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How do exchange rate movements affect Chinese exports? — A firm-level investigation

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ABSTRACT

This paper provides first-hand firm-level evidence on Chinese exporters' reaction to RMB exchange rate movements. We find that the RMB price response to exchange rate changes is very small, indicating relatively high exchange rate pass-through into foreign currency denominated prices, while the volume response is moderate and significant. Furthermore, exporters with higher productivity price more to market, though the pass-through is still very high. Other sources of heterogeneity, such as import intensity, distribution costs, income level of the destination countries, and foreign ownership also matter. Moreover, RMB appreciation reduces the probability of entry as well as the probability of continuing in the export market.

1. Introduction

Understanding the impact of exchange rate movements on cross-border trade is of particular interests to both researchers and policymakers, especially in the era of global imbalance. However, existing studies have generated widely-varying estimates of the exchange rate elasticity of export quantity and the exchange rate pass-through (henceforth ERPT) to price (Shambaugh, 2008; Colacelli, 2009). Most studies use aggregate data, which cannot separate the response of export price from that of volume. Moreover, although there is substantial heterogeneity across firms (Melitz, 2003), few studies have linked the exchange rate elasticity or ERPT to firm-level characteristics, with a few recent exceptions including Berman et al. (2012, henceforth BMM), Chatterjee et al. (2013), and Amiti et al. (2014). Burstein and Gopinath (2014) provide the most up-to-date survey on the relationship between international prices and exchange rates.

The valuation of the Chinese RMB and its impact on global trade, in particular on China's huge trade surplus with the United States, has been under the limelight for a long time. As shown in Fig. 1, China's export shipment more than quintupled since it joined the WTO in 2001, and its share in US imports has reached 16% by 2008. A flood of Chinese imports have exerted huge pressure on US producers and caused exit of firms and layoff of American workers (Autor et al., 2013), adding further tension to the US–China relationship. Many have urged that RMB appreciation would reduce its huge trade surplus (e.g., Krugman, 2010; Bergsten, 2010). Unfortunately, such an allegation has little empirical support. There are a few existing studies, but they reach strikingly different results depending on their data coverage.[1]

To fill this gap, we examine in this paper how bilateral real exchange rate (RER) movements affect Chinese exports and exporters, utilizing the census of Chinese exporters from 2000 to 2007. We provide evidence at both the macro- and micro-levels. The macro-analysis facilitates the comparisons with the existing findings. Our focus is the micro-analysis, in which we estimate both ERPT and volume elasticity, following the method of BMM (2012).

Our estimations at various aggregation levels and specifications consistently show significant but moderate volume elasticity and strikingly almost complete ERPT into RMB export price for Chinese exporters. A 10% appreciation in annual RER reduces export price (denominated in RMB) by less than 0.5%. The finding of high ERPT to foreign currency denominated price is in sharp contrast to the finding of low ERPT in

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[1] Using aggregate time-series data, a few studies find the exchange rate elasticity above unity (Aziz and Li, 2007; Ahmed, 2009; Garcia-Herrero and Koivu, 2009; Thorbecke and Smith, 2010). Marquez and Schindler (2007) find that a 10% RMB appreciation decreases the share of aggregate Chinese exports by nearly 1%. In contrast, Cheung et al. (2009) find no significant effect at all. On the ERPT of RMB appreciation, Bussiere and Peltonen (2008) reports full pass-through, while Cui et al. (2009) find it's less than 50%.

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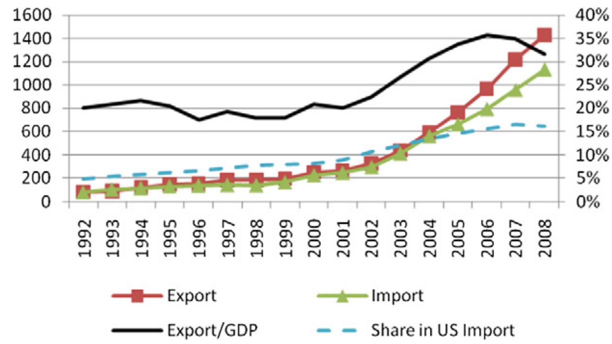


Data Source: China export and import data (in billion US$) from China Customs Office, China GDP from WDI, and US import data from US census. China export ratio to GDP and China's share in US import use the right axis.

Fig. 1. Growing China influence in international trade.

Campa and Goldberg (2005) and Gopinath and Rigobon (2008).[2] This finding, however, is consistent with BMM (2012) who also find very high ERPT using French firm-level data. The high ERPT does not translate into high volume elasticity: export volume correspondingly drops by only 2.2 to 4.1%.[3] Moreover, the RMB price and volume responses sum up to a total value response of 2.5–4.5%, implying RMB appreciation may not reduce China's huge trade surplus substantially.

We attempt to provide reasons for the high ERPT and the moderate exchange rate elasticity by exploring firm heterogeneity. Importantly, recent literature has emphasized that firm heterogeneity, such as productivity (BMM, 2012) and intensity of imported inputs (Amiti et al., 2014), may affect exporters' response to exchange rate movements. To study the role of firm heterogeneity, we match trade data with a set of performance measures. We find that more productive firms price more to market, thus have lower ERPT and lower volume responses. The direction of the impact of firm heterogeneity on price and volume responsiveness is consistent with empirical findings in BMM (2012) and theoretical framework suggested in Burstein and Gopinath (2014). However, even for an exporter with productivity one standard deviation above the average, the ERPT is still as high as 93%. We also investigate other potential reasons for the high ERPT. We find that high imported input intensity, large distribution costs, and high income level of destination markets increase (decrease) the price (volume) responsiveness to exchange rate changes. However, ERPT is still high even after we have accounted for these factors.

Our main results are robust to different sub-samples of firms, alternative measures of productivity, and corrections of sample selection (Heckman, 1979; Wooldridge, 1995). Interestingly, we also find that exporters pass through more during appreciation period (relative to depreciation period), reflecting price stickiness. And foreign-owned exporters pass through more, indicating different elasticity for intra-firm trade.

Finally, we further examine the impact of exchange rate appreciation on firms' adjustments at the extensive margin. Upon exchange rate fluctuations, firms may choose to enter or exit foreign markets. We find that RMB appreciation reduces both the probability that a firm exports to a new market and the probability that a firm survives in the existing market.

Our paper has important policy implications. It suggests that RMB appreciation would not substantially reduce China's huge trade surplus. In fact, although RMB has steadily appreciated against the US dollar since 2005, the growth of Chinese export to the US and the world has not slowed down,[4] as illustrated in Fig. 1. Our results further indicate that exporters do not change much of their export price and their export volume is only reduced moderately. However, our results also indicate substantial churning: appreciation may force exporters to exit foreign market.

The remainder of the paper is structured as follows. Section 2 describes our data. Section 3 provides an initial estimation at the aggregate country and country–product level. Section 4 proceeds to the firm level estimation on ERPT and volume elasticity. Section 5 investigates the effect on the extensive margin. Section 6 concludes.

2. Data description

Our empirical results draw on both a large and comprehensive micro-database of Chinese exporting firms and macro-level indicators, which are constructed from various data sources. We describe these data below.

2.1. Country level macro-data

We obtain year-average bilateral nominal exchange rates from the Penn World Table (PWT 7.1) and consumer price indices (CPIs) from the International Financial Statistics (IFS).[5] Following the convention, the CPI-based real exchange rate (RER_{ct}) is defined as the Chinese RMB against foreign currency, multiplied by foreign CPI and divided by Chinese CPI, which is

$$RER_{ct} = NER_{ct} \times CPI_{ct} / CPI_{CHN,t}$$

By this definition, an increase in RER_{ct} implies a real depreciation of the Chinese RMB against the currency of foreign country c.

Although the RMB/dollar nominal exchange rate has not changed very much before 2005, there have been substantial variations both

[2] Campa and Goldberg (2005) find the unweighted average of pass-through into the *import prices* across the OECD countries is about 46% over one quarter, and about 64% over the longer term, with the US among the lowest rates. Gopinath and Rigobon (2008) use the "*at the dock*" *prices* collected by the US Bureau of Labor Statistics and find exchange rate pass-through into US imports is low, at 22%, even conditional on a price change. Note both studies work with quarterly or monthly data, in contrast to our annual data.

[3] The low volume elasticity obtained in our paper adds to the growing firm level evidence on the "international elasticity puzzle", for example, BMM (2012) show that the average exporter increases export volume by 4% in response to a 10% RER depreciation. Other studies include Tang and Zhang (2012) and Fitzgerald and Haller (2014).

[4] Since July 2005, RMB has steadily appreciated against the US dollar and has appreciated from 8.3 yuan per dollar to 6.8 yuan per dollar by June 2008, which amounted to a total of 21%. During the global financial crisis, China re-pegged RMB to the US dollar until May 2010.

[5] Taiwan's CPI series are from Taiwan Ministry of Finance.

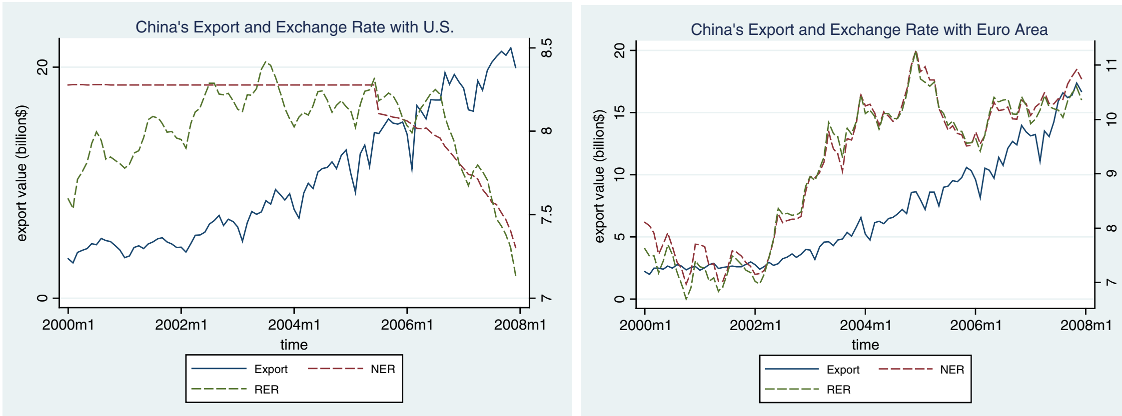
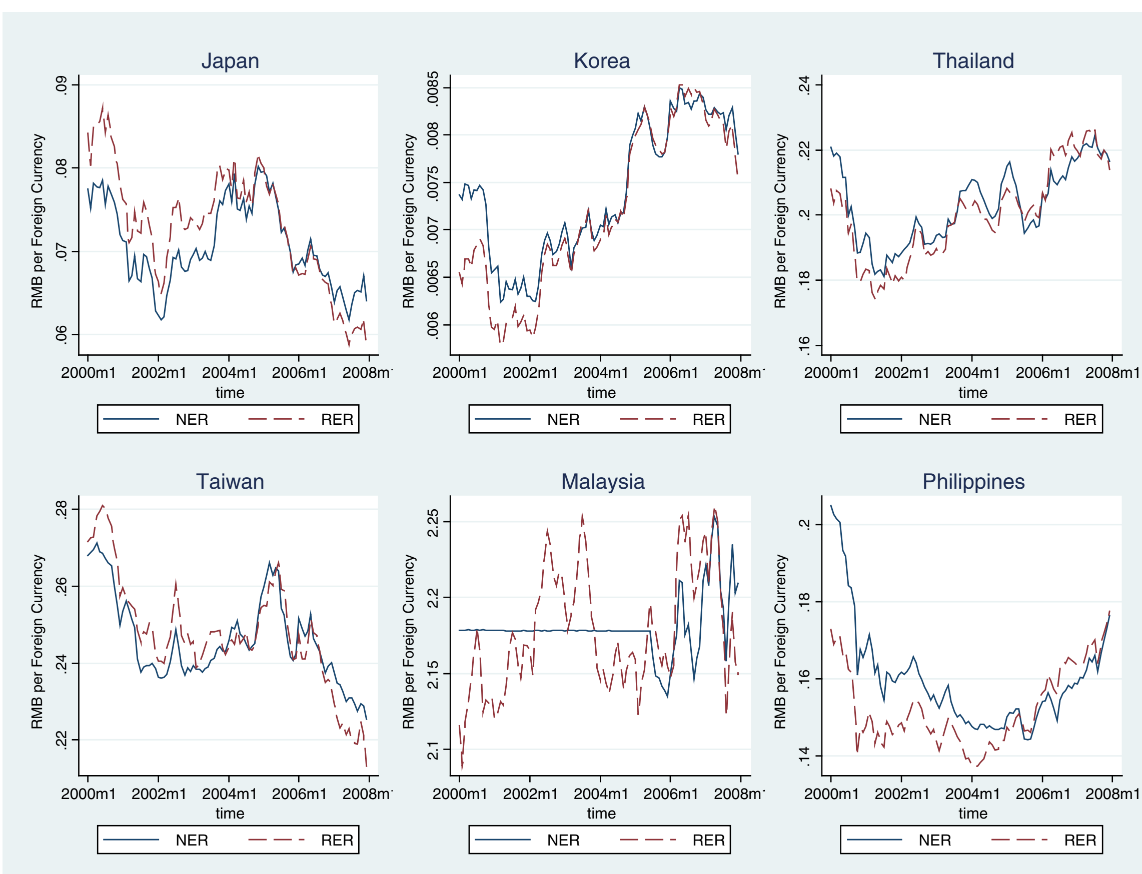


Fig. 2. China's bilateral exchange rates against dollar and euro.

across destinations and over time in the real RMB exchange rates relative to other countries. This is clear when we compare RMB exchange rate against US dollar with it against euro (Fig. 2), or with it against countries in the East and Southeast Asia (Fig. 3). Both figures show substantial variations of RMB against its trading partners. Euro started to appreciate against dollar since 2001, resulting in an appreciation against RMB during the same period until 2005. Although RMB appreciation accelerated in real term against Japan Yen and Taiwan dollar since mid-2005, it actually depreciated against Korean won or Philippine peso.

Other country variables we use in the analysis include real GDP and real GDP *per capita* of the destination countries, collected from PWT 7.1. GDP per capita is the real GDP per capita at constant price using Laspeyres index (*RGDPL*). RGDP is the multiplication of the real GDP per capita and population. We keep all China's trade partners that have no missing data, resulting in 154 destination countries. Those countries account for around 98% of Chinese exports. Table 1 panel A shows the summary statistics for changes in bilateral exchange rate, real GDP, GDP per capita and GDP deflator.



Data Source: The nominal exchange rate data and CPI are all from International Financial Statistics (IFS).

Fig. 3. China's bilateral exchange rates against East Asia Countries.

Table 1
Descriptive statistics for Chinese exporter–product–country triplets.

	#obs	Mean	Median	Std. dev	P10	P90
A: country variables						
RER_t/RER_{t-1}	1078	1.030	1.018	0.084	0.953	1.126
Real GDP_t/Real GDP_{t-1}	1078	1.049	1.044	0.051	1.003	1.097
Real $GDPPC_t$/Real $GDPPC_{t-1}$	1078	1.035	1.029	0.050	0.988	1.087
B: By firm–product–country–year						
uv_t/uv_{t-1}	7,179,605	1.1	1.021	0.379	0.701	1.564
q_t/q_{t-1}	7,179,605	1.9	1.041	2.471	0.246	4.612
#firms per product–country	832,310	8.6	2	30.8	1	17
C: By product–country–year						
uv_t/uv_{t-1}	1,016,221	1.14	1.032	0.539	0.615	1.743
q_t/q_{t-1}	1,016,221	2.12	1.234	2.755	0.404	4.582
D: By firm–product–country–year (matched with firm performance information)						
uv_t/uv_{t-1}	2,118,466	1.1	1.025	0.352	0.740	1.511
q_t/q_{t-1}	2,118,466	1.9	1.064	2.395	0.268	4.416
# products per firm	210,803	3.7	2	6.2	1	8
# destination per firm	210,803	5.5	3	7.2	1	14
# destination per firm–product	210,803	3.1	1.8	3.8	1	7
# products per firm–country	210,803	2.1	1.3	2.7	1	3.8

Data source: authors' own calculation based on the firm level data collected from the General Administration of Customs of China and the National Bureau of Statistics of China.

2.2. Firm level trade data

Our main data source is the census of annual firm-level export and import transactions in China for the period from 2000 to 2007, collected by the Chinese Customs Office.[6] We focus on manufacturing firms only. The data contain both *f.o.b.* (free on board) trade value, denoted as v_{fpct}, and trade volume, q_{fpct}. The subscripts are firm *f*, product *p*, and destination country *c*. Given that the values and quantities are at very disaggregate product categories (six-digit HS classification), the unit value, defined as $uv_{fpct} = v_{fpct}/q_{fpct}$, serves as a suitable proxy for the *f.o.b.* price.

We focus on the 6-digit HS product level, which is consistent across countries.[7] Notably, moving from HS-8 to HS-6 does not substantially change the sample, given the fact that a firm usually exports just one HS-8 product to a destination country under the same HS-6 category. Empirical results using 8-digit HS products are very similar and are available upon request.

We drop observations that are subject to noise or error: (1) products with inconsistent units or missing quantity information; (2) special product categories such as arms (HS 93), antiques (HS 97), and special categories (HS 98–HS 99); (3) export transactions that exist for only one year, since we need price and quantity changes over time; (4) observations for which the annual growth rate of unit value or volume was in the top or bottom 5 percentiles in the distribution, by sector and year. After dropping these outliers, we are left with a sample of about 7.5 million firm–product–destination observations. About 46 to 124 thousand manufacturing exporters ship more than 5000 HS-6 products to 154 destination markets in our sample from 2000 to 2007, which account for around 70% of total manufacturing exports.

In panel B of Table 1, we show the summary statistics. The annual average growth rate of unit values is around 10%, and that for trade volume is around 90%. For each product–country pair, there are on average 8.6 firms. Aggregating those firms in panel C, the mean and median growth rate of unit values are around 14% and 3.2% respectively, which are quite different from the same statistics shown in panel B for firm–product–country pair. Similar divergence is also found for the growth of quantity. Due to the diverse price and quantity growth within each country–product pair, estimation neglecting the within-product heterogeneity may be biased.

Panel D focuses on a subsample of exporters that we could successfully match with the production data. The number of observations is reduced to about 2.1 million firm–product–destination triplets. However, those exporters account for a lion's share of total Chinese exports and have shown the same pattern in price and quantity growth as the full sample in panel B. We also observe interesting patterns on firm scope: on average, each exporter exports 3.7 HS-6 products and exports to 5.5 destination markets. Each firm–product pair has 3.1 destination markets on average. An exporter exports 2.1 HS-6 products to the same foreign market. In the firm-level estimations in Section 4, we experiment with different subsamples that are generally within one or similar product category, the patterns of export price and volume across different subsamples are similar and are shown in the online appendix Table A1.

2.3. Firm level production data

For the matched sample of exporters described in Table 1 panel D, their production-side information is obtained from the Annual Surveys of Industrial Production (ASIP), conducted by the National Bureau of Statistics of China (NBSC). This dataset is the most comprehensive survey data for industrial firms in China, which accounts for over 90% of industrial output and over 70% of industrial employment in 2004 (Brandt et al., 2012). The surveys include all state-owned firms, and non-state firms with revenues above 5 million yuan (about US$ 600,000). There are between 150,000 and 310,000 manufacturing firms in the sample over the period 2000–2007, across more than 400 four-digit CIC (i.e., Chinese Industrial Classification) manufacturing industries. The accounting information, such as firms' gross output, material input costs, wage rate, capital stock, employment, enables us to construct firm performance measures.

[6] Although the data are available at monthly frequency for 2000–2006, we focus on annual growth because our balance-sheet data and other macro data are all annual. There are also concerns of seasonality and lumpiness in monthly data. Most firms do not export a given product to a given market in consecutive months. Relying on the annual export data in 2005, Manova and Zhang (2012) document the patterns and facts about Chinese export prices. Tang and Zhang (2012) estimate the exchange rate elasticity using monthly data of Chinese exporters, with results very close to ours using annual data (around 0.4 for value elasticity).

[7] Data are available at 8-digit HS level, but there is potential coding error at this level with the change of coding over time. For adjustments in HS-6 codes over time, we apply the publicly-available concordance for 2002 HS system to 2007 HS system to make product code consistent over time.

Our primary performance measure is total factor productivity (TFP), which is estimated by the control function approach developed by Levinsohn and Petrin (2003). To be specific, for each two digit CIC sector, we estimate a production function using the material input as a proxy for productivity shock, relying on the fact that more productive firms will use more materials. This helps to control for endogeneity between input levels and unobserved firm-specific productivity shocks. We use output and input deflators at 4-digit CIC level provided by Brandt et al. (2012) to deflate gross output and input, and the regional fixed asset price index by the NBSC to deflate capital stock. Admittedly, this measure of firm productivity is revenue-based and therefore confounds efficiency with firm level prices (De Loecker and Warzynski, 2012). As a consequence, our TFP measures are likely to capture both technical efficiency and the price-cost markups. Besides TFP, we also use labor productivity, defined as value-added over employment, as an alternative measure of firm performance. Summary statistics of firm level variables are reported in Table A2 in the Appendix, which shows that the key firm level characteristics are similar across different subsamples.

3. Country and country–product level regressions

To set the stage for our firm level analysis, we start with the more aggregate country and country–product level estimations. We first aggregate all firm-level export information to the country level and obtain a country panel with 154 destination countries during the period 2000–2007. We run a regression of export value on the bilateral real exchange rate between China and the destination country, controlling for destination demand variables, such as real GDP and real GDP per capita. To deal with possible non-stationarity of the data, we use first differences of log variables. To control for unobservable destination heterogeneity, we include destination fixed effects. More specifically, the model is

$$\Delta \ln EXP_{ct} = \mu + \alpha \Delta \ln RER_{ct} + \beta \Delta \ln RGDP_{ct} + \xi_c + \tau_t + \varepsilon_{ct}, \qquad (1)$$

where EXP_{ct} is China's export value to country c in year t deflated by CPI. RER_{ct} is the bilateral real exchange rate between China and country c. $RGDP_{ct}$ is the real GDP of the destination country measured at constant price. ξ_c represents country fixed effects and τ_t represents year dummies.

Results reported in column (1) of Table 2 show that the response of the bilateral export value to exchange rate changes is moderate. The estimated elasticity of exchange rate is 0.34, suggesting that an appreciation of RMB (a decrease in RER_{ct}) by 10% leads to a drop of total exports by around 3.4%.

To examine the effect of exchange rate on price and quantity adjustments separately, we explore the country–product level data. To be concrete, we disaggregate Chinese exports to each destination country to the level of 6-digit HS products. For each HS-6 product, we calculate its price (i.e., the unit value) by dividing the export value by the export quantity. This leads to a panel dataset of export unit values and quantities for over 5000 HS-6 products to 154 destination countries during 2000–2007. Our main specification is the same as in Eq. (1) except that each observation is a product–country pair in year t and the dependent variable is either export unit value or quantity. We perform within estimation by controlling country–product and year fixed effects.[8]

Results reported in columns (2)–(3) of Table 2 are striking: the effect of exchange rate movements on export takes place mainly on the quantity side. For a 10% appreciation of RMB, export quantity drops by 4.14% (column (3)), while export unit value drops by a tiny 0.25% (column (2)). This indicates a very low pricing-to-market coefficient and consequently a close-to-complete ERPT to export price.

Table 2
Country and country–product estimations, 2000–2007.

	(1)	(2)	(3)
	Country panel	Country–product panel	
	$\Delta\ln(EXP)$	$\Delta\ln(uv)$	$\Delta\ln(Q)$
$\Delta\ln RER_t$	0.340+	0.025**	0.414**
	(0.181)	(0.008)	(0.019)
$\Delta\ln RGDP_t$	−0.463	0.056*	0.993**
	(3.457)	(0.023)	(0.050)
Observations	1071	899,406	
Fixed effects	Country fixed effects	Product–country fixed effects	
Year dummies	Yes	Yes	

Robust standard errors clustered at country level; ** significant at 1%; * significant at 5%; + significant at 10%.
Note: The country panel includes Chinese export to 154 countries during 2000–2007, aggregated from firm–product–country–year observations. The country–product panel includes export unit value and quantities for over 5000 HS-6 products. All estimations include a constant term and fixed effects as specified.

4. Firm level estimations

4.1. Benchmark regressions

Country and country–product level regressions provide us an initial idea about exchange rate elasticity and pass-through. However, as shown in panel B of Table 1, for a given HS-6 product–country pair, there are on average eight firms exporting. There is information not observable at the aggregate level, which may bias the estimation (Dekle et al., 2007). Importantly, the price and quantity are also defined more precisely at the firm level. Thus, we further investigate the effect of exchange rate on export price and quantity adjustments at more detailed firm–product–country level. The number of observations increases substantially to nearly 7.5 million firm–product–country observations.

Our benchmark firm-level regression is specified as follows

$$\Delta \ln X_{fpct} = \mu + \alpha_X \Delta \ln RER_{ct} + \beta_X \Delta \ln RGDP_{ct} + \xi_{fpc} + \tau_t + \varepsilon_{fpct}, \qquad (2)$$

where X_{fpct} could be either unit value (UV_{fpct}) or quantity (Q_{fpct}) for firm f exporting product p to country c in year t. RER_{ct} is the bilateral real exchange rate between China and destination country c in year t. We control for destination demand using its real GDP. Furthermore, we systematically perform within estimations by including firm–product–destination fixed effects (ξ_{fpc}) to capture any time-invariant unobservables that are specific to firm, product, destination or their combinations. Year dummies (τ_t) are also included to control for macro-shocks that are common to all exporters.

The results reported in Table 3 confirm previous findings that use more aggregate data: Chinese exporters are more responsive in adjusting export quantity than price facing exchange rate movements. With a 10% appreciation of RMB (a decrease of RER_{ct}), export price drops by 0.35% (column (1)) and export volume drops by 2.26% (column (2)). The small coefficients for price adjustments indicate a high and close-to-complete ERPT to export price in destination currencies. To partially avoid selection issues caused by firm entry and exit, we use a truncated sample in columns (3) and (4), excluding observations in entry/exit years. The results are similar with the RMB price response increasing to 0.41% and the quantity response increasing to 2.98%.

Given the prevalence of multi-product exporters, one concern is that the within-firm adjustment along the "extensive margin" (i.e., the product scope) will interfere with the adjustment at the "intensive margin" (i.e., price and volume). As there is no ideal sample to isolate such effect of multi-product firms, we follow BMM and experiment with different subsamples. We first restrict our sample to each exporter's major

[8] We also estimate the model at both country and country–product levels using panel dynamic OLS method (DOLS) as in Thorbecke and Smith (2010) to account for possible cointegration relationship among variables. Results are very similar and available upon request.

Table 3
Firm level benchmark estimations.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\Delta\ln(uv)$	$\Delta\ln(Q)$	$\Delta\ln(uv)$	$\Delta\ln(Q)$	$\Delta\ln(uv)$	$\Delta\ln(Q)$	$\Delta\ln(uv)$	$\Delta\ln(Q)$
Sample	All		w/o entry/exit		Major HS4 sector		Single product	
$\Delta\ln RER_t$	0.035**	0.226**	0.041*	0.298**	0.034*	0.254**	0.030**	0.286**
	(0.011)	(0.075)	(0.020)	(0.107)	(0.014)	(0.083)	(0.009)	(0.079)
$\Delta\ln \text{RGDP}_t$	−0.018	0.774**	−0.103	0.751**	−0.029	0.913**	−0.008	1.036**
	(0.032)	(0.206)	(0.073)	(0.263)	(0.042)	(0.230)	(0.025)	(0.236)
Fixed effects	firm–product–country fixed effects + year dummies							
Observations	7,179,605		1,613,592		2,453,599		1,673,594	

Robust standard errors clustered at firm level; * significant at 5%; ** significant at 1%.
Note: this table reports the estimation results at the firm–product–country level during 2000–2007. Columns (1)–(2) use the sample of all manufacturing (non-agricultural) exporters. Columns (3)–(4) drop those observations that newly appear or exit next period. Columns (5)–(6) focus on exporters' major sector defined at four-digit HS level. Columns (7)–(8) focus on single product exporters — exporters that export one single product to a destination. All estimations include a constant term, firm–product–country fixed effects and year dummies.

four-digit HS sector in columns (5) and (6), and then follow BMM and Chatterjee et al. (2013) to include only single-product firms in columns (7) and (8), where we define single-product firms as those having only one product exported for a firm–destination–year triplet.[9] The patterns remain qualitatively unchanged. Combining the quantity and price coefficients, we could also infer the impact of exchange rate changes on export value: In total, a 10% appreciation of RMB will lead to a drop in the export value by 3%.[10]

Our estimates of high ERPT at both firm and product levels are actually in line with several findings in the literature. For example, Bussiere and Peltonen (2008), who study the relationship between aggregate export price indexes and exchange rate changes for more than 40 countries, find that export prices of China and India do not appear to be significantly affected by the exchange rate changes. Freund et al. (2011) work with a selected sample of products at HS-4 level during 1997 to 2005. Both of their value and quantity regressions give coefficients around 0.9, indicating a very small RMB price response to exchange rate. In their study of French firms, BMM (2012) find that in reaction to a 10% appreciation, an average exporter cuts their export price in euro by between 0.5% and 1.4% (a bit higher than ours). However, we also note that a few studies, in particular Campa and Goldberg (2005), find low ERPT into import price or consumer price using data from the US and other OECD countries, implying the importance of distribution costs in the destination market.

The high ERPT does not translate into high volume elasticity: with a 10% appreciation of RMB, export volume drops by only 2.26% (column (2)). This elasticity may look low compared with the international macro-literature that we surveyed in footnote 1. However, the low volume elasticity is not an exceptional finding. At firm-level, BMM (2012) also find the volume elasticity at similar magnitude. For example, for their benchmark regression, the average exporter increases export volume by 4% in response to a 10% RER depreciation. Tang and Zhang (2012) estimate the value elasticity of exchange rate at around 0.4 over one year using monthly Chinese export data. Fitzgerald and Haller (2014) use the Irish firm level export data and confirm the weak response of export revenue to real exchange rate shocks. Estimating a gravity-type regression separately for 136 exporting countries, Colacelli (2009) reports that the distribution of estimated RER elasticity concentrates in the range of (0, 1) with a mean of 0.22.

There are several reasons for such low volume elasticity.[11] First note here ERPT is pass-through into export price in RMB. If a large proportion of the final price paid by foreign buyers is attributed to the costs (e.g. the distribution costs) and markup that incurred in the local market, then quantity elasticity could be low despite very high EPRT into export price. We explore the role of distribution cost in Section 4.3.2. Secondly, high ERPT into export price may not simply cause large quantity elasticity. Indeed, it might be because of the quantity demanded elasticity is low so that exporters choose optimally to pass through exchange rate changes more completely. Consider the simplest price equation: $\Delta\ln p = \Delta\ln(mc) + \Delta\ln(markup)$, where p is the RMB export price, which can be decomposed into exporter's marginal cost and markup. Empirically-estimated high pass-through implies (1) markup is already at very low level (due to competition) so Chinese exporters cannot lower it facing RMB appreciation; or (2) marginal cost (in RMB) is not responsive to RMB appreciation. The second point can be explained by two possible reasons: first, the domestic materials and labor inputs take a large share in the total costs of exported products; second, there is relatively low level of EPRT into import price for the imported components used by Chinese producers (Bussiere and Peltonen, 2008).

4.2. Firm heterogeneity and ERPT

Firms are heterogeneous in their productivity and therefore their responses to exchange rate shocks may also be heterogeneous. One advantage of our firm level data is that we have information on not only a firm's exports but also its production. This enables us to connect firm's export responses with its production characteristics, such as productivity, and help us to understand the high ERPT.

We examine the role of firm heterogeneity by adding an interaction term of firm productivity with real exchange rate in our empirical specification. Our primary productivity measure is the total factor productivity (TFP), as defined in the data description part. As robustness tests, we also experiment alternative productivity measures, such as labor productivity and total export value. Our empirical specification is

$$\begin{aligned}\Delta\ln X_{fpct} = {} & \mu + \alpha_x \Delta\ln RER_{ct} + \beta_x \Delta\ln RER_{ct} \times \ln\varphi_{ft-1} + \gamma_x \ln\varphi_{ft-1} \\ & + \delta_x \Delta\ln\varphi_{ft} + \lambda_x \Delta\ln RGDP_{ct} + \xi_{fpc} + \tau_t + \varepsilon_{fpct}\end{aligned} \quad (3)$$

[9] Admittedly, we abuse the terminology a bit here. The exporter may export different products to different destinations, and they may also supply different products to the domestic market. Without further information on firms' production and domestic sales, we couldn't provide an ideal "single-product" sample. We thank a referee for pointing this out.

[10] Dropping the firm–product–destination fixed effect in our differenced regression will not change our results qualitatively. The estimated price and quantity coefficients are 0.032 and 0.396. We also experiment with an alternative specification with firm–product–year fixed effect, which instead identifies the effect from cross-country variations in RER changes. The main result remains unchanged. However, the interaction term between productivity and exchange rate that we examine in Section 4.2 becomes insignificant in some cases, suggesting that the heterogeneous responses of firms are more prevalent from cross-time variations than from cross-country variations.

[11] It is also possible that quantity responds slowly to exchange rate, as emphasized in the J-curve literature (Arkolakis et al., 2012; Bahmani-Oskooee and Ratha, 2004). However, in unreported results, we didn't detect such slow adjustment after one year. Consistent with our finding, Tang and Zhang (2012) find that most of the responses take place within the first 6 months after the shock, with the effects of the shocks vanishing within a year.

Table 4
Firm heterogeneity and responses to RER.

	(1)	(2)	(3)	(4)	(5)
Sample	All	Single product	Major product	Main IO sector	Main HS-4
Dependent variable: Δln(uv)					
Δln RER_t	0.036**	0.033**	0.025**	0.032**	0.034**
	(0.007)	(0.009)	(0.007)	(0.007)	(0.007)
$\text{lnTFP}_{t-1} \times \Delta\ln RER_t$	0.106**	0.071*	0.069**	0.101**	0.105**
	(0.024)	(0.030)	(0.025)	(0.026)	(0.026)
Δln RGDP_t	−0.019	0.027	0.016	−0.021	0.010
	(0.020)	(0.028)	(0.022)	(0.022)	(0.023)
lnTFP_{t-1}	−0.016**	−0.016**	−0.021**	−0.018**	−0.021**
	(0.004)	(0.005)	(0.004)	(0.005)	(0.005)
ΔlnTFP_t	−0.002	−0.003	−0.002	−0.002	−0.002
	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)
Increasing TFP by one s.d.	3.6 → 6.8	3.3 → 5.4	2.5 → 4.6	3.2 → 6.2	3.4 → 6.5
Dependent variable: Δln(Q)					
Δln RER_t	0.215**	0.269**	0.259**	0.215**	0.250**
	(0.025)	(0.035)	(0.028)	(0.027)	(0.028)
$\text{lnTFP}_{t-1} \times \Delta\ln RER_t$	−0.359**	−0.152	−0.197*	−0.336**	−0.389**
	(0.079)	(0.105)	(0.085)	(0.084)	(0.086)
Δln RGDP_t	0.802**	0.899**	0.806**	0.871**	0.813**
	(0.078)	(0.108)	(0.085)	(0.082)	(0.084)
lnTFP_{t-1}	−0.036**	−0.057**	−0.056**	−0.031*	−0.042**
	(0.013)	(0.019)	(0.015)	(0.014)	(0.015)
ΔlnTFP_t	0.030**	0.034*	0.039**	0.041**	0.038**
	(0.010)	(0.014)	(0.011)	(0.010)	(0.011)
Increase TFP by one s.d.	21.5 → 11.0	26.9 → 22.4	25.9 → 20.1	21.5 → 10.5	25.0 → 13.3
Fixed effects	firm–product–country FE + year dummies				
Observations	2,118,466	791,025	1,045,269	1,538,257	1,236,291

Robust standard errors clustered at firm level; * significant at 5%; ** significant at 1%.
Note: this table reports the estimation results at the firm–product–country level during 2000–2007. All estimations include a constant term, firm–product–country fixed effects and year dummies. The top panel reports the price response to exchange rate movements, while the bottom panel reports the response in export volume. Column (1) uses the full sample, column (2) uses the single firm–product–country triplet, column (3) uses each firm's core product exported to one destination, column (4) uses the products in the major Input–Output sector for each firm, column (5) uses the products in the major 4-digit HS sector for each firm.

where φ_{ft-1} is the TFP of firm f in year $t-1$. We use the lagged value of TFP to account for the possibility that TFP may be endogenous to price and quantity variations. For ease of interpretation, we normalize firm productivity by its sector average. Thus, the coefficient a_x is the price or quantity response for an exporter with the average productivity in each sector. β_x represents the additional adjustment that an exporter with higher or lower than average productivity makes. We expect β_x to be positive for the unit value regression, i.e. more productive firms are able to price more to market; and negative for the quantity regression, i.e. optimally pricing by more productive firms would reduce the impact on export quantity of a currency appreciation. In addition to the main regressors, we also control for the TFP level in the previous year, changes in real GDP (which proxy for changes in market demand), and changes in firms' TFP.[12]

Regressions reported in Table 4 indeed show that productivity heterogeneity affects firm responses to exchange rate movements. The response of an exporter with the sector-average productivity is the same as what we find in the benchmark regression: for a 10% appreciation of RMB, it reduces export price by 0.36% and export quantity by 2.2% (column (1) first row). However, as productivity increases, the RMB price response also increases, as suggested by the positive and significant coefficient for the interaction term (second row of column (1) in the upper panel). Correspondingly, high-TFP exporters are actually less affected in export volume by exchange rate movements (second row of column (1) in the lower panel).

An exporter may export multiple HS-6 products to the same destination. The pricing strategies for multiproduct firms may be different from those for single-product firms (Bernard et al., 2011). To deal with this issue, we experiment with different subsamples that are generally within one or similar product category, as in Table 3. Specifically, we have the following subsamples: a single product–destination pair for each firm (column (2)), each firm's major product in terms of export value (column (3)), each firm's major sector defined by the input–output table (column (4)),[13] and similarly each firm's major HS-4 product category (column (5)). The heterogeneous responses with respect to productivity remain qualitatively unchanged across all subsamples. In the last row of each column, we provide a quantitative assessment of the economic importance of the productivity heterogeneity by showing the change in the exchange rate elasticities following a one standard deviation increase in TFP. Our benchmark regression shows that increasing $ln(TFP)$ by one standard deviation, which is 0.3 in our data, will nearly double the price elasticity from 3.6% to 6.8% (or equivalently resulting in 93% ERPT), and the quantity elasticity will fall from 21.5% to 11%.

The heterogeneous responses of firms with different productivities are consistent with the results in BMM (2012), who propose two theoretical explanations.[14] The first is based on a monopolistic competition model of Melitz and Ottaviano (2008), which generates a linear demand

[12] In unreported results, we also experiment with specifications by adding an additional control for importer price index or including a country–year fixed effect to control for the "multilateral resistance" term, or controlling more firm heterogeneity cost variables such as firm's wage, and market demand variations such as real GDP per capita in the regressions. The results remain unchanged.

[13] That is, we keep for each firm the HS-6 products within its top IO sector in terms of export value. As in Amiti et al. (2014), focusing on the major IO sector assumes that an exporter uses similar production technology for all HS-6 products within an IO sector.

[14] The heterogeneous response to exchange rate movements hinges on endogenized markup over marginal costs, which could also be rationalized by monopolistic competition with translog utility (Bergin and Feenstra, 2009), or Cournot oligopoly among a finite number of firms and a representative consumer with CES utility (Atkeson and Burstein, 2008).

Table 5
The role of import intensity.

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta\ln(uv)$	$\Delta\ln(Q)$	$\Delta\ln(uv)$	$\Delta\ln(Q)$	$\Delta\ln(uv)$	$\Delta\ln(Q)$
	Φ = import/total inputs				Φ = import/sales	
$\Delta\ln \text{RER}_t$	0.021**	0.307**	0.024*	0.330**	0.024*	0.333**
	(0.008)	(0.030)	(0.011)	(0.039)	(0.011)	(0.038)
$\ln\text{TFP}_{t-1} \times \Delta\ln RER_t$	0.103**	−0.360**	0.122**	−0.373**	0.132**	−0.402**
	(0.024)	(0.079)	(0.028)	(0.090)	(0.028)	(0.091)
$\Phi_{t-1} \times \Delta\ln RER_t$	0.065**	−0.369**	0.076**	−0.243**	0.099**	−0.319**
	(0.022)	(0.072)	(0.024)	(0.081)	(0.029)	(0.096)
$\Delta\ln \text{RGDP}_t$	−0.016	0.790**	−0.038	0.891**	−0.038	0.889**
	(0.021)	(0.078)	(0.025)	(0.093)	(0.025)	(0.093)
$\ln\text{TFP}_{t-1}$	−0.018**	−0.034**	−0.013**	−0.047**	−0.009+	−0.055**
	(0.004)	(0.013)	(0.005)	(0.015)	(0.005)	(0.015)
Φ_{t-1}	0.020**	−0.063**	0.027**	−0.043**	0.028**	−0.065**
	(0.005)	(0.015)	(0.005)	(0.015)	(0.006)	(0.018)
$\Delta\ln \text{TFP}_t$	−0.001	0.024*	0.003	0.007	0.002	0.008
	(0.003)	(0.009)	(0.004)	(0.011)	(0.004)	(0.011)
ΔINPUT_PRICE			0.056**	0.009	0.056**	0.009
			(0.003)	(0.008)	(0.003)	(0.008)
Increase Φ_{t-1} from 0 to 20%	2.1 → 3.4	30.7 → 23.3	2.4 → 3.9	33.0 → 28.1	2.4 → 4.4	33.3 → 26.9
Fixed effects	firm–product–country fixed effects + year dummies					
Observations	2,092,926	2,092,926	1,477,455	1,477,455	1,477,455	1,477,455

Robust standard errors clustered at firm level; + significant at 10%; * significant at 5%; ** significant at 1%.
Note: this table reports the estimation results at the firm–product–country level during 2000–2007. All estimations include a constant term, firm–product–country fixed effects, and year dummies. All regressions use interaction between import intensity Φ_{t-1} and $\Delta\ln RER_t$, where columns (1)–(4) define Φ_{t-1} = total imports of inputs/total input costs in $t-1$; columns (5)–(6) define Φ_{t-1} = total imports of inputs/total sales in $t-1$.

and therefore endogenous markups across firms. Based on this framework, more productive firms will sell at larger quantity and therefore face less elastic demand and higher markups. As a result, more productive firms will be able to price more to market. The second model is a monopolistic competition model with a CES preference, but it assumes complementarity between production and retailing, following Burstein et al. (2003) and Corsetti and Dedola (2005). Assuming constant and additive distribution costs of exports that are paid in local currency, BMM (2012) show that the markup increases in productivity. A depreciation reduces demand elasticity and increases firms' markup, but more so for more productive firms.

4.3. Discussions

In this section, we further discuss the heterogeneous responses and the high ERPT observed at the firm level. We examine a number of alternative mechanisms that might be related to the heterogeneous responses and provide a few more explanations for the high ERPT.

4.3.1. Import intensity

A low value-added share in the total export may explain the inertia of price and quantity of Chinese exports in response to exchange rate movements. The foreign content of Chinese exports is estimated to account for 40% of China's exports (Koopman et al., 2012), due to the rising fragmentation of global production chain. Indeed, out of all manufacturing exporters in our matched sample, more than 70% are also importing intermediate inputs. Those importing exporters account for around 90% of total export value.[15] Furthermore, large exporters are often large importers of intermediate inputs. For such firms, exchange rate shocks will also affect input costs. Relying on a sample of Belgian exporters, Amiti et al. (2014) find that increasing imports in total costs could substantially reduce exchange rate pass-through.

Results reported in column (1) of Table 5 shows that producers who use more imported inputs are more responsive to exchange rate changes. We measure import intensity Φ_{ft}, as the ratio of total imported intermediate inputs by a firm relative to its total input cost. Compared with a firm with no imported inputs but with the same average productivity level, an exporter who imports 20% of its total inputs from abroad (the mean level of import intensity) tends to increase its RMB price response coefficient from 2.1 to 3.4 percentage points (bottom row).[16] Interestingly, after accounting for the heterogeneity in imported input intensity, heterogeneity in TFP continues to play a similar role in affecting export price responsiveness. Column (2) then shows that exporters who import intensively tend to respond less in quantity: increasing import intensity from zero to 20% will decrease the firm's volume response to exchange rate changes from 30.7 to 23.3 percentage points.

With information on firm's imported input, we could explicitly measure the changes of marginal cost due to price changes in inputs. As in Amiti et al. (2014), we construct a direct measure of imported input price changes as a Tornquvist price index,

$$\Delta \ln MC_{ft} = \sum_{j\in J, c\in C} \omega_{fjct} \times \Delta \ln \left(p^m_{fjct}\right),$$

where p^m_{fjct} is the price of imported intermediate input j by firm f from country c at time t, ω_{fjct} is the cost share of input j from country c, averaged over two consecutive years t and $t-1$.

Import intensity can affect export price through either changing the marginal cost, or changing the markup by selection. Thus in columns (3)–(4) we add $\Delta \ln MC_{ft}$ as an additional control of input price. The coefficients for the interaction between import intensity and exchange rate changes remain significant economically and statistically. Higher import cost, as reflected by an increase in $\ln MC_{ft}$, leads to higher export prices but has no significant impact on export volume. This may be due to the higher input cost actually means higher product quality. In columns (5)–(6), we test the sensitivity of the estimation by defining imported input intensity as imported input over total sales, the results are very similar.

[15] The distribution of import intensity among exporting firms is presented in the Appendix Table A3.

[16] Recall that we normalize firms' productivity by sector average, thus $\ln\text{TFP}_{t-1} = 0$ for the exporter with average productivity level. Therefore, the price response to exchange rate for an exporter with 20% import intensity is 0.021 + 0.065*(0.2) = 0.034. According to the appendix Table A3, about 28% of exporters have average import intensity exceeding 20%.

Table 6
Distribution costs and goods type.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Δln(*uv*)	Δln(*Q*)	Δln(*uv*)	Δln(*Q*)	Δln(*uv*)	Δln(*Q*)	Δln(*uv*)	Δln(*Q*)
	Distribution costs		Goods type					
	Goldberg and Campa		Input		Consumer goods		Demand Elasticity	
Δln RER_t	−0.073**	0.699**	0.029+	0.162*	0.046+	0.287**	0.012	0.291**
	(0.025)	(0.158)	(0.016)	(0.077)	(0.027)	(0.101)	(0.010)	(0.066)
Dist. Cost × Δln RER_t	0.613**	−2.743**						
	(0.186)	(0.976)						
Elasticity × Δln RER_t							0.061*	−0.184+
							(0.029)	(0.101)
lnTFP_{t-1} × Δln RER_t	0.104**	−0.339**	0.121**	−0.285*	0.065	−0.314+	0.104**	−0.359**
	(0.027)	(0.128)	(0.038)	(0.119)	(0.040)	(0.174)	(0.029)	(0.133)
ΔlnTFP_t	−0.002	0.030**	−0.008*	0.013	0.002	0.054**	−0.002	0.029**
	(0.002)	(0.009)	(0.003)	(0.016)	(0.003)	(0.013)	(0.002)	(0.009)
lnTFP_{t-1}	−0.016**	−0.036*	−0.017**	−0.070**	−0.024**	−0.003	−0.017**	−0.037**
	(0.003)	(0.015)	(0.005)	(0.024)	(0.005)	(0.011)	(0.003)	(0.015)
Δln $RGDP_t$	−0.022	0.803**	−0.029	0.931**	−0.001	0.693**	−0.015	0.803**
	(0.039)	(0.202)	(0.042)	(0.195)	(0.049)	(0.247)	(0.039)	(0.203)
Interquartile change in dist. cost:	1.0 → 4.8	32.7 → 15.9						
Fixed effects	firm–product–country fixed effects + year dummies							
Observations	2,047,198		881,566		961,335		2,090, 894	

Robust standard errors clustered at firm level; + significant at 10%; * significant at 5%; ** significant at 1%.
Note: this table reports the estimation results at the firm–product–country level during 2000–2007. All estimations include a constant term, firm–product–country fixed effects, and year dummies. Columns (1)–(2) interact the average industry distribution cost with Δln RER, where the distribution costs are adopted from Campa and Goldberg (2010). Columns (3)–(4) focus on exports of intermediate inputs, while columns (5)–(6) focus on exports of consumer goods, classified according to the UN-BEC. Columns (7)–(8) interact the import demand elasticity of HS goods with Δln RER.

4.3.2. Distribution costs and goods type

First, distribution costs also matter. Even though almost a full pass-through of exchange rate to export price is observed, there could still be much limited pass-through to import price if transportation and distribution costs denominated in the importer's currency accounts for a large share (Burstein et al., 2003; Campa and Goldberg, 2005). Hale and Hobijn (2011) find that on average, 55 cents out of every dollar spent on an item imported from China go for services produced in the United States. An essential theoretical insight in BMM (2012) is that the additive distribution costs work as an important factor to affect a firm's markup and consequently its pricing-to-market behavior.

Results reported in columns (1)–(2) of Table 6 suggest that high distribution costs increase the price responsiveness and reduce the quantity responsiveness. We adopt the average distribution margin at the sector level from Campa and Goldberg (2010), which is computed as the ratio of the value of trade and transport margins to the value of total supply in the industry at purchasers' prices for 29 industries.[17] We add an interaction term of the average industry distribution cost with the real exchange rate variable. Though not reported, we also adopt the domestic distribution cost from China's NBS (therefore the internal distribution cost) for 58 manufacturing sectors. For both measures, high distribution costs increase the price responsiveness and reduce the quantity responsiveness. The impact is quite large. In particular, in the bottom row of columns (1)–(2), we show the impact of inter-quartile change in the distribution costs on exchange rate responses: moving from a sector with the distribution cost at the 25 percentile level (13.53%, coke, refined petroleum products and nuclear fuel) to a sector with the distribution cost at the 75 percentile level (19.67%, food products and beverages), the RMB price response increases from 1.0 to 4.8 percentage point, while the quantity response decreases from 32.7 to 15.9 percentage point. Importantly, the impact of the interaction term between TFP and RER still remains its significance and magnitude.

We further explore the importance of distribution costs by comparing the different responses to exchange rate movements by final consumer goods versus intermediate inputs. As noted in BMM, the distribution costs are higher for final consumer goods than intermediate inputs. We use the UN-BEC concordance to classify each six-digit HS product as a consumer good or input, and report the estimation results for both types of goods separately in columns (3)–(6) in Table 6. As

Table 7
Alternative productivity measures and specifications.

	(1)	(2)	(3)	(4)	(5)
	Δln(*uv*)				
	Labor productivity	Total export value	Percentiles of TFP		
Δln RER_t	0.034**	0.026*	0.020*	0.001	0.005
	(0.007)	(0.011)	(0.009)	(0.014)	(0.021)
ln$PROD_{t-1}$ × Δln RER_t	0.039**	0.009+			
	(0.007)	(0.005)			
Top 50% TFP × Δln RER_t			0.032**		
			(0.012)		
Top 20% TFP × Δln RER_t				0.079**	
				(0.020)	
Top 10% TFP × Δln RER_t					0.082**
					(0.029)
Δln$PROD_t$	0.006**	0.029**			
	(0.001)	(0.001)			
Δln $RGDP_t$	−0.019	−0.004	−0.020	−0.021	−0.020
	(0.020)	(0.025)	(0.020)	(0.020)	(0.020)
Fixed effects	firm–product–country fixed effects + year dummies				
Observations	2,118,466	1,663,890	2,118,466		

Robust standard errors clustered at firm level; + significant at 10%; * significant at 5%; ** significant at 1%.
Note: this table reports the estimation results at the firm–product–country level during 2000–2007. All estimations include a constant term, firm–product–country fixed effects, and year dummies. Column (1) uses labor productivity to replace TFP. Column (2) uses a firm's total export value to replace TFP. Columns (3) to (5) still use the full set of TFP bins (i.e., median, quintiles, and deciles of TFP respectively) interacted with the real exchange rate changes. Additional controls including all other interactions with TFP bins other than the top performance group, as well as the TFP bins, and lagged productivity are not reported but are available in the Appendix Table A4.

[17] The distribution margins are calculated based on the Input–Output Tables of 20 countries. We use the sector-specific averages across countries to be able to use the whole sample.

expected, exporters of consumer goods respond more to exchange rate changes, given that they face higher distribution costs.

Finally, we explore the difference across goods with different import demand elasticity. We classify HS goods as high-elasticity goods and low-elasticity goods according to Broda et al. (2006). Columns (7)–(8) interact RER with an indicator variable that equals one if the import demand elasticity of that good is above median. The results indicate that firms that export goods with high demand elasticity respond more (less) in price (quantity) to exchange rate changes.

4.4. Robustness and extensions

In this section, we explore different sets of robustness exercises and extensions to the heterogeneous responses of export prices and quantities to exchange rate movements.

4.4.1. Alternative productivity measures and specifications

We first check whether the heterogeneous responses are robust to alternative measures of productivity. We explore two measures: labor productivity (column (1) of Table 7), defined as the value-added (in constant price) divided by the number of workers, and the total export value of a firm (column (2)). With these new productivity measures, the coefficients on the interaction term remain positive and significant, suggesting that more productive firms price more to the market.

We also experiment on alternative functional specifications for TFP, i.e., TFP dummies. In particular, we follow BMM and construct different bins of TFP based on its median, quintiles or deciles, with the bottom bins as the references (columns (3)–(5)). We use those bins as alternative measures of productivity and interact them with changes in RER. In each case, we report the coefficients for the interaction terms between RER and the top productivity group. The results confirm that exporters belonging to the top bins are more responsive to exchange rate movements.[18] Take column (5) as an example, in response to a 10% depreciation, the lowest decile of firms increases their price in RMB by 0.05%, whereas the top decile of firms increases their price by 0.87%.

4.4.2. Regions of destinations

We then check the robustness of our results to different regions of destinations, as one concern is that much of the variation in real exchange rate could be due to price movements in different regions instead of nominal exchange rate movements. In particular, the Chinese RMB was pegged to the US dollar (and therefore, the Hong Kong dollar) before July 2005, which means that the US–China (and Hong Kong–Mainland China) bilateral real exchange rate movements before 2005 come only from the variations in inflation. This effect can be important because the US and Hong Kong are major export destinations for Mainland Chinese firms. To avoid potential biases related to this, we exclude from our sample the U.S., Hong Kong, and other US dollar peggers, as defined in Klein and Shambaugh's (2006). Both the magnitudes and the heterogeneous responses remain unchanged, as can be seen from columns (1) and (2) of Table 8.

Moreover, the export price is much less responsive for exports to non-OECD countries (column (5)) than exports to OECD countries (column (3)). The heterogeneous responses across firms with different productivities remain largely unchanged. This suggests that there might be a relationship between exchange rate responsiveness and destination countries' income level. In contrast, the quantity response for export to non-OECD countries (column (6)) is larger than that for OECD countries (column (4)). With a sample of OECD countries, Campa and Goldberg (2005) find that countries with less variability in exchange rate and inflation have lower ERPT into import prices. Since non-OECD countries are likely countries with more exchange rate volatility and inflation volatility compared with OECD countries, our finding is consistent with theirs. More generally, we explore the heterogeneous response across destination countries with different income levels, as proxied by real GDP per capita.[19] Columns (7)–(8) show that exporters respond more (less) elastically in price (volume) to exchange rate changes in countries with higher income level.

4.4.3. Sample selection

Another concern is sample selection. Our estimations are based on an unbalanced panel, as firms may enter or exit a destination market, or/and add or drop a product from year to year. Therefore the estimations might be subject to sample selection bias. To correct for possible sample selection bias, we use two approaches.

The first is the Heckman (1979) two-stage procedure, similar to that used by Chatterjee et al. (2013). We first estimate a probit selection equation for whether a firm–product–country triplet (*fpc*) appears in year t ($y_{fpc,t} = 1$ or 0).[20] Then we construct the Inverse Mills Ratio (IMR) and add it as an additional control variable to the main estimation of price and quantity equations.

The second approach follows Wooldridge (1995). The Wooldridge's method is similar to the Heckman (1979) two-stage estimator. However, it proposes to parameterize the conditional expectations of unobserved heterogeneity by estimating, for each date t, a probit model of the dummy variable $y_{fpc,t}$ on the full sample (from $t = 1$ to T) of all the destination- and firm-level variables.[21] An IMR is then constructed for each date t. In the second stage, a pooled OLS regression is run for the price and quantity equations controlling for the IMRs.

For both approaches, identification requires at least one variable that affects a firm's decision to enter/exit the export market but does *not* affect its performance in the market (i.e., quantity and price). We experiment with two exclusive restrictions. One is the lagged dependent variable, that is, an indicator for whether the firm–product–destination triplet appeared in year $t - 1$. The idea is that previous exporting experience substantially reduces the fixed costs of exporting and thus enhances the possibility of exporting in the current period. However, one thing to note is that this exclusion variable will not work technically in the Wooldridge's estimator, as it would make the independent variable coincides with the dependent variable. Therefore we also try another exclusion variable: the "ease of doing business" index from the World Bank's Doing Business data. This index gives zero-to-ten ratings to each country according to the time and money it takes to start a new limited liability business. Countries where it takes longer or is more costly to start a new business are given lower ratings. This restriction will work if the ratings capture the fixed trade costs rather than the variable trade costs (Helpman et al., 2008).

Table 9 reports the results. As a benchmark, we report in columns (1) and (2) estimates without sample selection correction. Note that here we use a balanced sample during 2000–2007. Columns (3)–(6) report the results with Heckman's two-stage correction, in which we experiment with adding both two exclusive variables (columns (3) and (4)) and one exclusive variable (columns (5) and (6)). The detailed results for the first-stage regression are reported in the Appendix Table A5, which generally shows that both exclusive variables affect the appearance of the firm–product–country triplet significantly

[18] The full specification of the regression and the results are reported in the Appendix Table A4.

[19] For the ease of explanation, we normalize real GDP per capita by annual averages across countries.

[20] In the probit equation, instead of using firm–product–country fixed effects, which suffer from the "incidental parameters problem" in probit estimation, we control for time-invariant heterogeneity using a rich array of firm-specific variables (such as each firm's average employment, wage, productivity and net asset) and country fixed effects. Thus our first-stage regression includes (1) all variables included in the second-stage regression; (2) time-invariant firm variables; (3) country fixed effects; (4) year dummies; and (5) exclusive variables to be discussed next.

[21] In the first-stage, for each $t = 1, 2 \ldots T$, it estimates a probit model of y_{it} on $z_i = (z_{i1}, z_{i2}, \ldots, z_{iT})$, here i represents firm–product–country triplet, and z_i includes all variables included in the second-stage regression, exclusive variables and year dummies.

Table 8
Heterogeneous response across regions.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\Delta\ln(uv)$	$\Delta\ln(Q)$	$\Delta\ln(uv)$	$\Delta\ln(Q)$	$\Delta\ln(uv)$	$\Delta\ln(Q)$	$\Delta\ln(uv)$	$\Delta\ln(Q)$
	Non-dollar peggers		OECD		Non-OECD		Real income	
$\Delta\ln RER_t$	0.033**	0.229**	0.066**	0.189**	0.009	0.328**	0.012	0.305**
	(0.007)	(0.028)	(0.011)	(0.038)	(0.009)	(0.036)	(0.008)	(0.031)
$\ln TFP_{t-1} \times \Delta\ln RER_t$	0.098**	−0.347**	0.110**	−0.298**	0.098**	−0.451**	0.105**	−0.354**
	(0.024)	(0.082)	(0.030)	(0.102)	(0.032)	(0.115)	(0.024)	(0.079)
$\ln RGDPPC_t \times \Delta\ln RER_t$							0.029**	−0.079**
							(0.006)	(0.024)
$\Delta\ln TFP_t$	0.000	0.019+	−0.002	0.030**	−0.003	0.019	−0.002	0.030**
	(0.003)	(0.010)	(0.004)	(0.011)	(0.004)	(0.014)	(0.003)	(0.010)
$\Delta\ln RGDP_t$	0.038	0.924**	0.087+	1.018**	−0.074**	0.825**	−0.026	1.009**
	(0.023)	(0.092)	(0.045)	(0.163)	(0.024)	(0.097)	(0.022)	(0.083)
$\ln TFP_{t-1}$	−0.014**	−0.038*	−0.019**	−0.040**	−0.012*	−0.035+	−0.016**	−0.037**
	(0.004)	(0.015)	(0.004)	(0.015)	(0.006)	(0.018)	(0.004)	(0.013)
$\ln RGDPPC_t$							0.011	−0.298**
							(0.013)	(0.049)
Fixed effects	firm–product–country fixed effects + year dummies							
Observations	1,617,642		1,240,744		877,722		2,118,466	

Robust standard errors clustered at firm level; + significant at 10%; * significant at 5%; ** significant at 1%.
Note: this table reports the estimation results at the firm–product–country level during 2000–2007. All estimations include a constant term, firm–product–country fixed effects, and year dummies. Columns (1)–(2) use a subsample of countries that do not peg their currency to US dollar. Columns (3)–(4) use OECD member countries while columns (5)–(6) use countries that do not belong to the OECD. Columns (7)–(8) use the full sample but interact $\Delta\ln RER_t$ with the destination countries' real income (log real GDP *per capita*).

positive. Columns (7)–(8) report the results with Wooldridge's estimator, in which we only use one exclusive variable. Our results are robust to sample selection corrections. After correcting the sample selection bias, the main results still hold: the price elasticity is significant but small, indicating a large ERPT; the quantity elasticity is significant and is around 0.3; firms with different productivities respond differently, with higher productivity firms adjusting more in price and responding less in quantity.

Table 9
Robustness with sample selection correction.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Benchmark		Heckman two-stage				Wooldridge	
Dependent variable: $\Delta\ln(uv)$								
$\Delta\ln RER_t$	0.048**	0.047**	0.048**	0.047**	0.038**	0.037**	0.042**	0.042**
	(0.010)	(0.010)	(0.010)	(0.010)	(0.012)	(0.012)	(0.010)	(0.009)
$\ln TFP_{t-1} \times \Delta\ln RER_t$		0.136**		0.138**		0.134**		0.096**
		(0.029)		(0.043)		(0.029)		(0.036)
$\ln TFP_{t-1}$		−0.020**		−0.020**		−0.016**		−0.018**
		(0.004)		(0.007)		(0.004)		(0.003)
$\Delta\ln RGDP_t$	0.008	0.012	0.008	0.012	0.053	0.053	0.001	0.018
	(0.037)	(0.037)	(0.040)	(0.040)	(0.040)	(0.040)	(0.036)	(0.034)
$\Delta\ln TFP_t$		0.0001		−0.001		0.004		0.002
		(0.003)		(0.003)		(0.003)		(0.003)
IMR			0.004*	0.004*	−0.130*	−0.121*		
			(0.002)	(0.002)	(0.052)	(0.052)		
F-test for IMRs							16.55**	4.57**
Dependent variable: $\Delta\ln(Q)$								
$\Delta\ln RER_t$	0.309**	0.308**	0.377**	0.375**	0.327**	0.324**	0.257**	0.279**
	(0.036)	(0.036)	(0.041)	(0.041)	(0.046)	(0.046)	(0.036)	(0.035)
$\ln TFP_{t-1} \times \Delta\ln RER_t$		−0.427**		−0.252*		−0.422**		−0.157
		(0.100)		(0.113)		(0.123)		(0.102)
$\ln TFP_{t-1}$		−0.022		−0.035+		−0.027		−0.001
		(0.014)		(0.019)		(0.021)		(0.011)
$\Delta\ln RGDP_t$	1.290**	1.273**	1.237**	1.226**	1.210**	1.201**	1.082**	0.989**
	(0.136)	(0.135)	(0.159)	(0.159)	(0.147)	(0.147)	(0.115)	(0.134)
$\Delta\ln TFP_t$		0.033**		0.019+		0.027+		0.037**
		(0.011)		(0.011)		(0.016)		(0.013)
IMR			0.484**	0.484**	0.235	0.209		
			(0.006)	(0.007)	(0.171)	(0.171)		
F-test for IMRs							258.05**	49.88**
Fixed effects	firm–product–country fixed effects + year dummies						year dummies	
Observations	535,220	535,220	535,220	535,220	535,220	535,220	535,220	535,220

Robust standard errors clustered at firm level; + significant at 10%; * significant at 5%; ** significant at 1%.
Note: this table reports the estimation results with sample selection correction at firm–product–country level using a subsample of data during 2000–2007. Columns (1)–(2) report the benchmark results without any sample-selection correction. Columns (3)–(6) report the results with correction for sample selection using Heckman's two-stage procedure, in which columns (3) and (4) using two exclusive variables in the first stage estimation and columns (5) and (6) using only one exclusive variable in the first stage estimation. The details of the first stage estimation are reported in the Appendix Table A5. Columns (7)–(8) report the results with correction for sample selection using Wooldridge's estimator.

4.4.4. Extensions

In this section, we first examine the within-firm heterogeneity when a firm exports multiple products. As shown in Table 1 panel D, a firm exports 3.7 HS-6 products on average, and more than 50% of the firms export at least two products. For a multi-product exporter, we might expect the prices of the most productive product to be more sensitive to real exchange rate movements than other products of the same firm. In fact, Chatterjee et al. (2013) show that producer price increases more pronouncedly for products closer to the core competency. Since we do not observe productivity at the product level of a firm, we create two export rank variables in terms of sales, which serve as additional performance measures. The first is time-variant rank of product p among all products exported by firm f to country c in year t. The product with the highest sales is ranked zero, and larger value means lower rank. The time-invariant sales ranking is defined in terms of product p among all products exported by firm f to country c during the whole sample period.

Regression results reported in Table 10 indeed show that products closer to the core are more responsive to real exchange rate movements within a firm. We use four rank variables respectively: time-variant rank (column (1)), time-invariant rank (column (2)), an indicator for whether product p is below the median time-variant rank (column (3)), and an indicator for the product with lowest ranking (column (4)). For columns (1) and (2) we also control for the number of HS-6 products that a firm exports to separate the size effect from the ranking effect. In all specifications, the interaction term is negative and significant, confirming that besides heterogeneous responses across firms, products closer to the core (rank closer to 0) are more responsive to real exchange rate movements within each firm.

Another interesting but less studied question is whether exporters respond asymmetrically to appreciations and depreciations. In particular, it is relatively harder for firms to increase their export price during depreciation period, but relatively easier for firms to cut their export price during appreciation period. We investigate this asymmetric response by adding a depreciation dummy and its interaction with the real exchange rate variable in column (5) of Table 10. The negative and significant coefficient for the interaction term suggests that prices are more responsive to appreciations than depreciations.

Finally, there are also concerns that intra-firm transactions may be different from arms-length ones because in the former case prices are not driven by market forces. In the last column of Table 10, we separate the responses by wholly foreign-owned enterprises from domestic exporters by adding an interaction between foreign-owned dummy and the real exchange rate variable. Foreign-owned exporters respond less in price to exchange rate shocks compared with their domestic counterpart. However, the ERPT remains high for both types of exporters.

5. Extensive Margin: firm–market entry/exit

In this section, we examine the responses to exchange rate movements in the extensive margins, i.e., whether an appreciation deters entries and forces exits. We would like to see how the fluctuation in the bilateral exchange rate between China and the destination country affects the probability of firm f exporting to that destination. Let x_{fct} be a binary variable that equals 1 if firm f exports to destination country c in year t, and 0 otherwise. As in BMM (2012), we distinguish between new entries (i.e. $x_{fct} = 1$ and $x_{fct-1} = 0$) and continuing firms (i.e. $x_{fct} = 1$ and $x_{fct-1} = 1$), according to their export status in the previous period. Roberts and Tybout (1997) emphasize that firm's export participation decision is affected by its prior experience and other sources of persistence.

We estimate how exchange rate movements affect the probability of a firm exporting, using three estimation methods: the probit, logit and linear probability model (LPM). We control for a series of observable firm characteristics, such as firm's productivity and wage; market-level variables, such as real GDP and real GDP per capita. Instead of using firm–destination fixed effects in the probit estimation, which might suffer from the “incidental parameter problem” in nonlinear estimation, we control for time-invariant heterogeneity using a rich array of firm attributes, including average employment, wage, productivity, net assets and destination fixed effects. In the linear probability model, we experiment with including firm–destination fixed effects.[22]

Regression results (Table 11) are expected: exchange rate appreciation reduces the probability of firm export in all specifications. The probit, logit and LPM estimates give essentially the same results. Take the logit estimates for example; a 10% appreciation reduces the probability of new entry by 0.6% and the probability of continuing in the export market by 1.1%. These numbers are a bit lower than those in BMM (2012), who, using French data, find that a 10% appreciation reduces the probabilities of continuing and entry by 1.4%. Greenaway et al. (2007), on the other hand, find no significant effect of exchange rate on entry decisions for a sample of UK firms.[23]

6. Conclusion

In this paper we present first-hand firm-level evidence on Chinese exporters' reaction to RMB exchange rate movements. With detailed information on exporters' export price and quantity, our paper contributes to two large strands of literature, respectively on exchange rate pass-through and exchange rate elasticity. Throughout different specifications at different aggregation levels, we find that the export RMB price response to RMB exchange rate movements is very small, indicating relatively high ERPT into foreign currency denominated prices, while the volume response is moderate.

To explore the reasons for this lack of response to exchange rate, we further show that exporters with higher productivity have smaller pass-through (i.e., they price more to market). However, even for very productive exporters, the ERPT is still high. Such heterogeneous but weak response holds even when we include other channels of heterogeneity into consideration, such as import intensity, distribution costs, and income level of the destination countries. Our findings are also robust with different samples or with corrections for selection bias.

The high ERPT for Chinese exports challenges our understanding of the pricing behavior of Chinese exporters. In particular, our finding is in sharp contrast to the low ERPT in Gopinath and Rigobon (2008) using the at-the-dock prices for US imports. However, using the same data source but focusing on US–China trade exclusively, Kim et al. (2013) find that the lifelong ERPT into US import prices is close to one. Since most Chinese exporters lie on the low end of the value chain, high ERPT may reveal low profit margins so that exporters do not have room to price to market. Furthermore, considering the fact that the majority of Chinese exports are priced in US dollar and RMB has been pegged to the dollar until mid-2005, the high ERPT to import price in destination currency is consistent with a sticky price model with US dollar as the invoicing currency, at least for countries excluding the US and the ones that peg to dollar.

From a policy perspective, high ERPT does not necessarily imply that RMB appreciation would reduce China's huge trade surplus substantially. In fact, although RMB has appreciated for nearly 21% in nominal term and 50% in real term against the dollar (The Economist, 2010), the growth of the Chinese export to the US and the world has not slowed down. There could be several explanations for the lack of responses.

[22] We can also include firm–destination fixed effects in the logit estimation, which does a conditional maximum likelihood estimation to avoid incidental parameter problem, the results are similar qualitatively but the marginal effects cannot be computed in this case, so we didn't report it here.

[23] One thing to note is that our estimation of extensive margin is based on the sample of firm-destination pairs that appear at least once and have balanced information on the independent variables over the sample period. It is probably an upper bound of the overall effect that we would find if including all Chinese firms and hence all possible firm-destination pairs in the estimation.

Table 10
Extensions: within-firm margin and asymmetric responses.

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: $\Delta\ln(uv)$					
	Multiproduct				Asymmetric	Intra-firm
$\Delta\ln RER_t$	0.012	−0.001	0.060**	0.076**	0.122**	0.051**
	(0.008)	(0.009)	(0.010)	(0.015)	(0.014)	(0.008)
$\ln TFP_{t-1} \times \Delta\ln RER_t$	0.103**	0.104**	0.106**	0.178**	0.095**	0.107**
	(0.024)	(0.024)	(0.024)	(0.050)	(0.024)	(0.024)
RANK × $\Delta\ln RER_t$	−0.026*	−0.017+				
	(0.011)	(0.010)				
NUM × $\Delta\ln RER_t$	0.045**	0.039**				
	(0.009)	(0.008)				
BOTTOM × $\Delta\ln RER_t$			−0.034**			
			(0.010)			
END × $\Delta\ln RER_t$				−0.071**		
				(0.025)		
Depreciation × $\Delta\ln RER_t$					−0.143**	
					(0.018)	
Foreign × $\Delta\ln RER_t$						−0.040**
						(0.014)
$\Delta\ln TFP_t$	−0.002	−0.002	−0.002	0.001	−0.002	−0.001
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
$\Delta\ln RGDP_t$	−0.018	−0.019	−0.019	−0.108*	−0.046*	−0.017
	(0.039)	(0.039)	(0.039)	(0.054)	(0.021)	(0.021)
$\ln TFP_{t-1}$	−0.016**	−0.016**	−0.016**	−0.009	−0.016**	−0.015**
	(0.004)	(0.004)	(0.004)	(0.007)	(0.004)	(0.004)
Fixed effects	firm–product–country fixed effects + year dummies					
Observations	2,118,466	2,118,466	2,118,466	926,737	2,118,466	2,118,466

Robust standard errors clustered at firm level; + significant at 10%; * significant at 5%; ** significant at 1%.
Note: this table reports the estimation results at the firm–product–country level during 2000–2007. Column (1) uses the sales ranking of a product *p* among all products exported by firm f to country *c* in year *t*, column (2) uses the (time-invariant) sales ranking of a product *p* among all products exported by firm f to country *c*, column (3) use an indicator for whether product p is below the median ranking for sales of firm *f* to country *c* in year *t*, column (4) use an indicator for the product with lowest ranking. For columns (1)–(2) we also control for the number of HS-6 products exported by each firm. Column (5) tests the asymmetric responses for appreciation and depreciation. We add an interaction term between depreciation dummy and the real exchange rate variable into regression. Column (6) adds an interaction term between foreign-owned firm dummy and the real exchange rate variable into regression. All estimations include a constant term, firm–product–country fixed effects, and year dummies. Rank, NUM are in logs. We also include Rank, NUM, BOTTOM, END, Depreciation dummy, and foreign-owned dummy in the regressions accordingly.

First and foremost, the export volume responds to exchange rate changes only modestly. This may be due to factors such as the sunk cost of finding suppliers in other countries (which makes changing producer difficult). Or it could be due to that exporters' major competitors also experience appreciation of their own currency during the same period of time. Finally, the export price is not the price that consumers face, as the latter also includes tariffs, distribution costs in the destination country and retailer's margin. Those are interesting questions for future research.

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Table 11
Responses at the extensive margin.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Probit		Logit		LPM		LPM	
	Enter	Continue	Enter	Continue	Enter	Continue	Enter	Continue
$\Delta\ln RER_t$	0.171**	0.498**	0.272**	0.877**	0.057**	0.137**	0.071**	0.081**
	(0.034)	(0.041)	(0.056)	(0.071)	(0.011)	(0.011)	(0.012)	(0.011)
$\Delta\ln RGDP_t$	0.217+	1.030**	0.372*	1.783**	0.071+	0.243**	−0.012	0.178**
	(0.111)	(0.141)	(0.184)	(0.244)	(0.038)	(0.032)	(0.041)	(0.033)
$\Delta\ln TFP_t$	0.003	−0.009	0.004	−0.017	0.001	−0.002	0.0002	0.003
	(0.013)	(0.014)	(0.021)	(0.025)	(0.004)	(0.003)	(0.005)	(0.003)
Fixed effects	Time-invariant firm controls + country fixed effects + year dummies						Firm–country fixed effects + year dummies	
Observations	290,559	378,928	290,559	414,292	290,559	414,292	290,559	414,292
Marginal effects								
$\Delta\ln RER_t$	0.061**	0.118**	0.059**	0.113**				
	(0.012)	(0.010)	(0.012)	(0.009)				

Robust standard errors clustered at firm level; + significant at 10%; * significant at 5%; ** significant at 1%.
Note: this table reports the estimation results for the extensive margin at the firm–country level during 2000–2007. Column (1)–(2) report the results from probit estimation; columns (3)–(4) reports the results from logit estimation; columns (5)–(8) are linear probability estimation. All estimations include a constant term and fixed effects specified above. The time-invariant firm control includes firms' average employment, wage, productivity and net assets.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jinteco.2015.04.006.

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