CONTEMPORARY ECONOMIC POLICY

DOES APPRECIATION OF THE RENMINBI DECREASE IMPORTS TO THE UNITED STATES FROM CHINA?

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In 2005, China abated its fixed exchange rate against the U.S. dollar and began to appreciate the Renminbi (RMB). In this paper, I explore the effect of the appreciation of the RMB on imports to the United States from China by augmenting the gravity model with the exchange rate. Using an industrial panel data set during the period 2002–2008 and controlling for the endogeneity of the bilateral exchange rate, this extensive empirical analysis suggests that the appreciation of the RMB against the U.S. dollar significantly reduced imports to the United States from China. This finding is robust to a variety of econometric methods and to coverage in different periods. (*JEL* F1, F2)

I. INTRODUCTION

Exchange rate movement and its pass-through to changes in domestic prices have been topics of wide concern among economists. However, few studies have empirically investigated the relationship between exchange rate movements and trade flow. This paper fills this gap by investigating the effect of the appreciation of the Chinese Renminbi (RMB) on imports to the United States from China.

Today, China has replaced Mexico as the second-largest trading partner with the United States. In July 2005, China abated its fixed exchange rate to the U.S. dollar but pegged its currency to a basket of currencies. Since then, the RMB has appreciated by about 20% against the U.S. dollar, from 8.3 to 6.8 RMB per dollar. Simultaneously, China's bilateral trade surplus from the United States decreased from US$232 billion in 2006 to US$114 billion in 2008. This raises the question: has the RMB appreciation decreased the imports to the United States from China?

The economic intuition behind this question seems straightforward: The appreciation of the RMB resulted in more expensive Chinese exports; consequently, exports diminished while imports increased. However, answering the question is not, by any means, trivial. It is widely recognized that bilateral trade volumes are affected by the trading countries' gross domestic product (GDP), declining trade costs, and trade liberalization (Feenstra 1998). The appreciation of the RMB would have a pass-through effect on American import prices, which in turn would affect the amount of imports to the United States from China. By this means, the exchange rate has an effect on the domestic import price similar to that of tariffs, which has been recognized as the *symmetry* hypothesis between tariffs and the exchange rate (e.g., see Feenstra 1989). Therefore, the effect of

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ABBREVIATIONS

3SLS: Three-Stage Least-Square
CCE: Common Correlated Effects
c.i.f. cost, insurance, freight
f.o.b.: free on board
GATT: General Agreement on Tariffs and Trade
GDP: Gross Domestic Product
GMM: General Method of Moments
OLS: Ordinary Least Squares
PPI: Producer Price Index
RMB: Renminbi
SITC: Standard International Trade Classification

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exchange rate movements on bilateral trade remains an empirical issue.

The gravity model is perhaps the only one model that can successfully explain the growing trade volumes. In its simplest version, the gravity model suggests that the bilateral trade volume is directly proportional to the trading countries' GDP (Tinbergen 1962). I therefore adopt a theoretical gravity model with general equilibrium to access the effect of appreciation of the RMB on Sino-U.S. bilateral trade. The innovation of this paper is that I explicitly introduce the exchange rate into the theoretical gravity framework; hence I am able to estimate the effect of the yuan's revaluation on imports to the United States from China.[1] Extensive analysis suggests that the revaluation of the Chinese yuan significantly reduced imports to the United States from China. Chinese exchange rate movements are helpful in reducing the bilateral Sino-U.S. trade imbalance and accordingly in avoiding a possible trade war between the two countries.

This paper joins a growing literature on exchange rates and trade. As introduced by Goldberg and Knetter (1997), there are three related strands in the mainstream literature about exchange rates and goods prices. They cover the pass-through of exchange rates, the law of one price, and pricing-to-market. Feenstra (1989) finds that the symmetry hypothesis between tariffs and exchange rates is easily supported using Japanese and U.S. data. This seminal work also suggests that there is a symmetric response of import prices to changes in import tariffs and bilateral exchange rates.

Regarding the previous research on the Sino-U.S. trade and exchange rate, Thorbecke and Zhang (2006) estimate that the Sino-U.S. real exchange rate in the long run is around a unit. By including China's 33 main trading partners, Thorbecke and Smith (2010) rationalize that the appreciation of the RMB helps to rebalance China's trade. In particular, a 10% RMB appreciation leads to a decrease of 12% in ordinary exports and 4% in processing exports. The asymmetric effects of RMB appreciation on processing trade and ordinary trade are also explored by Mann and Plueck (2007). Bergin and Feenstra (2008) explore how a change in the share of U.S. imports from a country like China with a fixed exchange rate could affect the pass-through of the exchange rate to import prices in the United States. By way of comparison, the main aim of this paper is to determine how movements of the exchange rate affect imports to the United States from China when the terms of trade improvement for importers and the incomplete pass-through of the exchange rate are allowed. Last but not the least, Yu (2009) suggests that the RMB appreciation against the dollar significantly reduced China's exports to the United States but had no significant effects on China's exports to Japan by using three-stage least-square (3SLS) estimations.

To explore fully the effect of the RMB exchange rate on imports to the United States from China, my estimations are based on a theoretical gravity framework; however, I do not attempt to predict the exchange rate's influence theoretically, but rather to use a tightly specified theory to inform the empirical analysis. It turns out that the structural parameters based on the theoretical framework help us to understand the impact of the exchange rate on trade.

The remainder of this paper is organized as follows. Section II briefly introduces China's exchange rate reform in the past decade. Section III presents a theoretical gravity equation that includes the exchange rate. Section IV introduces the estimation methodology. Section V discusses the estimation results and presents robustness checks. Section VI concludes the paper.

II. CHINA'S EXCHANGE RATE REFORM

China claimed to move toward a market economy in 1992. Shortly afterward, the exchange rate in China was fixed at the level of 8.3 RMB per dollar in January 1994. During the East Asian Financial Crisis (1997–1998), many countries depreciated their own currencies to mitigate the negative shocks caused by the crisis. For example, the Thai baht was depreciated by around 40%. In contrast, China insisted on maintaining the value of the RMB at the pre-crisis level. However, in July 2005 the RMB against the dollar was revaluated at 2%. In addition, the RMB was no longer solely pegged to the U.S. dollar. The peg was changed to a basket of currencies, including the U.S. dollar and the Japanese yen, among others. Since then, the Chinese currency has appreciated to 6.83 RMB per dollar in December 2008, a 20% revaluation.

1. In this paper, I do not consider strategic trade policies used by either the home or foreign country to introduce the "terms of trade" changes. The only reason for terms of trade changes is the stylized fact that the United States is the largest economy in the world today.

Why did the Chinese government revalue the RMB in 2005? One important reason was the surging bilateral trade imbalance with the United States. From 2002 to 2006, the bilateral Sino-U.S. annual trade growth rate was more than 20%. In 2007, China had already replaced Mexico as America's second-largest trading partner when the bilateral trade total (including Hong Kong's re-exports) reached US$318 billion. Simultaneously, China also maintained a huge trade surplus with the United States. In 2004, the bilateral trade surplus was US$161 billion.

Equally importantly, the Multi-Fiber Agreements, which set an upper bound for textile exports from China to the United States, were automatically terminated in January 2005 according to the requirements set by the Agreement on Textiles and Clothing in the Uruguay Round of the GATT. As a result, China's textile exports to the United States increased dramatically. In response to demands by special interest groups, such as labor unions, the U.S. Congress threatened to impose trade sanctions on China if it did not "voluntarily" restrain its exports to the United States. To avoid a further bilateral trade war, the Chinese government agreed to revaluate its RMB against the dollar by 2% on July 21, 2005. In addition, the exchange rate was allowed to fluctuate within a restricted band.

In this paper, I focus on how the recent structural change in 2005 has affected the Sino-U.S. bilateral trade. At first glance, as shown in Figure 1, the imports to the United States from China kept an increasing trend over the years 2002–2008. Simultaneously, the Sino-U.S. exchange rate, measured as RMB per dollar, has kept declining since July 2005. Motivated by these observations, in the next section, I develop a theoretical framework aimed at exploring the relationship between exchange rate movements and bilateral trade.

III. THEORETICAL GRAVITY FRAMEWORK

Following Yu (2010), assume that each country produces unique product varieties. Let h represent the good, k the industry, and i the importer. The export of good h in industry k from country i to the importer (i.e., the United States) is identical to the consumption of good h in industry k in the United States. Exporter $i = 1,\dots,I$ has k industries. Industry $k \in K$ produces N_{ik} commodities. The United States faces an aggregate constant elasticity of substitution utility function:

$$(1)\quad U = \int_{i=1}^{I}\int_{k=1}^{K}\int_{h=1}^{N_{ik}} \left(C_{i,\mathrm{us},k}^{h}\right)^{\rho}\,\mathrm{d}h\mathrm{d}k\mathrm{d}i,\ (\rho > 0),$$

where $C_{i,\mathrm{us},k}^{h}$ is American consumption of good h in industry k produced by the country i. The elasticity of substitution σ is denoted as $\sigma = 1/(1-\rho)$.

I follow Anderson and van Wincoop (2003) and assume that, given each exporter i, $p_{i,\mathrm{us},k}^{h} = p_{i,\mathrm{us},k}^{h'}$ for all h and h' in $\{1,\dots,N_{ik}\}$, that is all the goods in industry k imported by the United States from country i have the same price $p_{i,\mathrm{us},k}$.[2] In addition, American consumption is identical over the entire line of products within industry k sold by country i, that is $C_{i,\mathrm{us},k}^{h} = C_{i,\mathrm{us},k}^{h'} = C_{i,\mathrm{us},k},\ \ \forall h \in \{1,\dots,N_{ik}\}$. Utility function (1) can then be expressed as:

$$(2)\quad U = \int_{i=1}^{I}\int_{k=1}^{K} N_{ik}\left(C_{i,\mathrm{us},k}\right)^{\rho}\,\mathrm{d}k\mathrm{d}i.$$

The representative consumer in the United States maximizes its utility (2) subject to the budget constraint:

$$(3)\quad Y^{\mathrm{us}} = \int_{i=1}^{I}\int_{k=1}^{K} N_{ik}\, p_{i,\mathrm{us},k}\, C_{i,\mathrm{us},k}\,\mathrm{d}k\mathrm{d}i,$$

where Y^{us} is the U.S. GDP. By solving this maximization problem, I obtain the demand function for each product:

$$(4)\quad C_{i,\mathrm{us},k} = (p_{i,\mathrm{us},k}/P_k)^{1/\rho-1}(Y^{\mathrm{us}}/P_k),$$

where the aggregate American price index, P_k, is defined as:

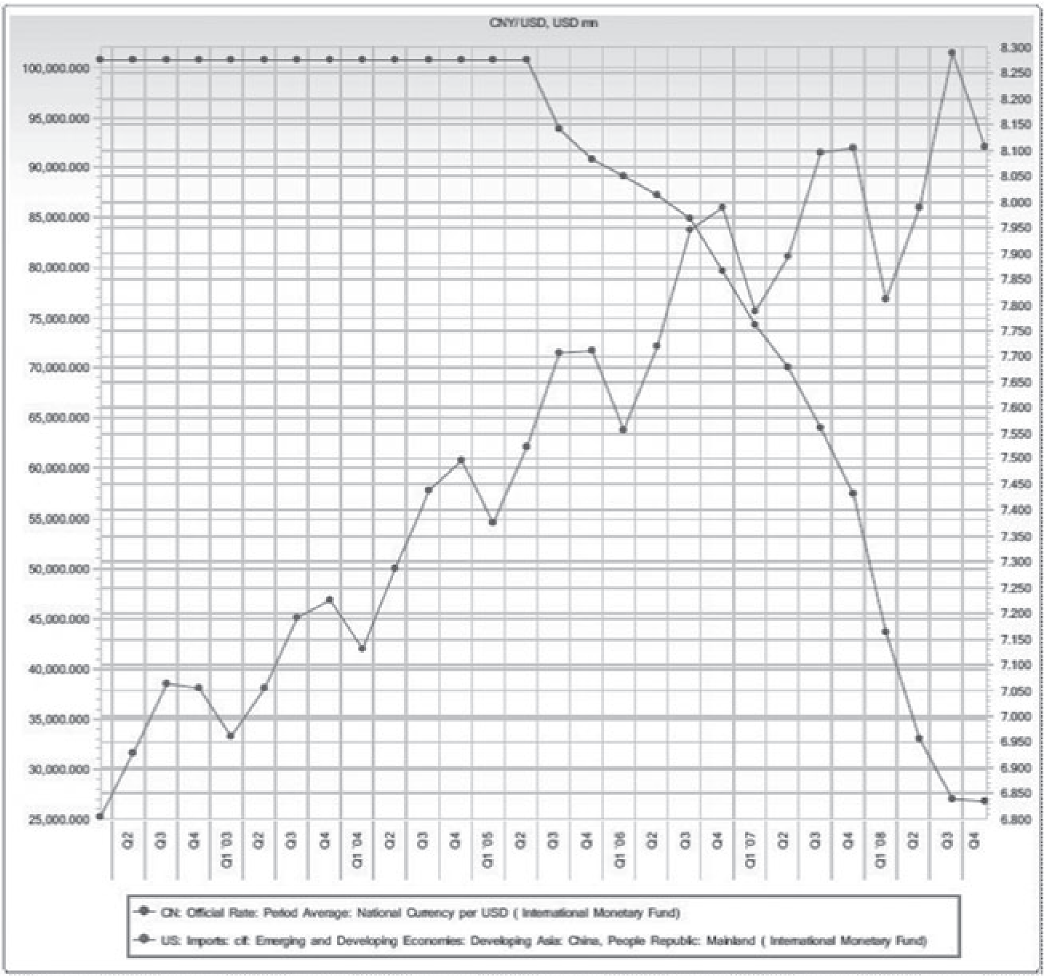
$$(5)\quad P_k \equiv \left[\int_{i=1}^{I}\int_{k=1}^{K} N_{ik}\ \left(p_{i,\mathrm{us},k}\right)^{\rho/\rho-1}\mathrm{d}k\mathrm{d}i\right]^{\rho-1/\rho}.$$

Hence, the total value of American imports from China ($i = \mathrm{ch}$) is:

$$(6)\quad X_{\mathrm{us},k}^{\mathrm{ch}} \equiv \int_{h=1}^{N_k^{\mathrm{ch}}} p_{\mathrm{ch,us},k}^{h}\, C_{\mathrm{ch,us},k}^{h}\,\mathrm{d}h = N_k^{\mathrm{ch}} p_{\mathrm{ch,us},k}\, C_{\mathrm{ch,us},k},$$

2. Note that prices of varieties are allowed to differ *across* industries. This assumption is roughly consistent with the reality: The price of a Chrysler-type automobile is close to that of a Ford, but it is very different from the price of a pencil.

FIGURE 1
The American Imports from China and the RMB Appreciation Trajectory (2002–2008)



Source: CEIC Database.

where the first equality follows the definition of export value, and the second one is because of the equal price assumption across varieties of goods. Combining Equations (4)–(6), I obtain the export value of industry k from China to the United States:

$$X_{\text{us},k}^{\text{ch}} = N_k^{\text{ch}} Y_k^{\text{us}} \left(p_{\text{ch,us},k} / P_k\right)^{\rho/1-\rho}. \tag{7}$$

However, bilateral trade is also affected by the number of varieties in the exporting country, N_k^{ch}, which is unfortunately unobservable. For estimation, I consider the monopolistic competition model presented originally by Krugman (1979), which helps us to eliminate the number of exporting varieties in my gravity equation (7).

Turning to the supply side, the representative firm in a country maximizes profits. Specifically, as in Krugman (1979), Baier and Bergstrand (2001), and Feenstra (2002), the production of goods (y_k^{ch}) incurs a fixed cost (κ_k^{ch}) and a constant marginal cost (φ_k^{ch}) given that labor (l_k^{ch}) is the representative firm's unique input in industry k:

$$l_k^{\text{ch}} = \kappa_k^{\text{ch}} + \varphi_k^{\text{ch}} y_k^{\text{ch}}. \tag{8}$$

The monopolistically competitive equilibrium implies two conditions for the representative firm. First, the marginal revenue should equal marginal cost for the representative firm. As the elasticity of demand equals the elasticity of substitution, σ, when China's number of goods N_k^{ch} is large, I obtain the first equilibrium condition:

$$\rho p_k^{ch} = \varphi_k^{ch} w^{ch}, \quad (9)$$

where the wage in China is denoted as w^{ch}.

Second, the representative firm obtains zero profits as a result of free entry. Given that the firm's profit function in China is $\pi_k^{ch} = p_k^{ch} y_k^{ch} - w^{ch}\left(\kappa_k^{ch} + \varphi_k^{ch} y_k^{ch}\right)$, I obtain the equilibrium production level, $\overline{y}_k^{ch}$, for such a representative firm in industry k in China:

$$\overline{y}_k^{ch} = \rho\kappa_k^{ch}/(1-\rho)\varphi_k^{ch},$$

where $\overline{y}_k^{ch}$ is a constant number given that ρ, κ_k^{ch}, and φ_k^{ch} are all constant parameters. By denoting the bilateral exchange rate (\$/RMB) as e, the GDP in China measured in dollars is $Y^{ch} = 1/s_k^{ch} e N_k^{ch} p_k^{ch} \overline{y}_k^{ch}$, where s_k^{ch} is the output share of industry k in China. Substituting this into Equation (7), I have:

(10)
$$X_{us,k}^{ch} = S_k^{ch} Y^{ch} Y_k^{us} / e p_k^{ch} \overline{y}_k^{ch} \left[p_{ch,us,k}/P_k\right]^{\rho/\rho-1}.$$

Therefore, bilateral trade depends on the bilateral exchange rate as well as the trading countries' GDP, China's industrial output share, the fixed production of China's representative firm, and various price indices. Note that in Equation (10), I use disaggregated industrial output to measure American income, but GDP to measure Chinese income. The reason is that I do not have data on disaggregated Chinese industrial data. For convenience, I include the main notation of the model in Table A1.

IV. EMPIRICAL METHODOLOGY

To estimate the gravity equation (10), I specify the estimating equation by taking logs on both sides:

$$\begin{aligned} \ln X_{us,k}^{ch} &= \ln(Y^{ch} Y_k^{us}) - \ln e - \ln p_k^{ch} \\ &+ \ln s_k^{ch} + (1-\sigma)\ln p_{ch,us,k} \quad (11) \\ &- (1-\sigma)\ln P_k - \ln \overline{y}_k^{ch}. \end{aligned}$$

Like tariffs, the bilateral exchange rate serves as a kind of "iceberg" trade cost across borders (Samuelson 1952). The RMB appreciation would have a partial pass-through effect on the domestic import prices in the United States. In other words, like imposing a tariff on the imports of a large country, the movement of the exchange rate lowers the exporter's (China) prices. We shall consider $p_{ch,us,k} = e(p_k^{ch})^{\delta}$, where $\delta < 1$ to capture this idea.[3] Note that $p_{ch,us,k}$ is the industrial price on a c.i.f. (cost, insurance, freight) basis, whereas p_k^{ch} is the industrial price on a f.o.b. (free on board) basis. By taking the log, we have:

$$\ln p_{ch,us,k} = \alpha_k + \ln e + \delta \ln p_k^{ch} + \mu_k. \quad (12)$$

Finally, the constant term, α_k, captures any other bilateral "border" effects that are not specified in Equation (12).

Now I obtain the estimating equation for each period by substituting Equation (12) into Equation (11):

$$\begin{aligned} \ln X_{us,kt}^{ch} &= \ln\left(Y_t^{ch} Y_{kt}^{us}\right) - \sigma \ln e_t \\ &+ (\delta(1-\sigma)-1)\ln p_{kt}^{ch} \quad (13) \\ &+ \left[(1-\sigma)\alpha_k - \ln \overline{y}_k^{ch} \ln s_{kt}^{ch}\right. \\ &\left.+ (\sigma-1)\ln P_{kt} + (1-\sigma)\mu_{kt}\right]. \end{aligned}$$

In this specification, the log directional imports to the United States from China, an indicator of trade openness, mainly depend on the trading countries' GDP, the bilateral exchange rate, and China's f.o.b. price index ($\ln p_k^{ch}$).

However, in Equation (13), in addition to the unspecified border effects (μ_{kt}), and the representative firm's production in China ($\overline{y}_{kt}^{ch}$), China's industrial output share (s_{kt}^{ch}) is unobservable. In addition, although the American aggregate price index, P_{kt}, in the specification (13) is also unobservable because it depends on the unobservable exporter's number of goods, N_k^{ch}, according to Equation (5), it is still worthwhile to use American producer price index (PPI) to serve as a proxy of American aggregate price index. Instead, all the other terms mentioned above are abstracted from the theoretical sense and may not have good empirical counterparts in the reality.[4] As a result, such terms are absorbed into the error term, ε_{kt}, which is as follows:

$$\varepsilon_{kt} = (1-\sigma)\alpha_k - \ln \overline{y}_k^{ch} + \ln s_{kt}^{ch} + (1-\sigma)\mu_{kt}.$$

Following Feenstra (1989), the expected exchange rate in each quarter is a log-linear function of the current and past three quarters'

3. Different specifications would not change the estimation results in the following section.

4. I thank a referee for suggesting this point.

average spot rates.[5] Accordingly, I have the following specification for the estimations:

$$\ln X^{ch}_{us,kt}/Y^{ch}_{t}Y^{us}_{kt} = \beta_0 \sum_{l=0}^{3} \beta_{1l} \ln e_{t-l}$$

$$+ \beta_2 \ln p^{ch}_{kt} + \beta_3 \ln P_{kt} + \varepsilon_{kt}. \quad (14)$$

Note that in this bilateral trade equation (estimate) I use trade share, $\ln X^{ch}_{us,kt}/Y^{ch}_{t}Y^{us}_{kt}$, as the regressand.[6] In this way, I can remove the endogeneity issue of having trading countries' GDP as regressors and make the present paper consistent with the numerous papers that follow Anderson and van Wincoop (2003).[7]

V. DATA, ECONOMETRICS, AND RESULTS

In this section, I first describe the data sets used in the paper, followed by a discussion of the econometric methods. I then address the possible endogeneity problems. Finally, the section concludes with various robustness checks.

A. Data

The sample covers 7 years (from the first quarter of 2002 to the last quarter of 2008). The reason for choosing this period is that the imports of the United States from China and accordingly the Sino-U.S. bilateral trade increased dramatically after China acceded to the WTO in 2001. The trade flow in the regressand of the estimate is the log of industrial imports from China to the United States at the Standard International Trade Classification (SITC) two-digit level. These directional imports are consistent with the prediction of the gravity model, which only considers one-way trade flow (Baldwin and Taglioni 2006). I also use import data to the United States rather than Chinese export data to avoid the imprecise measures because of China's re-export (from Hong Kong) situation (Feenstra and Hanson 2004). Among the independent variables, the spot exchange rate of the RMB against the dollar is measured by using quarterly average rates. The reason for not adopting the spot rate is to avoid its daily random error (Feenstra 1989).[8]

Turning to the price data, it is most appropriate to use China's wholesale unit-value f.o.b. prices to determine industrial prices in China. Unfortunately, such data are currently inaccessible. Following Baier and Bergstrand (2001), I use China's PPI to measure the f.o.b. price.[9] All data used in this paper are publicly available from the CEIC database.[10] Trading partners' GDP and GDP per capita are measured in constant U.S. dollars. Module A of Table 1 offers a concordance between the SITC two-digit categories and the PPI categories in China. Similarly, Module B of Table 1 provides a concordance between the U.S. output data and trade data at each industrial level.

B. Main Estimates

From (estimation), it is understood that bilateral trade is also affected by the representative firm's output in China ($\overline{y}^{k}_{us}$), which are unobservable. To control for these unobserved and hence omitted factors, I consider a fixed-effects specification as follows:

$$\varepsilon_{kt} = \eta_k + \phi_{yt} + \phi_{qt} + t + v_{kt}, \quad (15)$$

where η_k captures the unobserved, industry-specific, time-invariant fixed-effects, whereas t is the time trend, φ_{yt} is the year-varying fixed effects, and φ_{qt} is the quarter-varying fixed effects that capture the year (quarter)-variant factors, such as the global financial crisis in 2008. However, both the year-varying and quarter-varying fixed effects still do not completely capture the time-specific common factors here.[11] As the objective of this paper

5. Choosing different numbers of past quarterly average spot rates does not substantially change the estimation results.

6. Note that the estimation results vary very little by using trade flow as the regressand. I do not report those results in the text to save space, although available upon request.

7. I thank the co-editor for suggesting this point.

8. As pointed out by Meese and Rogoff (1983) and confirmed by Feenstra (1989), using the quarterly forward exchange rate does not change the results.

9. Note that data on PPI should be less volatile and have a lower mean than data on the wholesale unit-values f.o.b. price. As a result, using the PPI data may underestimate the economic magnitude of the price variable. However, one does not need to worry much about that because such a variable serves only as a control variable and is not the main particular interest in the paper. I thank a diligent referee for pointing this out.

10. CEIC Data Company Ltd. ("CEIC") specializes in providing high quality, comprehensive databases, focusing on Asian economic, industrial, and financial time series data. Data source: http://www.ceicdata.com.

11. Note that the 11 time-varying dummies included in the regressions here include 7 annual dummies to capture year-varying fixed effects and 4 quarterly dummies to capture the quarter-varying fixed effects, which are much fewer than the 28 year–quarter dummies when a quarter is treated as a unit of time.

TABLE 1
Concordance of Industries

Name of PPI Sectors	Sectoral Code for the Sino-US Trade
Module A: Concordance between China's PPI and Trade Sectors	
Metallurgical	20,42,43,44,45,66
Coal	16,22
Petroleum	23,24
Chemical	19,28,29,30,32,33,34,35,36,38
Machine manufacturing	46,47,48,49,50,51,52,53,54
Building materials	55,56
Timber	15,39
Food	1,2,3,4,5,6,7,8,9,10,11,12,14,21,25,26,27,31
Textile	18,41
Tailoring	57,58,59
Leather	13,37
Paper	17,40
Cultural, educational, and handicrafts article	60,61
Name of U.S. Industrial Sectors	**Sectoral Code for the Sino-US Trade**
Module B: Concordance between U.S. Industrial Sectors and Trade Sectors	
Agriculture, forestry, fishing, and hunting	1,2,3,4,5,6,7,8,9,13,14,16,21
Mining	20
Wood products	39
Nonmetallic mineral products	42
Primary metals	43,44
Fabricated metal products	45,55
Machinery	46,47,48,49
Computer and electronic products	50,51
Electrical equipment, appliances	52
Motor vehicles and parts	53
Other transportation equipment	54
Furniture and related products	56
Miscellaneous manufacturing	60,61,62
Food, beverage, and tobacco products	10,11,12,25,26,27
Textile mills and textile product mills	18,41
Apparel, leather, and allied products	37,57,58,59
Paper products	17,40
Printing and related support activities	30
Petroleum and coal products	15,22,23,24
Chemical products	19,28,29,31,32,33,36
Plastics and rubber products	34,35,38

Notes: In Module A the power industry is not included as it is not involved in the Sino-U.S. bilateral trade.

is to explore how the exchange rate variable, which has no cross-sectional variation and thus can be seen as a common time-variant factor for all industries, affects the Sino-U.S. trade, I am not able to use year-quarter-varying dummies to control completely for the time-varying fixed effect.[12] Instead, I have to rely on both the year-varying and quarter-varying fixed effects, in addition to the regular time-trend variable, and allow the exchange rate variable to pick up the residual effect after controlling for such fixed effects.

Table 2 presents the estimated effects of the value of the RMB in terms of the U.S. dollar on trade. Note that the exchange rate is measured in dollars per RMB in all the estimations. Therefore, an increase in the exchange rate indicates an appreciation of the RMB. Column (1) reports the industry-specific and time-specific fixed-effects results (estimate). The estimated coefficient of the log exchange rate in column (3) is reduced to −1.53, which implies

12. I thank a referee for insightfully pointing this out.

TABLE 2
Effects of RMB Revaluation on the Imports to the United States from China

	2002–2008				2005–2008			
Regressand: ln $(X^i_{US}/Y_i Y_{US})$	**OLS (1)**	**OLS (2)**	**IV (3)**	**IV (4)**	**OLS (5)**	**OLS (6)**	**IV (7)**	**IV (8)**
Log exchange rate $/RMB	−1.53**	−1.50**	−1.53**	−1.50**	−1.51**	−1.53**	−1.51**	−1.53**
	(−10.17)	(−9.98)	(−10.21)	(−10.03)	(−9.80)	(−9.84)	(−9.85)	(−9.91)
Log exchange rate (1-Lag)	—	0.12	—	0.12	—	0.09	—	0.09
		(1.37)		(1.37)		(0.98)		(0.98)
Log exchange rate (2-Lag)	—	0.10	—	0.10	—	0.07	—	0.07
		(1.15)		(1.15)		(0.84)		(0.84)
Log exchange rate (3-Lag)	—	0.13	—	0.13	—	0.09	—	0.09
		(1.58)		(1.58)		(1.04)		(1.05)
Log China's price index	−0.32**	−0.27*	−0.32**	−0.27*	−0.31**	−0.31**	−0.31**	−0.31**
	(−2.34)	(−1.93)	(−2.34)	(−1.94)	(−2.20)	(−2.17)	(−2.21)	(−2.19)
Log U.S. price index	0.80**	1.11**	0.80**	1.11**	1.50**	1.44**	1.50**	1.44**
	(4.88)	(5.95)	(4.90)	(5.98)	(4.83)	(4.54)	(4.86)	(4.57)
Time trend	−0.001	−0.006**	−0.102**	−0.089**	−0.004*	−0.007*	−0.110**	−0.098**
	(−1.17)	(−2.77)	(−7.28)	(−5.45)	(−1.61)	(−1.88)	(−6.22)	(−4.69)
Year-specific fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter-specific fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-specific fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
First-stage F-statistics	—	—	17.41†	24.43†	—	—	15.63†	56.29†
Kleibergen-Paap rk LM statistic	—	—	17.35†	1.06	—	—	15.51†	49.98†
Kleibergen-Paap rk Wald statistic	—	—	17.54	1.06	—	—	15.78†	56.82†
Anderson-Rubin χ^2 statistic	—	—	1.14	6.51	—	—	0.95	19.87†
Stock-Wright LM S statistic	—	—	1.14	6.48	—	—	0.95	19.45†
Prob.>F or Prob.>χ^2	.00	.00	.00	.00	.00	.00	.00	.00
Number of observations	1,730	1,544	1,730	1,544	990	990	990	990

Notes: Numbers in parenthesis are t-values.

*Significant at 1%; **significant at 5%; †The p-value of the statistic is less than 0.01. The first-stage F-statistic value reports the F-statistic result in the first-stage regression with log of current exchange rate as the regressand.

that a 1 percentage point increase in the value of the RMB tends to have a 1.53 percentage point decrease in imports to the United States from China. The coefficient of China's prices is negative and significant at the conventional level, which implies that increased export prices are associated with decreased exports from China.

In column (2), following Feenstra (1989), I include the quarterly lags of exchange rates in the regressions because the previous exchange rates might affect their current bilateral directional trade. It turns out that the coefficient of the log exchange rate in the current period remains stable and is broadly consistent with estimates in column (1). In addition, it suggests that lags of previous periods in the exchange rate have no significant effects on bilateral trade after controlling for the two-way fixed effects.

C. *Endogeneity Issues*

The bilateral exchange rate is not exogenously given, but is indeed affected by the volume of imports to the United States from China. In reality, there may be a variety of channels through which bilateral trade would reversely affect the bilateral exchange rate. One possible channel is that China's higher trade surplus from the United States could increase the U.S. political pressure on China to appreciate the RMB. In early 2005, the termination of the Multi-Fiber Agreement led to a surge in textile exports from China into the United States. As a result, the Sino-U.S. trade imbalance increased dramatically, which in turn caused special interest groups in the United States to demand that the domestic textile producers be protected. To avoid possible trade sanctions from the United States, the Chinese government agreed to appreciate the RMB against the dollar by 2% in

July 2005.[13] Moreover, the RMB was no longer pegged to the U.S. dollar alone but to a basket of currencies. Therefore, the volume of imports to the United States from China reversely affected the bilateral exchange rate.

To control for the endogeneity of the bilateral exchange rate, IV estimation is a powerful econometric method.[14] To obtain accurate estimates, I chose China's monetary stock (M1) as the instrument variable to perform the two-step general method of moments (GMM) estimation. The main reason for adopting the GMM was that it requires fewer assumptions about the error terms and has the ability to generate heteroskedasticity-robust standard errors as compared with the general least-squares method (Hall 2004). I report the estimation results of the second-stage GMM in columns (3) and (4) of Table 2.

The economic rationale for choosing M1 as an instrument for the exchange rate follows that of Bergin and Feenstra (2008): with a tight monetary policy caused by a decreasing money supply, Chinese interest rates increase. As a result, the surging demand for the RMB pushes its exchange rate up.[15] With a stronger RMB, the Chinese exports to the United States are expected to decrease. To validate this instrument variable, I performed several statistical tests.

First, the F-statistic test in the first stage shows that the instrument is highly statistically significant. The F-statistics are also definitely high enough to pass the F-test. Second, in columns (3) and (4) of Table 2 I go further to check whether such an exclusive instrument was "relevant" or not, that is, whether it is correlated with the endogenous regressor (i.e., the exchange rate). In my econometric model, the error term is assumed to be heteroskedastic: $\varepsilon_{ijt} \sim N(0, \sigma_{ij}^2)$. Therefore, the usual Anderson (1984) canonical correlation likelihood ratio test is invalid as it only works under assumption. Instead, I use the Kleibergen and Paap (2006) Wald statistic to check whether the excluded instrument correlates with the endogenous regressors. The null hypothesis that the model is under-identified is rejected at the 1% significance level.

Third, I test whether the instrument (i.e., Chinese M1) is weakly correlated with the exchange rate or not. If so, then the estimates will perform poorly in the IV estimate. The Kleibergen and Paap (2006) F-statistics provide strong evidence to reject the null hypothesis that the first stage is weakly identified at a highly significant level.[16] Finally, both the Anderson and Rubin (1949) statistic (which is an LM test) and the Stock and Wright S statistic (which is a GMM distance test) reject the null hypothesis that the coefficient of the endogenous regressor is equal to zero. In short, these statistical tests provide sufficient evidence that the instrument performs well and therefore the specification is well justified.

Column (3) of Table 2 reports the two-way fixed-effects estimation results using the Chinese M1 as an instrument. After controlling for the two-way fixed effects, the estimated magnitude of the log of the exchange rate was reduced to 1.53, which is also identical to its counterpart in column (1) without controlling for the endogeneity. In column (4), by including lags of exchange rate as additional regressions, the coefficient of current exchange rate remains stable as in previous estimations. In addition, the coefficients of the lags of exchange rate are, again, insignificant at the conventional statistical level.

D. Additional Robustness Checks

To repeat, China's exchange rate against the U.S. dollar changed after July 2005. Therefore, it is reasonable to suspect that the pass-through of the exchange rate and accordingly its impact on the bilateral trade volume are underestimated when data from before the structural change are included in the model. I therefore re-estimate the effects by including only the samples after the 2005 change.

Columns (5)–(8) of Table 2 report the Sino-U.S. estimations for the samples during

13. Although the Chinese officials would be reluctant to admit that the U.S. diplomacy has a key role to play in the development of the RMB, I thank a referee for correctly pointing this out.

14. The IV approach is a good way to control the endogeneity issues raised by various possible sources: reverse causality (i.e., simultaneity), omitted variables, and measurement errors. Wooldridge (2002, chapter 5) carefully scrutinizes this topic. Therefore, the IV estimates here control for the endogeneity caused by the reverse causality of the bilateral exchange rate as well as the one caused by the omitted variables in Equation (14).

15. One caveat here is that China currently still, to some extent, has capital control. A possible related concern is that the historical link between the money supply and the exchange rate may be weak. However, the simple correlation between the two variables in my data set is quite sizable (*corr.* = 0.47), hence the concern mentioned above should not be so severe. I thank a referee for suggesting this check.

16. Note that the Cragg and Donald (1993) F-statistic is no longer valid as it only works under the i.i.d. assumption.

2005–2008. Briefly, the point elasticity of bilateral trade with respect to the exchange rate in all the specifications has the same statistically significant signs and close magnitudes to their counterparts shown in columns (1)–(4) of Table 2. In particular, in column (5), after controlling for the two-way fixed effects, the appreciation of the RMB was found to have a similar magnitude as its counterpart in column (1) once again. Similarly, the estimate in column (6) with lags of exchange rate ascertains that lags of exchange rate have no significant effects on bilateral trade. After controlling for the endogeneity and the two-way fixed-effects, in column (8) I find that the effect of RMB appreciation on the American import from China is slightly larger than its counterpart in column (4) by using the whole sample during 2002–2008.

Moreover, columns (1) and (2) of Table 3 include both countries' GDP per capita in the estimations to check if they have significant effects on bilateral trade as these variables are standard in recent gravity models (e.g., see Rose 2004; Subramanian and Wei 2007). In column (1), China's GDP per capita has a significant and positive sign, whereas the U.S. counterparts are insignificant at the conventional statistical level. Nevertheless, the appreciation of the RMB still has a significantly negative effect on the imports to the United States from China. After controlling for the endogeneity issue in column (2), the coefficients of nominal exchange rate, as well as GDP per capita of both China and the United States still have anticipated signs, although statistically insignificant.

E. Alternative Measures on Exchange Rate

As the inflation rate in China and the United States certainly did not track exactly over 2002–2008, it is worthwhile exploring how the real Sino-U.S. exchange rate affects the American imports from China. Following previous works, such as Zhang (2001), I proxy the real exchange rate as the product of the nominal exchange rate (e) and a fraction of the American PPI (PPI_{US}) in the denominator and China's PPI (PPI_{CH}) in the numerator: $e \times PPI_{CH}/PPI_{US}$. The fixed-effects estimate in column (3) of Table 3 suggests that real exchange rate appreciation leads to low American imports from China. These results are still robust even when the three-quarter lags of real exchange rate realizations are included, as shown in column (4).

After controlling for the endogeneity of real exchange rate, the fixed-effects estimate in column (5) shows that the effect of real exchange rate on the American import from China is no longer significant. Adding the lag variables of real exchange rate in column (6) does not change the results substantially. This is possibly because of the lack of consideration of GDP per capita. Therefore, in columns (7) and (8), by including trading countries' GDP per capita, I find that the coefficients of real exchange rate turn to be significant at the conventional statistical level.

F. Further Estimates on Sectoral Heterogeneity[17]

In all the estimations above, the exchange rate variable varies over years but does not change across industries. The homogeneity assumption on the exchange rate coefficient may be acceptable if the aggregate trade flow is of interest. However, the exchange rate pass-through, as a function of market (pricing) power, would vary considerably across industries. Hence, it is important for us to study the heterogeneous effect of the exchange rate on the industry-level bilateral trade.

The common correlated effects (CCE) approach is a good way to identify such heterogeneous effects of the exchange rate across industries. As introduced by Pesaran (2006), the basic idea is to filter the industry-specific regressors by means of cross-sectional averages. In this way, as the number of industries becomes larger and larger, the differential effects of unobserved common factors converge to zero asymptotically. In particular, the CCE estimator is obtained by two steps following Eberhardt and Teal (2009). First, I perform 62 ordinary least squares (OLS) estimations by each industry i and obtain its coefficients $\hat{\mathbf{b}}_i$. Second, the CCE estimators are those averaged across sectors: $\hat{\mathbf{b}}_{CCE} = \sum_i \hat{\mathbf{b}}_i/62$.

Columns (1)–(4) of Table 4 report the estimation results by using this common factor approach to spatial heterogeneity, in which I adopt the import ratio divided by the product of trading countries' GDPs as the regressand. The point elasticity of bilateral imports with respect to the exchange rate is −0.96 in column 1, which

17. I am most grateful to two anonymous referees for their insightful suggestions on subsections V(F) and V(G).

TABLE 3
More Robustness Checks for the Imports to the United States from China (2002–2008)

	OLS	IV	OLS	OLS	IV	IV	OLS	IV
Regressand: ln(X^i_{US}/Y_iY_{US})	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Log exchange rate ($/RMB)	−1.69**	−1.81	—	—	—	—	—	—
	(−10.50)	(−1.10)						
Log real exchange rate $\frac{\$}{RMB}\frac{PPI\_CH}{PPI\_US}$	—	—	−0.56**	−0.52**	524.9	34.7	−0.57**	−0.57**
			(−4.23)	(−2.61)	(0.06)	(1.21)	(−4.16)	(−4.18)
Log real exchange rate (1-Lag)	—	—	—	−0.31	—	−18.85	—	—
				(−1.21)		(−0.51)		
Log real exchange rate (2-Lag)	—	—	—	0.35	—	35.11	—	—
				(1.36)		(1.00)		
Log real exchange rate (3-Lag)	—	—	—	−0.15	—	−15.64	—	—
				(−0.60)		(−0.73)		
Log China's price index	−0.45**	−0.56	—	—	—	—	—	—
	(−3.10)	(−0.41)						
Log U.S. price index	0.83**	0.86*	—	—	—	—	—	
	(5.03)	(1.76)						
Log GDP per capita of United States	1.06	1.00	—	—	—	—	1.31	1.31
	(0.82)	(0.67)					(0.91)	(0.91)
Log GDP per capita of China	1.24**	1.36	—	—	—	—	0.27	0.27
	(2.83)	(0.84)					(0.57)	(0.57)
Time trend	−0.03**	−0.10**	−0.003**	−0.006**	−0.261	−0.066	−0.015	−0.19**
	(−2.88)	(−4.05)	(−3.14)	(−4.58)	(−0.13)	(−0.29)	(−1.28)	(−12.30)
Year-specific fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter-specific fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-specific fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
First-stage F-statistics	—	15.74†	—	—	0.00	1.97	—	172.2†
Kleibergen-Paap rk LM statistic	—	15.72†	—	—	0.01	0.85	—	157.1†
Kleibergen-Paap rk Wald statistic	—	15.87†	—	—	0.01	0.85	—	173.4†
Anderson-Rubin χ^2 statistic	—	1.14	—	—	29.44	106.2†	—	29.64†
Stock-Wright LM S statistic	—	1.14	—	—	28.93	98.94†	—	29.12†
Prob.>F or Prob.>	.00	.00	.00	.00	.00	.00	.00	.00
Number of observations	1,730	1,730	1,730	1,544	1,544	1,544	1,730	1,730

Notes: Numbers in parenthesis are t-values.

*Significant at 1%; **significant at 5%; †The p-value of the statistic is less than .01. The first-stage F-statistic value reports the F-statistic result in the first-stage regression with log of current exchange rate as the regressand.

is smaller than its counterpart obtained by OLS in column (1) of Table 2. However, once the trading partners' per capita GDPs are considered in column (2), the coefficient of the exchange rate, −3.25, turns to be much larger than its counterpart in column (1) of Table 3: −1.69. Column (4) replaces nominal exchange rate with real exchange rate and still obtains an exact identical magnitude of the CCE estimator of the exchange rate as in column (2). Nevertheless, in any case, all the CCE estimates suggest that the appreciation of the RMB against the dollar significantly reduced the imports to the United States from China.

G. Additional Estimates with Other Competing Trading Partners

As highlighted by Anderson and van Wincooop (2003), to estimate the gravity model precisely, it is essential for researchers to control for the "multilateral resistance." The basic idea is that the bilateral trade flow is not simply affected by the two trading countries' economic factors but is also affected by factors from all other trading countries. That is, trade volumes are determined by relative export barriers but not by absolute trade barriers. Although the theoretical model above suggests that the American imports from China explicitly depend on the United States and Chinese incomes, the Sino-U.S. exchange rate, and the prices of traded goods in China and the United States, it also implies that the American imports from China are also affected by imports from other countries.[18] In fact, it is possible that the American imports from China are affected by its imports from some Asian countries that have patterns of exports similar to China.[19] Indeed, the exchange rates in such countries also adjust after the dollar depreciation against the RMB. Therefore, it is worthwhile seeing how the variations of such an American exporter's exchange rate as well as that of the RMB vis-à-vis the US dollar affect the U.S. imports.

To address this concern, I include data of Indonesia, Japan, Korea, Thailand, and Vietnam as well as China in the sample.[20] Columns (5)–(8) of Table 4 report the estimation results using such Asian sample in which the number of observations increases to 6,305. Note that here the regressands, once again, are the ratio of American import from its Asian trading partners over the product of GDPs. Column (5) reports the estimation results by including country-specific, industry-specific, and time-specific fixed effects. It turns out that the coefficient of the exchange rate has an anticipated negative sign but statistically insignificant. I suspect that this is because of the lack of the complete control for the "multilateral resistance" effect in my gravity model.

I therefore follow Baldwin and Taglioni (2006) to perform the estimates with the *time-varying country-specific* fixed effects as well as the regular industry-specific fixed effects in column (6). As the panel in my sample includes six American trading countries with 28 time spans, I generate 168 (i.e., 6 × 28) dummies for unidirectional trade data (e.g., exports from China to the United States) in addition to the regular industry-specific fixed effects. The estimation results there clearly suggest that the appreciation of the exporter's exchange rate against the U.S. dollar decreases the ratio of American imports from such Asian trading partners (i.e., the U.S. imports over the product of the two trading countries' GDPs). In particular, a 10% appreciation of the exporter's exchange rate is associated with an 11% decrease in the ratio of U.S. imports from such countries. Finally, it is also worthwhile to check the effect of real exchange rate movement on the import ratio of the United States from such trading countries. By including industry-specific and time-specific fixed effects, the estimate in column (7) clearly suggests that real exchange appreciation significantly reduces the U.S. imports from such Asian trading partners. Finally, the last column of Table 4 reports the estimate with time-varying country fixed-effects. The coefficient of log real exchange rate seems to have an unanticipated positive sign. However, one does not need to worry much on that given that it is statistically insignificant.

18. To see this point, note that the American aggregate industrial price index in the derived gravity equation (Logarithm Gravity) depends on many exporters' numbers of varieties, as shown in Aggregate Price Index.

19. I thank a referee for insightfully suggesting this point.

20. Here data of Hong Kong are not included because Hong Kong kept a fixed exchange rate against the U.S. dollar over time and hence it is impossible to explore the effects of the movement of the exchange rate on bilateral trade.

VI. CONCLUDING REMARKS

In this paper, I investigate the effect of the RMB appreciation on imports to the United States from China using industrial panel data from 2002 to 2008. In contrast to other pure reduced-form estimations, my estimations are guided by an augmented theoretical gravity model. Structural parameters based on a theoretical framework will help us to understand the magnitude of RMB revaluation on Sino-U.S. bilateral trade. The estimation results clearly suggest that the RMB appreciation against the dollar significantly reduced imports to the United States from China. These findings are robust to different econometric methods and different data periods.

This finding has policy implications. First, if appreciation of the RMB does significantly reduce the Sino-U.S. bilateral trade imbalance, then it would have the beneficial effect of relieving the trade tensions between the two giants. Second, RMB appreciation would make it more difficult for Chinese exporters to export to the U.S. *ceteris paribus*, which in turn would require Chinese exporting firms to make every effort to boost their productivity to survive in the global competition.

Several extensions and possible generalizations merit special consideration. One of them is to replace the industrial price index with

TABLE 4
Alternative Estimates of the American Imports from China and Other Asian Countries (2002–2008)

	US-China Sample				Asian Sample			
	CCE	CCE	CCE	CCE	OLS	OLS	OLS	OLS
Regressand: $\ln(X^i_{US}/Y_i Y_{US})$	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Log exchange rate	−0.96**	−3.25**	—	—	−1.05	−1.10**	—	—
	(−3.08)	(−5.60)			(−1.26)	(−2.86)		
Log real exchange rate	—	—	−0.67**	−3.25**	—	—	−2.15**	0.16
			(−2.41)	(−6.13)			(−21.56)	(0.13)
Log exporter's price index	0.41	−1.94**	—	—	0.28	0.75	—	—
	−1.22	(−3.56)			(0.27)	(0.39)		
Log U.S. price index	1.23*	2.53**	—	—	0.67	0.61	—	—
	(1.89)	(3.41)			(0.53)	(0.43)		
Log GDP per capita of United States	—	−0.37	—	2.72**	—	—	—	—
		(−0.34)		(6.84)				
Log GDP per capita of China	—	2.05**	—	2.73**	—	—	—	—
		(4.56)		(2.57)				
Time trend	−0.01**	−0.03**	−0.01**	−0.06**	−0.005	—	−0.000	—
	(−2.48)	(−4.36)	(−3.36)	(−8.12)	(−0.66)		(−0.16)	
Year-specific fixed effects	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Quarter-specific fixed effects	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Industry-specific fixed effects	No	No	No	No	Yes	Yes	Yes	Yes
Country-specific fixed effects	No	No	No	No	Yes	No	No	No
Time-varying country fixed effects	No	No	No	No	No	Yes	No	Yes
Prob.$>F$	.00	.00	.00	.00	.00	.00	.00	.00
Number of observations	1,736	1,736	1,736	1,736	6,305	6,305	6,305	6,305

Notes: Columns (1)–(4) adopt the common correlated effects (CCE) approach to perform the estimations, in which X^i_{US} denotes imports to the United States from China. In columns (5)–(8), X^i_{US} denotes imports to the United States from exporter i and the exporters include China, Indonesia, Japan, Korea, Thailand, and Vietnam. The exchange rates (e_i) in columns (1)–(4) are defined as dollar per RMB whereas those in columns (5)–(8) are defined as per exporter i's currency. There are 168 (i.e., 6 × 28) time-varying country dummies and 68 industrial dummies in the FE estimations. Numbers in parenthesis are t-values.

*Significant at 1%; **significant at 5%.

actual unit-value f.o.b. prices, if the data are available. In this manner, the exchange rate pass-through can be more precisely identified. Another possible extension is to include import tariffs in the model and to examine the symmetry hypothesis between the exchange rate and the tariffs. Because of the data constraint, I am not able to explore these issues here. However, these are some possible research topics to pursue in the future.

APPENDIX

TABLE A1
Main Notation for the Models

Symbol	**Definition**
Panel A: Theoretical Framework	
$C^h_{i,\text{us},k}$	Amount of goods h of industry k produced in country i and consumed in the United States
N_{ik}	Number of goods of industry k produced in country i
σ	Elasticity of substitution, $\sigma > 1$

TABLE A1
Continued

Symbol	Definition
e	Sino-U.S. bilateral exchange rate ($/RMB)
Y^{ch}	Level of GDP in China
Y_k^{us}	Output level of industry k in the United States
$p_{\text{ch,us},k}$	Price of industry k on an American c.i.f. basis
$p_{\text{ch},k}$	Price of industry k on a f.o.b. basis
$X_{\text{us},k}^{\text{ch}}$	Value of exports of industry k from China to the United States
P_k	American aggregate price index of industry k
w^{ch}	Wages in China
l_k^{ch}	Labor input for the representative firm of industry k in China
y_k^{ch}	Output of China's representative firm of industry k, which is a fixed number in equilibrium: $y_k^{\text{ch}} = \overline{y}_k^{\text{ch}}$
κ_k^{ch}	Fixed cost for the representative firm of industry k in China
s_k^{ch}	Industry k's output share in China
ϕ_k^{ch}	Constant marginal cost for the representative firm of industry k in China
Panel B: Empirical Specification	
α_k	Unspecified industrial bilateral border effect
ε_{kt}	Error term in specification (estimate)
η_k	Industry-specific random variable
φ_{yt}	Year-specific random variable
φ_{qt}	Quarter-specific random variable
ν_{kt}	Industrial idiosyncratic random variable

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