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China-U.S. Trade: A global outlier

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Abstract

This paper investigates whether China's exports to the United States are an outlier. Gravity model results indicate that these exports have exceeded their predicted values by more than $100 billion in every year since 2005, and that both processed exports produced within regional value chains and ordinary exports produced using domestic inputs far exceed their predicted values. Exports of parts and components from South Korea and Taiwan, the two leading supply chain economies, to China are also outliers. Cointegration evidence indicates that exchange rates throughout the supply chain impact China's exports. While the Chinese renminbi has appreciated since 2005, exchange rates in supply chain countries have depreciated and contributed to China's outsized exports to the United States.

Keywords: Chinese exports, Exchange rate elasticities, Gravity model
JEL classification: F10, F40

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1. Introduction

Many believe that U.S. imbalances with China are falling. For instance, *The Financial Times* (2014, p. 8) reported that "global imbalances, especially between China and the U.S., have also narrowed." In actuality, the U.S. trade deficit with China increased by 40 percent between 2006 and 2014. At the same time, the U.S. deficit with other countries fell by 45 percent. At the end of 2014, the U.S. deficit with China exceeded the U.S. deficit with all other countries combined (see Figure 1). However, U.S. exports to China equaled only $120 billion in 2014 as compared to $1.5 trillion for U.S. exports to all other countries. Thus, U.S. trade with China now generates the same-sized deficit as U.S. trade with all other countries, even though U.S. exports to China are only one-twelfth of U.S. exports to the rest of the world. This suggests that China's exports to the U.S. are disproportionate.

To investigate quantitatively whether they are this paper uses a gravity model. As Leamer and Levinsohn (1995) and Baltagi, Egger, and Pfaffermayr (2014) discussed, gravity models yield some of the clearest and most robust findings not only in international economics but in all of economics. They are thus useful for studying bilateral exports from China to the U.S.

Employing the gravity model and exports between 31 leading exporting nations over the last 25 years, the results indicate that China's exports to the US have been more than $100 billion greater than predicted in every year since 2005. China's exports to the US are perennially twice as large as predicted.

What is the reason for this gap?[1] One explanation involves the role of production networks and global value chains. China serves as a regional export hub, importing parts and components from other East Asian countries and exporting final goods to the rest of the world (Iapadre and Tajoli, 2014). China's gross exports to the U.S. could be more than predicted by

[1] I am deeply indebted to colleagues for the discussion in this paragraph.

the gravity model because they incorporate a large share of foreign value added. This does not explain, though, why China's gross exports to the U.S. would be so much more than predicted while China's gross exports to other countries are not.

To shed further light on this issue, the gravity model is re-estimated with China's processed and ordinary exports included separately. Processed exports are produced through intricate production and distribution networks centered in East Asian countries while ordinary exports are produced primarily using domestic inputs (see Gaulier, Lemoine, and Unal-Kesenci, 2005). Processed exports therefore contain significant foreign value-added while ordinary exports contain primarily domestic value-added.

The findings indicate that both processed exports and ordinary exports to the U.S. in 2012 are $100 billion or more than predicted in 11 of the 12 specifications. For processed exports, the average of the 6 specifications indicates that exports to the U.S. are $194 billion more than predicted. For ordinary exports, this average is $122 billion more than predicted. This value for processed exports is $100 billion more than for the next leading importer of processed goods and the value for ordinary exports is $70 billion more than for the next leading importer. In addition, imports for processing flowing from the two leading suppliers of parts and components (South Korea and Taiwan) to China are major outliers relative to South Korea and Taiwan's exports to every other country. The result that China's processed exports to the U.S. and the imports for processing of the newly industrialized economies (NIEs) of South Korea and Taiwan to China are both major outliers implies that China's and the NIE's export structures are focused disproportionately on the U.S. The finding that China's ordinary exports to the U.S. are also much more than predicted implies that Chinese exports to the U.S. are not an outlier only because China's exports include a large share of foreign value added.

A second explanation for why China's exports may be an outlier concerns the role of the exchange rate. Up until recently the People's Bank of China (PBOC) intervened to keep the renminbi from appreciating. For instance, the PBOC reported that China's foreign exchange reserves increased by $508 billion in 2013, the largest one year increase ever, and by $125 billion in the first quarter of 2014 (see Troutman, 2014).[2]

Thorbecke (2006), Cheung, Chinn, and Fujii (2010), Cheung, Chinn, and Qian (2015), and others have investigated how the renminbi exchange rate affects China's exports to the U.S. Thorbecke, using Johansen maximum likelihood and dynamic ordinary least squares (DOLS) techniques and quarterly data over the 1987Q1-2005Q4 period, found that a ten percent appreciation of the CPI-deflated renminbi/dollar exchange rate would reduce China's exports to the U.S. by about 10 percent. To control for competition with other countries he included the exchange rates between ASEAN currencies and the U.S. dollar and found that a 10 percent depreciation of these currencies would reduce China's exports by 7 percent. Cheung, Chinn, and Fujii, employing DOLS estimation and quarterly data over the 1993Q4-2006Q2 period, reported that a 10 percent appreciation of the CPI-deflated renminbi/dollar exchange rate would reduce the volume of China's exports to the U.S. by more than 10 percent. Cheung, Chinn, and Qian, employing the Pesaran, Shin and Smith (2001) bounds test methodology and quarterly data over the 2001Q1-2012Q4 period, reported that a 10 percent appreciation of the CPI-deflated renminbi/dollar exchange rate would reduce the volume of China's processed exports to the U.S. on average by 15 percent and China's ordinary exports to the U.S.by even more. To control for competition with other countries they included exchange rates between ASEAN currencies and

[2] After this, reserve accumulation by the PBOC slowed, but net private capital exports accelerated. For instance, in 2014Q4 China reported the largest capital outflow in more than a decade (Qi, 2015).

the dollar and reported that a 10 percent depreciation of ASEAN currencies would reduce China's ordinary exports by between 4 and 11 percent.

Since much of the value-added of China's exports comes from East Asian supply chain countries, Yoshitomi (2007) emphasized the need to take account of exchange rates in upstream countries as well as the renminbi exchange rate when investigating China's exports. He noted that an appreciation of the renminbi against the dollar would only increase the relative dollar price of China's value-added in exports while a joint appreciation of Asian currencies against the dollar would increase the relative dollar price of the entire value of China's exports. Yoshitomi noted that a joint appreciation against the dollar would thus do much more to resolve imbalances between China and the U.S. than an appreciation of the renminbi alone against the dollar.

Thorbecke (2015) presented evidence that exchange rates throughout the region (the integrated exchange rate) affect China's multilateral exports. Cheung, Chinn, and Qian (2015) investigated whether the integrated exchange rate affects China's exports specifically to the U.S. and found that it did not in most specifications. However, the version of the integrated exchange rate that they used was constructed for China's exports to the whole world, not for China's exports to the U.S. This paper employs a version of the weighted exchange rate in supply chain countries that applies specifically to China's exports to the U.S. and investigates whether this variable affects China's exports.

The results indicate that both the weighted exchange rate in supply chain countries and the renminbi exchange rate exert important effects on China's exports to the U.S. The weighted exchange rate especially affects China's exports of sophisticated goods such as smart phones and computers that are produced with parts and components from the rest of Asia. This suggests that not only the value of the renminbi but also the values of the New Taiwan dollar, the Korean won, and exchange rates in other supply chain countries contribute to China's prodigious exports to the U.S.

The next section uses the gravity model to investigate whether China's exports to the U.S. are an outlier. Section 3 examines exchange rate elasticities for China's exports to the US. Section 4 concludes and draws policy implications.

2. Using a Gravity Model to Explain China's Exports

2.1 Data and Methodology

The gravity model is a workhorse for estimating bilateral trade flows. Traditional gravity models, as developed by Tinbergen (1962), posit that bilateral trade between two countries is directly proportional to GDP in the two countries and inversely proportional to the distance between them. In addition to GDP and distance these models typically include other factors affecting bilateral trade costs such as whether trading partners share a common language. As Leamer and Levinsohn (1995) and Baltagi, Egger, and Pfaffermayr (2014) discussed, gravity models yield some of the clearest and most robust findings not only in international economics but in all of economics. This model is thus used to predict China's exports.

Traditional gravity models take the form:

$$\ln Ex_{ijt} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln DIST_{ij} + \beta_4 LANG + \partial_i + \Omega_j + \pi_t + \varepsilon_{ijt} \qquad (1)$$

where Ex_{ijt} represents real exports from country *i* to country *j*, *t* represents time, Y represents GDP, DIST represents the geodesic distance between two countries, LANG is a dummy variables equaling 1 if the countries share a common language and 0 otherwise, and ∂i , Ωj , and π_t are country i, country j, and time fixed effects.

Anderson and Van Wincoop (2003) have derived theoretical foundations for the gravity model. They showed that exports should depend on outward and inward multilateral resistance terms. These terms capture the fact that exports and imports between two countries depend, not only on trade costs between the two countries, but also on changing trade costs between third countries. For instance, exports from country *i* to country *j* can be affected if country *i* enters a preferential trade agreement with a third country *k*.

Theoretically based gravity models can be estimated by the equation:

$$lnEx_{ijt} = \beta_0 + \beta_3 lnDIST_{ij} + \beta_4 LANG + \partial_i + \Omega_j + \varepsilon_{ijt} \qquad (2)$$

where the variables are as defined above. Here the distance and language variables capture trade costs for exports between countries *i* and j and the exporter and importer fixed effects variables capture the multilateral resistance terms. Time-varying fixed effects can also be included.

Equations (1) and (2) are log-linear models and are often estimated using panel least squares methods. Santos Silva and Tenreyro (2006) have shown that this approach can lead to biased estimates when there is heteroskedasticity in the data-generating process. They reported simulation results indicating that Poisson pseudo-maximum-likelihood (PPML) estimators perform better both in terms of bias and efficiency in several cases.

Since the goal in this paper is to try to predict China's exports, a variety of specifications are employed. These include the models in equation (1) and (2) and models estimated using both panel least squares and PPML techniques. The results are similar across all of these specifications. [3]

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[3] Thorbecke and Komoto (2010) reported that China's exports to the US were an outlier in 2007 using one specification of a gravity model. This paper examines whether China's exports to the US, Europe, and East Asian

Anderson, Vesselovsky, and Yotov (2013) have shown that exchange rates can exert real effects in the context of structural gravity models when there is incomplete pass-through or scale effects. The exchange rate is thus included as another explanatory variable.

Data on exports, GDP, and real exchange rates are obtained from the CEPII-CHELEM data base. Nominal exports are employed.[4] The real exchange rate is the CPI-deflated bilateral real exchange rate between the exporting and importing countries measured in levels.

Data on distance and common language are obtained from www.cepii.fr. Distance is measured in kilometers and represents the geodesic distance between economic centers. Common language is a dummy variable equaling 1 if two countries share a common language and 0 otherwise.

The gravity model is estimated as a panel using annual data for 31 countries over the 1988-2012 sample period. The countries are Australia, Austria, Brazil, Canada, China, Denmark, Finland, France, Germany, India, Indonesia, Ireland, Italy, Japan, Malaysia, Mexico, the Netherlands, Norway, the Philippines, Poland, Saudi Arabia, Singapore, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, the United Kingdom, and the United States.

2.2 Results

Table 1 presents gravity estimates across all six specifications. The coefficients on distance, common language, importer GDP, and exporter GDP are of the expected signs and statistically significant. The results in every specification indicate that distance is an important

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countries are outliers for every year between 2004 and 2012 using six different specifications of the gravity model. It also investigates whether the results differ for China's ordinary and processed exports.

[4] Traditional models have been estimated using real exports while structural models are estimated using nominal exports. The results in this paper were very similar using either measure. When GDP is included in the estimation here, real GDP is employed following previous researchers (e.g., Bénassy-Quéré and Lahrèche-Révil, 2003). The results are again similar using real or nominal GDP.

deterrent of trade and that sharing a common language is an important facilitator of trade. The results in columns (5) and (6) indicate that GDP in exporting and importing countries are also strongly related with trade.

The coefficient on the real exchange rate is positive in three cases and negative in three cases. One reason why the results for the exchange rate may be inconclusive is because the model constrains the exchange rate coefficient to be the same across all country pairs. The results reported in the next paragraph are almost identical when the exchange rate is excluded from the model.

Figure 2 plots the average of predicted and actual exports in 2012 across the six specifications in Table 1. The Appendix reports these results for each of the six specifications individually. In Figure 2 values above the diagonal line indicate that exports are more than predicted and values below the line indicate that exports are less than predicted. The vertical distance between the observation and the diagonal line measures the degree of over- or under-prediction. The figure indicates that China's predicted exports to the US in 2012 were $209 billion while China's actual exports were $395 billion. Thus China's exports to the US were almost twice as large as predicted, with the difference between the actual and predicted values equaling $186 billion. The results in the Appendix indicate that China's exports to the US in every specification were at least $120 billion more than predicted in 2012. There is thus robust evidence across all of the specifications that China's exports to the US are an outlier.

Figure 2 also shows that China's exports to Germany were $21 billion or 33 percent more than predicted. In some of the specifications in the Appendix, though, China's exports to Germany in 2012 were less than or equal to their predicted values.

Figure 2 also indicates that China's exports to South Korea, Taiwan, Japan, and Singapore in 2012 were much less than predicted. For South Korea, the shortfall was $107 billion; for Taiwan, $83 billion; for Japan, $81 billion, and for Singapore $22 billion. In percentage terms, South Korea's exports were 42 percent of the predicted value; Taiwan's were 32 percent of the predicted value; Japan's were 69 percent of the predicted value; and Singapore's were 52 percent of the predicted value. The results in the appendix indicate that China's exports to South Korea and Taiwan in 2012 were large negative outliers in both percentage terms and in value terms across all six specifications.

Figure 3 plots the difference between actual and predicted exports from China to the US, Europe, Japan, South Korea, and Taiwan over the 2004 to 2012 period.[5] The figure again plots the average across all six specifications. The results for each of the individual specifications are presented in the Appendix. Figure 3 indicates that China's exports to the US were $160 billion more than predicted just before the global crisis in 2007. With the crisis, they fell to $138 billion more than predicted in 2009 and then rose steadily to $186 more than predicted in 2012. The same pattern, with China's exports far more than predicted before the crisis and falling slightly before expanding again, is evident in all six of the specifications reported in the Appendix.

China's exports to Europe in Figure 3 were $75 billion more than predicted in 2010. However, with the European crisis this fell to $37 billion more than predicted in 2012. Across the six specifications in the Appendix there is no robust evidence that China's exports to Europe are an outlier.

Figure 3 also indicates that the shortfall in China's exports to Japan, South Korea, and Taiwan has been larger than $50 billion in every year since 2007. The Appendix indicates that

[5] Europe includes Austria, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

South Korea's and Taiwan's exports in every specification are perennially less than one would expect based on the gravity model.

The important implication of these results is that China's exports to the US year after year are far more than one would predict based on the workhorse gravity model. How can we understand this finding? It could reflect China's role as a regional export hub, importing parts and components from other East Asian countries and exporting final goods to the rest of the world.

To investigate this issue, the gravity model is re-estimated with China's processing and ordinary trade included separately. Imports for processing are goods that are imported under a special customs regime and that can only be used to produce goods (processed exports) for re-export. Processed exports are produced through intricate production and distribution networks centered in East Asian countries. [6] Ordinary imports, on the other hand, are intended primarily for the domestic market and ordinary exports are produced primarily using domestic inputs. Processed exports therefore contain significant foreign value-added while ordinary exports contain primarily local content.

China is thus treated as two separate economies in this new gravity model. One economy receives imports for processing (parts and components) from the other countries in the sample and sends processed exports (final assembled goods) to these countries. The other receives ordinary imports (imports for the domestic market) from these countries and sends ordinary exports (exports with high domestic value added) to them.

Data on ordinary and processing trade over the 1992 to 2012 sample period come from the China Customs Statistics. Data are obtained for all of the countries used in the previous

[6] See Gaulier, Lemoine, and Unal-Kesenci (2005) and other papers from the Centre D'Etudes Prospectives et D'Information Internationales (available at www.cepii.fr) for in depth studies of China's ordinary and processing trade.

model except for India, Norway, Poland, Saudi Arabia, Switzerland, and Turkey. These countries are thus dropped from the estimation.

The results indicate that both processed exports and ordinary exports to the U.S. in 2012 are $100 billion or more than predicted in 11 of the 12 specifications.[7] For processed exports, the average of the 6 specifications indicates that exports to the U.S. are $194 billion more than predicted. For ordinary exports, this average is $122 billion more than predicted. This value for processed exports is $100 billion more than for the next leading importer of processed goods and the value for ordinary exports is $70 billion more than for the next leading importer.

Since much of the value-added of China's processed exports comes from upstream countries, one can also investigate whether imports for processing coming into China from upstream countries are outliers. The leading suppliers of imports for processing are South Korea, Taiwan, Japan, the United States, Malaysia, Thailand, Singapore, Germany, and the Philippines.

Figure 4 shows that South Korea and Taiwan's exports for processing (China's imports for processing) in 2012 are twice as large as predicted. While the figure combines values for South Korea and Taiwan, similar findings hold for each economy individually. The NIEs' exports for processing to China have also been much more than predicted in every year since 2005. For the other upstream countries, exports for processing are not major outliers.

The result that China's processed exports to the U.S. and the NIEs exports for processing to China are both major outliers implies that China's and the NIE's export structures are focused disproportionately on the U.S. In both cases exports to Asian neighbors are much less than predicted and value-added that ultimately flows to the U.S. is much more than predicted. The result that China's ordinary exports to the U.S. are also much more than predicted implies that Chinese exports to the U.S. are not an outlier only because China's exports include a large share

[7] Detailed results are available on request.

of foreign value added. The next section investigates whether exchange rates in China and in supply chain countries affect China's exports.

3. Estimating Export Elasticities for China

3.1 Data and Methodology

The imperfect substitutes model is a workhorse for estimating trade elasticities. In this framework, exports are modeled as a function of the real exchange rate and real income:

$$ex_t = \alpha_{10} + \alpha_{11}\, rer_t + \alpha_{12}\, rgdp_t + \varepsilon_t \qquad (3)$$

where ex_t represents the log of real exports, rer_t represents the log of the real exchange rate, and $rgdp$ represents the log of foreign real income.

The U.S. Census Bureau provides data on China's exports to the US. 51 percent of China's exports to the US in 2013 were in SITC category 7. These were primarily cell phones, computers, and white goods. Another 32 percent were in SITC category 8. These were labor-intensive goods such as clothing, furniture, footwear, toys, and sporting goods. 11 percent were in SITC category 6. These were largely metals, metal products, textiles, and rubber. Over the last 20 years between 79 and 87 percent of China's exports to the US have been in SITC categories 7 and 8 and between 92 and 96 percent have been in SITC categories 6, 7, and 8.

The Bureau of Labor Statistics (BLS) provides a price deflator for China's exports to the US beginning in 2003. Before this the BLS provides a deflator for manufacturing exports to the

US coming from non-industrial countries.[8] These two series are spliced together to obtain a deflator for China's exports to the US.[9]

The real exchange rate employed here is constructed using the consumer price index (CPI). Data on the consumer price index in the US and China are obtained from the OECD. Data on the nominal renminbi/dollar exchange rate and US real GDP are obtained from the Federal Reserve Bank of St. Louis FRED database.[10]

Data on the Chinese CPI are available from the OECD beginning in 1993Q1, so the sample period extends from 1993q1 to 2013Q3. In 1994 China unified its dual exchange rate system. For the exchange rate variable used here, this shows up as a 30 percent spike in the real exchange rate in 1994Q1. By 1996Q1, rer_t had returned to its pre-spike value. To ensure that these unusual changes are not driving the results, in one specification elasticities are estimated over the 1996Q1-2013Q3 period.

China's exports increased ten times between 1996 and 2013. There has been an enormous increase in China's productive capacity during this time. To control for this China's capital stock is included as an independent variable.

Data on the Chinese capital stock up until 2011are obtained from Berlemann and Wesselhöft (2012).[11] The capital stock is assumed to grow 11 percent in 2012 and 2013. Linear interpolation is used to obtain quarterly data.

Some of China exports in each of the SITC categories are processed exports. As discussed above, these are final goods produced using parts and components that are imported duty free. The price competitiveness of processed exports should be influenced by exchange

[8] The websites for these data are: www.bls.gov and www.census.gov.
[9] Chinn (2006) also combined these two series to deflate China's exports to the US.
[10] The websites for these data are www.oecd.org and research.stlouisfed.org/fred2/ .
[11] The website for these data is http://www.hsu-hh.de/berlemann/index_VQxdoUqt6VmSoYt6.html .

rates in the countries providing intermediate inputs. To control for exchange rates in these countries, in some specifications a weighted exchange rate in supply chain countries relative to the U.S. dollar (CUSWRER) is included. CUSWRER is constructed using the following formula:

$$CUSWRER_t = CUSWRER_{t-1} \prod_{i=1}^{9} (r_{i,t} / r_{i,t-1})^{w_{i,t}}, \tag{4}$$

where the number 9 above the product operator indicates that the nine leading supply chain economies are used, $r_{i,t}$ represents the CPI-deflated real exchange rate in supply chain country i relative to the US dollar, and $w_{i,t}$ is the value of parts and components (imports for processing) coming into China from supply chain economy i divided by the value of parts and components coming from all 9 suppliers together. The sum of the $w_{i,t}$ thus equals one. The nine leading supply chain economies, arranged according to the value of parts and components they provided in 2013, are South Korea, Taiwan, Japan, the United States, Malaysia, Thailand, Singapore, Germany, and the Philippines.[12] Data on the share of parts and components coming from each of the nine supplier economies are obtained from the China Customs Statistics.[13] Data on nominal exchange rates relative to the US dollar and on consumer prices indices are obtained from the Federal Reserve Bank of St. Louis FRED database, the OECD, and the websites of the supplier countries' central banks. SSRER is set equal to 100 in 1993Q1.

According to augmented Dickey-Fuller tests, most of the variables appear to be integrated of order one. The results in Table 2 indicate that the trace and maximum eigenvalue

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[12] The results reported below are similar when the U.S. and Germany are excluded when calculating SSRER.
[13] The website is http://www.customs-info.com/

statistics permit rejection of the null of no cointegrating relations against the alternative of one cointegrating relation in almost every case. Johansen maximum likelihood estimation. a technique for estimating cointegrating relations, is thus employed.

To specify the Johansen model, the imperfect substitutes model with the addition of the Chinese capital stock can be written in vector error correction form as:

$$\Delta ex_t = \beta_{10} + \varphi_1(ex_{t-1} - \alpha_{10} - \alpha_{11}rer_{t-1} - \alpha_{12}rgdp_{t-1}^* - \alpha_{13}KStock_{t-1}) + \beta_{11}(L)\Delta ex_{t-1} + \beta_{12}(L)\Delta\, rer_{t-1} + \beta_{13}(L)\Delta rgdp_{t-1}^* + \beta_{14}(L)\Delta KStock_{t-1} + \nu_{1t} \quad (5a)$$

$$\Delta rer_t = \beta_{20} + \varphi_2(ex_{t-1} - \alpha_{10} - \alpha_{11}rer_{t-1} - \alpha_{12}rgdp_{t-1}^* - \alpha_{13}KStock_{t-1}) + \beta_{21}(L)\Delta ex_{t-1} + \beta_{22}(L)\Delta\, rer_{t-1} + \beta_{23}(L)\Delta rgdp_{t-1}^* + \beta_{24}(L)\Delta KStock_{t-1} + \nu_{2t} \quad (5b)$$

$$\Delta rgdp_t^* = \beta_{30} + \varphi_3(ex_{t-1} - \alpha_{10} - \alpha_{11}rer_{t-1} - \alpha_{12}rgdp_{t-1}^* - \alpha_{13}KStock_{t-1}) + \beta_{31}(L)\Delta ex_{t-1} + \beta_{32}(L)\Delta\, rer_{t-1} + B_{33}(L)\Delta rgdp_{t-1}^* + \beta_{34}(L)\Delta KStock_{t-1} + \nu_{3t} \quad (5c)$$

$$\Delta KStock_t^* = \beta_{40} + \varphi_4(ex_{t-1} - \alpha_{10} - \alpha_{11}rer_{t-1} - \alpha_{12}rgdp_{t-1}^* - \alpha_{13}KStock_{t-1}) + \beta_{41}(L)\Delta ex_{t-1} + \beta_{42}(L)\Delta\, rer_{t-1} + B_{43}(L)\Delta rgdp_{t-1}^* + \beta_{44}(L)\Delta KStock_{t-1} + \nu_{4t} \quad (5d)$$

where the φ's are the error correction coefficients, the L's represent polynomials in the lag operator, KStock represents the Chinese capital stock, and the other variables are defined after equation (3). In some specifications the weighted exchange rate in supply chain countries (CUSWRER) is also included. The coefficient φ_1 measures how quickly exports respond to disequilibria. If exports move towards their equilibrium values, then φ_1 will be negative and statistically significant.

3.2 Results

Table 2 presents the Johansen maximum likelihood estimates from equations (5a)-(5d). The first row presents results for all goods, the second for SITC category 7 exports, the third for

SITC category 8 exports, and the fourth for SITC category 6 exports. In all cases the coefficients on the real exchange rate and US GDP are of the expected signs and statistically significant.

For all goods, the results indicate that a 1 percent appreciation of the RMB would decrease China's exports by 1.36 percent and a 1 percent increase in US GDP would increase exports by 2.42 percent. For SITC category 7, a 1 percent appreciation would decrease exports by 1.62 percent and a 1 percent increase in US GDP would increase exports by 3.82 percent. For SITC category 8, a 1 percent appreciation would decrease exports by 0.79 percent and a 1 percent increase in US GDP would increase exports by 3.2 percent. For SITC category 6, a 1 percent appreciation would decrease exports by 1.33 percent and a 1 percent increase in US GDP would increase exports by 4.9 percent.

The Chinese capital stock is associated with an increase in exports for SITC category 7 but not for categories 6 or 8. China's SITC 7 exports are primarily capital intensive goods such as cell phones and computers; while the other categories contain many labor intensive goods such as clothing, furniture, footwear, toys, textiles, and sporting goods.

The error correction coefficient φ_1 for exports is negative and statistically significant in every case, implying that exports move towards their equilibrium values. The results in the first row indicate that the gap between the actual and the long run values closes at a rate of 21 percent per quarter; the results in the second row indicate that the gap closes at a rate of 16 percent per quarter; the results in the third row indicate that the gap closes at a rate of 29 percent per quarter; the results in the fourth row indicate that the gap closes at a rate of 22 percent per quarter.

The error correction coefficient φ_2 for the renminbi/dollar real exchange rate is positive and statistically significant in every case, indicating that the renminbi/dollar rate moves away from its equilibrium value. In other words, an unexpected surge in China's exports to the US tends to be followed by a depreciation of the renminbi against the dollar. The effect is quantitatively large, with the gap between actual and long run values expanding at a rate of 20 percent per quarter. This may reflect China's interventions in the foreign exchange market.

The results for the seasonal dummies, not reported, indicate that *ceteris paribus* aggregate exports are 16 percent less in the first quarter of the year compared with the previous quarter. Exports are lower in the first quarter because the Chinese New Year holidays occur at this time.

The model was re-estimated over the 1996Q1-2013Q3 period to see whether the unusual exchange rate changes over the 1994-96 period affected the findings. The results, available on request, indicate that exchange rate elasticities in all categories are larger over the later sample period. Thus the pre-1996 exchange rate spike is not driving the results,

Table 3 presents the findings controlling for exchange rates in supply chain countries. Cointegration tests yield mixed results for all exports and SITC category 7 exports, with the trace test indicating one cointegrating relation and the maximum eigenvalue test indicating no cointegrating relations. For category 7 goods, the maximum eigenvalue statistic does permit rejection of the null of no cointegrating relations at the 0.065 significance level. For SITC category 8 goods, both tests point to one cointegrating relation.

The elasticities for the RMB/Dollar rate are larger in Table 3 than in Table 2 for all goods and for category 7 goods. The elasticity is almost the same for category 8 goods. Thus, controlling for exchange rates throughout the supply chain, the renminbi still exerts important effects on China's exports. In addition, the elasticities for the weighted exchange rates in supply chain countries are positive and statistically significant for category 7 and category 8 goods, indicating that an appreciation in supply chain countries relative to the US dollar would reduce

China's exports. The results imply that a 10 percent appreciation in supply chain countries would reduce category 7 exports by 10 percent and category 8 exports by 6 percent.

The findings in Table 3 indicate that including real exchange rates in supply chain countries reduces the significance of the income elasticities for category 7 goods. The income elasticities remain highly significant for category 6 and 8 goods. The lower income elasticity for category 7 goods causes the income elasticity for all goods in the first row to also be insignificant. One reason why the income elasticity for category 7 goods is not significant is that, as Table 2 shows, the Chinese capital stock is closely correlated with the export of these capital intensive goods. In addition, the Chinese capital stock and U.S. GDP are highly correlated in the sample (the simple correlation between the two variables equals 0.97). The multicollinearity between the two variables reduces the measured significance of the income elasticity for category 7 goods.

Overall the results in Table 3 are most compelling for category 8 goods. Not only do the trace and maximum eigenvalue tests both indicate one cointegrating relation for this category, the error correction coefficient φ_1 implies a very tight relationship between exports and the independent variables. The gap between actual exports and their long run equilibrium values closes at a rate of 36 percent per quarter. Thus if a shock causes exports to deviate from equilibrium values, *ceteris paribus* 85 percent of the gap will close after 4 quarters.

It might seem puzzling that the results including exchange rates in supply chain countries works best for labor-intensive exports (category 8). However, evidence reported in Feenstra and Wei (2010) indicates that textiles were the largest category of processed exports at the beginning of the sample period and that more than half of processed exports at that time were labor-intensive goods such as textiles, footwear, headwear, and miscellaneous manufacturing. Since these goods were produced with imported inputs coming from supply chain countries, exchange rates throughout the supply chain influenced their competitiveness.

The error correction coefficient for the renminbi/dollar real exchange rate and for exchange rates in supply chain countries are positive and statistically significant, indicating that both the renminbi and exchange rates in supply chain countries tend to move away from their equilibrium values. This may reflect interventions in the foreign exchange market by China and other East Asian countries.

The important implication of the results presented here is that the renminbi/dollar exchange rate exerts first order effects on Chinese exports. The elasticities are especially large for China's SITC category 7 exports. The weighted exchange rate in supply chain countries relative to the U.S. dollar also has a large effect of category 7 exports. This category is composed primarily of computers, cell phones, and other sophisticated goods.

4. Conclusion

China's exports to the US in 2014 were four times larger than US exports to China. The US trade deficit with China now exceeds the US trade deficit with all other countries combined. However, US exports to China equaled only $120 billion while US exports to the rest of the world equaled $1.5 trillion. These facts suggest that China's exports to the US are disproportionate.

This paper investigates whether they are an outlier. Using a gravity model and exports between 31 leading exporting nations over the last 25 years, the results indicate that China's exports to the US have been more than $100 billion greater than predicted year after year.

This gap could reflect the role of global value chains, since China imports parts and components from other East Asian countries and exports final goods to the rest of the world. China's gross exports to the U.S. could thus be outsized because they incorporate a large share of foreign value added. This does not explain, though, why China's gross exports to the U.S. would be so much more than predicted while China's gross exports to other countries are not.

To investigate this issue, the gravity model is re-estimated with China's processed and ordinary exports included separately. Processed exports contain significant foreign value-added while ordinary exports contain primarily domestic value-added. Both processed exports and ordinary exports to the U.S. in 2012 are $100 billion or more than predicted in 11 of the 12 specifications. In addition, imports for processing flowing from the two leading suppliers of parts and components (South Korea and Taiwan) to China are twice as large as predicted and major outliers relative to South Korea's and Taiwan's exports to every other country. China and the NIE's exports to Asian neighbors are much less than predicted. These results suggest that that China's and the NIE's export structures are focused disproportionately on the U.S. The finding that China's ordinary exports to the U.S. are also much more than predicted implies that Chinese exports to the U.S. are not an outlier only because China's exports include a large share of foreign value added.

This paper then investigates whether exchange rates affect China's exports to the U.S. Johansen maximum likelihood estimates indicate that RMB/dollar elasticities for exports of cell phones, computers, and other SITC category 7 goods that comprise the majority of China's exports to the U.S. vary between 16 and 23 percent. In addition, a 10 percent currency depreciation in key supply chain economies such as Korea and Taiwan relative to the U.S. dollar would produce a 10 percent increase in China's category 7 exports.

China, South Korea and Taiwan have run large surpluses. Their global current account surpluses between 2005 and 2014 averaged more than 5 percent of GDP, more than 3 percent of GDP and more than 9 percent of GDP, respectively. Their 2015 global current account surpluses are also on target to equal 3.2 percent for China, 12.4 percent for Taiwan and 7.4 percent for Korea (see IMF, 2015).

These large surpluses generate appreciation pressure. China, Taiwan and Korea have used foreign exchange reserve intervention to resist currency appreciation. Nevertheless the renminbi has appreciated by more than 40 percent in real effective terms and by more than 28 percent relative to the U.S. dollar between the beginning of 2005 and the first quarter of 2015. On the other hand, the New Taiwan dollar over this period has appreciated by less than 3 percent both in real effective terms and against the dollar and the Korean won has depreciated according to both measures. The weighted exchange rate in supply chain countries has thus depreciated since 2005. The results in this paper indicate that this depreciation in supply chain countries reduces the impact of the renminbi appreciation on China's exports.

China's exports to the U.S. remain disproportionate year after year. An appreciation throughout the supply chain would help to rebalance this trade. It would be facilitated if countries in the region adopted more flexible exchange rate regimes and refrained from using foreign exchange intervention to prevent needed adjustments.

A joint appreciation would also provide benefits to East Asia. It would increase the purchasing power of Asian consumers. This would be helpful, since China's consumption imports per capita divided by income per capita is the lowest in 2012 for all 84 countries that the CEPII-CHELEM database provides data for and the corresponding values for South Korea and Taiwan are far below average. A concerted appreciation in the region would redirect consumption goods to Asian consumers. A joint appreciation would also have an attenuated effect on Asian countries' real effective exchange rates since exchange rates would not change much relative to regional trading partners. Finally, if currencies appreciated together it would help maintain intra-regional exchange rate stability, facilitating the flow of parts and components within Asian supply chains (see Tang, 2014).

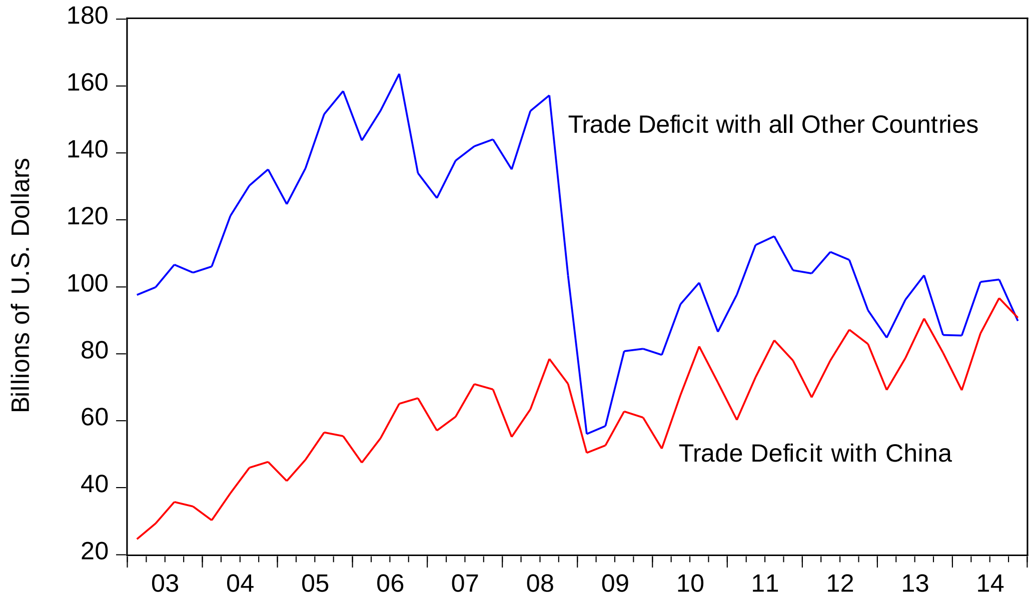

Figure 1. US Trade Deficit with China and All Other Countries.
Source: US Census Bureau.

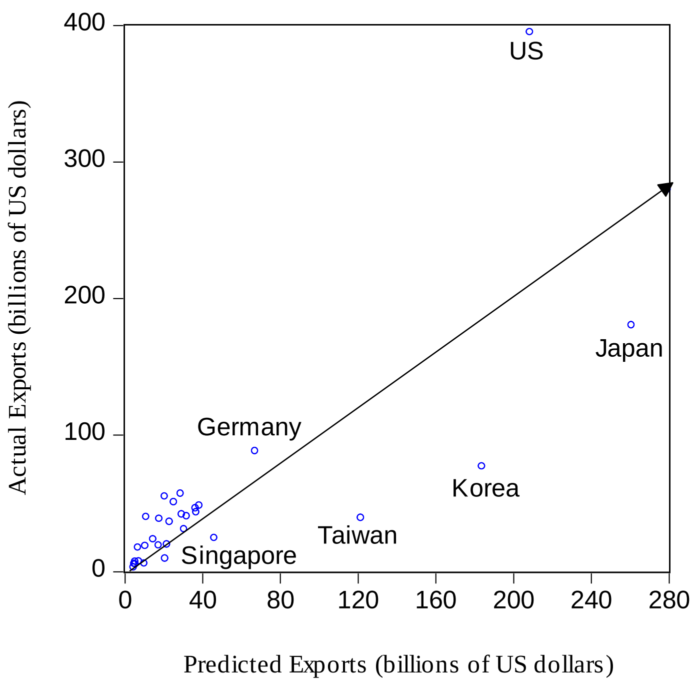

Figure 2. China's Actual and Predicted Exports to 30 Countries in 2012.
Note: Predicted exports are determined by a gravity model for trade between 31 leading exporters over the 1988-2012 period.
Source: CEPII-CHELEM Database and calculations by the author.

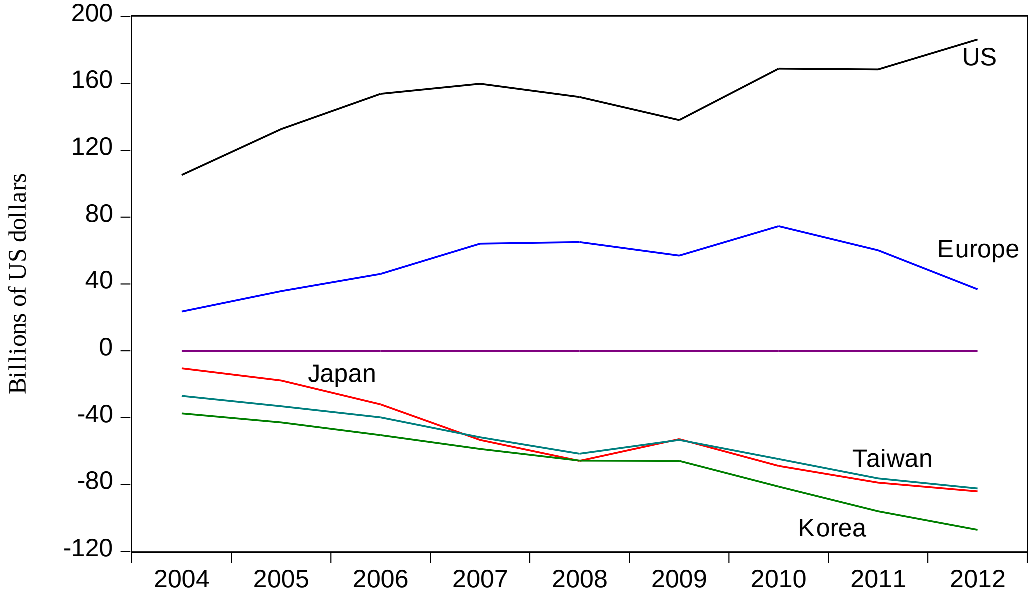

Figure 3. The Difference between China's Actual and Predicted Exports to the US, Europe, Japan, South Korea, and Taiwan.

Note: Predicted exports are determined by a gravity model for trade between 31 leading exporters over the 1988-2012 period. Europe includes Austria, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

Source: CEPII-CHELEM Database and calculations by the author.

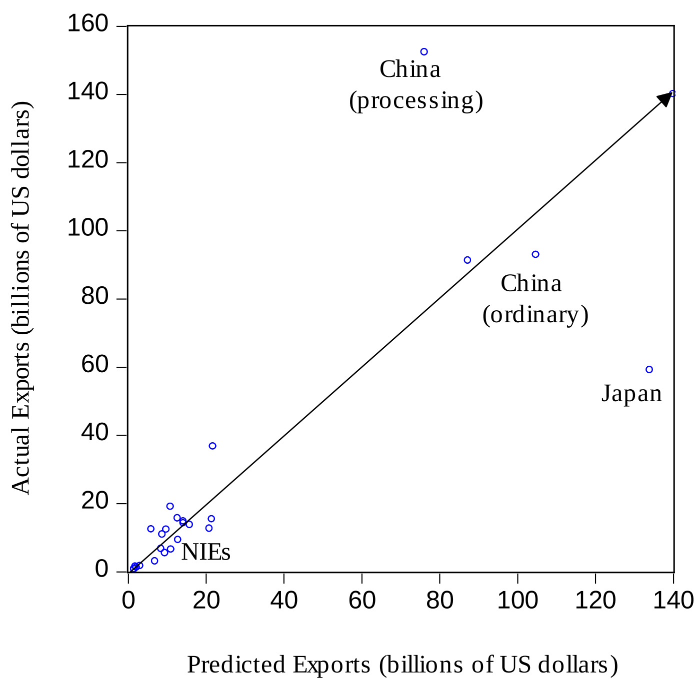

Figure 4. South Korea's and Taiwan's (the NIEs) Actual and Predicted Exports to 25 Countries in 2012.
Note: Predicted exports are determined by a gravity model for trade between 26 leading exporters over the 1992-2012 period. Processing represents exports sent to China under the processing customs regime and ordinary represents exports sent under the ordinary customs regime.
Source: CEPII-CHELEM Database, China Customs Statistics Database, and calculations by the author.

Table 1 Panel OLS and PPML gravity estimates, 1998-2012

	(1)	(2)	(3)	(4)	(5)	(6)
Distance	-0.83***	-0.99***	-0.76***	-0.91***	-0.82***	-0.99***
	(0.01)	(0.01)	(0.00)	(0.03)	(0.01)	(0.01)
Common Language	0.27***	0.38***	0.45***	0.58***	0.26***	0.39***
	(0.03)	(0.02)	(0.00)	(0.08)	(0.03)	(0.01)
Bilateral Real Exchange Rate	0.09	-0.23***	0.02***	0.33	-0.11**	-0.28***
	(0.07)	(0.03)	(0.00)	(0.56)	(0.05)	(0.05)
Exporter GDP					1.17***	1.28***
					(0.05)	(0.02)
Importer GDP					0.87***	0.66**
					(0.03)	(0.06)
Constant	20.3***	20.9***	17.6***	19.5***	-13.6***	-10.6***
	(0.12)	(0.08)	(0.00)	(0.56)	(1.0)	(0.93)
Estimation Technique	PPML	OLS	PPML	OLS	PPML	OLS
Fixed Effects Specification	Exporter, Importer, Time	Exporter, Importer, Time	Time-varying exporter, importer	Time-varying exporter, importer	Exporter, Importer, Time	Exporter, Importer, Time
Adjusted R-squared		0.82		0.80		0.83
No. of observations	23224	23199	23224	23199	23224	23199
Sample Period	1988-2012	1988-2012	1988-2012	1988-2012	1988-2012	1988-2012

Notes: The table contains panel OLS and Poisson Pseudo Maximum Likelihood (PPML) estimates of gravity models. Bilateral exports from 31 major exporters to each of the other 30 countries over the 1988-2012 period are included. For the panel OLS estimates, heteroskedasticity-consistent standard errors are in parentheses. For the PPML estimates, Huber-White standard errors are in parentheses.
*** (**) denotes significance at the 1% (5%) level.

Table 2 Johansen MLE estimates for Chinese exports to the United States[1].

	Number of Cointe-grating Vectors	Number of Obser-vations	RMB-Dollar Real Exchange Rate	Income	Chinese Capital Stock	Error Correction Coefficients:			
						Exports	RMB-Dollar Real Exchange Rate	Income	Capital Stock
All Goods (Lags: 1; Sample: 1993:III-2013:III; Trend in data; Seasonal dummies for the first, second, and third quarters included)	1,1	81	1.36*** (0.26)	2.42*** (0.60)	0.75*** (0.16)	-0.21*** (0.07)	0.20*** (0.05)	0.01 (0.01)	0.00 (0.00)
SITC 7 (Lags: 1; Sample: 1993:III-2013:III; Trend in data; Seasonal dummies for the first, second, and third quarters included)	1,1	81	1.62*** (0.30)	3.82*** (0.68)	0.87*** (0.19)	-0.16*** (0.06)	0.20*** (0.05)	0.01 (0.01)	0.00 (0.00)
SITC 8 (Lags: 1; Sample: 1993:III-2013:III; Trend in data; Seasonal dummies for the first, second, and third quarters included)	1,1	81	0.79*** (0.20)	3.20*** (0.45)	0.17 (0.13)	-0.29*** (0.09)	0.23*** (0.07)	0.02 (0.01)	0.00 (0.00)
SITC 6 (Lags: 1; Sample: 1993:III-2013:III; Trend in data; Seasonal dummies for the first, second, and third quarters included)	1,0	81	1.33*** (0.34)	4.90*** (0.78)	0.28 (0.22)	-0.22*** (0.07)	0.17*** (0.04)	0.00 (0.00)	0.001** (0.00)

[1]Number of Cointegrating Vectors indicates the number of cointegrating relations according to the trace and maximum eigenvalue test using 5% asymptotic critical values.
*** (**) denotes significance at the 1% (5%) level.

Table 3 Johansen MLE estimates for Chinese exports to the United States[1].

	Number of Cointe-grating Vectors	Number of Obser-vations	RMB-Dollar Real Exchange Rate	Weighted Real Exchange Rate in Supply Chain Countries	Income	Chinese Capital Stock	Error Correction Coefficients: Exports	Error Correction Coefficients: RMB-Dollar Real Exchange Rate	Error Correction Coefficients: Weighted Real Exchange Rate in Supply Chain Countries	Error Correction Coefficients: Income	Error Correction Coefficients: Capital Stock
All Goods (Lags: 1; Sample: 1993:III-2013:III; Trend in data; Seasonal dummies for the first, second, and third quarters included)	1,0	81	1.68*** (0.33)	0.61* (0.32)	0.87 (0.85)	1.09*** (0.21)	-0.16*** (0.05)	0.13*** (0.04)	0.08*** (0.03)	-0.00 (0.01)	0.00 (0.00)
SITC 7 (Lags: 1; Sample: 1993:III-2013:III; Trend in data; Seasonal dummies for the first, second, and third quarters included)	1,0	81	2.25*** (0.40)	1.00*** (0.38)	0.86 (1.03)	1.54*** (0.26)	-0.14*** (0.04)	0.11*** (0.03)	0.07*** (0.03)	0.00 (0.00)	0.00* (0.00)
SITC 8 (Lags: 1; Sample: 1993:III-2013:III; Trend in data; Seasonal dummies for the first, second, and third quarters included)	1,1	81	0.72*** (0.17)	0.63*** (0.17)	2.23*** (0.45)	0.32*** (0.12)	-0.36*** (0.09)	0.20*** (0.07)	0.14** (0.05)	0.01 (0.01)	0.00 (0.00)
SITC 6 (Lags: 1; Sample: 1993:III-2013:III; Trend in data;	0,0	81	0.90*** (0.33)	0.28 (0.32)	6.20*** (0.87)	0.05 (0.22)	-0.24*** (0.08)	0.17*** (0.05)	-0.04 (0.01)	0.00 (0.01)	0.00 (0.00)

Seasonal
dummies for
the first,
second, and
third
quarters
included)

[1]Number of Cointegrating Vectors indicates the number of cointegrating relations according to the trace and maximum eigenvalue test using 5% asymptotic critical values.

*** (**) denotes significance at the 1% (5%) level.

Appendix

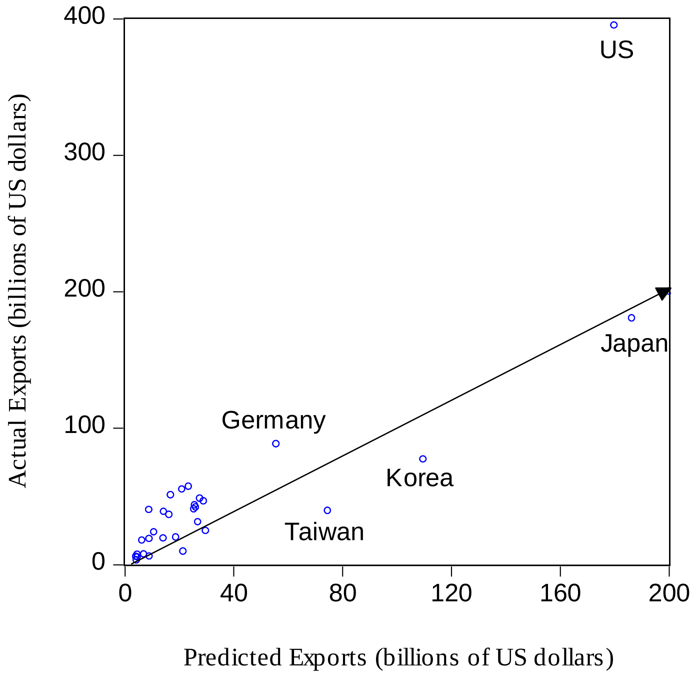

Figure A1. Results for 2012 from Poisson Pseudo Maximum Likelihood Estimation of Theoretical Gravity Model with Exporter, Importer, and Time Fixed Effects.

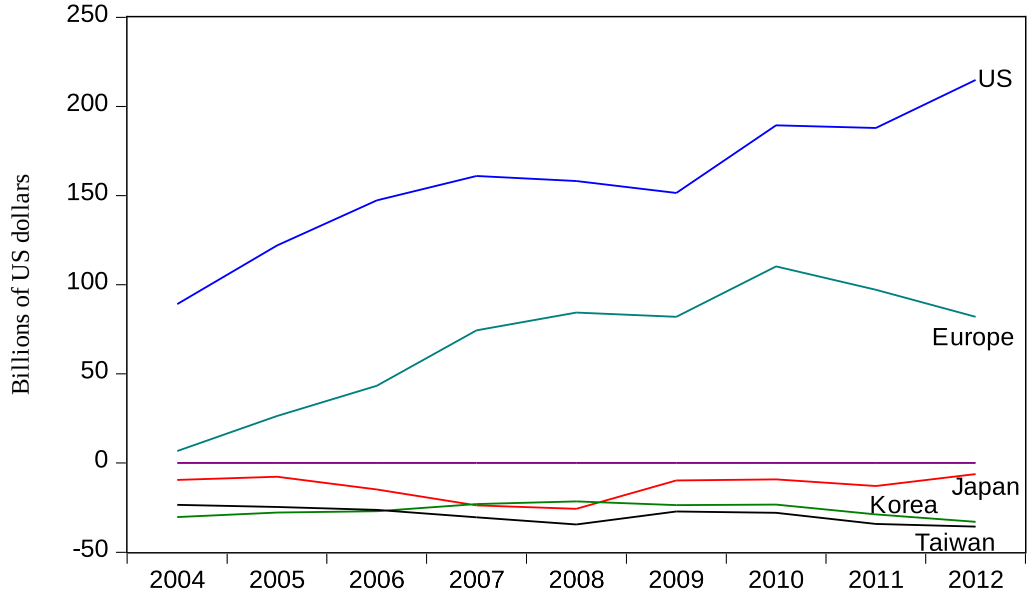

Figure A2. Results for 2004-2012 from Poisson Pseudo Maximum Likelihood Estimation of Theoretical Gravity Model with Exporter, Importer, and Time Fixed Effects.

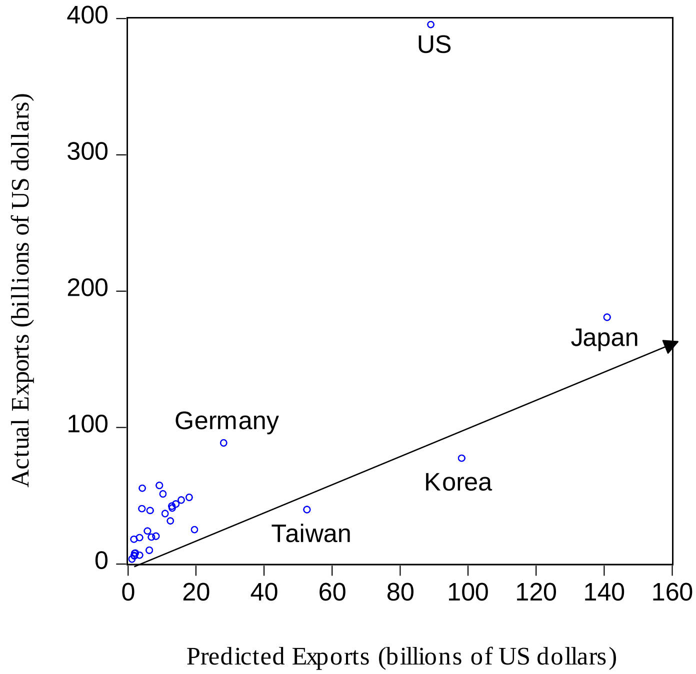

Figure A3. Results for 2012 from Panel OLS Estimation of Theoretical Gravity Model with exporter, importer, and time fixed effects.

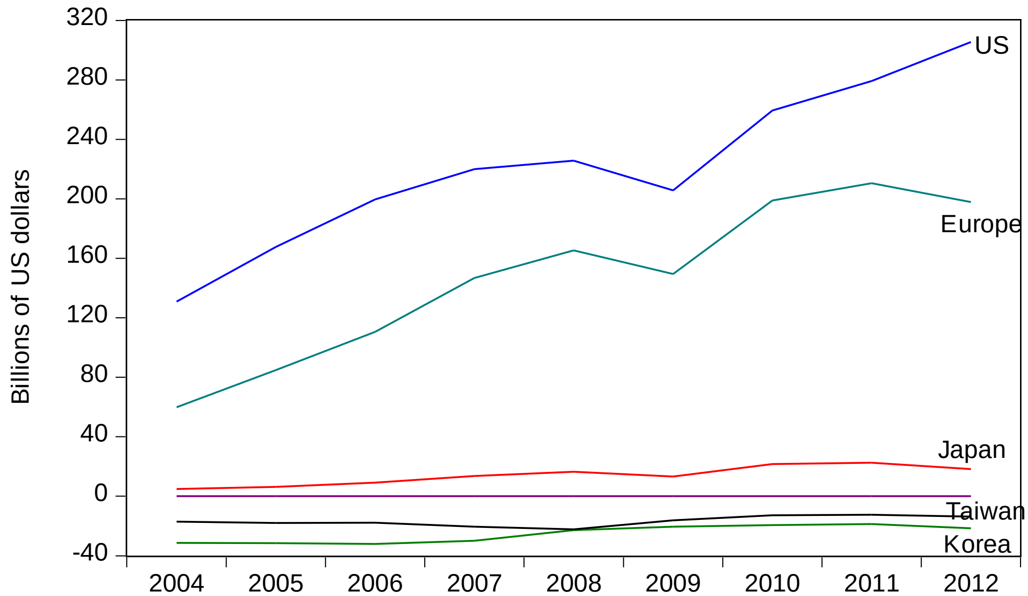

Figure A4. Results for 2004-2012from Panel OLS Estimation of Theoretical Gravity Model with exporter, importer, and time fixed effects.

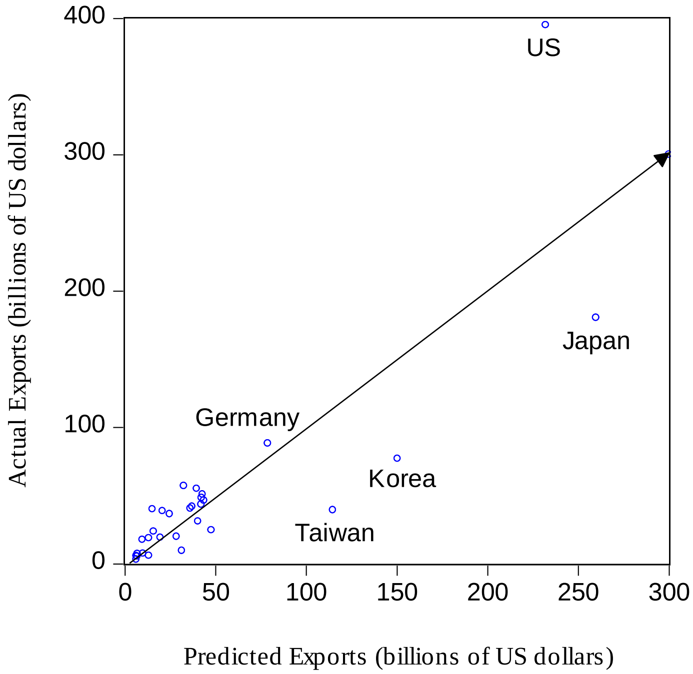

Figure A5. Results for 2012from Poisson Pseudo Maximum Likelihood Estimation of Theoretical Gravity Model with Time-varying Exporter Fixed Effects and Importer Fixed Effects.

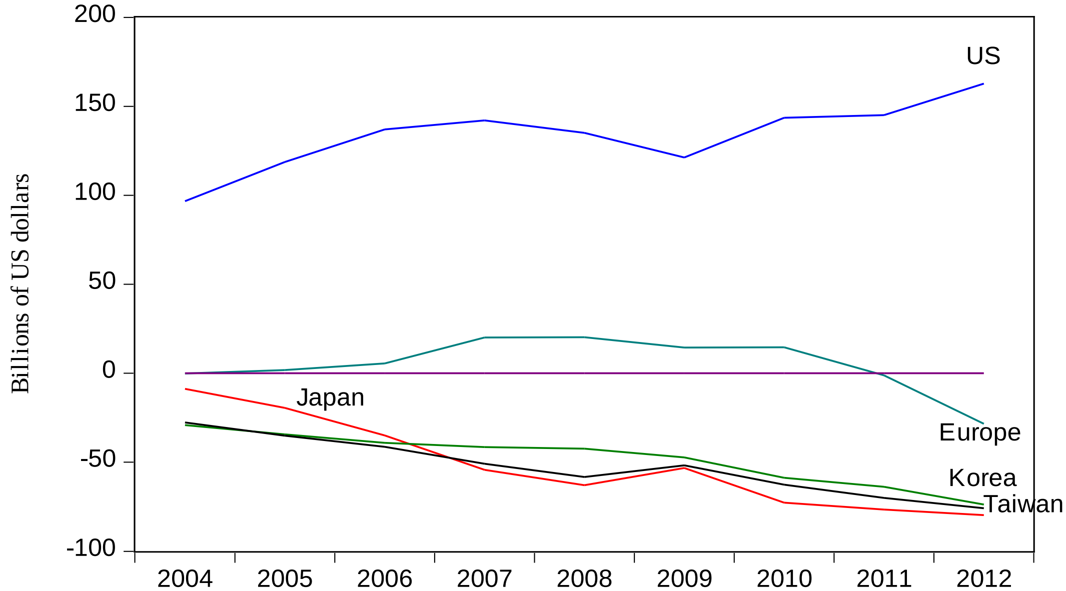

Figure A6. Results for 2004-2012 from Poisson Pseudo Maximum Likelihood Estimation of Theoretical Gravity Model with Time-varying Exporter Fixed Effects and Importer Fixed Effects.

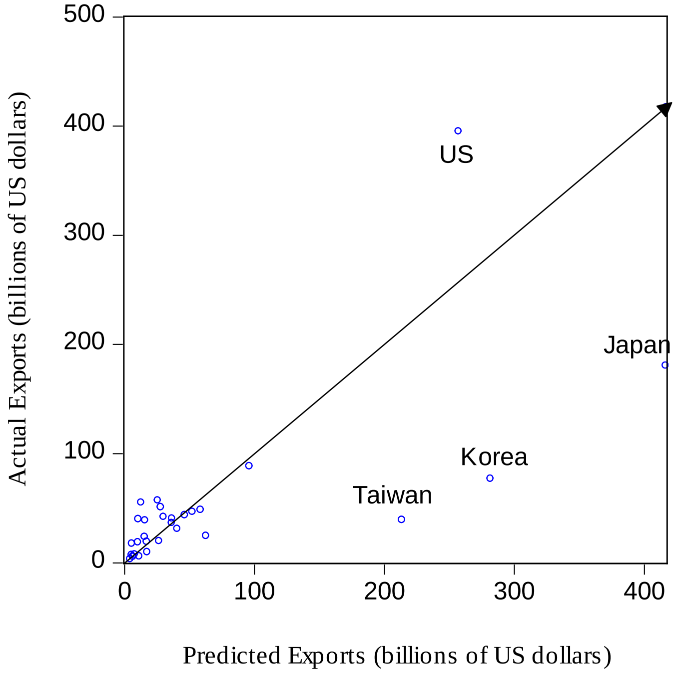

Figure A7. Results for 2012from Panel OLS Estimation of Theoretical Gravity Model with Time-varying Exporter Fixed Effects and Importer Fixed Effects.

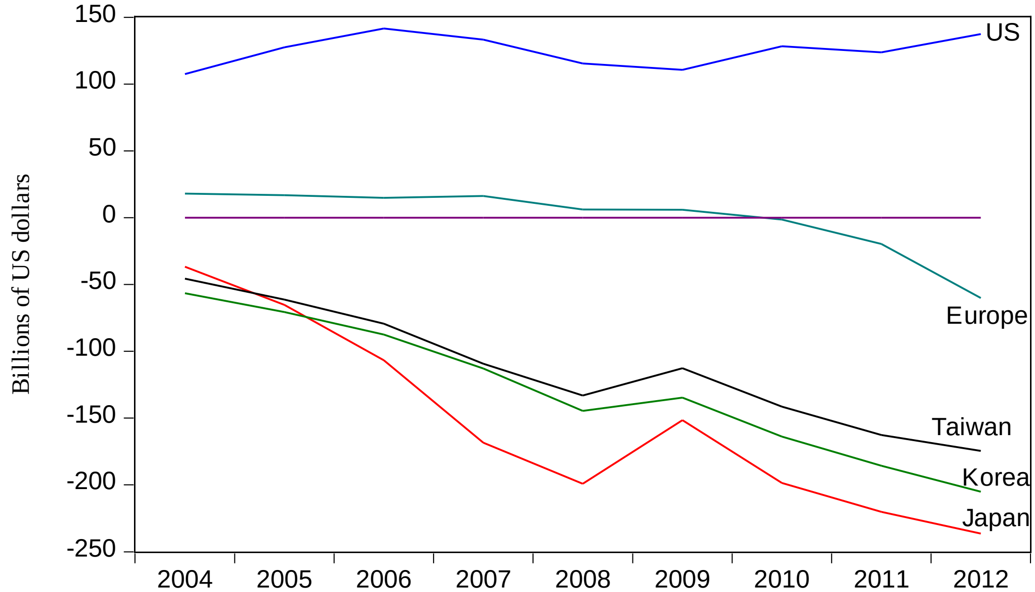

Figure A8. Results for 2004-2012 from Panel OLS Estimation of Theoretical Gravity Model with Time-varying Exporter Fixed Effects and Importer Fixed Effects.

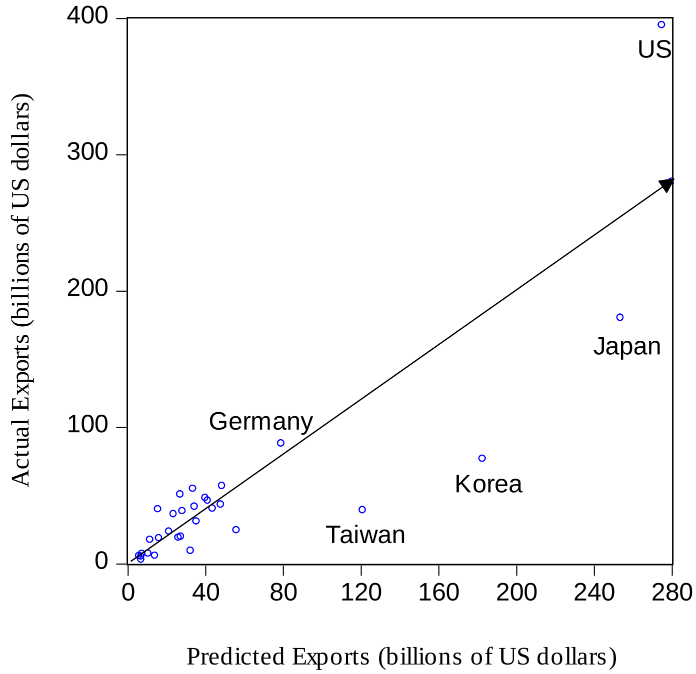

Figure A9. Results for 2012 from Poisson Pseudo Maximum Likelihood Estimation of Traditional Gravity Model with exporter, importer, and time fixed effects.

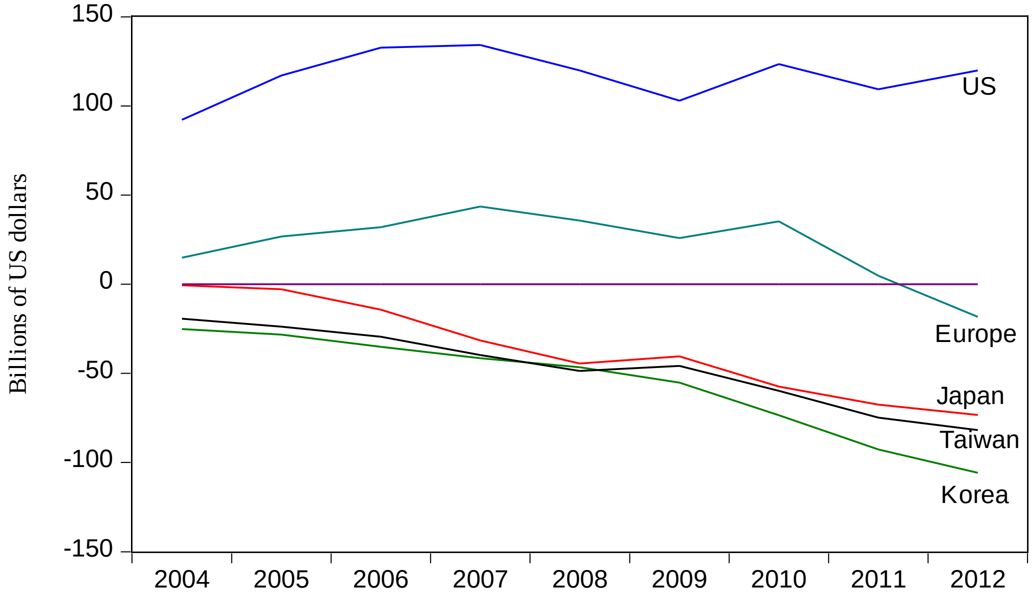

Figure A10. Results for 2004-2012 from Poisson Pseudo Maximum Likelihood Estimation of Traditional Gravity Model with exporter, importer, and time fixed effects.

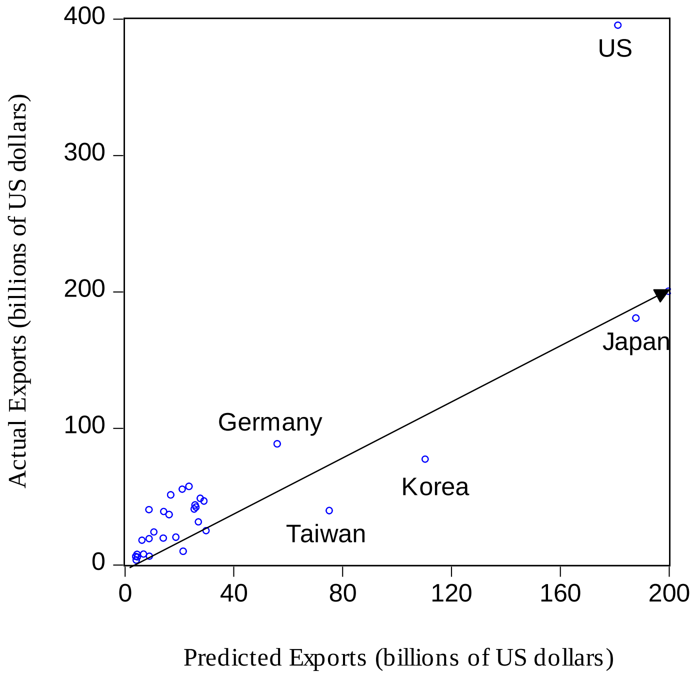

Figure A11. Results for 2012 from Panel OLS Estimation of Traditional Gravity Model with exporter, importer, and time fixed effects.

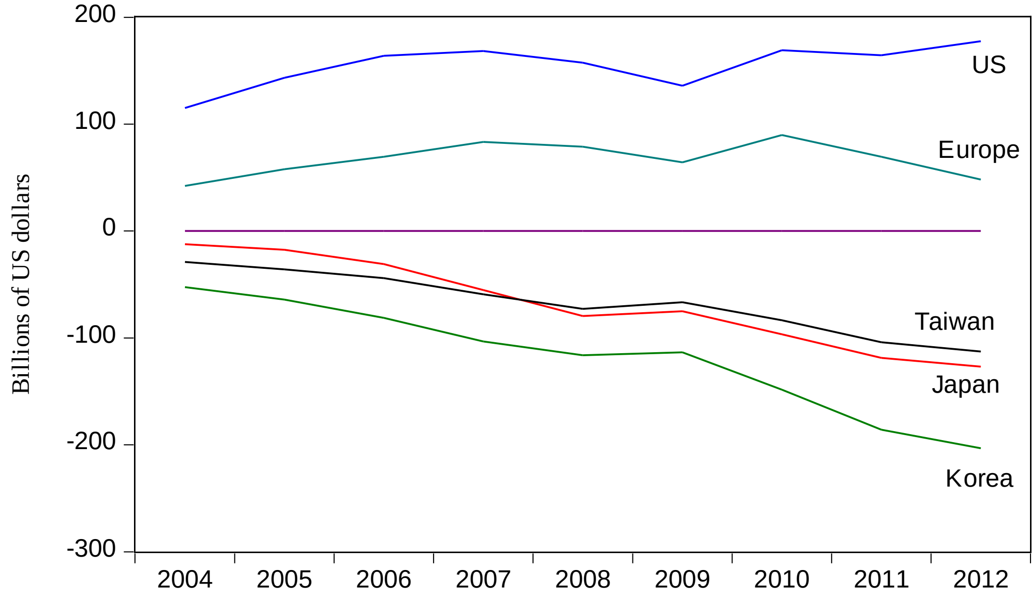

Figure A12. Results for 2004-2012 from Panel OLS Estimation of Traditional Gravity Model with exporter, importer, and time fixed effects.

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