructing the REER.

$$REER_{it} = \prod_{j=1}^{k} (RER_{jt})^{\omega_{jt}^{i}}$$

where $\omega_{jt}^{i} = \frac{X_i}{X_i + M_i} * \frac{\sum_{t-3}^{t-1} ex_{jt}^{i}}{\sum_{j=1}^{k}\sum_{t-3}^{t-1} ex_{jt}^{i}} + \frac{M_i}{X_i + M_i} * \frac{\sum_{t-3}^{t-1} im_{jt}^{i}}{\sum_{j=1}^{k}\sum_{t-3}^{t-1} im_{jt}^{i}}$, RER_{jt} represents the bilateral real exchange rate index of the RMB (deflated by PPI) relative to trading partner j in year t.[8] ω_{jt}^{i} is the bilateral trade weight for China and trading partner j in industry i. ex_{jt}^{i} and im_{jt}^{i} respectively represent the bilateral export volume and import volume between China and trading partner j for the four-digit manufacturing industry i in year t. As ex_{jt}^{i} and im_{jt}^{i} could be both affected by changes in the bilateral real exchange rate, to avoid the simultaneity bias of trade weights and exchange rate changes, we use the average of ex_{jt}^{i} and im_{jt}^{i} over the past three years, i.e., $t-1, t-2, t-3$, as the weighted values. $X_i/(X_i + M_i)$ and $M_i/(X_i + M_i)$ respectively represent the average share of the exports and imports in the total trade volume for the corresponding industry for 1997-2013. k represents China's main trade partners based on trade volume weights.

We construct industry-specific real effective exchange rates for 464 four-digit manufacturing industries in China from 1999 to 2014.[9] In Figure 4, we show the annual $REERM_{it}$ and $REERX_{it}$ of 16 randomly selected four-digit manufacturing industries. The $REERX_{it}$ for most of these 16 industries show a trend of appreciation from 1999-2001, while from 2001 to 2004, they show a trend of depreciation; after 2005, they, again, show a general trend of appreciation. The magnitude of the appreciation and depreciation varies substantially across industries. In addition, the $REERM_{it}$ and $REERX_{it}$ movements are not strictly consistent for these industries; for some industries, these two indices even presented divergent trends in some periods. However, there is a significant difference in the magnitude of appreciation and depreciation as measured by $REERM_{it}$ and $REERX_{it}$.

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[8] $RER_{jt} = NER_{jt}(P_{ct} / P_{jt})$, where NER_{jt} represents the nominal exchange rate of the RMB against. trading partner j (in terms of how much foreign currency can be purchased per unit of RMB or the indirect exchange rate); P_c is the PPI of China, and P_j denotes the PPI of trading partner j.

[9] We construct this index from 1999 because before 1999 currencies of European countries are not uniform, which makes it difficult to compare the nominal exchange rates between them.

In Figure 5, we provide the monthly $REERM_{it}$ and $REERX_{it}$ for random selected 16 four-digit manufacturing industries during 1999 to 2014. The messages delivered from Figure 5 are very similar to those shown in Figure 4, i.e., real exchange rate movements are obviously distinct by industry; $REERM_{it}$ and $REERX_{it}$ movements are not strictly consistent for most of the industries. The trends and the magnitude of appreciation (and depreciation) are clearly different across industries and over different periods. These features are key to our empirical analysis, i.e., the large variation in real exchange movements across industries and over time provides us a with very good experiment to examine the impacts of real exchange rate movements on markup dispersion within industries.

Figure 4 Industry Specific Real Effective Exchange Rate by Year (REER2005==100, Based on PPI)

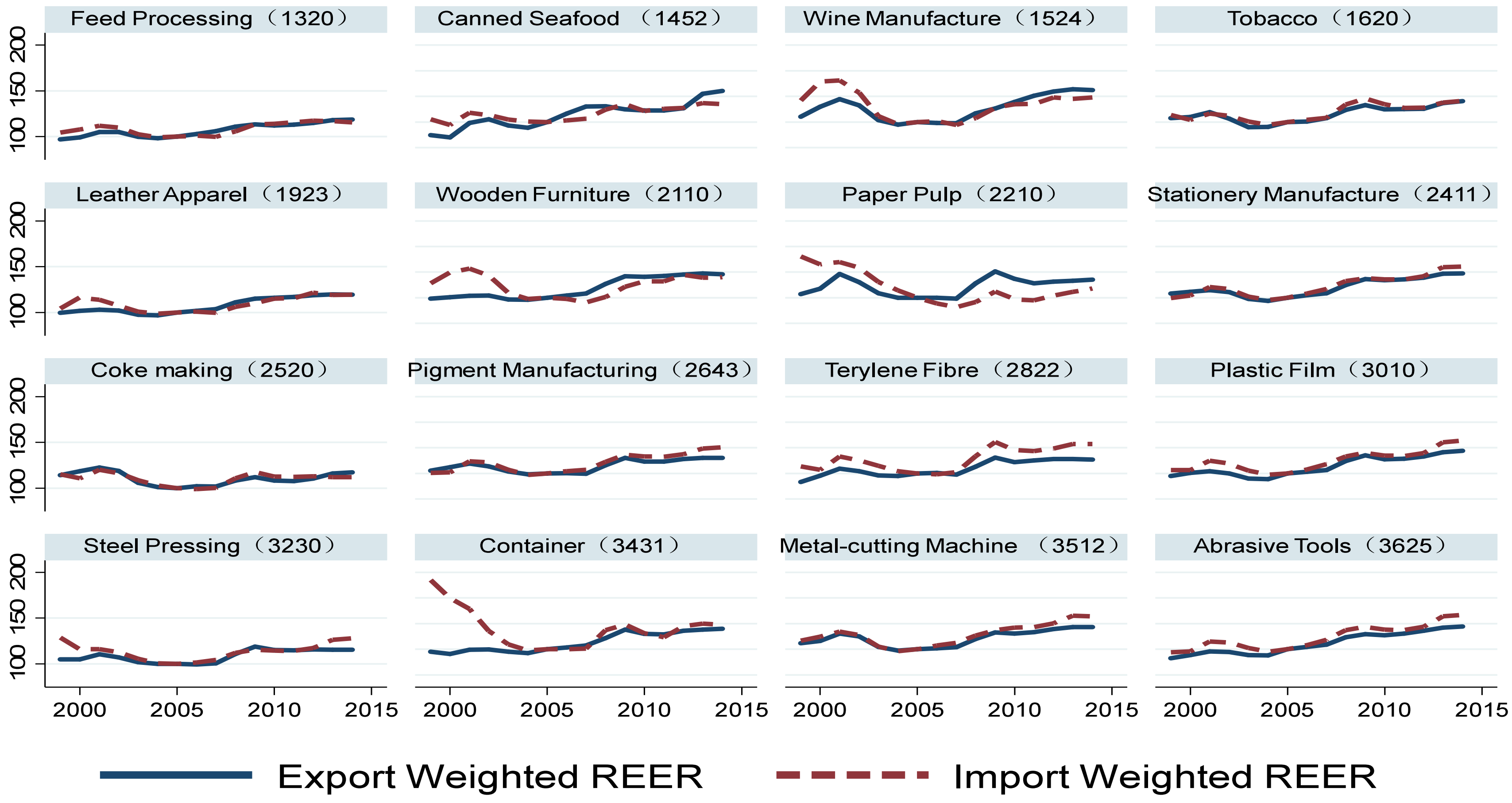
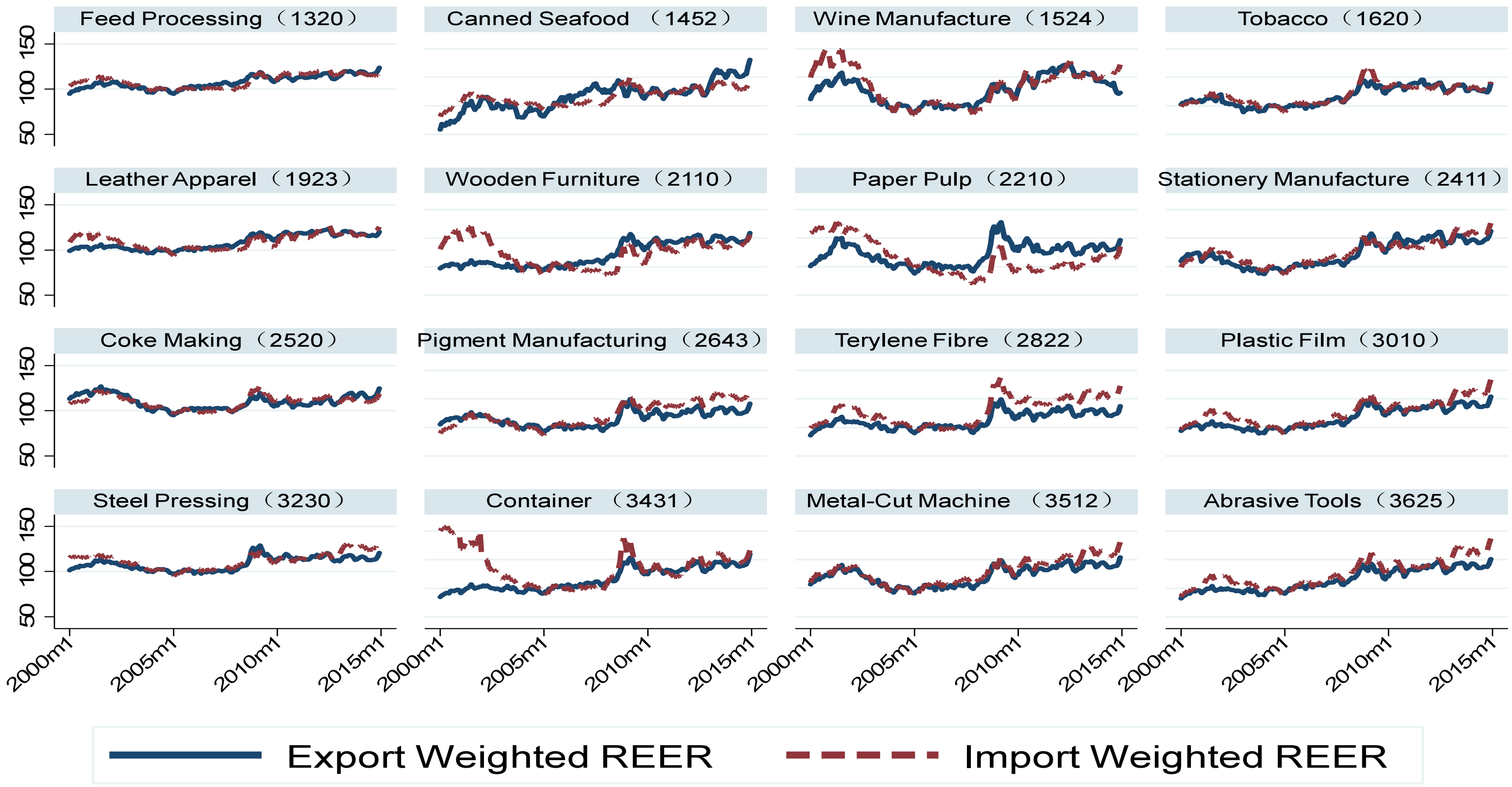


Figure 5: Industy Specific Real Effective Exchange Rate by Month（REER2005==100, Based on PPI）



4. Empirical analysis

4.1. Baseline regressions

We first examine the overall impacts of real exchange rate movements on markup dispersion using a baseline empirical equation. By referring to our theoretical predictions as well as previous empirical studies on evaluating the impacts of real exchange rate movements on employment, investment and export (e.g., Klein *et al.*, 2003; Campa and Goldberg, 2005, 2010; Moser *et al.*, 2010; Berman *et al.,* 2012; Li *et al.,* 2015), we construct the following benchmark regression model:

$$\Delta \ln Mdisp_{it} = \mu + \alpha \Delta \ln REER_{it} + \Delta X'_{it} \cdot \beta + \delta_i + \gamma_t + \varepsilon_{it} \qquad \text{(E8)}$$

where $Mdisp_{it}$ is the markup dispersion of industry i in year t, measured by the Theil entropy index and two additional measurements of dispersion. $REER_{it}$ is the real effective exchange rate for a narrowly defined industry (four-digit CIC). $X_{it} = \left[\ln VREER_{it}, SOE_{it}, FDI_{it}, AGE_{it}, LnN_{it}\right]$, is a vector of time-varying industry level control variables that have potential effects on markup dispersion; Specifically,

$\ln VREER_{it}$ denotes the annual volatility of the REER (in natural logarithm) for industry i, measured by a rolling standard deviation of monthly real exchange rates over a 12-month window. Prior studies (Knetter, 1994; Kanas, 1997) claim that the markup of firms is not only affected by exchange rate changes but also by exchange rate risks. Hence, markup dispersion within industries may also be affected by real exchange rate volatility at the industry level.

SOE_{it} is the share of state-owned enterprises (SOEs) within narrowly defined manufacturing industries (compared to the number of firms). Prior studies have indicated that the less market-oriented SOEs are an important source of misallocation in China (Hsieh and Klenow, 2009; Hsieh and Song, 2015). Therefore, their impacts on markup dispersion should be allowed for in the regression equations.

FDI_{it} is the share of firms that are a result of foreign direct investment (FDI) (excluding firms in Hong Kong, Taiwan and Macao) within narrowly defined industries (in terms of the number of firms). As a large number of FDI have surged into Chinese manufacturing industries, particularly in export sectors, since the late 1990's, they could have a mixed influence on the markup dispersion of an industry. On one hand, the entry of FDI lower the markup of incumbent firms and thus improved allocation efficiency within the industry due to intensified market competition. On the other hand, allocation efficiency within industries could also deteriorate because these foreign-invested firms

(FIEs) increased their market share due to their advantages in technology and marketing, which could expand the markup gap between FIEs and domestic firms within the same industries.

AGE_{it} is the average survival period of firms within each industry, which may also affect the markup distribution across firms within industries.

$\ln N_{it}$ represents the number of firms within industries (in natural logarithm), which is important for calculating market share concentration and competition conditions within industries.

δ_i is industry fixed effects, controlling for unobservable and time-invariant industry heterogeneity; and γ_t is time fixed effects, which are the same across different industries in certain years. To deal with possible non-stationarity of the data, we use first differences of log variables following Li *et al*. (2015).

It is worth noting that our estimation is less affected by the heterogeneity issues because our identification strategy hinges upon precisely defined industry-level REER, which are exogenous to firm-level markup changes. The reason is that industrial-level movement in exchange rates is less likely to be affected by behaviors or characteristics of any single firms; it mainly reflects the changes in real exchange rates at national level or any adjustment in industrial-specific trading patterns. Therefore, our key interest independent variable, industry-specific REER, should be exogenous to our dependent variable, markup dispersion of an industry.

Table 1 Summary Statistics for Key Variables (1998-2007)

Year	No. of Firms	No. of Export Firms	FIE Ratio	SOE Ratio	No. of Employees	Export Ratio	Import Input Ratio	Import Penetration Ratio	Profit Ratio
1998	124,889	42,075	0.086	0.442	411	0.148	——	——	0.024
1999	142,630	47,470	0.081	0.411	358	0.145	——	0.155	0.032
2000	137,618	49,563	0.086	0.374	351	0.158	0.088	0.172	0.052
2001	147,040	56,629	0.088	0.324	327	0.166	0.082	0.168	0.051
2002	158,295	62,999	0.100	0.282	310	0.174	0.082	0.168	0.053
2003	169,146	70,011	0.106	0.224	304	0.183	0.084	0.172	0.06
2004	220,055	91,805	0.121	0.164	253	0.198	0.083	0.173	0.061
2005	240,378	96,543	0.123	0.143	256	0.179	0.071	0.149	0.060
2006	274,389	103,148	0.117	0.196	246	0.169	0.063	0.139	0.063
2007	304,418	104,772	0.119	0.168	237	0.159	0.052	0.123	0.068
Average	191,886	72,502	0.103	0.273	305	0.168	0.076	0.158	0.052

Note: 1. FDI does not include firms in Hong Kong, Macao and Taiwan (HMT); 2. The import input ratio is measured by the share of imported inputs over total intermediate inputs plus total wages in an industry. 3. Exporters are defined as firms that have export records from 1998 to 2007. FIEs are defined as firms for which more than 50% of total assets are foreign registered assets (not including HMT capital). SOEs are defined as firms for which more than 50% of total assets are state-owned assets.

Table 1 provides the summary statistics of the key variables used in this study. As shown in columns 2 and 3, roughly one-third of the firms in our sample are export firms from 1998-2007. Columns 3 and 4 show that the share of FIEs steadily increases, particularly from 1998-2005, while the share of SOEs declines quickly and persistently during the same period. The average firm size (in terms of employment) has a decreasing trend, as shown in column 5, indicating that the size of manufacturing firms decreased during our study period. Regarding trade dependence measures, the export dependence of the sample firms (measured as the export ratio of total output) was increasing before 2004, reached its highest level of 19.8% in 2004, and then declined gradually afterwards. The average import competition (measured as import penetration ratio) and import dependence (measured as import input ratio) have a similar trends; both show a declining trend after 2004, indicating that the import of final products and imported inputs used by Chinese firms in manufacturing industries are declining over time, which aligns with previous empirical findings (e.g., Kee and Tang, 2016).

Table 2 Baseline Regression Results (Dependent Var.=$\Delta \ln Theil\_mkp_{it}$)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln REER_{it}$	-1.322***	-1.536**	-1.657***	-2.190***	-1.984***	-2.320**
	(0.504)	(0.667)	(0.516)	(0.703)	(0.758)	(1.026)
$\Delta \ln VREER_{it}$			-0.049	-0.045	-0.064	-0.050
			(0.053)	(0.059)	(0.057)	(0.070)
Covariates	No	No	No	No	Yes	Yes
Industry dummies	No	Yes	No	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Ind dummies*year	No	No	No	No	No	Yes
Observations	3,222	3,222	2,824	2,824	2,802	2,802
R-squared	0.041	0.062	0.048	0.076	0.086	0.152
Sector	406	406	406	406	405	405

Note: standard errors, clustered at four-digit industry level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1; all control variables, except for the volatility of the real exchange rate, specified in baseline regression models are represented as Covariates, and are included in the last two columns.

Table 2 reports estimation results of equation (E8). The first row is the estimated coefficients of real exchange rate changes ($\Delta \ln REER_{it}$) on firm markup dispersion ($\Delta \ln Theil\_Mkpm_{it}$). We also report the estimated coefficients of $\Delta \ln VREER_{it}$ in the second row. Each column corresponds to the different choices of the right-hand-side variables.

Considering the first-differenced variables used in the baseline equation, we include only time fixed effects as the control variables in column 1 of Table 2. The results show that the elasticity of markup dispersion to real exchange rate is as large as -1.322 (significant at the 1% level). Thus, an appreciation of the REER at the industry level by 1% will reduce the markup dispersion of firms within industries by roughly 1.322%, which is significant both economically and statistically, indicating that a very important efficiency change can be generated by exchange rate movements.

In column 2, we add both industry and time fixed effects in the baseline equation. The estimated coefficient remains negative and significant at the 5% level. The estimated coefficient indicates that an 1% increase in the real exchange rate at the industry level will cause the markup dispersion within the industry to decline more than 1.5% percent, which is highly consistent with the empirical results in column 1.

In column 3, we add another variable, REER volatility ($\Delta \ln VREER_{it}$), to the baseline equation and only control for time fixed effects. The result shows that the estimated coefficient for REER volatility is insignificant, but the coefficient for real exchange rate movements remains negative and significant at the 1% level even if we control the volatility of the real exchange rate, which yields estimates that are rather consistent with column 1. The new estimate in column 3 indicates that the elasticity of markup dispersion to the exchange rate becomes even higher, i.e., -1.657.

In column 4, we continue to check the empirical results of the real exchange rate and its volatility by controlling for both industry and time fixed effects. The estimation results remain highly consistent with the empirical results in column 3. We add all the other control variables with the exception of the volatility of the real exchange rate, simultaneously controlling for both industry and time fixed effects in column 5. The estimated results remain significant at the 1% level and show that the elasticity of the markup dispersion to real exchange increases to almost -2, which suggests that real exchange rate movements could have substantial effects on allocation efficiency within industries.

Finally, in column 6, we test whether the above results are sensitive to industry-specific time trends. The results, as expected, are largely the same when the interaction terms between industry dummies and year trends are included. Overall, the baseline results consistently suggest that the appreciation (depreciation) of real exchange rates of RMB significantly reduces (increases) firm markup dispersions. In terms of magnitude, the coefficient estimates for the real exchange rate are between -1.3 and -2.3. Therefore, the industry Theil entropy index of markup dispersion will change, on average, by 2% for every 1% change in the real exchange rate. These findings are consistent with our expectation that an appreciation (depreciation) intensifies (reduces) intra-industry competition and reduces firm heterogeneities in markups within an industry.

4.2. Robustness checks

Firstly, we further check the robustness of the baseline regression results using two additional measures of markup dispersion, i.e., GINI and COV. In columns 1 and 2 of Table 3, the impacts of real exchange rate movements on the GINI and COV indexes of markup are checked, controlling for all other covariates and two-way fixed effects. The estimated coefficients for real exchange rate movements ($\Delta \ln REER_{it}$) are negative and significant at the 1% level, while the estimated coefficient for the volatility of the exchange rate remains insignificant, which consistently supports the baseline estimation results reported in Table 2. In columns 3 and 4 of Table 2, the interaction terms of industry dummies and time trends are also added into the regression equations to control for more confounding factors and omitted variables. The estimated elasticities of markup dispersion measured both by the GINI and COV index remain negative and significant at the 5% significance level. In terms of magnitude, a 1% change in the real exchange rate will cause the GINI of markup to change roughly 0.8% and the COV index of markup to change roughly 1.3%.

All the empirical results above consistently indicate that real exchange rate movements of the RMB can have significant and substantial effects on allocation efficiency within manufacturing industries.

Table 3 Robustness checks using different measurements of markup dispersion

	(1)	(2)	(3)	(4)
Dependent Var.=	$\Delta\ln Gini\_mkp_{it}$	$\Delta\ln Cov\_mkp_{it}$	$\Delta\ln Gini\_mkp_{it}$	$\Delta\ln Cov\_mkp_{it}$
$\Delta \ln REER_{it}$	-0.800***	-1.259***	-0.784**	-1.369**
	(0.243)	(0.434)	(0.365)	(0.624)
$\Delta \ln VREER_{it}$	-0.013	-0.023	-0.016	-0.026
	(0.022)	(0.036)	(0.026)	(0.044)
Covariates	Y	Y	Y	Y
Industry dummies	Y	Y	Y	Y
Year dummies	Y	Y	Y	Y
Industry dummies*year	N	N	Y	Y
Observations	2,824	2,824	2,802	2,802
R-squared	0.096	0.069	0.173	0.142
sector	406	406	405	405

Note: standard errors, clustered at four-digit industry level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1; all control variables, except for the volatility of the real exchange rate, specified in baseline regression models are represented as Covariates, and are included in the last two columns.

Secondly, the high response of markup dispersion to exchange rate movements at the industry level also implies that firms with high markups react to currency fluctuations differently than firms with low markups that operate in the same industry. To evaluate the different impacts of exchange rate movements on firm markup distribution, we measure markup distribution at 9 percentiles, i.e. 10%, 20%,…, 90%, at the four-digit industry level and examine the variations in the impact of real exchange rates changes on markup at these 9 percentile levels. We conduct a robustness check by estimating markup equations at the percentile level, which is carried out using both non-differenced and first-differenced equations, as shown in Table 4.

In section 1 of Table 4, we first check the impacts of real exchange rate movements on markup at different percentiles using non-differenced equations after controlling for all other covariates and two-way fixed effects; the empirical results indicate that exchange rate movements have small and insignificant effects on the markup of firms at low percentiles (p10 and p20), but the significance and magnitude of those impacts increase gradually with the rise in the markup percentiles. Exchange rate changes have the greatest impact on markup concentrates at percentile 60 to percentile 80, and all the estimated coefficients are significant at the 5% level, which suggests that firms with a higher markup ratio are more likely to be affected by exchange rate changes. Therefore, the overall markup dispersion at the industry level will change substantially when there are large variations in markup at higher percentiles generated by real exchange rate fluctuations.

In section 2 of Table 4, we use the first-differenced equation to further check the impacts of exchange rate movements on markup at different percentiles. The estimated coefficients of markup at different percentiles also consistently show that the magnitude of those impacts increase in a step-wise fashion with higher markup percentiles. The estimations for the 70% and 80% percentiles remain significant at the 10% level after controlling for all the covariates and fixed effects both at the industry level and for time trends.

The estimations for the markup percentiles in Table 4 provide us with strong evidence that firms with high markups are more sensitive to exchange rate fluctuations and are more likely to adjust markup in response to exchange rate shocks. This result is not only consistent with the pricing to market behavior of firms, as numerous studies have emphasized (Krugman, 1980; Marston, 1990; Knetter, 1994), but also indicates that the appreciation (depreciation) of the exchange rate will strengthen (reduce) market competition and reduce (increase) the markup gaps among firms within industries.

Table 4 Robustness Checks (Estimation by Percentiles)

Section 1

	(1) mkp_p10_{it}	(2) mkp_p20_{it}	(3) mkp_p30_{it}	(4) mkp_p40_{it}	(5) mkp_p50_{it}	(6) mkp_p60_{it}	(7) mkp_p70_{it}	(8) mkp_p80_{it}	(9) mkp_p90_{it}
$\ln REER_{it}$	-0.010	-0.034	-0.055*	-0.087***	-0.120**	-0.201**	-0.248***	-0.218**	-0.096
	(0.042)	(0.032)	(0.028)	(0.033)	(0.050)	(0.080)	(0.082)	(0.089)	(0.135)
$\ln VREER_{it}$	0.005	0.007**	0.006*	0.008**	0.010**	0.013*	0.014*	0.007	-0.012
	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.007)	(0.008)	(0.009)	(0.014)
Covariates	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry Dummies.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year Dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	3,214	3,214	3,214	3,214	3,214	3,214	3,214	3,214	3,214
R-squared	0.308	0.356	0.409	0.348	0.334	0.237	0.205	0.146	0.098
Sector	405	405	405	405	405	405	405	405	405

Section 2

VARIABLES	(1) Δmkp_p10_{it}	(2) Δmkp_p20_{it}	(3) Δmkp_p30_{it}	(4) Δmkp_p40_{it}	(5) Δmkp_p50_{it}	(6) Δmkp_p60_{it}	(7) Δmkp_p70_{it}	(8) Δmkp_p80_{it}	(9) Δmkp_p90_{it}
$\Delta \ln REER_{it}$	-0.009	-0.071	-0.061	-0.068	-0.079	-0.080	-0.125**	-0.241*	-0.245
	(0.073)	(0.045)	(0.041)	(0.053)	(0.056)	(0.100)	(0.062)	(0.138)	(0.219)
$\Delta \ln VREER_{it}$	0.000	0.002	-0.001	0.002	0.007	0.010	0.011	0.002	-0.007
	(0.007)	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)	(0.007)	(0.009)	(0.015)
Covariates	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry Dummies.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year Dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	2,801	2,801	2,801	2,801	2,801	2,801	2,801	2,801	2,801
R-squared	0.118	0.133	0.147	0.136	0.146	0.149	0.131	0.122	0.104
Sector	405	405	405	405	405	405	405	405	405

Note: standard errors in parentheses are clustered at four-digit industry level; *** p<0.01, ** p<0.05, * p<0.1

5. Discussion on the mechanism

The existing literature (e.g., Campa and Goldberg, 2001, 2005, 2010; Ekholm *et al*., 2012)have documented that a change in real exchange rate may affect a firm's performance through three different channels, i.e. export sales, imported inputs, and import competition in domestic market. First, export channel directly affects the selling price and sales volume of exported products in the international markets if the currency exchange rate between two countries changes (refer to as price to market, or price pass-through in literature). Second, imported inputs channel directly affects the costs of a final product with all or part of its components imported from foreign countries no matter it sells in domestic market or international market. Third, import competition channel usually brings price pressure to domestic producers from imported foreign products during the period of appreciation of local currency. Obviously, these channels all directly linked to the markup of a firm, which is the ratio of price over marginal cost. In theory, non-exporters without importing inputs are least affected by exchange rate change (only competition matters), followed by non-exporters with imported inputs (cost and competition both matter), then followed by exporters with imported inputs, specifically, all three channels matter for ordinary exporters; and both price and cost matter for processing traders). Even for the same type of firms as described above, the impact of exchange rate on its markup also depends on how much the firm is exposed to international trade, namely, the ratio of export, the ratio of import, and the import penetration ratio facing the firm.

5.1 The three channels

As shown in equation (31), it is clear that the exchange rate movements also impact the markup dispersion of an industry through three major channels, i.e., export dependence (export ratio θ), import dependence (import input ratio $1\text{-}\alpha\text{-}\beta$), and import competition (import penetration ratio M). These channels has also emphasized in previous literature on the impacts of exchange rate movements on firm performances (Ekholm *et al*., 2012).

In the following, we discuss the mechanism through which markup dispersion can be affected by exchange rate fluctuations through these three channels. First, through the export dependence channel, with an appreciation of the exchange rate, the markup of export firms could reduce significantly more than non-export firms, and if the markup of export firms is higher than that of non-export firms, as indicated by existing trade theories, the markup dispersion of exporters and non-exporters that operate in the same industry tend to converge, thus reducing the markup dispersion among these firms. Therefore, an appreciation of the exchange rate could help improve allocation efficiency through this specific hannel. However, in contrast to the predictions of existing trade theories, some empirical studies consistently show that the productivity of China's exporting firms is significantly lower than that of its non-exporting firms (Lu *et al.*, 2010; Dai *et al.*,2016); and the measurement results of this study also clearly show that the average markup of China's exporting firms is significantly lower than that of non-exporting firms (as shown in Figure 2 of section 3). For this specific case, an appreciation of the RMB real exchange rate could further reduce the markup of China's exporting firms, causing the gap between the markup of exporting and non-exporting firms operating in the same industry to widen. Therefore, we hypothesize that an appreciation of RMB through the export dependence channel is likely to further intensify resource misallocation within China's manufacturing industries.

Second, from the perspective of imported inputs, in the case of appreciation, export firms are more likely to reduce costs and increase their markup through the import dependence channel than non-export firms. This occurs because the import dependence of firms for inputs is highly related to their export dependence (Amiti *et al.*, 2014), which seems particularly evident in China as a large percentage of China's export firms conduct processing trade and are highly dependent on imported inputs. Therefore, given the low markup rate of export firms compared to their non-export counterparts in China, it is reasonable to expect that an appreciation of the real exchange rate in terms of imported inputs could help reduce the markup gap between exporters and non-exporters by lifting the markup of exporters, thus reduce the markup dispersion of the whole industry and lead to allocation efficiency improvement.

Third, from the perspective of import competition, an increase in the import penetration of an industry may generate higher competition between domestic products and imported products, and the average price and markup of domestic firms should decrease accordingly, as indicated by most existing trade theories. Thus, an appreciation in the exchange rate should reduce markup dispersion and promote better allocation efficiency across firms operating within the same industry by enhancing market competition from foreign products.

5.2 Empirical tests of the three channels

To empirically test the abovementioned three channels, we construct three industry-level variables, and each one is used to measure one channel; that is, we quantify how much an industry is exposed to trade in terms of these channels. More specifically, the export dependence channel, EX, is defined as the ratio of an industry's total exports to its total output. IM is defined as an industry's expenditures for imported inputs as a share of the total expenditures on intermediates inputs plus total paid wages. We obtain the value of imported inputs for each industry from a trade product information database compiled by China's Customs for 2000 to 2012. Specifically, first, we identify the import inputs and imported final products according to detailed trade patterns and purposes defined at the 8-digit HS product level. Then, by mapping the 8-digit HS code to the 4-digit CIC code, we can calculate the import inputs for each 4-digit industry.

The import competition degree, IMS, is defined as an industry's import penetration ratio, measured as follows:

$$IMS_{it} = \frac{IMP_{it}}{Y_{it} + IMP_{it} - EXP_{it}}$$

where EXP_{it}, IMP_{it} and Y_{it} respectively represent the export value, the import value, and the domestic sales value for narrowly defined manufacturing industries.

For the second step, we further examine these three channels. Specifically, we add an interaction term between real exchange rate movements ($\Delta \ln REER_{it}$) and a measure of one of these trade channels, denoted as TD, into the empirical equation. The baseline empirical equation is thus specified as follows.

$$\Delta \ln Mdisp_{it} = \mu + \alpha \Delta \ln REER_{it} + \beta \Delta \ln REER_{it} * TD_{it-1} + \lambda TD_{it-1} + \gamma \Delta X'_{it} + \delta_i + \varphi_t + \varepsilon_{it} \quad \text{(E9)}$$

where TD represents EX, IM, or IMS; β is the estimated coefficient of interest capturing the additional effect of trade dependence besides the main effect α, which captured the impact of real exchange rate changes on markup dispersion. Trade dependence may also be affected by exchange rate changes that occur in the same period, causing the potential endogeneity issues (specifically, simultaneity bias) of the interaction terms in estimation equation (E9). To address this concern, we use one-year lagged trade dependence TD_{it-1} in the interaction terms.

Table 5 shows the results for our investigation of the three channels through which real exchange rate changes may affect firm markup dispersion. Column 1 reports the estimation results of real exchange rate changes and its interaction term with export dependence when other covariates (excluding the volatility of the exchange rate) and two-way fixed effects are controlled for. The estimated coefficient for exchange rate changes remains negative and significant at the 1% level, while the interaction term of exchange rate changes with export dependence is insignificant, which indicates that the impacts of exchange rate movements on markup dispersion are not significantly associated with the overall export percentage of China's manufacturing industries.

In column 2, we check the impacts of exchange rate movements on markup dispersion through the import competition channel. Like column 1, we add in the estimation the interaction term of exchange rate changes and IMS, and the estimated coefficient for the interaction term is negative and significant at the 5% level, while the coefficient for exchange rate changes remains negative but insignificant, indicating that the appreciation (depreciation) of the real exchange rate through the import competition channel will significantly improve (deteriorate) allocation efficiency within industries as predicted.

In column 3, we examine the impacts of real exchange movements on markup dispersion through the import dependence channel. The estimated coefficients for both real exchange rate changes and its interaction term with the imported input ratio are negative and significant at the 5% level, which also suggests that an appreciation (depreciation) through the import dependence channel can significantly improve (reduce) allocation efficiency within industries, which is also consistent with our predictions.

Table 5 Test of three channels of the impact of REER movements on markup dispersion (Dependent Var.=$\Delta\ln Theil\_mkp_{it}$)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\ln REER_{it}$	-1.829***	-0.940	-1.742**	-2.497**	-1.155	-1.780*
	(0.694)	(0.758)	(0.781)	(1.042)	(1.210)	(1.066)
EX_{it-1}	-0.143			-0.050		
	(0.191)			(0.589)		
$\Delta\ln REER_{it} * EX_{it-1}$	1.730			1.052		
	(1.725)			(2.353)		
IMS_{it-1}		-0.001			-1.244*	
		(0.245)			(0.716)	
$\Delta\ln REER_{it} * IMS_{it-1}$		-4.301**			-8.061***	
		(2.077)			(2.939)	
IM_{it-1}			-0.065			-0.158
			(0.435)			(0.803)
$\Delta\ln REER_{it} * IM_{it-1}$			-8.735**			-12.673**
			(3.767)			(5.297)
$\Delta\ln VREER_{it}$				-0.045	-0.019	-0.034
				(0.072)	(0.072)	(0.072)
Covariates	Y	Y	Y	Y	Y	Y
Industry and Year Fixed Effects	Y	Y	Y	Y	Y	Y
Industry*year	N	N	N	Y	Y	Y
Observations	3,222	3,222	2,811	2,802	2,802	2,802
R-squared	0.063	0.065	0.081	0.156	0.165	0.164
Sectors	406	406	405	405	405	405

Note: standard errors in parentheses are clustered at four-digit industry level; *** p<0.01, ** p<0.05, * p<0.1

To further check the robustness of our baseline results, in columns 4 to 6 of Table 5, we add more covariates, including the volatility of real exchange rate and interaction terms of industry dummies and time trends in the extended empirical equations. The estimated coefficients remain highly consistent with the empirical results in columns 1 to 3. All the empirical evidence strongly suggests that overall, real exchange rate movements are more likely to affect markup dispersion through import channels than export channels. An appreciation (depreciation) in the exchange rate helps to improve (reduce) allocation efficiency through both import competition channel and import dependence channel.

6. Further discussion

6.1. Entry and exit

In section 5, we discuss the roles of export dependence, import penetration and import dependence in determining the relationship between real exchange rate movements and markup distribution. One question remains to be answered thus far: Do changes in markup dispersion occur because of changes in the markup levels of incumbent firms, the entry and exit of firms, or both. Table 6 shows the estimation results that we focus only on incumbent firms. Specifically, we exclude firms that have recently entered or exited from the sample used in the previous analysis. The variables used in Table 6 are generated from this subsample of incumbent firms.

The results in Table 6 show a dramatic difference from the previous results that used the full sample: in columns 1-6, we find that the effects of exchange rate fluctuations are no longer significant. These results suggest that real exchange movements seem have little impact on the markup ratios of incumbent firms—and markup dispersion within industries. Therefore, we assume that firm entry and exit should play a more important role in affecting markup dispersion.

Interestingly, if we add interaction terms in estimation model to further check the mechanism through which exchange rate movements affect the markup dispersion of incumbent firms, the results in columns 3 to 6 of Table 6 are dramatically different from those shown in Table 5. All the estimated coefficients for the interaction terms of exchange rate changes with export dependence are positive and significant at the 5% level, which is very robust. We use different checks by controlling for various variables and fixed effects, implying that the negative impacts of an appreciation in the exchange rate on the markup dispersion of incumbent firms will decrease significantly with an increase in export openness. It is likely that the markup dispersion of incumbent firms in exporting industries will increase even more with an appreciation. The vastly different results for the interactions of exchange rate changes with export dependence, as shown in Tables 5 and 6, also make sense. As we emphasized in Figure 2 of section

3, the average markup of China's exporting firms is significantly lower than that of non-exporting firms, which contradicts the predictions of trade theories; thus, in more export-dependent industries, the markup gap between export and non-export incumbent firms will be more likely to expand with an appreciation in the exchange rate. The estimated results for the interactions terms of exchange rate changes and export dependence in Tables 5 and 6 also suggest that currency fluctuations that effect markup dispersion through the export channel mainly occur among incumbent firms (intensive margin effects).

Table 6 Real exchange rate changes and the markup dispersion of incumbent firms (Dependent Var.=$\Delta\ln Theil\_mkp_{it}$)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\ln REER_{it}$	-0.964	-1.031	-1.213	-1.306	-0.805	-0.997
	(0.614)	(0.916)	(1.072)	(1.011)	(1.535)	(1.485)
$\Delta\ln VREER_{it}$	-0.117**	-0.112*	-0.110*	-0.106	-0.092	-0.093
	(0.058)	(0.065)	(0.065)	(0.067)	(0.084)	(0.085)
EX_{it-1}			0.064	0.025	0.478	0.450
			(0.354)	(0.354)	(0.793)	(0.795)
$\Delta\ln REER_{it} * EX_{it-1}$			4.360**	4.204**	6.066**	5.941**
			(2.036)	(2.127)	(2.543)	(2.645)
IMS_{it-1}			-0.279		-0.380	
			(0.269)		(0.549)	
$\Delta\ln REER_{it} * IMS_{it-1}$			-3.367		-4.664	
			(2.565)		(3.060)	
IM_{it-1}				-0.074		-0.321
				(0.497)		(0.870)
$\Delta\ln REER_{it} * IM_{it-1}$				-4.080		-5.244
				(4.027)		(5.299)
Covariates	N	N	N	N	Y	Y
Industry and Year Fixed Effects	Y	Y	Y	Y	Y	Y
Industry*year	N	N	N	N	Y	Y
Observations	2,819	2,819	2,819	2,806	2,819	2,806
R-squared	0.034	0.066	0.070	0.067	0.152	0.150
Sectors	406	406	406	405	406	405

Robust standard errors appear in parentheses and are clustered at the 4-digit industry level. *** p<0.01, ** p<0.05, * p<0.1

On the other hand, the estimated coefficients for the interaction terms of exchange rate changes and import ratios (including import penetration ratio and imported input ratio) are all insignificant in columns 3 to 6 of Table 6. We experiment with controlling for various covariates and fixed effects, and the results indicate that the effects of exchange rate fluctuations on the markup dispersion of incumbent firms are not significantly associated with import channels, implying that the impacts of exchange rate changes on markup dispersion are mainly generated by affecting the entry and exit of firms (extensive margin effects) within the same industry.

To further check the robustness of the empirical results in Tables 5 and 6, in Table 7, we estimate the impacts of exchange rate changes on the entry and exit ratio (the ratio of the number of firms that enter and exit to total firms) at the industry level. In columns 1 to 3, we check the effects of exchange rate movements on firms' exit and entry, and exit/entry ratios at the industry level. The estimated results show that overall, exchange rate movements do not have any significant effects on the exit of firms but have significant (at the 10% level) effects on firms' entry ratio; in addition, there are positive and significant (at the 5% level) effects on the entry and exit ratio when we control for all other covariates and two-way fixed effects. The estimation coefficient of real exchange rate changes in column 3 suggests that a 10% appreciation in the exchange rate will accelerate a firm' exit and entry rate by roughly 3.3%, indicating that exchange rate changes play an important role in affecting firm's turnover rates within industries.

Table 7 Real Exchange Rates and Firm Entry and Exit Rates.

	(1)	(2)	(3)	(4)	(5)	(6)
	ΔEX_{it}	ΔEN_{it}	$\Delta EXEN_{it}$	$\Delta EXEN_{it}$	$\Delta EXEN_{it}$	$\Delta EXEN_{it}$
$\Delta\ln REER_{it}$	0.026	0.306*	0.331**	0.436*	0.208	0.351**
	(0.107)	(0.170)	(0.163)	(0.235)	(0.144)	(0.149)
$\Delta\ln VREER_{it}$	0.002	-0.009	-0.007	-0.008	-0.012	-0.008
	(0.006)	(0.007)	(0.008)	(0.009)	(0.009)	(0.009)
EX_{it-1}				-0.037		
				(0.082)		
$\Delta\ln REER_{it} * EX_{it-1}$				-0.034		
				(0.352)		
IMS_{it-1}					0.330***	
					(0.066)	
$\Delta\ln REER_{it} * IMS_{it-1}$					0.841**	
					(0.391)	
IM_{it-1}						0.229**
						(0.089)
$\Delta\ln REER_{it} * IM_{it-1}$						1.493*
						(0.770)
Covariates	Y	Y	Y	Y	Y	Y
Industry and Year Fixed Effects	Y	Y	Y	Y	Y	Y
Industry*Year	N	N	N	Y	Y	Y
Observations	2,850	2,850	2,850	2,850	2,850	2,831
R-squared	0.645	0.800	0.676	0.740	0.750	0.745
sector	409	409	409	409	409	408

Note: Standard errors in parentheses are clustered at 4-digit industry level, *** p<0.01, ** p<0.05, * p<0.1

In columns 4 to 6 in Table 7, we also check the impacts of exchange rate movements on the entry and exit ratio through these trade channels by adding the same interaction terms and other control variables, as in Tables 5 and 6. We add industry-specific time trends to control for unobservable confounding factors. The estimated coefficients of the interaction terms strongly suggest that exchange rate movements do not affect the entry and exit ratio through the export dependence channel but have positive and significant effects on the entry and exit ratio through both the import competition and import dependence channels. The results consistently show that an appreciation of the exchange rate accelerates firm turnover in industries. This effect is mainly generated through import channels, as predicted by the empirical results in Tables 5 and 6, which imply that a firm's entry and exit ratio is a more important force that affects allocation efficiency driven by real exchange rate fluctuations.

6.2. Asymmetric impacts of REER on markup dispersion

Lastly, we conduct an investigation on the asymmetric effects of real exchange rate movements. As previous studies have suggested (Knetter, 1994), markup adjustment is asymmetric with respect to exchange rate movements in at least two circumstances. If firms face either capacity constraints in distribution networks or quantitative trade restrictions, then firms may engage in more pricing to market behavior when the exporter's currency depreciates (bottleneck hypothesis). If firms attempt to build market share that is subject to the threat of trade restrictions, then firms may engage in more pricing to market behavior when the exporter's currency appreciates (market share hypothesis). Recent empirical studies on firm pricing behavior suggest that export enterprises are more likely to adjust their markup rates to secure market share (Amiti, e*t al.*, 2014). The different responses of export firms in terms of their pricing behavior to currency fluctuations also implies that exchange rate changes have asymmetric impacts on markup dispersion across firms because export firms play an important role in the overall markup distribution within industries.

Given the above motivations, Table 8 shows the results of testing the possible asymmetry effects of real exchange rate changes on markup dispersion. For this test, we first add a dummy variable, Dum_{APR}, (which is set to 1 when there is appreciation in this year comparing to the last year and 0 otherwise) to indicate the directions of exchange rate changes (see also Li *et al.,* 2015).

The results in columns 1 and 2 in Table 8 indicate that the interaction term between real exchange rate changes and the dummy variable for appreciation are all significant and positive; their magnitudes are almost the same as the main effect of exchange rate changes, implying that the effect of REER movements on markup dispersions is close to zero during the period of its appreciation, while the negative effects of real exchange rate on markup dispersion will be strengthened during its depreciation period. Hence, the magnitude of the effects of exchange rate movement on markup dispersion is substantially larger in currency depreciation period than in currency appreciation period. In columns 3 and 4, we check the robustness of the asymmetric effects of currency fluctuations by controlling for all other covariates and two-way fixed effects. The empirical results of the interaction term are still consistently positive and significant at the 5% level, and the estimated magnitude of the interaction terms are approximately equal to the main effects of currency fluctuations, which further verify our findings. In columns 5 and 6, we further check the robustness by simultaneously controlling for all the covariates, fixed effects and industry-specific time trends. The estimated coefficients remain positive and significant at the 10% level.

Depreciation in the real exchange rate has a greater impact on the markup dispersion of firms than appreciation for several reasons. On one hand, incumbent exporting firms significantly reduce their markups to secure market share when the exchange rate appreciates. Since the markups of China's export enterprises are significantly lower than those of non-export enterprises, an appreciation in the exchange rate will widen the markup gaps between export and non-export firms, which will also widen the markup gaps among incumbent firms (intensive margin), as suggested in Table 6.

On the other hand, an appreciation in the exchange rate will also significantly accelerate the entry and exit rate of firms (extensive margin), which will improve allocation efficiency, as suggested in Table 7. Therefore, an appreciation of the exchange rate affects the markup dispersion through alternating intensive margins and extensive margins that potentially offset each other, which, overall would have a small effect on markup dispersions.

When the exchange rates depreciate, exporting firms are more inclined to maintain the stability of their export price (complete pass-through), which stimulates the expansion of the export market share through the price advantage caused by the depreciation. One major advantage that exporting firms in China’s manufacturing industries have in the global market is their low export price or cost, as suggested in Figure 2 of section 3. This result aligns with prior studies (Lu *et al.*, 2010; Dai *et al.*,2016). Therefore, the markups of export firms will not quickly improve as the fierce competition occurs when exchange rates depreciate. Thus, the markup gap between export and non-export incumbent firms will not be significantly narrowed when exchange rates depreciate (intensive margin). However, depreciation will also significantly hinder the entry and exit rate of firms, as suggested in Table 7, which will result in a significant reduction in allocation efficiency. Therefore, when the exchange rate depreciates, the possibility of narrowing the gap between incumbent firm lowers, and allocation efficiency will be reduced because the turnover rate in industries will also be reduced. Therefore, the misallocation effects caused by depreciation are much greater than the effects of appreciation that improve allocation efficiency (Marston, 1990; Kasa, 1992; Kanas, 1997; Knetter, 1994; Koutmos and Martin, 2003; Fang, et al.,2009).

Table 8 Asymmetric Effects of Exchange Rate Fluctuations

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta\ln Theil\_mkp_{it}$	$\Delta\ln Gini\_mkp_{it}$	$\Delta\ln Theil\_mkp_{it}$	$\Delta\ln Gini\_mkp_{it}$	$\Delta\ln Theil\_mkp_{it}$	$\Delta\ln Gini\_mkp_{it}$
$\Delta\ln REER_{it}$	-3.594***	-1.314***	-3.409***	-1.239***	-3.641***	-1.339***
	(1.066)	(0.374)	(1.110)	(0.374)	(1.331)	(0.480)
APR_{it}	-0.073	-0.019	-0.065	-0.017	-0.088	-0.022
	(0.050)	(0.018)	(0.052)	(0.019)	(0.072)	(0.026)
$\Delta\ln REER_{it} * APR_{it}$	3.731**	1.277**	3.576**	1.255**	4.033*	1.526*
	(1.552)	(0.553)	(1.577)	(0.539)	(2.280)	(0.819)
$\Delta\ln VREER_{it}$	-0.041	-0.011	-0.058	-0.018	-0.045	-0.013
	(0.060)	(0.023)	(0.058)	(0.022)	(0.072)	(0.027)
Covariates	N	N	Y	Y	Y	Y
Industry and Year Dum	Y	Y	Y	Y	Y	Y
Industry*Year	N	N	N	N	Y	Y
Observations	2,824	2,824	2,802	2,802	2,802	2,802
R-squared	0.079	0.098	0.092	0.118	0.159	0.184
sector	406	406	405	405	405	405

Robust standard errors appear in parentheses and are clustered at the 4-digit industry level; *** p<0.01, ** p<0.05, * p<0.1

7 Conclusion

In this paper, we evaluate the impacts of the exchange rate on allocation efficiency. Motivated by the recent literature, we use markup dispersion as a proxy of allocation efficiency within industries. Our results show that changes in the real exchange rate have significant and substantial effects on markup dispersion. A depreciation in the exchange rate will greatly increase markup dispersion—by increasing misallocation within industries. Our investigation on the mechanisms for the effects of exchange rate changes suggests that overall, currency fluctuations affecting markup dispersion are more significantly associated with import penetration and imported inputs ratio than export ratio.

Our empirical results also consistently suggest that the effects that exchange rate fluctuations have on markup dispersion can occur at both the extensive and intensive margins. Specifically, the effects that exchange rate movements have on the markup dispersion of incumbent firms are mainly generated through the export dependence channel, while markup dispersion due to the entry and exit of firms caused by exchange rate fluctuations only takes place through import channels.

In addition, we find strong evidence that exchange rate changes have asymmetric effects on allocation efficiency. Specifically, a depreciation in the exchange rate has a greater effect on misallocation within sectors for which the effects on allocation efficiency improvement were caused by appreciation, which may be explained by the asymmetric pricing to market behavior of exporting firms combined with the impacts of exchange rate changes on the entry and exit rates of firms.

The primary implications of this study include the following: A depreciation in the real exchange rate will significantly increase the degree of misallocation within China's manufacturing industry, as China's export firms compete with low prices to expand their market share for long periods. Currency devaluation will not significantly narrow the gap between the markup rate of export and non-export enterprises. Moreover, devaluation will significantly hinder firm turnover in industry sectors, which is not conducive to promoting efficiency and competitiveness in China's manufacturing industries.

Another implication is that the effects that real exchange rate changes have on allocation efficiency mainly take place through import channels. Promoting the further development of trade liberalization and actively expanding the import share of industries are important ways to improve the overall competitiveness of China's manufacturing industries.

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