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The asymmetric impact of exchange rate changes on bilateral trade balance: evidence from China and its trade partners

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ABSTRACT

The purpose of this paper is to re-examine the impact of exchange rate changes on the trade balance of China and its major trading partners. In the past, many studies have been focussed on the linear effect of exchange rate change, but in this paper, a non-linear Autoregressive Distribution Lag (NARDL) model is proposed. Empirical results show that there are nonlinear and asymmetric effects on the trade balance of exchange rate. In particular, the effect of exchange rate appreciation on Sino-US trade balance is more significant than that of depreciation. A genuine devaluation of the domestic currency would improve the balance of the domestic trade. However, the opposite effect is found in the case of Sino-Japan and the Euro, and the depreciation of the currency will make the trade balance worse. These results provide a solid basis for understanding the relation of exchange rate variation and trade balance. In terms of economic reality, it is also a useful reference for adjusting exchange rate and commercial policy.

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1. Introduction

The impacts of exchange rate fluctuations on trade have always been a long-standing issue, which has aroused the concern of scholars and authorities. Since the outbreak of COVID-19, global uncertainty has increased significantly, and exchange rate fluctuations have also become more intense. Coupled with the rise of trade protectionism, people's attention to the relation of exchange rate and trade has once again strengthened. However, early studies were based on the linearity and symmetry hypothesis, which were not in line with reality. Until recently, there has been a new trend to relax the symmetry hypothesis in related research. More and more works of literature recognise that even if the magnitude of currency depreciation or appreciation is the same, it affects a country or region's trade balance in different directions and degrees.

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In other words, there is a growing acceptance of the idea that the impact of exchange rate fluctuations on the trade balance is asymmetric. According to the view given by international trade theory, the reason why exchange rate changes can influence or improve a country's trade balance is that the currency's depreciation or appreciation can be reflected in the price of the goods traded. But prices are quick to react to changes in exchange rates, but the trade balance is slow and asymmetric. On this basis, the NARDL approach is applied to find evidence to support the argument that exchange rate variation has an asymmetry relation.

In this paper, China is chosen as the research target, which has always been a large trading country. According to data from the World Trade Organization, the growth rate of Chinese external trade exceeds that of the world's 65 largest economies. In this paper, we review the relationship between Chinese exchange rate and trade balance with its three major trading partners. The Chinese Foreign Trade Situation Report Autumn 2019 shows that the European Union, the United States and Japan are among the main trading partners of China. These three economies play a vital role in China's economy and trade, accounting for a third of China's total trade. The trade volume between each country and China accounts for 15.6%, 12%, and 6.9% of China. Nevertheless, the rise of the 'COVID-19'and trade protection and other things that aren't certain have greatly influenced the stabilisation of the steady improvement of trade and RMB's exchange rate. Therefore, the study of China's exchange rate fluctuations and bilateral trade balance should receive more attention. In this paper, we use the NARDL model to study the relation between exchange rate variation and trade balance.

All the time, In exploring the relationship between exchange rate changes and trade balance, many scholars have made a lot of efforts (Hacker & Hatemi, 2004; Miles, 1979; Sahoo et al., 2019; Stone & Haynes, 1982). However, due to the different periods under consideration, the exchange rate system and the methodology, their results are different in terms of signs, extent and importance. Many studies have not really paid attention to this asymmetry, which exists between the exchange rate and the trade balance. In this paper, the non-linear and asymmetric relation of exchange rate and trade balance are analysed. And the NARDL method is adopted to study this relationship more accurately. On the other hand, many studies focus on total trade data (Augustine et al., 2017; Kim, 2007). But it can result in aggregation bias, as the trade flows of different countries are likely to react differently to exchange rate changes. In this paper, we use bilateral rather than aggregate data to reduce bias, which can more support this asymmetry strongly. It is found that there is an asymmetric relationship between long-term and short-term exchange rate fluctuations and trade balance.

Compared with the previous research, this paper provides some notable contributions. Firstly, the linear and symmetric assumptions are relaxed, and the NARDL model is used to examine the asymmetry of exchange rate on the trade balance. The NARDL model, which is an extension of Autoregressive Distributed Lag (ARDL), provides a novel nonlinear nonsymmetric cointegration approach. This model can be divided into two parts, which can be used to verify the moderating effect of positive and negative variation on the explanatory variables. The NARDL method largely overcomes the defects of the previous linear and symmetric assumptions. Secondly, this paper makes use of the data of the bilateral real exchange rate and the bilateral trade balance between China and its main trading partners to overcome the 'aggregate bias', and improves the validity of the test results. Finally, this paper draws results that are different from most previous studies.

The result of this thesis is that the change of RMB's bilateral real exchange rate has a significant asymmetry effect on bilateral trade balance. In addition, in China and the United States, we have found that a drop in the RMB exchange rate would add to the United States trade surplus and improve the bilateral trade balance. However, the depreciation of the RMB will reduce Chinese trade surplus. That is, RMB real exchange rate depreciation did not improve the trade balance. Just as with the European Union, the devaluation of the RMB will also reduce the Chinese trade surplus with Japan. This means that the Marshall-Lerner condition can be implemented only between the United States and China, but neither the European Union nor Japan. Clearly, our results are inconsistent with previous research. Moreover, the asymmetric effect of the exchange rate on the trade balance is probably related to the structure of the trade product and the elasticity of commodity. We will give a detailed analysis in the empirical section.

The paper's remaining part proceeds as follows: The second part is literature review. The third part discusses model and estimation method. The fourth part is the data description and analysis of data. The fifth part is the demonstration result analysis. The last part are conclusions and policy recommendations.

2. Literature review

The effect of exchange rate changes on trade balance has always been an issue of great concern to scholars, and the literatures is rich, which explain the relationship between the two in several ways. However, scholars have not reached a unified view and opinion on this issue. This article will review the existing literature from three aspects.

From the perspective of exchange rate theory, previous studies were mainly based on Marshall-Lerner conditions or J-Curve effects. Firstly, in the study of the Marshall-Lerner Condition, early scholars believed that the is easy to satisfy because the sum of price elasticities is greater than one; therefore, the depreciation of the domestic currency will improve the trade deficit (Arize, 1990; Goldstein & Khan, 1978; Shirvani & Wilbratte, 1997). However, with the exchange rate changes and the trade development, scholars have found that the Marshall-Lerner condition is not perfect (Are, 2019). Mahmud et al. (2004) confirmed that the Marshall-Lerner condition is more likely to be satisfied only under a fixed exchange rate system. Furthermore, Carnevali et al. (2020) pointed out that the Marshall-Lerner condition is only a special case because it has an implicit assumption that exchange rate fluctuations will be completely converted into commodity prices. In fact, the Marshall-Lerner condition is not even a 'useful approximation' of a general condition. As to whether the Marshall-Lerner condition is satisfied, no consensus has been reached yet. Whether to meet the Marshall-Lerner condition should probably depend to a greater extent on the trade situation of the specific country or region under study. On the other hand, the J-Curve effect is another theoretical basis for the study. The same as the Marshall-Lerner condition, there is no consensus on whether the J-Curve effect exists. Some scholars believed that there is a J-Curve effect (Bahmani-Oskooee et al., 2017; Gurtler, 2019; Hacker & Hatemi, 2004; Paz & Gomes, 2005; Wang, 2012). However, other scholars held the opposite view (Akbostanci, 2004; Narayan, 2006; Shahbaz et al., 2012; Yazgan & Ozturk, 2019), they believed that the J-Curve effect does not exist.

In the past, most of the research was based on linear and symmetric analysis, so that the asymmetry of exchange rate fluctuations and trade balance was neglected. But it is a fact that the way in which traders react and how much they react to currency appreciation and depreciation varies. On the contrary, more and more researches focus on the asymmetric impact of exchange rate changes on the trade balance (Bahmani-Oskooee & Fariditavana, 2014; Nguyen et al., 2019; Verheyen, 2013). Verheyen (2013) has discovered exports react asymmetrically to the appreciations and depreciation of the Euro by introducing nonlinearity in the inspection process for the first time. Bahmani-Oskooee and Fariditavana (2014) put forward again a reason for failing to detect exchange rate changes' important impacts on trade balance may be the adoption of linear patterns. Once they adopted the non-linear pattern, they could actually present that the changes within exchange rates significantly influence trade balance and the impact was asymmetric. Olufemi (2019) also came up with asymmetric results based on Uganda's data. At the micro-level, Bahmani-Oskooee and Gelan (2020) carried out an empirical study on trade performance in 25 United States and South Africa. He also arrived at the same asymmetry when he used data from the United States and South Korea.

It was found that there was an asymmetry in the real exchange rate on the balance of trade. It is also worth noting that although some scholars have paid attention to the asymmetric relationship between exchange rate fluctuations and trade balance, most of them employ trade balance data at the aggregate level between one country and the rest of the world (Augustine et al., 2017; Kim, 2007), which lead to the so-called 'aggregation bias' problem. Therefore, we consider the trade data of China and its main trading partners at the bilateral level to avoid this deviation. In fact, the use of bilateral data can indeed improve the aggregation bias (Baak, 2007; Hooy & Baharumshah, 2015). Bahmani-Oskooee and Baek (2021) also used bilateral data in his research to study the asymmetry of Korean-U.S. commodity trade. Both Bahmani-Oskooee and Baek (2021) and our study involve asymmetry, but our research objects and results are very different. Firstly, the objects are different. In this paper, China is our main research object because of its important position in the world economy and trade. Our focus is on the asymmetry of exchange rate fluctuations and bilateral trade balances, based on data from China and its trading partners, as well as on how policy authorities should operate in the context of this asymmetry. However, Bahmani-Oskooee and Baek (2021) focussed on Korea's micro enterprises. Secondly, the research conclusions are different. Our study shows that there is a significant non-linear and asymmetric influence on the trade balance. Both positive and negative impacts of exchange rate change have different signs and sizes. In particular, the effect of exchange rate appreciation on Sino-US trade balance is more significant than that of depreciation. A real depreciation in the domestic currency would improve the balance of the domestic trade. However, the opposite effect is found in the case of Sino-Japan and the Euro, and the depreciation of the currency will make the trade balance worse.

In light of all that has been said so far, most of the literature has examined the relationship between the exchange rate and the balance of trade on the basis of linear models. Relatively few studies have focused on the nonlinear and asymmetric effects of exchange rate fluctuations on the trade balance. Moreover, there is little research on the effect of RMB exchange rate on the bilateral trade balance. Previous studies have provided a clear idea for this thesis. In this paper, we use the asymmetrical NARDL method to analyse the effect of RMB exchange rate fluctuation on Chinese trade balance. Then, based on the research findings, the relevant policy recommendations are proposed.

3. The model and estimation method

In this paper, we use the NARDL method which was shown in a paper by Shin et al. (2014). NARDL, which extends the Autoregressive Distribution Lag (ARDL) model in terms of asymmetry and nonlinearity, breaks down the explanatory variables into a sum of positive and negative variations, to capture both short-and long- term nonlinearity and asymmetry. NARDL also allows the relationship to show short-term asymmetry, long-term asymmetry, or a combination of both.

The structure of the model is as follows. First, the variation in the explanatory variable x_t is divided into positive or negative variations (Hatemi, 2012):

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j, 0) \tag{1}$$

$$x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min(\Delta x_j, 0) \tag{2}$$

$$x_t = x_0 + x_t^+ + x_t^- \tag{3}$$

where x_t^+ and x_t^- represent the positive and negative sum of the explanatory variables, respectively, and, $\Delta x_t = x_t - x_{t-1}$. Then, we examine the effects of the variation of the independent variables. Equation (4) gives the expression for the asymmetric covariance:

$$y_t = \beta^+ x_t^+ + \beta^- x_t^- + \mu_t \tag{4}$$

where y_t is the explanatory variable. β^+ and $\beta^-$are the parameters that represent a long run relationship, and $\mu_t \sim iid(0, \sigma_\mu^2)$.

Taking into account the short- and long-term asymmetry, Shin et al. (2014) extends the Equation (4). Thus, a broader, cointegrated NARDL has been developed that reflects both long-term and short-term asymmetric adjustment dynamics:

$$\Delta y_t = \rho y_{t-1} + \theta^+ x^+_{t-1} + \theta^- x^-_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \sum_{i=1}^{q-1} (\pi_i^+ \Delta x^+_{t-i} + \pi_i^- \Delta x^-_{t-i}) + \varepsilon_t \tag{5}$$

This model can also be expressed as:

$$\Delta y_t = \rho \xi_{t-1} + \sum_{i=1}^{q_1} \gamma_i \Delta y_{t-i} + \sum_{i=0}^{q_2} (\pi_i^+ \Delta x^+_{t-i} + \pi_i^- \Delta x^-_{t-i}) + \varepsilon_t \tag{6}$$

where q_1 and q_2 represent the maximum value of the lag order of dependent and explanatory variables, and $\varepsilon_t \sim iid(0, \sigma^2_\varepsilon)$, $\xi_{t-1} = y_{t-1} - \beta^+ x^+_{t-1} + \beta^- x^-_{t-1}.\beta^+ = -\theta^+/\rho$ and $\beta^- = -\theta^-/\rho$ are the coefficients that capture the long-term relationship. π_i^+ and π_i^- are the coefficients that capture the short-term relationship.

We refer to the research of Augustine (2017), and set the trade equation between China and its core trading partners from China's point of view:

$$\ln TB_t = \alpha_0 + \alpha_1 \ln REX_t + \alpha_2 \ln Y_t + \alpha_3 \ln Y_t^f + \varepsilon_t \tag{7}$$

In this case, TB_t represents China's trade balance with its trading partners, and TB_t is measured by the ratio of Chinese exports to imports. Both imports and exports are denominated in dollars. Y_t and Y_t^f represent the income of China and the trading partners, respectively. REX_t represents the bilateral real exchange rate under the indirect pricing method between China and the trading partners, which increase may reflect the appreciation of RMB;ε_t is a disturbance term, $\varepsilon_t \sim iid(0, \sigma^2_\varepsilon)$.

However, Formula (7) only takes into account the linear effect of exchange rate on the trade balance, and does not consider the impact of asymmetry on the trade balance.

Next, we expand Equation (7) to NARDL based on the work of Shin et al. (2014):

$$\ln REX_t^+ = \sum_{i=1}^{t} \Delta \ln REX_t^+ = \sum_{i=1}^{t} \max(\Delta \ln REX_t^+, 0) \tag{8}$$

$$\ln REX_t^- = \sum_{i=1}^{t} \Delta \ln REX_t^- = \sum_{i=1}^{t} \max(\Delta \ln REX_t^-, 0) \tag{9}$$

In addition, the asymmetric co-integration of the exchange rate and the trade balance can be expressed by Equation (10):

$$\ln TB_t = \beta^+ \ln REX_t^+ + \beta^- \ln REX_t^- + \mu_t \tag{10}$$

The trade balance equation based on the NARDL method can be expressed as the following:

$$\begin{aligned}\Delta\ln TB_t = {} & \rho\ln TB_{t-1} + \theta_1\ln REX^+_{t-1} + \theta_2\ln REX^-_{t-1} + \theta_3\ln y_{t-1} + \theta_4\ln y^f_{t-1} \\ & + \sum_{i=1}^{q_1}\gamma_{i1}\Delta\ln TB_{t-1} + \sum_{i=1}^{q_2}\gamma_{i2}\ln REX^+_{t-1} + \sum_{i=1}^{q_3}\gamma_{i3}\Delta\ln REX^-_{t-1} \\ & + \sum_{i=1}^{q_4}\gamma_{i4}\Delta\ln y_{t-1} + \sum_{i=1}^{q_5}\gamma_{i5}\Delta\ln\ln y^f_{t-1} + \varepsilon_t\end{aligned} \tag{11}$$

where q_1, q_2, q_3, q_4, q_5 are the maximum lags order of each variable. $\beta^+ = -\theta^+/\rho$ and $\beta^- = -\theta^-/\rho$ are the long-term influence coefficient. Equation (11) shows the possibility that asymmetry will occur in just the short-term, long-term, or in both. We estimate Equation (11) by following steps:

First, it is assumed that there are no restrictions on the model, to estimate Equation (9) using a normal Least Squares (OLS) method.

Secondly, we examine the long-term stability of exchange rate fluctuation and trade balance. In this case, t-test and F-test are used as the main bound test to examine the cointegration relationship. The null hypothesis of t_{BDM} is $H_0 : \rho = 0(H_1 : \rho<0)$. $\rho<0$is to be able to make the model we apply dynamic and balanced. The F-test tests the null hypothesis that $H_0 :\ \theta_1 = \theta_2 = 0$.

Third, the Wald test is applied to verify the short-and long-term asymmetry between the exchange rate and the trade balance. $\beta^+ \neq \beta^-$ means that asymmetry exists.

Finally, the dynamic asymmetry response of the trade balance to the sum of the unit impact of exchange rate is calculated.:

$$m_h^+ = \sum_{j=0}^{h}\frac{\partial\ln TB_{t+j}}{\partial\ln REX_t^+}, m_h^- = \sum_{j=0}^{h}\frac{\partial\ln TB_{t+j}}{\partial\ln REX_t^-}, h = 0, 1, 2, \ldots \tag{12}$$

where $h \to \infty$, $m_h^+ \to \beta^+$, $m_h^- \to \beta^-$. If the asymmetric error correction model is not constructed directly, and only the asymmetric dynamic multiplier is obtained, the asymmetric adjustment path of the variable may still be observed. This is an outstanding characteristic of the nonlinear distributed lag model.

4. Data

4.1. Data description

The NARDL model about exchange rate and trade balance is estimated for China to partners using quarterly data over the period 2000: Q1-2020: Q4. The three trade partners examined in this study are The United States, Japan and the European Union. The variables considered in this paper are TB, REX, $Y$and Y^f. Among that, $TB$is the bilateral trade balance, measured by the ratio of exports to imports. REX is the bilateral exchange rate between China and the trading partner, expressed in indirect quotation method.$Y$and$Y^f$are the values of GDP in China and the trading partners respectively, priced in US dollars.

Figures 1 and 2 portray the fluctuations of the real exchange rate and bilateral trade since 2000. As you can see from Figure 1, Sino-US exchange rate fluctuations show an appreciation trend. After the financial crisis, the appreciation of the RMB

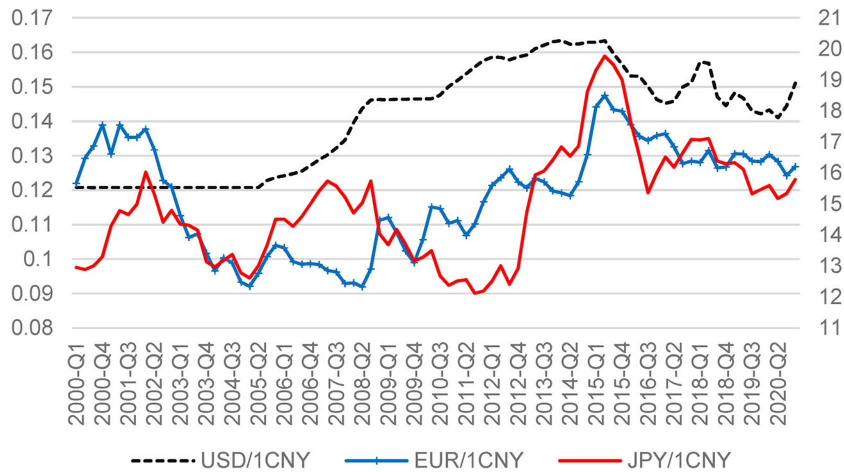

Figure 1. Plot of volatility measure of the real exchange rate (REX).
Source: IMF's International Financial Statistics.

against the U.S. dollar has slowed, but the trend of appreciation has been maintained. Overall, the RMB has appreciated against the yen. RMB appreciated against the euro first, then depreciated and appreciated again. Observing Figure 2, we can find that the Sino-US trade balance is less than 0 during the sample period. The Sino-Japanese trade balance is greater than 0. This suggests there is trade deficit with the US, and trade surplus with Japan and the EU from China's point of view.

In order to clearly understand the nature of the data, we generate descriptive data for all variables and display them in Table 1. Table 1 reports the mean, skewness Kurtosis, and the Jarque-Bera of all data from each case, respectively. The data shows that from a statistical point of view, there is a significant difference between the bilateral real exchange rate data and the bilateral trade balance data.

It was tested that only the data for GDP is seasonal while the other data is not (as shown in Figure 3). Therefore, we adjusted the time series of GDP for seasonality. The article uses the Census X-12 method to seasonally adjust the data. Figure 4 shows the time series trend graph excluding seasonality. In the empirical tests that follow, we will base our analysis on the seasonally adjusted GDP data.

4.2. Unit root test

The precondition for the NARDL method's operation is that there must be a long-term stable relationship between variables. Therefore, in this paper, we first test the stationarity of the variable sequence by the unit root test to verify whether there are integral of order two, I(2). Referring to previous literature, the general method to test data stationarity is the Augmented Dickey-Fuller (ADF) method. The results of the test are given in Table 2. We also tested this by using the PP method, the results of which are presented in Table 3. The results indicate that no variable is integrated as I (2), which satisfies the assumptions of nonlinear ARDL model.

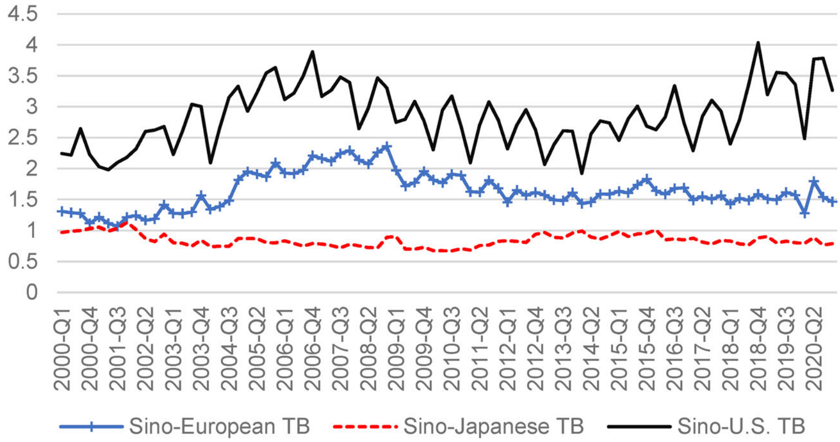

Figure 2. Plot of volatility measure of the trade balance (TB).
Source: IMF's Direction of Trade.

Table 1. Descriptive statistics.

	Trade partner	USA	Japan	EU
TB	Mean	2.848848	0.846695	1.634641
	Median	2.786780	0.832117	1.586365
	Maximum	4.034387	1.129674	2.357754
	Minimum	1.921568	0.674850	1.067858
	Std.Dev.	0.486645	0.100498	0.301830
	Skewness	0.183236	0.452445	0.392904
	Kurtosis	2.424315	2.640666	2.609399
	Jarque-Bera	5.167706	3.317814	2.695218
	Probability	0.075483	0.190347	0.259861
REX	Mean	0.140924	14.92419	0.118265
	Median	0.146025	14.79040	0.121696
	Maximum	0.163462	19.76719	0.147517
	Minimum	0.120785	12.12250	0.091993
	Std.Dev.	0.015473	1.801226	0.015291
	Skewness	−0.15476	0.571138	−0.16004
	Kurtosis	1.526254	2.976350	1.827787
	Jarque-Bera	7.937121	4.568732	5.167706
	Probability	0.018901	0.101839	0.075483

Source: Author's estimation.

4.3. Co-integration test

Table 4 shows the final cointegration test results. The test minimum value is 4.7155 from the USA, the maximum value is 6.2758 from Japan. In all three cases, the values of F_{PSS} exceed the upper limit of critical value at the 1% level, which implies the existence of a cointegration relationships among the variables.

5. Empirical results

5.1. Asymmetric result

After providing proof that all variables meet the necessary conditions for a NARDL model, we turned our attention to the technology itself. The results of NARDL model are reported respectively in Tables 5 and 6, and the results of long- and short-run asymmetry tests by Wald test are summarised in Table 7.

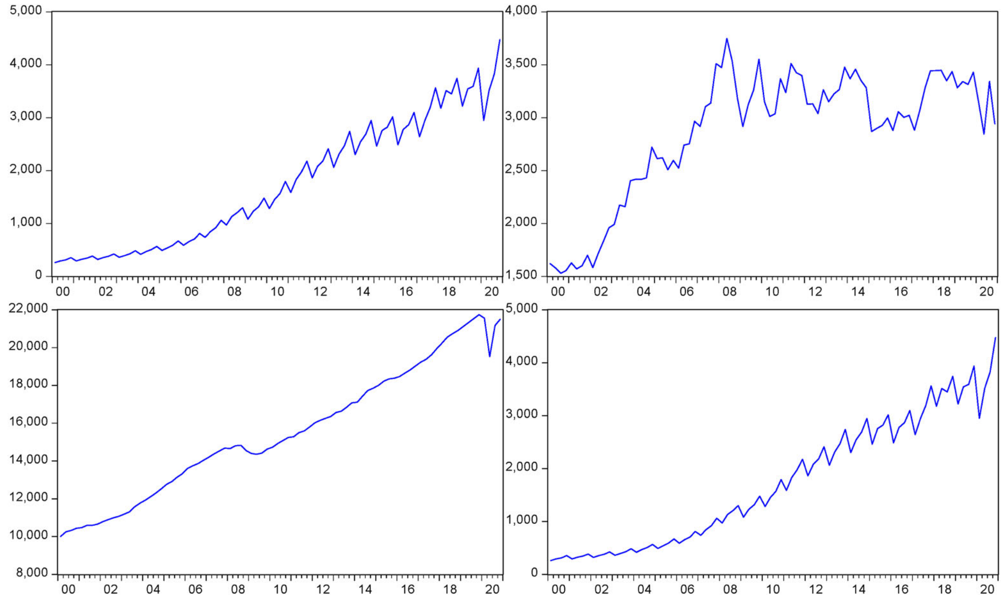

Figure 3. Plot of GDP by economy (before seasonal adjustment).
Source: Author's estimation.

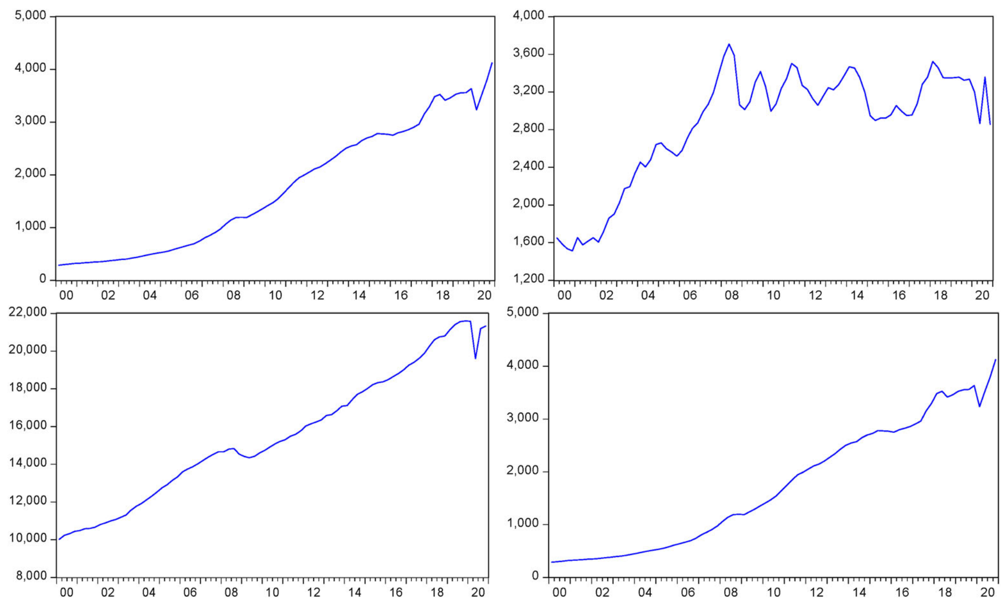

Figure 4. Plot of GDP by economy (after seasonal adjustment).
Source: Author's estimation.

The superscripts '+'and '-' represent positive and negative changes of variables, respectively.

Table 5 reports that the long-run results of non-linear ARDL model, which are represented by (β^+, β^-). We focus on the values and signs of $\beta^+$and β^-.The long-

Table 2. Time series properties of the variables (with trend and first difference).

	Time series properties					
	ADF $H_0: X_t \sim I(1)$ $H_a: X_t \sim I(0)$			ADF $H_0: X_t \sim I(0)$ $H_a: X_t \sim I(1)$		
	With trend			First difference		
Trade partner	*TB*	*REX*	Y^f	*TB*	*REX*	Y^f
USA	−2.2083*	−1.3327	0.0290	−4.5153***	−3.4952**	11.4895***
	($p = 0.2051$)	($p = 0.6108$)	($p = 0.9580$)	($p = 0.0004$)	($p = 0.0106$)	($p = 0.0001$)
EU	−2.0189	−1.7983	−2.1604	−3.8111***	−6.0840***	−6.7795***
	($p = 0.2783$)	($p = 0.3790$)	($p = 0.2223$)	($p = 0.0042$)	($p = 0.0000$)	($p = 0.0000$)
JAPAN	−2.9411**	−2.2879	−2.8627*	−4.2942***	−6.5571***	−3.7629**
	($p = 0.0452$)	($p = 0.1783$)	($p = 0.0544$)	($p = 0.0009$)	($p = 0.0000$)	($p = 0.0049$)

Note: ***, ** and * represent significance level of 1%, 5% and 10%, respectively.
Source: Author's estimation.

Table 3. Time series properties of the variables (with trend and first difference).

	Time series properties					
	PP $H_0: X_t \sim I(1)$ $H_a: X_t \sim I(0)$			PP $H_0: X_t \sim I(0)$ $H_a: X_t \sim I(1)$		
	With trend			First difference		
Trade partner	*TB*	*REX*	Y^f	*TB*	*REX*	Y^f
USA	−4.8793***	−1.2043	0.099873	−16.5594***	−5.1587**	12.1651***
	($p = 0.0001$)	($p = 0.6694$)	($p = 0.9639$)	($p = 0.0001$)	($p = 0.0106$)	($p = 0.0001$)
EU	−2.1668	−1.4783	−2.1363	−11.9887***	−6.9411***	−10.7428***
	($p = 0.2199$)	($p = 0.5397$)	($p = 0.2313$)	($p = 0.0001$)	($p = 0.0000$)	($p = 0.0001$)
JAPAN	−3.2488**	−2.0053	−2.6051*	−20.9218***	−6.6235***	−10.9481***
	($p = 0.0206$)	($p = 0.2841$)	(p=.0960)	($p = 0.0001$)	($p = 0.0000$)	($p = 0.0001$)

Note: ***, ** and * represent significance level of 1%, 5% and 10%, respectively.
Source: Author's estimation.

Table 4. Cointegration tests.

Trade partner	F_{PSS}	Significance level	Critical value
USA	4.7155***		
		10%	3.09
		5%	3.49
		1%	4.37
EU	5.6714***		
		10%	3.09
		5%	3.49
		1%	4.37
JAPAN	6.2758***		
		10%	3.09
		5%	3.49
		1%	4.37

Note: *** represent significance level of 1%.
Source: Author's estimation.

term coefficient (β^+, β^-) captures the change in the trade balance when the exchange rate changes by 10%. As shown from the Table 5, in United States, $\beta^+$is equal to **−3.6999**, which means that if the exchange rate increases by 10%, then the trade balance will worsen by 3.69%.The variable $\beta^-$is the negative long-term coefficient and the value is equal to -1.27314, which means that if the exchange rate decreases by 10%, then the bilateral trade balance will be improved by 3.69%. From the long-term

Table 5. The long-run results of non-linear ARDL model.

Trade partner Variables	USA	EU	Japan
$lntb_{t-1}$	−0.4903***	−0.302683***	−0.579199***
$lnrex^{+}_{t-1}$	−1.814082**	1.122956**	1.611382***
$lnrex^{-}_{t-1}$	−0.624221	0.372254	1.256416***
lny_{t-1}	0.178672	−0.610093**	−0.368519***
lny^{f}_{t-1}	0.455406	0.983668**	1.764077***
β^{+}	−3.6999**	3.71001**	2.7821***
β^{-}	−1.27314	1.2298	2.1692***

Note: β^{+} and $\beta^{-}$are the long-term coefficient, which indicates the long-term transmission effect of exchange changes; the superscripts '+' and '−' represent positive and negative components of the corresponding variables, respectively ***, ** represent significance level of 1% and 5%.
Source: Author's estimation.

Table 6. The short-run results of non-linear ARDL model.

Trade partner Variables	USA	EU	Japan
$\Delta lntb_{t-1}$		−0.278499**	
$\Delta lntb_{t-2}$		−0.341825***	
$\Delta lntb_{t-3}$			
$\Delta lnrex^{+}$	−3.4404**	−0.437115	0.506130
$\Delta lnrex^{+}_{t-1}$		−1.3744**	−1.2511**
$\Delta lnrex^{+}_{t-2}$	−3.0102**		−0.795606
$\Delta lnrex^{+}_{t-3}$			
$\Delta lnrex^{-}$	−1.3050	−0.557459	−0.503458
$\Delta lnrex^{-}_{t-1}$	0.771942	−0.175376	−0.663275
$\Delta lnrex^{-}_{t-2}$	−1.527528	0.821452	
$\Delta lnrex^{-}_{t-3}$	−0.171828		
Δlny	0.783797***	0.442683***	−0.371532**
Δlny_{t-1}	−0.294125	0.852398***	0.144514
Δlny_{t-2}	−0.501897***	0.452053***	0.155996
Δlny_{t-3}			−0.333279*
Δlny^{f}	−0.875089	−0.746158**	−0.31011
Δlny^{f}_{t-1}	−0.756531	−1.086990**	−1.502366***
Δlny^{f}_{t-2}	−1.939309**		−1.118951***
Δlny^{f}_{t-3}	2.983265*		−0.463240**

Note: β^{+} and $\beta^{-}$are the long-term coefficient, which indicates the long-term transmission effect of exchange rate appreciation and depreciation on bilateral trade balance; the superscripts '+' and '−' represent positive and negative components of the corresponding variables, respectively ***, ** and * represent significance level of 1%, 5%, 10%, respectively.
Source: Author's estimation.

Table 7. Results of long- and short-run asymmetry tests.

Country Variables	USA	EU	Japan
W_{SR}	1.690734	4.6094*	7.768203*
	(0.1935)	(0.0998)	(0.0511)
W_{LR}	7.5361***	10.3981***	4.84104**
	(0.0060)	(0.0013)	(0.0278)

Note: W_{LR} means the long-term symmetry test result in Wald test;W_{SR} the short-term symmetry test result in Wald test ***, ** and * represent significance level of 1%, 5%, 10%, respectively.
Source: Author's estimation.

coefficient, the quantity value of $\beta^{+}$is higher than β^{-}, the deeper meaning of what this represents is the effect of RMB appreciation is more significant. The impact of negative exchange rate change is smaller, implying that the effect of RMB depreciation on Sino-US trade balance is relatively small. To sum up, when we look at the long-term exchange rate relationship between China and the U.S., the negative impact of exchange rate changes on the Sino-US trade balance is significant. Moreover, this effect is asymmetric in nature. The adjustment effect of RMB appreciation is stronger than the adjustment effect of depreciation.

However, when the attention is turned to the European Union and Japan, the opposite result is reached. In European Union, the values of $\beta^+$and $\beta^-$are equal to 3.7100 and 1.2298, respectively. These mean that if the exchange rate increases by 10%, then the bilateral trade balance will be improved by 3.71%. But if the exchange rate decreases by 10%, then the bilateral trade balance will worsen by 1.23%. And the value of $\beta^+$is higher than that of β^-, which means that the positive changes of exchange rate have a stronger impact on the balance of trade. From a long-term perspective, there is a positive connection between the fluctuation of the RMB exchange rate against the euro and the China -Europe trade balance. The adjustment effect of RMB exchange rate fluctuations on the trade balance is asymmetric, and the adjustment effect of RMB appreciation is greater than that of depreciation.

In Japan, the long-term coefficients are also positive. $\beta^+$and$\beta^-$are equal to 2.7821 and 2.1692, which means a 10% increase (appreciation) in the exchange rate will cause improvement in the trade balance by 2.7821%, and a 10% decrease (depreciation) in the bilateral exchange rate will cause deterioration in the bilateral trade balance by 2.1692%. The effects of positive exchange rate changes and negative exchange rate changes are very close. The asymmetry of RMB depreciation and appreciation on the Sino-Japanese trade balance is thus manifested, although it is very small. In the long-term, RMB exchange rate change' adjustment effect on the trade balance is asymmetric, specifically, the adjustment effect of RMB appreciation is greater than the adjustment effect of depreciation.

Table 6 shows an asymmetry in the impact of exchange rate fluctuations on the short-term balance. While we focus on the U.S., there are three periods of lag in the short-term coefficient of positive exchange rate fluctuations, and it is significant in the first and third periods of lag. $\Delta\ln rex^+$is equal to -3.4404, and $\Delta\ln rex^+_{t-2}$ is equal to -3.0102, which show that positive exchange rate fluctuations, that is, if the RMB appreciates, then the trade balance between the US and China will become very bad as a result. And the short-term coefficient of negative exchange rate fluctuations ($\Delta\ln rex^-$) is not significant. What this can reflect is a significant asymmetry that exists between exchange rate movements and the Sino-US trade balance. Moreover, from the perspective of the period, this asymmetry is presented in the short term. In Europe Union, the short-term coefficient of positive exchange rate fluctuations ($\Delta\ln rex^+_{t-1}$) is equal to -1.3744. But the short-term coefficient ($\Delta\ln rex^-$) is not significant. It can be seen that short-term exchange rate changes' effect on China-Europe trade balance is asymmetry. In Japan, the short-term coefficient of positive exchange rate fluctuations ($\Delta\ln rex^+_{t-1}$) is equal to -1.2511, and the short-term coefficient of negative exchange rate fluctuations ($\Delta\ln rex^-$) is not significant.

Table 7 shows the test results of long- and short-run asymmetry tests. The results of Wald test show that exchange rate fluctuations have significant asymmetric effects on trade balance in three cases. When we focus on the situation between the US and China, we can see, the long-term Wald test coefficient W_{LR} is 7.5361. The short-term

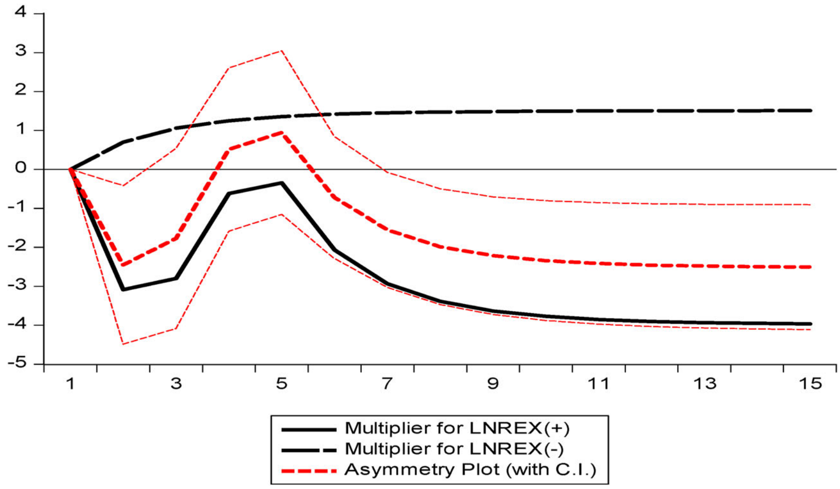

Figure 5. Dynamic multipliers for exchange rate changes and bilateral trade balance (USA).
Source: Author's estimation.

Wald test coefficient W_{SR} failed the significance test. What this means on a deeper level is that the exchange rate changes have a significant long-term asymmetrical impact on Sino-US trade balance. The coefficients of the Wald test W_{SR} and W_{LR} of EU are equal to 4.6094 and 10.3981. This means that both in the long and short term, RMB exchange rate movements will have an asymmetric impact on China-EU trade. Similarly, Japan's Wald long-term coefficient W_{LR} and short-term coefficient W_{SR} are significant at the 1% and 5% levels, indicating that the RMB exchange rate changes have both long-term and short-term asymmetric effects on China-Japan trade balance.

5.2. Cumulative dynamic multiplier effect

Next, we will turn our attention to the dynamic multiplier graph. Figures 5–7 show the RMB exchange rate's dynamic impact when we consider balance of trade in China and its trading regions, respectively. The dynamic multiplier diagram clearly captures the nature of this response, whether symmetric or asymmetric. Thus, the presence of this asymmetric influence can be clearly captured by the diagram.

Figure 5 shows asymmetric dynamic multiplier graph of the changes of RMB exchange rate, which contains both positive and negative changes, on the Sino-US trade balance. Firstly, the dynamic adjustment effect of RMB exchange rate changes on Sino-US bilateral trade balance. In the short run, the effect of the RMB exchange rate appreciation on the dynamic adjustment of the bilateral real exchange rate is stronger than the effect of the RMB exchange rate depreciation. Moreover, when we turn our attention to the long term, we can see that the effects of RMB appreciation is not offset by the impact of depreciation. Therefore, this asymmetry is significant. As shown in Figure 5, the RMB's appreciation will lead to a rapid deterioration of the Sino-US bilateral trade balance, reaching a trough in the third period. After that, the trade balance adjusts to equilibrium and return to equilibrium in the fifth period,

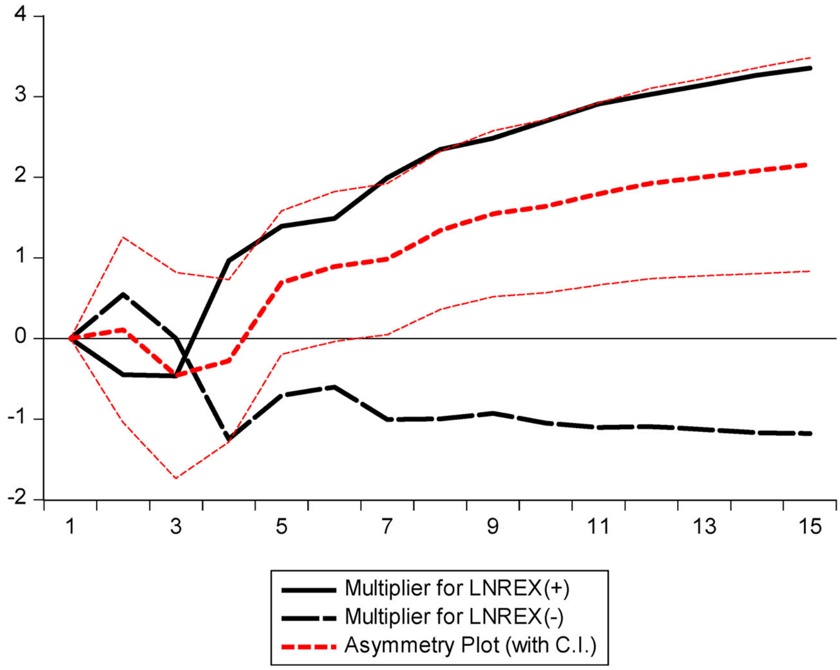

Figure 6. Dynamic multipliers for exchange rate changes and bilateral trade balance (EU).
Source: Author's estimation.

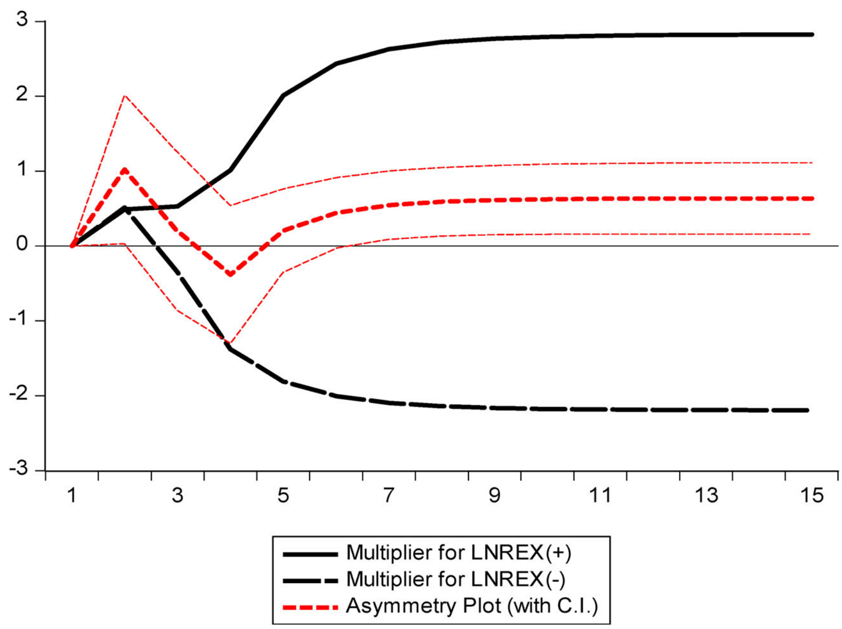

Figure 7. Dynamic multipliers for exchange rate changes to bilateral trade balance (Japan).
Source: Author's estimation.

but it will deteriorate for a long-run. Obviously, the general exchange rate theory and Marshall-Lerner conditions were met in the US case.

The dynamic adjustment of the Sino-European trade balance to the positive or negative volatility impact of the RMB exchange rate is shown in Figure 6. The asymmetric curve shows that the dynamic multiplier effect of the Sino-European trade balance on the impact of the negative volatility of the RMB exchange rate is positive at the beginning, and then becomes negative gradually. This shows that the short-term RMB depreciation can make the Sino-EU trade balance better. But, the RMB depreciation worsens the Sino-EU trade balance in the long-term. That's the appealing part of this paper. Our empirical study shows that the Marshall-Lerner condition does not have been satisfied between China and EU. The depreciation of RMB against the euro would worsen the Sino-EU bilateral trade balance, while RMB's appreciation would improve it. This is related to the commodity structure of Sino-EU trade. In general, the demand for the final product is more elastic than the intermediate product, and this elasticity refers to the price elasticity. In terms of trade activity between China and the EU region, although imports and exports are close to the full range of goods, the volume of final products imported by China from the EU region is somewhat higher in comparison each year, such as some branded categories of cars, BMW and Mercedes. So, it is not surprising that the appreciation of RMB would improve the balance of trade with the EU.

The asymmetry of the impact of exchange rate changes on the Sino-Japanese trade balance is clearly illustrated in Figure 7. As can be seen from Figure 7, in the first three periods, the dynamic response of the Sino-Japanese trade balance is positive. After the third period, the dynamic adjustment of the Sino-Japanese trade balance to the impact of RMB depreciation changed is in negative direction, while there is a positive dynamic adjustment to the RMB appreciation. It is very clear that in the short run, the response of Sino-Japanese trade balance to a unit shock of exchange rate changes is asymmetric. The dynamic adjustment effect shows that the RMB appreciation improves the Sino-Japanese trade balance, but the depreciation worsens the trade balance between China and Japan in the long run, which is similar to the results of some existing literature on exchange rate fluctuations and trade balances. It can be noticed that the Marshall-Lerner condition is also unproven in this case. The RMB depreciation cannot improve the Sino-Japanese trade balance, and the adjustment speed to the long-term equilibrium is slow. We believe that the key to the trade issue between China and Japan lies in the structure of the commodity structure of the trading economy, not just the exchange rate. It is well known that the Marshall-Lerner condition is established because the sum of elasticity is greater than a unit. But the main products traded between China and Japan are less elastic. For Japan, the appreciation of RMB means that the imported goods' price has a rising trend, which will decrease the demand for commodities. Because the price elasticity of commodities is relatively small, it will not decrease much. That is to say, China's exports to Japan will not decrease. But for China, RMB appreciation means that the prices of Chinese imports from Japan have fallen, but demand will not increase because of the low elasticity. Therefore, China's imports from Japan will not increase much. In general, under the premise of low elasticity of commodity demand, the appreciation of the RMB will not increase China's imports to Japan by

Table 8. Results of long- and short-run asymmetry tests.

Country / Variables	USA	EU	Japan
W_{SR}	2.5902	5.0738*	13.0172***
	(0.1075)	(0.0791)	(0.0051)
W_{LR}	5.7274**	7.8644***	5.1423**
	(0.0167)	(0.0050)	(0.0473)

Note: W_{LR} means the long-term symmetry test result in Wald test;W_{SR} the short-term symmetry test result in Wald test. ***, ** and * represent significance level of 1%, 5%, 10%, respectively.
Source: Author's estimation.

more than the number of China's exports. This means that instead of worsening Japan-China trade, the appreciation of the RMB has an improving effect on the trade balance involving both sides.

5.3. Robustness testing: with a financial crisis

In this section, we take into account the impact of the financial crisis that occurred in 2008. We add the financial crisis as a dummy variable to the model and denote the financial crisis by *ec*. The years 2008 and 2009 are denoted as 1 and the remaining years are denoted as 0. Similar to Equation (11), the trade balance equation that incorporates the financial crisis can be expressed as follows:

$$\begin{aligned}\Delta \ln TB_t = {} & \rho \ln TB_{t-1} + \theta_1 \ln REX^{+}_{t-1} + \theta_2 \ln REX^{-}_{t-1} + \theta_3 \ln y_{t-1} + \theta_4 \ln y^{f}_{t-1} + \theta_5 \ln ec_{t-1} \\ & + \sum_{i=1}^{q_1} \gamma_{i1} \Delta \ln TB_{t-1} + \sum_{i=1}^{q_2} \gamma_{i2} \ln REX^{+}_{t-1} + \sum_{i=1}^{q_3} \gamma_{i3} \Delta \ln REX^{-}_{t-1} \\ & + \sum_{i=1}^{q_4} \gamma_{i4} \Delta \ln y_{t-1} + \sum_{i=1}^{q_5} \gamma_{i5} \Delta \ln y^{f}_{t-1} + \sum_{i=1}^{q_6} \gamma_{i6} \Delta \ln ec_{t-1} + \varepsilon_t\end{aligned} \tag{13}$$

The results of robustness tests can be observed in Table 8, which gives the results of the Wald-test.

Table 8 shows the test results of the asymmetric relationship between exchange rate volatility and trade balance in the long-term and short-term. The long-term Wald test coefficients W_{LR} are 5.7274, 7.8644 and 5.1423, which are significant at 5%, 1% and 5% levels respectively. Japan's Wald long-term coefficient W_{LR} and European's Wald long-term W_{LR} are significant at the 10% and 1% levels respectively.

Figures 8–10 show dynamic multiplier plots of exchange rate changes' impact on trade balance in the context of the financial crisis, from which we can see visually the asymmetric impact of exchange rate changes on the trade balance. Qualitatively, the results in this section are consistent with the above results. However, the asymmetric nature of exchange rate changes' impact on the trade balance are independent of external shocks. This also provides evidence that the impact of exchange rate fluctuations on the trade balance is asymmetric.

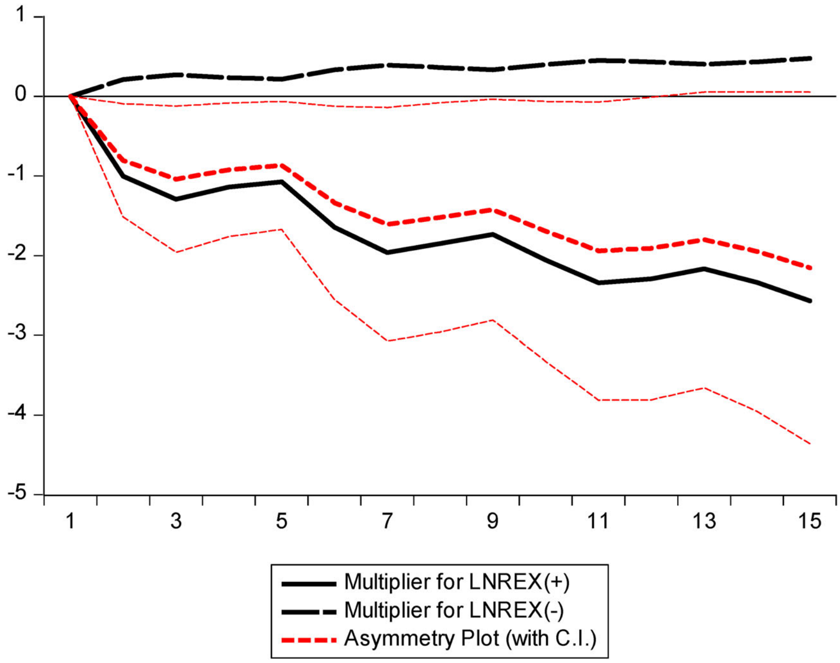

Figure 8. Dynamic multipliers for exchange rate changes to bilateral trade balance with the financial crisis (USA).
Source: Author's estimation.

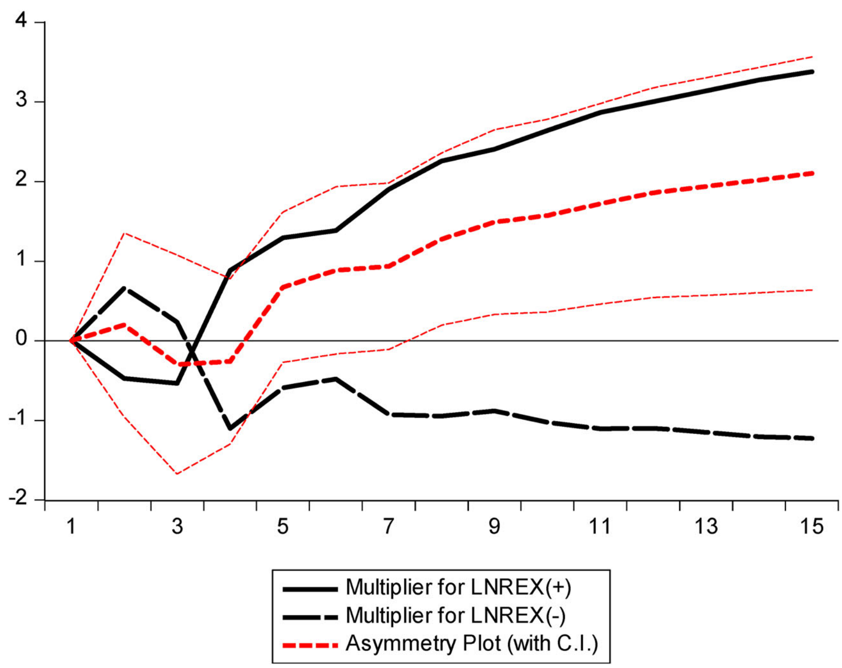

Figure 9. Dynamic multipliers for exchange rate changes to bilateral trade balance with the financial crisis (EU).
Source: Author's estimation.

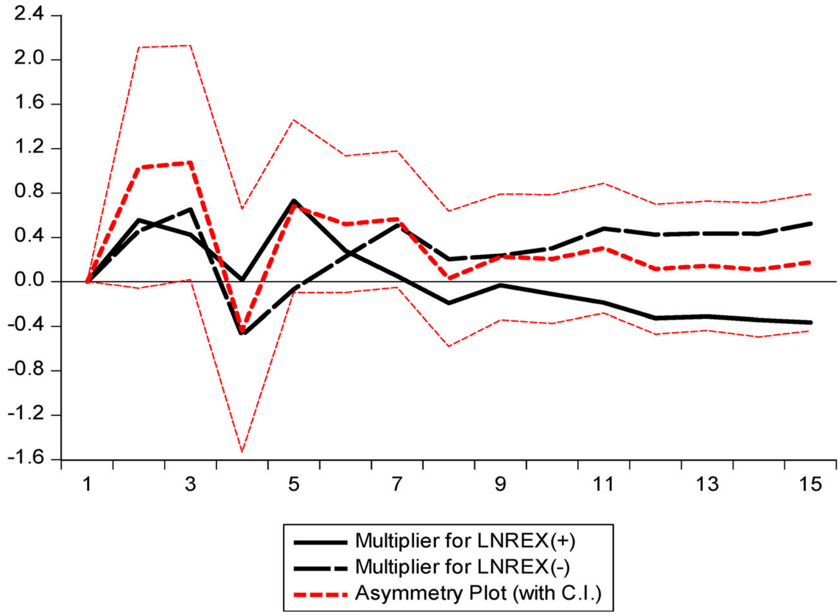

Figure 10. Dynamic multipliers for exchange rate changes to bilateral trade balance with the financial crisis (Japan).
Source: Author's estimation.

6. Conclusions and policy implications

This study explores the asymmetric and non-linear effects of RMB exchange rate changes in China's bilateral trade balance by employing NARDL technology. The NARDL model decomposes the bilateral real exchange rate into two parts. On this basis, we examine the asymmetric and non-linear effects of RMB exchange rate changes on China's trade balance. The results indicate that the effects of RMB exchange rate fluctuations on China's bilateral trade balance is non-linear and asymmetry in both the long and short term. The conclusions are as follows:

Firstly, the first result derived is that there is a significant co-integration relationship between exchange rate changes and bilateral trade balance. That is, although in the short run there may be an uncertain and variable relationship between the two, when we focus on a longer period, the relationship is not unstable, but ten presents a very solid and trusting relationship. This shows an obvious non-linear effect between the exchange rate and the trade balance.

Secondly, the RMB exchange rate changes' impact on trade balance is asymmetry, and this asymmetry is not an accidental situation. In contrast, this asymmetry is significantly present whether we fix our gaze on the current or longer period. That is, it is an intrinsic nature rather than an accidental or random situation. The study also concludes that the trade balance between China and its different trading partners responds inconsistently, or even in reverse, to changes in the RMB exchange rate. The Sino-US trade balance responds more obviously to the RMB exchange rate's appreciation. In contrast, the RMB exchange rate's depreciation has a relatively small impact on the trade balance. In the case of the European Union and Japan, the opposite is true.

Finally, A more important finding is that in each case there is a unique long-term relationship. In the model of China and the US, the Marshall-Lerner condition is satisfied that the decrease of the RMB exchange rate against dollars would improve the bilateral trade balance. In the long run, this asymmetry is more apparent. While for the EU and Japan, the depreciation of RMB will worsen the balance of trade. That is, the Marshall-Lerner Condition was not met in the EU and Japan. To summarise, the asymmetric impact of the RMB exchange rate on the bilateral trade balance varies based on the actual situation in different countries.

In light of our research results, this paper presents the following several policy suggestions. Firstly, we need to be alert to the impact of RMB bilateral exchange rate fluctuations. In particular, we need to maintain a high level of vigilance against the negative response of the bilateral trade balance to large fluctuations in the RMB exchange rate. On the other hand, the reference for RMB exchange rate movements should be regulated in greater depth. Especially at the present time, when China is adopting a policy of staking a basket of currencies, it is important to carefully consider the weight of each trading country or trading region's currency in the referenced basket. By adjusting the weighting of the various currencies, the monetary authorities should form a more reasonable and stable RMB exchange rate mechanism that is more conducive to the healthy development of the RMB, China's trade and economy.

Secondly, we should try to reduce or avoid the RMB exchange rate volatility. RMB exchange rate changes will increase trade instability in China, and this not conduct conducive improving bilateral trade balance. Moreover, trade participants' expectations of the RMB exchange rate also impact exchange rate stability. Therefore, improving or strengthening public expectations of the RMB exchange rate is an important way to maintain exchange rate stability and trade surplus, which is also the key point that China's exchange rate authorities should pay attention to.

Third, the commodity structure of trade between China and its trading partners should receive more attention. A devaluation of the RMB will not necessarily improve trade with all trading partners. Therefore, it is not feasible to rely solely on currency value changes to improve the trade balance. When China cooperates with its trading partners, it should reasonably choose specific commodities that can meet market demand and balance the scale of import and export trade, based on its comparative advantage and market demand, so as to promote a win-win relationship with deeply intertwined interests and stabilise China's foreign trade.

Finally, given the RMB exchange rate's depreciation (appreciation) has different or even opposite effects, the government should take full account of the current political, social, and economic conditions when formulating exchange rate or trade policy, and formulate supplementary policies based on overall policy. After all, in the final analysis, we are in a complete economic system, and only when each part of the economy is systematically and logically linked and cooperates with each other can we ensure the healthy operation of the entire economic system.

Compared with previous studies, this paper has obvious innovations, but there are also certain limitations, such as the fact that only three of China's trading partners have been selected for the study. Relatively this only yields the nature of asymmetry in a limited scope and condition. Thus, the evidence on the idea that asymmetry is universal is insufficient. In the future, selecting more samples and conducting asymmetric research on exchange rate changes on the trade balance in a wider context would be the next research direction.

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