Do Exports Respond to Exchange Rate Changes? Inferences from China's Exchange Rate Reform

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Abstract

Political and commercial circles and the academia have contrasting views from those of academia regarding whether exports respond to exchange rate changes. We revisit the empirical evidence by using monthly data and exploiting the unexpected exchange rate reform in China as a natural experiment. A difference-in-differences estimation uncovers a negative and statistically significant effect of a currency appreciation on exports: a 1% currency appreciation is found to cause total exports to fall by 1.61%. We find no trade deflection by Chinese exporters after the currency appreciation, both intensive-margin and extensive-margin effects of exchange rate changes on exports, and heterogeneous effects across regions, firms and industries/products.

Keyword: Export Response; Exchange Rate Disconnect Puzzle; Difference-in-Differences Estimation; China's Exchange Rate Reform
JEL Classification: E52, F14, F31, F32

1 Introduction

"Japanese exporters could be badly hurt by the yen's recent rapid rise, Mr. Gaishi Hiraiwa, chairman of the Keidanren, the country's federation of economic organizations, warned yesterday ..." — *Financial Times*, September 29 1992[1]

"In a weekend interview, Finance Minister Guido Mantega stated flatly that Brazil 'will not let the real appreciate.' A strong Brazilian real, Mr. Mantega said, hurts exports and manufacturers" — *The Wall Street Journal*, September 20 2012[2]

Government officials and commerical circles across the world are concerned about the severe consequences of a currency appreciation on exports and domestic production, as exemplified by the above quotes. However, academic studies show that the exchange rate movement is largely disconnected from fundamentals such as exports (this is referred to as the *exchange rate disconnect puzzle*. See Obstfeld and Rogoff, 2000).[3] For example, Dekle, Jeong and Ryoo (2010) find that the elasticity of exports with respect to the exchange rate is not statistically different from zero for every G-7 country for the period of 1982-1997.[4] The contrasting views between political/commercial circles and academia present an interesting research question: do exports respond to exchange rate changes?

Our study contributes to the aforementioned debate by revisiting the empirical evidence in two new manners. Firstly, in contrast to the yearly data commonly used in the literature, our empirical analysis uses monthly data, which gives us more variations with which to calculate the effect of exchange rate changes on exports. Secondly, and more importantly, instead of resorting to a micro-level analysis (i.e., using firm-destination or firm-product-destination data) as in some of the recently-emerged literature,[5] we stick to the macro-level analysis but explore a natural experiment setting in China to carefully address the estimation biases due to the endogeneity associated with exchange rate changes (i.e., omitted variables bias and reverse causality).[6] Specifically, the Chinese government

[1] See "Japanese fear rising yen will hurt exports" by Financial Times (http://www.lexisnexis.com.libproxy1.nus.edu.sg/ap/academic/) Access date: October 9 2012

[2] See "Brazil Faces Currency Appreciation After Fed Move -Bradesco" by The Wall Street Journal (http://online.wsj.com/article/BT-CO-20120920-709858.html) Access date: October 9 2012

[3] Papers linking import prices to exchange rates include Goldberg and Knetter (1997) and Campa and Goldberg (2005, 2010), among others.

[4] See also Kenen and Rodrik (1986), Hooper, Johnson and Marquez (2000), and Colacelli (2009) for similar findings.

[5] See, for example, Dekle, Jeong, and Ryoo, (2010); Berman, Martin, and Mayer (2012); Amiti, Itskhoki and Konings (2013); Chatterjee, Dix-Carneiro, and Vichyanond (2013).

[6] Understanding the aggregate-level response is important for both policy and academic purposes. Firstly, whether total exports respond to exchange rate movement or not is what concerns policy makers and its answer has implication for other monetary policies like interest rate, current account management, etc. Secondly, as one of the major puzzles in international macroeconomics, the small elasticity of export

unexpectedly revalued its currency against the US dollar on July 21, 2005, which resulted in an immediate appreciation of 2.1% (for more description of this episode, see Section 3). Such an exogenous shock provides us with an opportunity to consistently estimate the effect of exchange rate changes on exports by comparing China's monthly exports to the U.S. (the treatment group) with those to other countries (the control group) before and after the currency revaluation, or a difference-in-differences estimation specification. Meanwhile, we also control for those potential omitted variables implied by the micro-level analysis, such as producer dispersion (Dekle, Jeong, and Ryoo, 2010; Berman, Martin, and Mayer, 2012) and import value (Amiti, Itskhoki and Konings, 2013).

We find a negative and statistically significant effect of a currency appreciation on exports. In terms of economic magnitude, a 1% currency appreciation is found to cause total exports to fall by 1.61%. Given that China exported US$1.904 trillion worth of goods in 2011, a 1% currency appreciation means a US$30.65 billion decrease in Chinese exports to the U.S., a significant number, which may justify the concerns by government officials and exporters. Our estimation results are robust to various checks on the validity of the DID estimation, including the control for country-specific month effects and country-specific linear time trends, a check on the pre-treatment differential trends between the treatment and control groups, a placebo test using homogeneous goods as the regression sample, and a difference-in-difference-in-differences (triple difference) estimation. Meanwhile, we find that the currency appreciation did not lead to trade diversion to other countries by Chinese exporters, suggesting that the fall in exports resulted in substantial exits of Chinese exporters from the exporting market. Moreover, we find the export response to exchange rate changes to be more prominent in China's coastal regions, among Chinese state-owned enterprises, within time sensitive industries, and for non-necessities.

To understand how exchange rate changes affect exports, we extend the Melitz and Ottaviano (2008) model to incorporate the role of exchange rate movements (see the Appendix for details). It is found that the effect of exchange rate changes on the aggregate export value can be decomposed into two parts, the intensive and the extensive margins. Specifically, the currency appreciation increases the final prices of exports in foreign markets as well as decreases the free on board (FOB) export price due to incomplete pass-through, which causes FOB export revenues to fall (the intensive-margin effect). In the meantime, as exporters differ in their production efficiency, some less productive exporters find that their export profits become negative and hence choose to exit the foreign markets (the extensive-margin effect). By exploring our comprehensive data, we find support for both intensive-margin and extensive-margin effects, that is, fewer firms

to exchange rate has generated a vast number of studies to understand the underlying reasons and to evaluate the potential welfare impacts of related policies (e.g., Duarte, 2003). However, there is still no consensus regarding the empirical association between exchange rate changes and total exports, due to the prevailing endogeneity issues.

export and for continuing exporters, each exports less, after a currency appreciation.

In addition to the aforementioned macro-level literature on the exchange rate puzzle, our study is related to recent studies using firm-level data to examine the effect of exchange rate changes on exports. For example, Dekle, Jeong, and Ryoo (2010) use panel data of Japanese exporters for the period of 1982-1997 and find the exchange-rate elasticity of exports to be statistically significant and have a value of -0.77. Drawing on French firm-level data for the period of 1995-2005, Berman, Martin, and Mayer (2012) uncover the heterogeneous reaction of exporters to real exchange rate changes: high-performance exporters increase their markup but reduce their export volume in response to a currency depreciation. Amiti, Itskhoki and Konings (2013), using Belgian firm-product level data, uncover that larger exporters also import a large amount of intermediate inputs, thereby offsetting exchange rate effects on their marginal costs and explaining the low pass-through of exchange rate changes. Chatterjee, Dix-Carneiro, and Vichyanond (2013) study the effect of exchange rate shocks on export behavior (including the adjustments of prices, quantities, product scope, and sales distribution across products) of multi-product firms. The departure of our work from these studies is that firstly we look at the aggregate export response as those in the previous literature on the exchange rate disconnect puzzle, and secondly we use a quasi-natural experiment setting to carefully control for the endogeneity problems.

Our work is also related to the literature on China's exchange rate movement. Using the same data as ours, Tang and Zhang (2012) find a significant effect of exchange rate appreciation on the exit and entry of Chinese exporters as well as on product churning. Li, Ma, Xu, and Xiong (2012) use detailed Chinese firm-level data to examine the effect of exchange rate changes on firms' exporting behavior, such as export volume, export price, the probability of exporting, and product scope. The main difference between our work and this literature lies in the identification strategy: while we explore the currency revaluation in July 2005 as an exogenous variation, these papers mostly rely on the panel fixed-effect estimation.

2 Estimation Strategy

2.1 Data

Our study draws on data from two sources. The first one is the China customs data from 2000 (the earliest year of the data) to 2006 (the most recent year the authors have access to). This data set covers a universe of all monthly import and export transactions by Chinese exporters and importers, specifically including product information (HS 8-digit level classification), trade value, identity of Chinese importers and exporters, and import and export destinations. The second data source is the International Financial Statistics

(IFS) maintained by the International Monetary Fund (IMF), from which we obtain the monthly bilateral nominal exchange rates between China and other foreign countries as well as CPIs for the 2000-2006 period.

After combining the China customs data with the IFS data and excluding countries without monthly export value, import value and nominal exchange rate, we end up with a total of 88 countries. We then go through a few steps of data cleaning. First, we exclude 30 countries (including 9 oil-producing countries) whose currencies were pegged to the U.S. dollar in some years during our sample but unpegged in other years (see Obstfeld and Rogoff, 1995, for the same practice). Second, we exclude Hong Kong and Macao, which are largely trading centers for Chinese exports (i.e., re-export a lot of their imports from China).[7]

Table 1 lists the 56 countries used in our regression analysis. During our sample period, these 56 countries capture the majority of Chinese total exports, i.e., around 70%. However, one may be concerned that the revaluation of the Chinese currency coincides with a large share of exports going to countries other than those covered in the regression analysis, which would lead to an overestimation of the effect of the exchange rate change. To check such a possibility, we plot in Figure 1 the share of Chinese total exports covered in our regression analysis by month throughout the sample period. It is found that this number hooves around 70% and more importantly, there is no discontinuity at the time of the revaluation of the Chinese currency. These findings largely dispel the concern that our estimates may be biased due to a trade diversion to countries out of our regression sample.

[Insert Table 1]

[Insert Figure 1]

Of 55 non-U.S. countries, none has its currency pegged to the U.S. dollar. Hence, we have one treatment country, the U.S., and 55 countries in the control group. Our final regression sample contains $56 \times 84 = 4,704$ country-month observations.

2.2 China's Exchange Rate Reform in July 2005

Timeline. After the financial crackdown in 1994, China adopted a decade-old fixed exchange rate regime, in which its currency (RMB) was pegged to the U.S. dollar at an exchange rate of 8.28. At 19:00 of July 21, 2005 (Beijing time), the People's Bank of China (PBOC, the central bank of China) suddenly announced a revaluation of the Chinese currency against the U.S. dollar, which was set to be traded at an exchange

[7] Results including these two economies remain qualitatively the same (available upon request).

rate of 8.11 immediately, i.e., an appreciation of about 2.1%. Meanwhile, the PBOC announced its abandonment of the fixed exchange rate regime and that it would allow RMB to be traded flexibly with a *reference basket* of currencies with the target for RMB set by the PBOC every day. Figure 2 displays the trends of exchange rates of the U.S. dollar and other currencies against Renminbi during 2000-2006 (see Table 1 for the 55 other countries used in the analysis). It is clear that there was a sudden drop in the exchange rate of the Chinese currency against the US dollar in July 2005, and a steady and continuous decrease after that. By the end of 2006, the Renminbi had appreciated by about 5.5% against the US dollar. In the meantime, after a period of two-years depreciation, the Renminbi remained quite stable against other currencies between 2004 and 2006.

[Insert Figure 2]

Exogeneity. Despite the fact that the revaluation of the Chinese currency happened during a period of enormous international pressures on the Chinese government to appreciate its undervalued currency, the timing of the change is widely considered as "unexpected". There is much anecdotal evidence as well as many academic studies supporting this statement. First, foreign pressures on the Renminbi for an appreciation had existed for more than two years, and the Chinese government regarded its exchange rate policy as a matter of China's sovereignty and rejected any political pressure on this issue. For example, on June 26, 2005, China's Premier Wen Jiabao said at the Sixth Asia-Europe Finance Ministers Meeting in Tianjin that China would "independently determine the modality, timing and content of reforms" and rejected foreign pressures for an immediate shift in the nation's currency regime.[8] One day later, Zhou Xiaochuan, the governor of the PBOC, said that it was too soon to drop the decade-old fixed exchange rate regime and that he had no plans to discuss the currency issue at the weekend meeting of the global central bankers in Basel, Switzerland.[9] On July 15, one week before the exchange rate system reform, the PBOC denied that it was planning to announce a revaluation of its currency.[10] On July 19, even two days before the reform, the PBOC still insisted that it would continue to keep the exchange rate stable and at a reasonable and balanced level in the second half of the year.[11]

[8] See "Chinese premier warns against yuan reform haste" by the Wall Street Journal (http://online.wsj.com/article/0,,SB111975074805069620,00.html) Access date: October 9 2012

[9] See "China's Zhou Says 'Time Is Not Ripe' to Drop Yuan Peg to Dollar" by Bloomberg (http://www.bloomberg.com/apps/news?pid=newsarchive&sid=a7n6HBTVapBA&refer=home) Access date: October 9 2012

[10] See "Central bank denies revaluation in August" by People's Daily (http://english.peopledaily.com.cn/200507/17/eng20050717_196621.html) Access date: October 9 2012

[11] See "China to keep RMB exchange rate basically stable: central bank" by People's Daily (http://english.peopledaily.com.cn/200507/20/eng20050720_197148.html) Access date: October 9 2012

Second, as elaborated by Yuan (2012), there was division in Chinese policy makers regarding whether the Chinese currency should be appreciated during that period. Specifically, the Ministry of Commerce opposed the currency appreciation (so as to maintain the competitiveness of China's export sector), while the other three central governmental agencies, the People's Bank of China, the National Development and Reform Commission, and the Ministry of Finance, all proposed revaluing the Chinese currency.

Third, after the reform, both the domestic and international media responded to the revaluation as completely unexpected. For example, CNN reported the episode as "The surprise move by China, ...".[12] The *Financial Times* wrote in its famous "Lex Column" on July 22, 2005 that "China likes to do things [in] its own way. After resisting pressure to revalue the Renminbi for so long, Beijing has moved sooner than even John Snow, the U.S. Treasury secretary, expected".[13] On July 22, 2005 the BBC *Worldwide Monitoring* said that "The People's Bank of China unexpectedly announced last night that the Renminbi will appreciate by 2 per cent and will no longer be pegged to the US dollar".[14]

Fourth, academic studies also imply that the change in the exchange rate policy in July 2005 was unexpected. For example, Eichengreen and Tong (2011) study the impact of the Renminbi revaluation announcement on firm value in the 2005-2010 period. Using the change of stock prices before and after the announcement of the revaluation for 6,050 firms in 44 countries, they find that the Renminbi appreciation significantly increased firm values for those exporting to China while significantly decreasing firm values for those competing with Chinese firms in their home markets, suggesting the exogeneity of the policy change.

2.3 Estimation Specification

The benchmark model (or its variants) used in the literature to investigate the response of exports to exchange rate is[15]

$$\ln V_{it} = \beta \ln e_{it} + \gamma_i + \eta_t + \varepsilon_{it}, \tag{1}$$

where V_{it} is the export value from the Home country to foreign country i at time t; e_{it} is the nominal exchange rate of foreign country i's currency against the Home currency

[12] See "World events rattle futures" by CNN (http://money.cnn.com/2005/07/21/ markets/stockswatch/index.htm) Access date: October 9 2012

[13] See "Renminimal THE LEX COLUMN" by Financial Times (http://www.lexisnexis.com.libproxy1.nus.edu.sg/ap/academic/) Access date: October 9 2012

[14] See "Hong Kong daily says exchange rate reform advantageous overall" by BBC Worldwide Monitoring (http://www.lexisnexis.com.libproxy1.nus.edu.sg/ap/academic/) Access date: October 9 2012

[15] For example, Kenen and Rodrik (1986) and Perée and Steinherr (1989) use a time series version of Equation (1) and find that the estimated coefficient β is smaller than 1 in most of their sample countries. Colacelli (2009) uses the same specification in a sample of 136 countries for the 1981-1997 period and also find a very small estimated coefficient β (equal to 0.055).

at time t; γ_i and η_t are the foreign country and time fixed effects, respectively; and ε_{it} is the error term.

However, a crucial assumption to obtain an unbiased estimate of β in Equation (1) is that conditional on all the control variables, the exchange rate is uncorrelated with the error term, i.e.,

$$E\left[\ln e_{it} \cdot \varepsilon_{it} | \gamma_i, \eta_t\right] = 0. \tag{2}$$

It is reasonable to doubt that this identifying assumption holds. For example, Dekle, Jeong and Ryoo (2010) show that producer heterogeneity is an important missing variable in the estimation of Equation (1). Meanwhile, export transactions involve buying and selling currencies, which in aggregate may influence the determination of the exchange rate. The violation of the identifying assumption (2) (due to the omitted variables bias and reverse causality) may explain why the literature has only uncovered small values of β, which should theoretically be bigger than 1.[16]

To improve the identification, we use monthly data instead of the commonly-used yearly data, which precludes any potential omitted variables that do not vary monthly. Secondly, and more importantly, we use the sudden and unexpected exchange rate reform in China in July 2005 to conduct a difference-in-differences estimation. Specifically, we compare exports to the U.S. before and after July 2005 with exports to other countries during the same period. The DID estimation specification is

$$\ln V_{it} = \delta Treatment_i \times Post_t + \gamma_i + \eta_t + \upsilon_{it}, \tag{3}$$

where $Treatment_i$ is the treatment status indicator, which takes value 1 if the country is the U.S. (the treatment group) and 0 otherwise (the control group); and $Post_t$ is the post-appreciation period indicator, which takes value 1 if it is after July 2005 and 0 otherwise. To adjust the potential serial correlation and heteroskedasticity, we use the robust standard error clustered at the country level (see Bertrand, Duflo, and Mullainathan, 2004).

Note that in the pre-revaluation period exchange rates of the Chinese currency (RMB) against other non-U.S. countries (say for example, the UK pound) were set by the cross rate between the dollar-RMB rate and the pound-dollar rate. If such approach was still applied and the pound-dollar rate did not change much in the post-revaluation period, the change in the pound-RMB exchange rate was then entirely driven by the change in the dollar-RMB rate, making our DID estimation strategy invalid. Two pieces of evidence help us relieve such concern. Firstly, after the revaluation in July 2005, the RMB was traded flexibly with a *reference basket* of currencies with the rate set by the PBOC every day; in other words, the cross-rate approach was largely not applied in the post-revaluation period. Secondly, as shown in Figure 2, the trade-weighted exchange

[16] See Berman, Martin, and Mayer (2012) for the proof.

rate of the RMB against other currencies remained quite stable in a two-year window of the revaluation time, and similar results are found for individual countries (results available upon request).

The identifying assumption associated with the DID estimation specification (3) is that conditional on a whole list of controls (γ_i, η_t), our regressor of interest, $Treatment_i \times Post_t$, is uncorrelated with the error term, υ_{it}, i.e.,

$$E\left[Treatment_i \times Post_t \cdot \upsilon_{it} | \gamma_i, \eta_t\right] = 0. \tag{4}$$

As discussed in Section 3, the revaluation of the Chinese currency against the US dollar in July 2005 was highly unexpected, and therefore can be considered largely as an exogenous shock to Chinese exporters, which implies the satisfaction of the identifying assumption (4). Nonetheless, we conduct a battery of robustness checks to corroborate the claim that the identifying assumption (4) holds. These include a control for country-specific month effects and a country-specific linear time trend, a check on the pre-treatment differential trends between the treatment and control groups, a placebo test using homogeneous goods as the regression sample, and a difference-in-difference-in-differences (triple difference) estimation. For details, see Section 5.3.

3 Empirical Findings

3.1 Graphical Presentation

We start with a visual examination of the difference between Chinese exports to the treatment group (i.e., the U.S.) and the control group (i.e., other 55 countries) over time in Figure 3. The solid vertical line marks the time of China's exchange rate reform (i.e., July 2005), while the dashed vertical line represents one year before the reform. Evidently, the U.S. vs. non-U.S. export differential exhibits a four-stage pattern over our sample period (i.e., 2000-2006): from 2000 to late 2001, the export differential was quite stable; then it started a clear downward trend until the decline flattened out around mid-2004, or one year before the exchange rate reform in July 2005; and finally after the reform, Chinese exports to the U.S. decreased sharply against Chinese exports to the rest of our sample countries.

[Insert Figure3]

The above export-differential pattern coincides with that of the exchange rate differential displayed in Figure 2. For example, other currencies started to appreciate against the Chinese currency starting in early 2002 and stabilized around early 2004, during which period Chinese currency remained pegged to the US dollar. Between 2004 and 2006, while these other currencies stayed quite stable against the Chinese currency (despite of some ups and downs), U.S. dollar began to continuously depreciate against Chinese currency after China's exchange rate reform in July 2005.

A few results emerge from these two figures. First, a currency appreciation has a visible, negative effect on exports as demonstrated by the negative correlation between the U.S. vs. non-U.S. export differential and their currency differential. Second, there is no clear differential patterns between U.S. and non-U.S. exports one year before the exchange rate reform, indicating that the reform is plausibly exogenous to exporters. Third, while after the reform in July 2005, the US dollar started to continuously depreciate against Chinese currency, other currencies remained quite stable throughout the period of 2004-2006, which justifies the use of the difference-in-differences estimation. However, as we include all sample periods in our analysis, one may be concerned that the results from the comparison of U.S. exports before and after the exchange rate reform with non-U.S. exports during the same period could be driven by the negative correlation between exports and currency changes happened during the period of 2002-2004. To address this concern, in a robustness check, we restrict our analysis to the period of 2004-2006.

3.2 Main Results

Regression results corresponding to Equation (3) are reported in column 1 of Table 2. It is found that $Treatment_i \times Post_t$ is negative and statistically significant, implying that the appreciation of the Chinese currency against the US dollar significantly reduced Chinese exports to the U.S. Meanwhile, the fall in exports is found to be substantial, i.e., the reform caused Chinese exports to the U.S. to fall by 17.6%.

[Insert Table 2]

In column 2 of Table 2, we include monthly imports (in logarithm), as the reform may make imports to China cheaper, and hence affect the production and exporting behavior of Chinese exporters (i.e., through the use of imported intermediate inputs and the increased domestic competition by imported final goods; see Amiti, Itskhoki, and Konings, 2013 foran elaboration on this point). In column 3 of Table 3, we further include a measure of producer heterogeneity (i.e., the mean of export value divided by its standard deviation), the omission of which has been argued to seriously bias previous estimates in the literature (see Dekle, Jeong and Ryoo, 2010). Clearly, we find a quite similar negative estimate with the inclusion of these two additional controls.

Despite the fact that the reform was exogenous to Chinese exporters, one may be concerned that the decision to appreciate the currency in July 2005 by the Chinese central government was strategic. In other words, the drop in exports to the U.S. following the currency revaluation in July 2005 could have been driven by the U.S.-specific month effect, specifically, the U.S.-July effect. To address this concern, we further include the country-specific month effect (i.e., $\gamma_i \times M_t$, where M_t is a month indicator such as January, February, ..., December), and the identification for example comes now from the comparison of U.S.-vs.-non-U.S. in July 2005 with U.S.-vs.-non-U.S. in July 2004. As shown in column 4 of Table 2, our main results regarding the effect of the exchange rate on exports barely change in either statistical significance or magnitude, suggesting that our results are not driven by the country-specific month effect.

3.3 Robustness Checks

In this sub-section, we present a battery of robustness checks on our aforementioned estimation results.

Control for country-specific linear time trend. One concern is that it seems other currencies also started a depreciation trend against the Chinese currency after January 2005, continuing even after July 2005, the time of the exchange rate reform. To address the concern that our estimates may be contaminated by these similar depreciation time trends, we saturate the model with the inclusion of a country-specific linear time trend, $\gamma_i \times t$. Hence, our identification comes from the discontinuity in the time trend caused by the revaluation of the Chinese currency against the US dollar in July 2005, a strategy similar to the regression discontinuity method. Despite a significant drop in its magnitude, $Treatment_i \times Post_t$ remains negative and statistically significant (column 1 of Table 3).

[Insert Table 3]

Check on pre-reform differential trends. A corollary of the identifying assumption (4) is that exports to the U.S. and other countries followed similar patterns before the revaluation in July 2005. Figure 3 clearly shows that the U.S. vs. non-U.S. export differential was quite stable one year before the reform, but sharply declined right after the reform. To establish these results more formally, we first divide the whole 2000-2006 period into four periods (i.e., before July 2004, July 2004 - June 2005, July 2005, and August 2005 onward), and then construct interactions between $Treatment_i$ and indicators of the three periods with July 2005 being the omitted category. The regression results are reported in column 2 of Table 3. Consistent with the findings in Figure 3, the coefficient of $Treatment_i \times 07/2004 - 06/2005$ is highly insignificant, further confirming that U.S. exports and non-U.S. exports had similar patterns one year before the reform. Meanwhile, $Treatment_i \times Before$ 07/2004 is positive and statistically significant, consistent with the fact that during this period there was a depreciation of the Chinese currency against other non-U.S. countries in our regression sample. Finally, our main result, the coefficient of $Treatment_i \times$ 08/2005 *onward*, remains negative and statistically significant.[17]

[17]Interestingly, the coefficients of $Treatment \times$ 08/2005 *onward* and $Treatment \times Before$ 07/2004 have similar magnitudes but opposite signs, as the former captures the appreciation effect of the dollar-

A sub-sample of the 2004-2006 period. As discussed in the Section 5.1, there is a concern that our findings of the negative impact of exchange rate appreciation on exports could be driven by the movement in earlier months, i.e., 2002-2004. Meanwhile, the exchange rate of currencies other than the US dollar remained quite stable against the Chinese currency during the period of 2004-2006, making the difference-in-differences analysis using just the data of 2004-2006 more appealing. To these ends, we conduct a robustness check by restricting our analysis to the sample of 2004-2006. Regression results are reported in column 3 of Table 3. Despite a drop in the estimated magnitude, $Treatment_i \times Post_t$ remains negative and statistically significant, implying the robustness of our previous findings.

A placebo test using homogeneous goods. The identification from our difference-in-differences estimation comes from the fact that the exported goods are priced differently across the treatment and control groups, and hence the appreciation of the treatment country's currency makes the exported goods more expensive in the treatment country, thus producing a fall in total exports to that country, given that the situations in the control group remain unchanged. However, if the exported goods are charged with the same prices across countries and hence the export prices are detached from the exchange rate, then we should not spot any significant effects from the difference-in-differences estimation. One example of these special exported goods are commodities traded on the exchange market, or the group of homogeneous goods as classified by Rauch (1999). Using Rauch (1999)'s classification, we divide the whole set of Chinese exported goods into two groups, differentiated and homogeneous goods, and then conduct a placebo test using the sample of homogeneous goods. The regression results are reported in column 4 of Table 3. Consistent with our argument, the coefficient of $Treatment_i \times Post_t$ is highly insignificant, lending further support to our identification.

A difference-in-difference-in-differences estimation. Further exploring the difference between differentiated and homogeneous goods, we conduct a difference-in-difference-in-differences (or triple difference) estimation. Specifically, we estimate the following equation:

$$\ln V_{igt} = \delta Treatment_i \times Post_t \times Differentiated_g + \mathbf{X}'_{igt}\boldsymbol{\varphi} + \gamma_{ig} + \eta_{gt} + \chi_{it} + \upsilon_{igt}, \quad (5)$$

where g indicates the group of the exported goods, i.e., differentiated or homogeneous goods group; $Differentiated_g$ is an indicator of the differentiated goods group; and $\mathbf{X}_{igt}$ is a vector of controls (i.e., the logarithm of imports and producer heterogeneity).[18] The beauty of the triple difference estimation is that it allows us to include a full set

RMB rate with other exchange rates unchanged, while the latter reflects the depreciation effect of the Chinese currency against other non-U.S. countries with the dollar-RMB rate unchanged.

[18]Note that the number of observations increase as the regression unit is now at the group-country-month level.

of the country-group fixed effects γ_{ig}, the group-time fixed effects η_{gt}, and the country-time fixed effects χ_{it}.[19] For example, the inclusion of the country-time fixed effects means controlling for all observed or unobserved time-invariant and time varying country characteristics, which are the main concerns violating our above difference-in-differences identifying assumption (4). As shown in column 5 of Table 3, the triple interaction term is found to be negative and statistically significant. This further reinforces our aforementioned difference-in-differences estimation results, i.e., our findings are not biased due to some omitted time-varying country characteristics.

3.4 Exchange Rate Elasticity

Although in the previous sections we have established that the exchange rate reform (or the currency appreciation) had a negative effect on exports, it is interesting to know the exchange rate elasticity of exports. To this end, we use the exchange rate reform in China to construct an instrumental variable for the exchange rate and estimate Equation (1) with the two-stage-least-squares (2SLS) method.

We start with the estimation of eEuation (1) without instrumenting the exchange rate in column 1 of Table 4. Though statistically significant, the estimated coefficient of exchange rate has only a value of -0.454, a magnitude similar to those found in the literature (e.g., Colacelli, 2009).

[Insert Table 4]

The instrumental variable estimation results are reported in column 2 of Table 4. The first-stage results (not included here but available upon request) show a positive and statistical relation between the instrument ($Treatment_c \times Post_t$) and the regressor of interest ($\ln ER_{ct}$). And the F-test of excluded instruments in the first-stage has a value of 27.02, substantially higher than the critical value 10 of the "safety zone" for strong instruments suggested by Straight and Stock (1997). These results suggest that our proposed instrument is both relevant and strong.

With respect to our central issue, the exchange rate, after being instrumented, still casts a negative and statistically significant impact on total exports. More importantly, there is a substantial increase in the estimated magnitude: a 1% appreciation causes total exports to fall by 1.61%, confirming the theoretical prediction that the exchange

[19] In estimating the Equation (5), we first difference exports across the two groups within a country-month cell, and then estimate the resulting double-difference equation:

$$\ln \tilde{V}_{it} = \delta Treatment_i \times Post_t + \tilde{\mathbf{X}}_{it}\boldsymbol{\varphi} + \gamma_i + \eta_t + \tilde{\nu}_{it},$$

where tilded variables mean cross-group differenced, e.g., $\ln \tilde{V}_{it} \equiv \triangle \ln V_{igt}$. Otherwise, we encounter the computational burdens as the original triple difference equation involves too many dummy variables, i.e., $56 \times 84 = 4,704$ country-time dummies, $56 \times 2 = 112$ country-group dummies and $84 \times 2 = 168$ group-time dummies.

rate elasticity of exports is greater than 1 and the existence of a significant bias in the previous OLS estimations. Put the number into a real context: given that China exported US$1.904 trillion worth of goods in 2011, a 1% currency appreciation means a US$30.65 billion loss in China's export sector, a significant number justifying why government officials and businessmen are greatly concerned about the currency appreciation.

In columns 3-4 of Table 4, we replace the nominal exchange rate with the real exchange rate. Clearly, we still identify a statistically significant effect of the exchange rate on total exports, although the magnitude of the IV estimate drops from -1.605 to -1.125.

3.5 Trade Diversion

From a policy viewpoint, it is important to know whether the fall in exports to the treatment group (i.e., the U.S.) after the currency appreciation causes a withdrawn by Chinese exporters from the exporting market or the diversion from the affected destination (i.e., the U.S.) to some unaffected destinations in our regression sample. If it is the latter, then for governments, the propspects after a currency appreciation may not be that gloomy.

Based on the premise that it is easier to divert exports to countries (such as other OECD countries) with similar consumer preferences as those of the U.S., we conduct two exercises to shed light on the possibility of trade diversion. Firstly, we exclude OECD countries from our control group and re-estimate Equation (3). If there were trade diversion, we should expect a smaller estimation coefficient. However, we find in column 1 of Table 5 that the coefficient of $Treatment_i \times Post_t$ increases slightly to -0.186 from -0.165 (in column 4 of Table 2; with all countries in the regression), despite of the increase being statistically insignificant.

[Insert Table 5]

Secondly, we compare Chinese exports to OECD countries (excluding the U.S.) before and after the exchange rate reform with the corresponding exports to the rest of the countries in our sample during the same period. If there were trade diversion, we should expect that following the appreciation of the Chinese currency against the US dollar, Chinese exports to other OECD countries have increased relative to Chinese exports to other sample countries, given that these countries' currencies remained stable against the Chinese currency during this period. However, as shown in column 2 of Table 5, $Treatment_i \times Post_t$ is highly insignificant.

These two exercises demonstrate that there is no substantial evidence to support trade diversion hypothesis after the exchange rate reform, and much of the falls in Chinese exports to the U.S. are due to exits of Chinese exporters from the exporting market.

3.6 Mechanism

While our objective is to investigate the export response to changes in the exchange rate at the macro-level, our customs data contain observations disaggregated at the firm-product-month-country level, which allows us to investigate some underlying mechanism about how currency appreciation affects total exports. In the Appendix, we show that the effect of exchange rate changes on aggregate exports operates on two margins, the intensive- and the extensive-margins. Specifically, a currency appreciation causes the final price in the foreign market to increase and the FOB export price to decrease, due to an incomplete pass-through. The final price increase may reduce the demand, which, combined with the decreased FOB price, will reduce the total export revenue, damping the effect of the appreciation at the intensive margin. Moreover, the adverse effect of a currency appreciation is stronger for less productive exporters, making them unprofitable in and hence exit the foreign market (an extensive-margin effect).

The regression results are reported in Table 6. In columns 1-2, we investigate the extensive-margin effect, that is, regressing the total number of firms and the total number of HS-8 product categories exported to the U.S. on $Treatment_c \times Post_t$ along with a full set of controls. It is found that, consistent with our model featuring heterogenous firms, the Chinese currency appreciation significantly reduced the number of total exporters and the number of HS-8 product categories, specifically, by 6.6% and 29.2%, respectively, in magnitude.

[Insert Table 6]

In columns 3-5, we investigate the intensive-margin effect from different dimensions as suggested by the model. Specifically, we focus on the sample of surviving exporters (firms continuing to export after the currency appreciation) and regress the mean values of export price, export volume and export revenue at the firm-product-month-country level on $Treatment_c \times Post_t$ along with a full set of controls. Our model predicts that, due to incomplete pass-through, the appreciation of Renminbi will decrease the FOB export price. This prediction is confirmed by the estimate in column 3, i.e., the appreciation brings down the price by about 1.3%, which is very significant both statistically and economically. Also consistent with the model, the effect on export volume (shown in column 4) is found to be negative, albeit not precisely estimated. The total intensive margin effect of the Renminbi appreciation is shown in column 5. Given the negative effects of the appreciation on the price and the volume, it is natural that the appreciation has strong negative impact on export revenue, i.e., a fall of 4.1%.

In summary, we find support for both extensive-margin and intensive-margin effects of exchange rate movement on exports.

3.7 Heterogeneous Effects

In the last part of our empirical investigation, we examine possible heterogeneous effects across different regions (i.e., inland versus coastal regions), across different types of firms (i.e., state-owned enterprises versus private enterprises), and across different industries/products (i.e., time sensitive versus time insensitive industries; different product categories in the PPI basket). The estimation specification we use is the triple difference Equation (5), with different definitions of the group indicator in different investigations.

Coastal versus inland regions. We start in column 1 of Table 7 the investigation of differential exports response to exchange rate changes between coastal and inland regions. The group indicator takes a value of 1 for coastal regions and 0 for inland regions. The triple interaction term is found to be negative and statistically significant, indicating that exports to the U.S. fell more in coastal regions than in inland regions after the appreciation of the Chinese currency against the US dollar. One possible explanation is that as the transport costs are lower in coastal regions, the initial cut-off productivity levels of exporting is lower in coastal regions than in inland regions. The currency appreciation increases the cut-off productivity levels of exporting in both coastal and inland regions, but as there are more weaker exporters in coastal regions, more exporters from coastal regions exit the exporting market than their counterparts from inland regions.[20]

[Insert Table 7]

State-owned versus private enterprises. In column 2 of Table 7, we investigate the possible different responses between state-owned enterprises and private enterprises, with the group variable indicating a state-owned enterprise. Clearly, we find that state-owned enterprises respond more to exchange rate changes than private enterprises, i.e., the former's exports fall more than the latter's. One possible explanation is that state-owned enterprises in China receive many subsidies from the governments (such as trade credit, export rebate, etc), making the cut-off productivity levels of exporting for state-owned enterprises lower than those for private enterprises. Then after the currency appreciation, some weaker state-owned enterprises are driven out of the exporting market, if the government subsidies remain rigid in the short-run.

Time sensitive versus time insensitive industries. Thirdly, we divide industries into two groups, time sensitive (assigned a value of 1 for the group indicator) and time insensitive industries (assigned a value of 0 for the group indicator), following the classification used by Djankov, Freund, and Pham (2013). Specifically, time sensitive industries are the three 2-digit manufacturing industries (i.e., office equipment, electric power machinery, and photographic equipment) having the highest probability of using

[20] Using the theoretical model laid out in the Appendix, we can show that $\frac{\partial^2 V_i}{\partial e_i \partial \tau_i} > 0$.

air transport, whereas time insensitive industries are the three 2-digit manufacturing industries (i.e., textile yarns, cement, and plumbing fixtures) with the lowest probability (the probability was estimated by Hummels, 2001). As shown in column 3 of Table 7, time sensitive industries experienced more of a fall in exports after the revaluation of the exchange rate in July 2005 than time insensitive industries. One possible explanation is that production and shipment are easier to adjust and hence more responsive to exchange rate movements in time sensitive industries than in time insensitive industries.

Different product categories in the PPI basket. Finally, following Vermeulen et al. (2007), we group products into 6 categories used in the PPI basket (i.e., food products, non-durable non-food non-durable products, durable products, intermediate goods, energy, and capital goods) to examine whether there are differential appreciation effects. Regression results are reported in columns 4-9 of Table 7. It is found that the currency appreciation had significant and negative effects on exports in non-food non-durable products, durable products, intermediate goods and capital goods, but insignficant effects in food products and energy. Intuitively, food and energy are necessities of life, which make them non-responsive to exchange rate changes.

4 Conclusion

The effect of exchange rate changes on exports has attracted extensive attention from policy makers, commercial circles, and academia. In this paper, we revisit the question of whether exports respond to exchange rate changes and contribute to the literature by carefully addressing the identification issues. Specifically, we employ monthly, rather than yearly data usually used in the literature, to take advantage of more variations in the key variables. And to address the potential endogeneity problem in the estimation, we use the unexpected exchange rate regime switch by the Chinese government in July 2005 as a natural experiment.

The difference-in-differences estimation uncovers a statistically and economically significant and negative effect of a currency appreciation on exports. Specifically, our main estimation result shows that a 1% exchange rate appreciation decreases total exports by 1.61%, which, in the context of year 2011 China, represents a US$30.65 billion decrease in total exports. This negative effect is robust to various checks on the validity of the difference-in-differences estimation and other econometric concerns. Meanwhile, we do not find any trade diversion by Chinese exporters after the currency appreciation, but uncover both intensive-margin and extensive-margin effects of exchange rate changes on exports, and heterogeneous effects across regions, firms, and industries/products.

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Table 1: List of Countries

Australia	Finland	Malta	Russian Federation
Austria	France	Mauritius	Singapore
Belgium	Germany	Mexico	Slovak Republic
Brazil	Greece	Morocco	Slovenia
Bulgaria	Hungary	Myanmar	South Africa
Cameroon	Iceland	Nepal	Spain
Canada	Indonesia	Netherlands	Sri Lanka
Chile	Ireland	New Zealand	Sweden
Colombia	Israel	Norway	Switzerland
Costa Rica	Italy	Papua New Guinea	Thailand
Croatia	Japan	Paraguay	Turkey
Czech Republic	Korea, Republic of	Poland	United Kingdom
Denmark	Luxembourg	Portugal	United States
Estonia	Madagascar	Romania	Uruguay

Table 2: Main Results

	(1)	(2)	(3)	(4)
Dependent Variable	Ln(Export Value)			
Treatment*Post	-0.176***	-0.154***	-0.154***	-0.165***
	(0.052)	(0.054)	(0.054)	(0.059)
Month Fixed Effect	X	X	X	X
Country Fixed Effect	X	X	X	
Ln (Import Value)		X	X	X
Producer Heterogeneity			X	X
Country-Specific Month Effect				X
Number of Observations	4704	4704	4704	4704

Notes: Standard errors, clustered at the country level, are reported in the parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Robustness Checks

	(1)	(2)	(3)	(4)	(5)
Dependent Variable	Ln (Export Value)				
Specification	Incl. Country Time Trend	Incl. Pre-Reform Trend	2004-2006	Homogeneous	Triple Difference
Treatment*Post	-0.068**		-0.087**	0.030	
	(0.032)		(0.037)	(0.055)	
Treatment*08/2005 onward		-0.088**			
		(0.043)			
Treatment*07/2004-06/2005		-0.006			
		(0.025)			
Treatment*Before 07/2004		0.095***			
		(0.035)			
Treatment*Post*Differentiated					-0.199***
					(0.047)
Month Fixed Effect	X	X	X	X	
Country Fixed Effect	X	X	X	X	
Ln (Import Value)	X	X	X	X	X
Producer Heterogeneity	X	X	X	X	X
Country-Specific Month Effect	X	X	X	X	
Country-Month Fixed Effect					X
Country-Product Fixed Effect					X
Product-Month Fixed Effect					X
Number of Observations	4704	4704	2016	3528	7056

Notes: Standard errors, clustered at the country level, are reported in the parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Exchange Rate Elasticity

	(1)	(2)	(3)	(4)
Specification	OLS		2SLS	
	Nominal Exchange Rate	Real Exchange Rate	Nominal Exchange Rate	Real Exchange Rate
Dependent Variable	Ln (Export Value)			
Ln (Exchange Rate)	-0.454**	-0.685**	-1.605***	-1.125***
	(0.190)	(0.332)	(0.546)	(0.359)
F test of Excluded Instruments			[27.02]	[59.21]
Month Fixed Effect	X	X	X	X
Ln (Import Value)	X	X	X	X
Producer Heterogeneity	X	X	X	X
Country-Specific Month Effect	X	X	X	X
Number of Observations	4704	4367	4704	4367

Notes: Standard errors, clustered at the country level, are reported in the parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Trade Deflection

	(1)	(2)
Dependent Variable	Ln (Export Value)	
Specification	Exclude OECD	OCED versus the Rest (excl. U.S.)
Treatment*Post	-0.186**	-0.029
	(0.091)	(0.116)
Month Fixed Effect	X	X
Ln (Import Value)	X	X
Producer Heterogeneity	X	X
Country-Specific Month Effect	X	X
Number of Observations	2268	4620

Notes: Standard errors, clustered at the country level, are reported in the parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 6: The Effect of Exchange Rate Reform on Extensive and Intensive Margins

	(1)	(2)	(3)	(4)	(5)
	Extensive Margin		Intensive Margin		
Dependent Variable	Ln(Number of Firms)	Ln(Number of HS8)	Ln(Price)	Ln(Quantity)	Ln(Revenue)
Treatment*Post	-0.066**	-0.292***	-0.013***	-0.027	-0.041***
	(0.029)	(0.029)	(0.005)	(0.020)	(0.018)
Month Fixed Effect	X	X	X	X	X
Product Fixed Effect	X	X	X	X	X
Ln(Import Value)	X	X	X	X	X
Producer Heterogeneity	X	X	X	X	X
Country-Specific Month Effect	X	X	X	X	X
Number of Observations	4704	4704	3522562	3522562	3522562

Notes: Standard errors, clustered at the country level, are reported in the parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Heterogeneous Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable	Ln (Export Value)								
Specification	Coastal vs. Inland	SOE vs. Private	Time Sensitive vs. Insensitive	Consumer Food Products	Consumer Non-food Non-durables	Consumer Durables	Intermediate Goods	Energy	Capital Goods
Treatment*Post*Group	-0.432***	-0.187***	-0.134**						
	(0.056)	(0.040)	(0.057)						
Treatment*Post				-0.028	-0.176***	-0.280***	-0.107*	0.139	-0.363***
				(0.082)	(0.069)	(0.080)	(0.057)	(0.193)	(0.127)
Country-Month Fixed Effect	X	X	X						
Country-Group Fixed Effect	X	X	X						
Group-Month Fixed Effect	X	X	X						
Month Fixed Effect				X	X	X	X	X	X
Ln (Import Value)	X	X	X	X	X	X	X	X	X
Producer Heterogeneity	X	X	X	X	X	X	X	X	X
Country-Specific Month Effect				X	X	X	X	X	X
Number of Observations	5880	3192	5712	4444	4704	4700	4704	2582	4696

Notes: Standard errors, clustered at the country level, are reported in the parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Figure 1: The Ratio of Exports in Our Regression Sample over Total Exports (2000-2006)

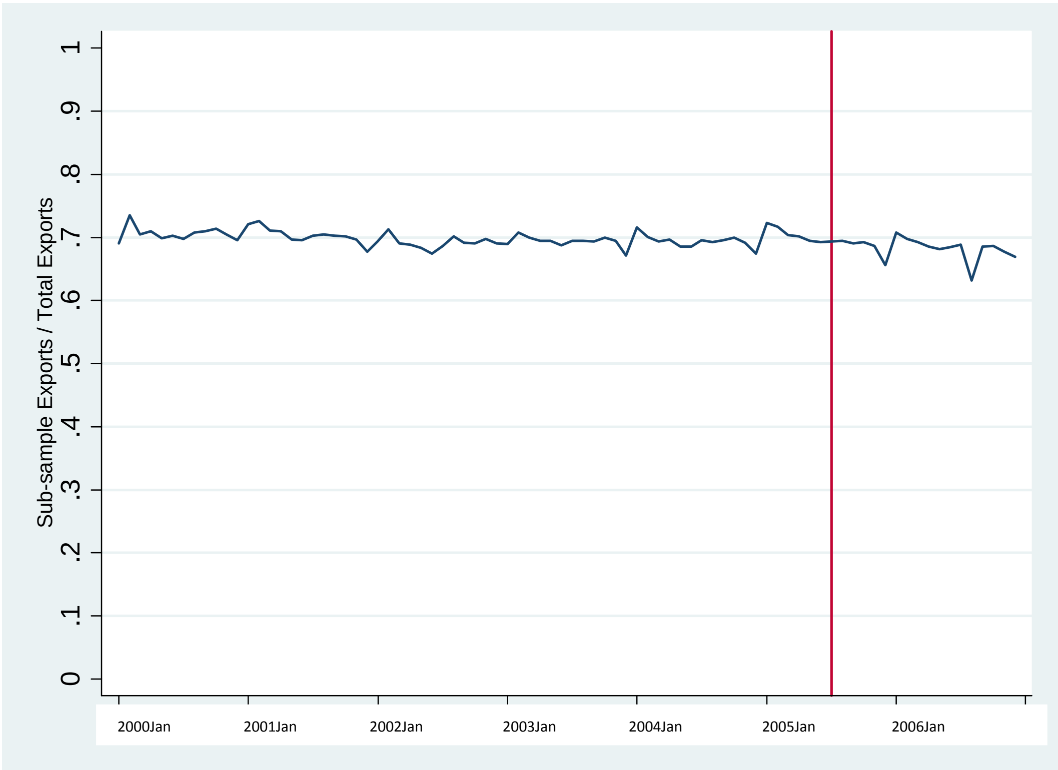


Figure 2: Monthly Nominal RMB Exchange Rates (2000-2006)

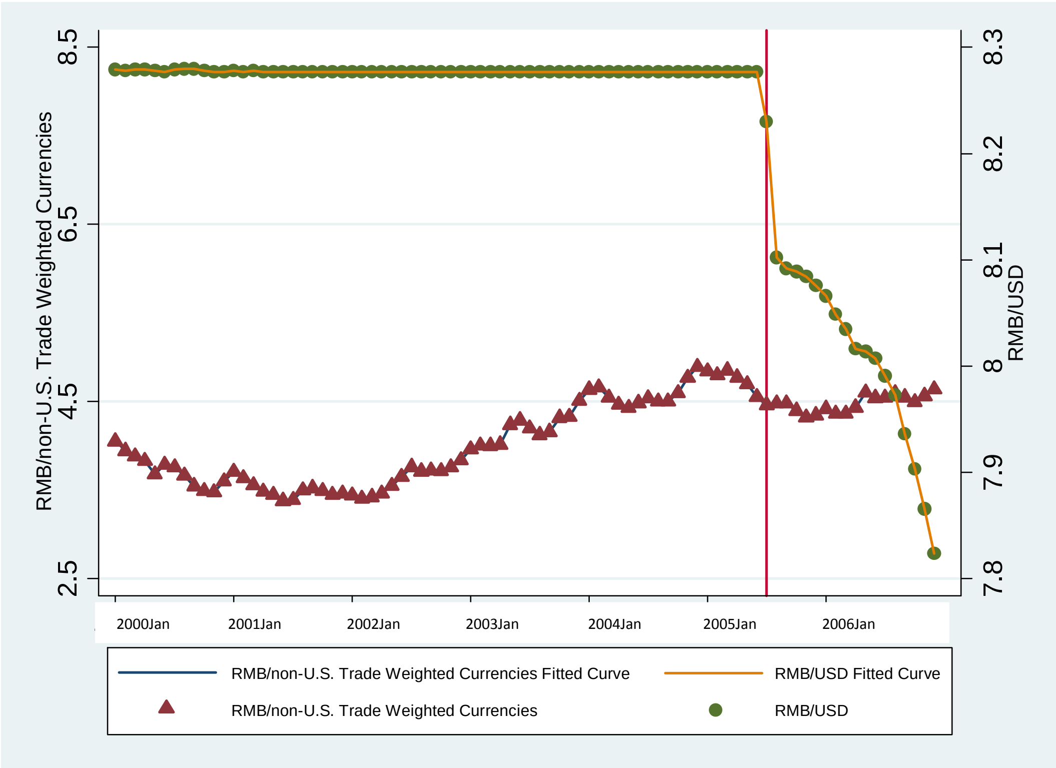
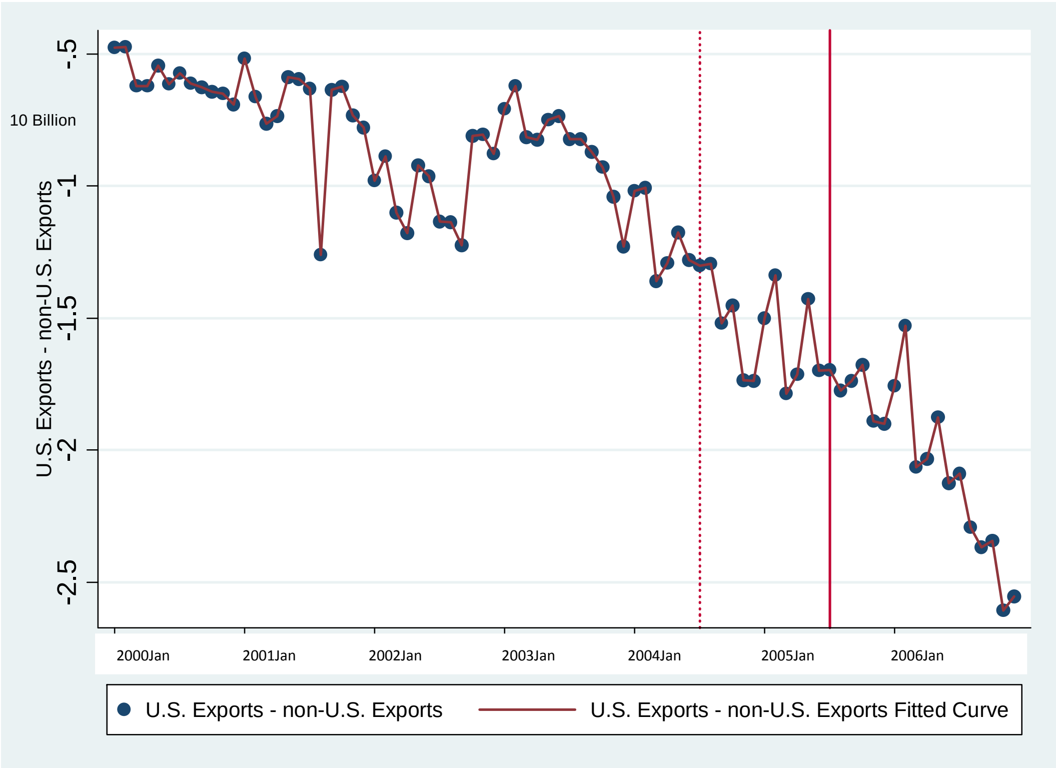


Figure 3: Difference between Exports to U.S. and Exports to Other Non-U.S. Countries in Our Regression Sample



Appendix

In this Appendix, we outline a partial equilibrium model to illustrate how an exogenous shock to exchange rate affects exporting behavior. Specifically, we extend Melitz and Ottaviano (2008)'s model to incorporate the role of exchange rate movement.[21] There are totally $N+1$ countries, a Home country (H) and N foreign countries, indexed by $i \in \{1, ..., N\}$. Each firm produces a unique variety, competes in the monopolistic-competition manner, and is indexed by its productivity level φ that is drawn from a cumulative distribution function $G(\varphi)$. Without loss of generality, we look only at how the change in Home country's exchange rate against foreign country i affects its exports to that foreign country.

The inverse demand function for a variety produced by firm φ from Home and exported to foreign country i is:[22]

$$p_i(\varphi)e_i = \alpha - \gamma q_i(\varphi) - \eta Q_i, \tag{6}$$

where $p_i(\varphi)$ are FOB export prices in foreign country i denominated in Home currency, respectively; e_i is the exchange rate of Foreign currency against Home currency (hence, an increase in e_i means a appreciation in Home currency against foreign country i's); $q_i(\varphi)$ is the demand of variety φ in foreign country i; and $Q_i \equiv \int_\varphi q_i(\varphi)d\varphi$ is the total demand in foreign country i. The demand parameters, α, γ,and η, are all positive.

Profit maximization yields the following equilibrium FOB export price:[23]

$$p_i^*(\varphi) = \frac{1}{2}\omega\tau_i(\frac{1}{\varphi_i^*} + \frac{1}{\varphi}), \tag{7}$$

where $\frac{1}{\varphi_i^*} \equiv \frac{1}{\omega e_i}\frac{\alpha - \eta Q_i}{\tau_i}$is the productivity threshold of exporting, that is, the level for which operating profits from foreign country i are zero; ω is the Home wage rate (denominated in Home currency); and $\tau_i > 1$ is the iceberg trade cost between Home and foreign country i (i.e., for every τ_i units shipped, only one unit arrives at the destination). For an active exporter φ in Home, its export volume to foreign country i is:

$$q_i^*(\varphi) = \frac{1}{2}\omega\tau_i e_i(\frac{1}{\varphi_i^*} - \frac{1}{\varphi}). \tag{8}$$

Hence, the aggregate export value V_i (denominated in Home currency) from Home to foreign country i is the sum of all active individual exporters' export revenues ($r(\varphi) \equiv$

[21] Similar results regarding the effect of exchange rate on exports can be derived using another commonly-used model, i.e., Melitz (2003)'s framework. See also Berman, Martin, and Mayer (2012).

[22] This inverse demand function can be derived from the maximization of a quadratic linear utility function. For more details, see Melitz and Ottaviano (2008).

[23] Here we abuse the term FOB price a little, because $p_i(\varphi)$ includes the trade cost τ_i. In the gravity model of our empirical part, we control for τ_i with country fixed effects.

$p_i^*(\varphi)q_i^*(\varphi))$, i.e.,

$$V_i = \int_{\varphi_i^*}^{\infty} r(\varphi)dG(\varphi) = \int_{\varphi_i^*}^{\infty} p_i^*(\varphi)q_i^*(\varphi)dG(\varphi). \tag{9}$$

And the effect of the change in the exchange rate e_i on the aggregate export value V_i is

$$\frac{\partial V_i}{\partial e_i} = \underbrace{\int_{\varphi_i^*}^{\infty} \frac{\partial[p_i^*(\varphi)q_i^*(\varphi)]}{\partial e_i} dG(\varphi)}_{intensive\ margin} - \underbrace{p_i^*(\varphi_i^*)q_i^*(\varphi_i^*)G'(\varphi_i^*)\frac{\partial \varphi_i^*}{\partial e_i}}_{extensive\ margin}. \tag{10}$$

The first term on the right-hand of equation (10) represents the effect from continuing exporters (or the intensive-margin effect), which can be shown to be negative, i.e.,

$$\frac{\partial r(\varphi)}{\partial e_i} = \frac{\partial[p_i^*(\varphi)q_i^*(\varphi)]}{\partial e_i} < 0 \ \forall \varphi \geq \varphi_i^*. \tag{11}$$

Meanwhile, the intensive-margin effect can be further decomposed into a price effect ($\frac{\partial p_i^*(\varphi)}{\partial e_i}$) and a volume effect ($\frac{\partial q_i^*(\varphi)}{\partial e_i}$), both of which can be proved to be negative, i.e.,

$$\underbrace{\frac{\partial p_i^*(\varphi)}{\partial e_i}}_{price\ effect} < 0, \quad \underbrace{\frac{\partial q_i^*(\varphi)}{\partial e_i}}_{quantity\ effect} < 0 \ \forall \varphi \geq \varphi_i^*. \tag{12}$$

The second term on the right-hand of equation (10) captures the extensive-margin effect, that is, the effect due to the change in the number of exporters, which is a monotonically decreasing function of φ_i^*. It can be proved that the productivity threshold of exporting φ_i^* is a increasing function of e_i, i.e.,

$$\frac{\partial \varphi_i^*}{\partial e_i} > 0, \tag{13}$$

therefore, we have a negative extensive margin effect of a currency appreciation.

Combining equations (11) and (13), we have

$$\frac{\partial V_i}{\partial e_i} < 0, \tag{14}$$

that is, an appreciation in Home currency against foreign country i's results in a decrease in aggregate export value from Home to foreign country i.

The intuition for equation (14) is as follows. There is an incomplete pass-through of an exchange rate appreciation: Home exporters absorb partially the appreciation effect by lowering its FOB export prices, but final prices (denominated in foreign country i's currency) in foreign country i still increase, which consequently leads to a fall in the final demand. As a result, such incomplete pass-through reduces FOB export revenues that Home exporters can obtain in foreign country i, and hence decreases the aggregate export value to that country. Moreover, given that the reduction in export revenue is more significant for less productive exporters (i.e., $\frac{\partial^2 r(\varphi)}{\partial e_i \partial \varphi} > 0$), some (least productive) exporters find it not profitable to sell in and hence choose to exit foreign country i, which further decreases the aggregate export value to that country.