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DOES A TRADE SURPLUS RAISE THE EXCHANGE RATE EXPOSURE? A PERSPECTIVE ON SINO-US RELATIONS

This research examines dynamic causality between trade surplus (TS) and exchange rate exposure (ERE), utilizing the bootstrap sub-sample rolling window test. The empirical findings indicate that there is the time-varying bidirectional causality in TS and ERE within certain sub-periods. Specifically, ERE manifests both positive and negative influences on TS. In turn, TS has a positive effect on ERE which proves the export-oriented model proposed by Bodnar *et al*. (2002). Furthermore, due to the complex changes in Sino-US trade policies during the trade war, ERE is still stimulated under the overall downward trend of TS. This means that the widening TS can inevitably increase ERE, which may cause more trade frictions with the US. By studying the time-varying relation between these two variables, investors can reasonably allocate assets according to the changes of TS and avoid losses caused by market panic. Policy-makers could restrict the abnormal flow of international capital and promote multilateral trade cooperation, especially in times of structural economic change, to reduce trade friction and maintain a relatively stable ERE level.

Keywords: exchange rate exposure, trade surplus, rolling window, bootstrap

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1. INTRODUCTION

The main purpose of this paper was to examine the dynamic causality between trade surplus (TS) and exchange rate exposure (ERE). With the continuous ferment of the trade war in Sino-US relations, and the outbreak of the Covid-19 pandemic, TS has become an important indicator to measure the trade activities between the two countries (Bolt *et al*., 2019), and ERE has also become a hot aspect to study the foreign exchange market (McKibbin and Fernando, 2020). As the ultimate influencing factor of trade policy, the volume of TS could affect investors' decision in the foreign exchange market due to accompanying fluctuation of ERE (Marston, 2001). In the existing literature, expanding TS is expected to contribute to the growth in ERE (Parsley and Popper, 2006). On the one hand, the accumulation of ERE implies the higher cost of raw materials and uncertainty of profits (Miao *et al*., 2013). If exporters' performance falls sharply, it will certainly affect investment market expectations (Aizenman and Glick, 2009). On the other hand, expanding TS triggers inevitable trade frictions which could lead to the increasing ERE (Auboin and Ruta, 2013). However, this view is not established in all cases, as it largely depends on the state of the foreign exchange market and policy.

When the economy is in a period of significant change, leading to a sharp contraction in trade, TS can be used as an effective index to explain high ERE (Melvin and Taylor, 2009). The steady development of trade activities between the two countries will have a positive impact on exchange rate expectations (Jongen *et al*., 2008). In addition, since trade activities have a significant impact on the foreign exchange market, the prediction of the fluctuation of ERE based on TS is reliable (Min, 2012). In turn, ERE fluctuations can dampen international trade volumes by increasing the risks associated with cross-border transactions (Goldberg and Campa, 2010). In addition, higher ERE promotes the abnormal flow of international capital which destabilizes TS (Forbes and Warnock, 2012). Therefore, these two variables demonstrate significant correlation in the foreign exchange market (Bartram *et al*., 2010; Ito *et al*., 2018). Investors can reasonably allocate assets and avoid financial risks by studying the causes between TS and ERE in this paper, when the changes in Sino-US trade policies lead to instability in the foreign exchange market. The government can also predict the degree of foreign exchange risk based on TS, and introduce policies to stabilize the foreign exchange market in advance to avoid capital outflow caused by market panic.

The economic closeness between China and the USA has a vast impact on global trade activity (Gulley *et al*., 2018; Zhang *et al*., 2018), and trade is one of the key factors influencing ERE in Sino-US relations (De *et al*., 2017). As trade liberalization has deepened, China's long-term export-oriented economy has led to a widening TS in Sino-US activities as from 1993 (Dong and Guan, 2010). Since 2001, when China first participated in the World Trade Organization (WTO), the widening TS with the US has exposed exporters, especially for export-oriented China (Aggarwal *et al*, 2011). Furthermore, TS with the USA has grown at an average annual rate of more than 6% from 2008, and reached 275.8 billion dollars at the end of 2017 (Lu, 2018). In line with the deepening of trade globalization, China's massive TS inevitably turned into trade friction (Rodrik, 2010), which caused the foreign exchange market to fluctuate violently (Baum and Caglayan, 2010).

The other factor that one cannot ignore is the change of foreign exchange policy. After the reform of the RMB exchange rate formation mechanism in July 2005, the RMB exchange rate has shown an overall appreciation trend (Yu, 2009; Yu *et al*., 2017). As of September 2018, the exchange rate of RMB against the US dollar appreciated by 16.75% compared with July 2005. This led to massive capital inflows from the US which has resulted in rapid growth in foreign exchange reserves (Yang *et al*., 2011). With the accumulation of foreign exchange reserves, China is increasingly unable to maintain the independence of monetary policy (Glick and Hutchison, 2009). The increasing internationalization of the Renminbi (RMB) may gradually threaten the status of the dollar as the world currency (Li *et al*., 2016). From the end of 2017, the US has significantly increased tariffs on goods imported from China to improve the competitiveness of domestic enterprises (Lau, 2018). The protectionist policies may have a temporary effect on China's TS, but it could also accumulate ERE (Sheng, 2018). As a result of this series of emergencies, the exchange rate changed from stable appreciation to sharp depreciation in the short term, and the trade activities also decreased compared with the same period (Lau, 2018). However, compared with the US, China's foreign exchange supervision system is not perfect, and its ability to withstand shocks is insufficient (Meng, 2012). This leaves China's exporters to consider the impact of ERE on their trade volume. China's trade policy toward the USA has undergone positive changes and is no longer pursuing large TS (Krugman, 2010). In order to achieve the upgrading of industrial structure and the sustainable development of trade activities, the balance of import and export have become the goal of China's trade policy (Yang *et al*., 2012). Therefore, the evolving process of causality between TS and ERE deserves to be explored to better study the mechanism that widening the trade surplus with the US may lead to potential foreign exchange risks.

This paper has made certain contribution to the existing body of research that considers the time-varying causality between TS and ERE. Firstly, most existing studies focus on how TS affects ERE and proposes measures to reduce foreign exchange risk (Sun, 2013). However, from the opposite perspective, one finds that ERE can also affect the volume of TS under a certain condition which provides evidence that foreign exchange markets should have an impact on economic development. Moreover, the earlier empirical literature only examined the causal relationship between ERE and TS, and inaccurate results may occur when the parameters are unstable due to structural changes in the potential time series of the full-sample (Balcilar *et al*., 2010). This inaccurate result can be solved by allowing the causality between two series to be changed with time (Balcilar and Ozdemir, 2013). In this way, the time-varying causality can provide an effective basis for evaluating the trade policy decisions (Sally, 2011).

The rest of this paper is arranged as follows: Section 2 presents the literature review; Section 3 introduces the export-oriented model of exchange rate exposure and trade surplus; Section 4 presents the test models of causality; Section 5 describes the corresponding data; Section 6 analyses the results of the empirical analysis; Section 7 concludes the paper.

2. LITERATURE REVIEW

Doidge *et al*. (2002) proved that there is a positive impact of TS on ERE in the perspective of export industries. Lee (2005) argued that the short-term sharp rise of TS causes the positive correction process of ERE in the long run. Bartram and Karolyi (2006) indicated that the ERE of different exporters depends on their foreign trade volume, and the exporters of smaller size face higher risks. Kanagaraj and Sikarwar (2011) also certified that the widening TS can make ERE respond positively by changing the international flow of monetary assets. Bergbrant *et al*. (2014) argued that foreign trade companies with a higher proportion of import business will usually have a relatively high ERE. Arize *et al*. (2017) showed that TS has significant positive effects on ERE in an asymmetric model. Cavallino (2017) indicated that international capital flows caused by large trade activities can significantly affect ERE. Hook and Boon (2017) proved that the transmission channel of TS's dynamic causal effect on ERE is the change of relative price. Cuestas *et al*. (2018) argued that the decreasing trade volume has a stronger influence on ERE than the increasing trade volume after 2009.

From the other perspective, Auboin and Ruta (2013) explored the influence of ERE on international trade flows and showed a negative impact result. Miao *et al*. (2013) argued that ERE also has a great impact on the production cost and profit of the raw materials, which directly affects the import and export of trade. Tang (2015) found that the performance of exporters' returns can be easily influenced by unexpected changes in the ERE, which could indirectly change their trading decisions. Tunc and Solakoglu (2017) stated that ERE has a depressing impact on TS and different types of goods have different degrees of impact. ERE fluctuations adversely affect TS in the short run, but there is an opposite impact in the long term (Senadza and Diaba, 2017). Chou *et al*. (2017) revealed that the influences of ERE on their trade income vary enormously for different currencies.

The short-term correlation between TS and ERE is often confirmed, especially after China joined the WTO (Lu and Dai, 2005). Luo and Jiang (2007) proved that over 28.36% of Chinese exporters have high ERE, which is above the average for developed countries. In an open economy, Ni (2011) found that the ERE of Chinese exporters is closely related to their trade activities and liabilities. Sun (2013) suggested that the inflow of international capital into China caused by trade activities can also indirectly reflect ERE. Li *et al*. (2015) indicated that the transaction price of goods from Chinese exporters is affected by ERE pass-through effects which seriously influence trade cost and TS. On the contrary, TS with the US also has a lagging effect on industry earnings, which has a long-term impact on ERE (Cuestas and Tang, 2017). Chen and Liu (2018) argued that currency fluctuations have negative effects on China's export volume, especially in household and personal goods.

In terms of methodology, almost all of the existing empirical studies estimate the relation between TS and ERE by using the co-integration technique and its derivatives. However, these empirical results using all of the sample data may ignore the time-varying characteristics. The dynamic relation between these two series was demonstrated over the past decade by the fact that the global financial crisis and policy changes may have led to some structural disruption in the global foreign exchange markets. Entorf and Jamin (2007) proved that the impact of TS on ERE is rather unstable and time-varied. Pierdzioch and Kizys (2010) also noted that the causal relationship between TS and ERE may have time-varying changes, which depends on the ability of exporters to absorb foreign exchange losses. In this paper, the authors try to use the bootstrap sub-sample rolling-window to estimate test analyses of the link between two variables, which is much in line with policy formulating principles in the context of global economic instability.

3. THE EXPORT-ORIENTED MODEL OF EXCHANGE RATE EXPOSURE AND TRADE SURPLUS

The paper explores the impact of import and export on ERE by using the export-oriented model (Bodnar *et al*., 2002). It assumes that all the enterprises in industry have both import and export business, ignoring the differences among the enterprises. Since the exchange rate fluctuations have the same effect on various industries, one can use the sum of the industry's ERE to represent the country's ERE (Bartram *et al*., 2010). The authors explore the model causality between foreign exchange fluctuations and enterprise value with the goal of profit maximisation (Dixit and Stiglitz, 1977).

Let X_{11} and X_{21} be the domestic and foreign sales of the products produced in their own country, respectively. Assuming that C_{11} and C_{21} are, respectively, the domestic and overseas costs required for the domestic productions, then S is the bilateral exchange rate under the direct quotation method. Industry profit expressed in local currency is π. The profits π of exporters are shown as:

$$\pi = [X_{11} + SX_{21} - C_{11} - SC_{21}] + [X_{12} + SX_{22} - C_{12} - SC_{22}]. \tag{1}$$

The derivative of this industry's profit with respect to the bilateral exchange rate can be calculated as:

$$\frac{d\pi}{dS} = \frac{d\pi}{dX_{11}} \cdot \frac{dX_{11}}{dS} + \frac{d\pi}{dX_{12}} \cdot \frac{dX_{12}}{dS} + (X_{21} - C_{21}) + (X_{22} - C_{22}). \tag{2}$$

According to equation (1), changes of exchange rate have two effects on industrial earnings. Firstly, the change of *S* influences the production output, secondly, *dS* also affects the enterprise's overseas net income. It is known that the industry has already reached the equilibrium output, so the first effect is zero at present equilibrium. Hence equation (2) can be simplified as follows, under the current equilibrium state:

$$\frac{d\pi}{dS} = (X_{21} - C_{21}) + (X_{22} - C_{22}). \tag{3}$$

This paper considers the relation between the enterprise's future cash flow and net asset value based on the considered exchange rate fluctuation (Adler and Dumas, 1984). The definition of exchange rate exposure is the degree of impact of exchange rate fluctuations on enterprise value, then the enterprise value (*V*) is regarded as the discounted value of the future cash flow. Therefore, the concise way to measure *ERE* can be formulated as follows:

$$ERE = \frac{d \ln V}{d \ln S}. \tag{4}$$

Assume that the value of enterprise (*V*) is the discounted value of after-tax profit, and the discount rate and profit growth rate remain unchanged. Thus, ERE can be expressed as a percentage change in profits resulting from a percentage change in the exchange rate:

$$ERE = \frac{d \ln \pi}{d \ln S}. \tag{5}$$

From equation (5), one can derive the exchange rate exposure in view of enterprises by referring to the concept of Adler and Dumas (1984). The combined equations (3) and (5), the exchange rate exposure of industry, can also be expressed as ERE' in the same way, which can be expressed as:

$$ERE' = \frac{d \ln \pi}{d \ln S} = [(X_{21} - C_{21}) + (X_{22} - C_{22})]\frac{S}{\pi}. \tag{6}$$

Let h_1 and h_2 respectively represent the ratio of the foreign currency income and cost to the total income of the industry. Furthermore, *m* is the profit margin in the industry. The total ERE of the import and export industry in equation (6) can be transformed into a simple form and expressed as:

$$ERE' = h_1 + (h_1 - h_2)(1/m - 1). \tag{7}$$

From equation (7), when $h_2 = 0$, the industry is a net export industry, $ERE' = h_1/m$. When $h_1 = 0$ the industry is a net import industry, $ERE' = (1 - 1/m)h_2$. Thus it can be seen that the difference in ERE between net export and import industry depends on the different overseas business activities of these industries. In equation (7), h_1/m and h_2/m respectively represent the rate of change of the export and import volumes, therefore ERE can be expressed in terms of TS. The larger value of h_1 and the smaller value of h_2 all lead to widening TS and more trade frictions, which constitute the main reasons for the increase of ERE.

The transmission mechanism of the above model demonstrates that more export activities would lead to the detriment of importing countries. A massive TS can lead to large global capital flows which cause a higher exchange rate exposure. The study found that this kind of mutual relationship between importing and exporting countries makes TS effectively lead to higher ERE, which confirms the result of Bodnar *et al*. (2002).

4. METHODOLOGY

4.1. Bootstrap full-sample causality test

The test statistics in the traditional method of testing causality based on the traditional vector autoregression (VAR) model may not obey the standard asymptotic distributions (Sims *et al*., 1990). Thus, Toda and Yamamoto (1995) proposed the modified Granger test, which can properly adapt high order co-integration relations. Shukur and Mantalos (2000) indicated the residual based bootstrap (*RB*) method's critical values, and proved that this method can improve the causality test. At the same time, Shukur and Mantalos (2000) also found that the *RB* method effectively increases the robustness of the Granger test compared with the corrected likelihood ratio (*LR*) tests. Therefore, the authors used the *RB*-based modified-*LR* statistic to explore the causality between ERE and TS. The bivariate VAR (p) process is considered as follows:

$$\begin{bmatrix} ERE_{1t} \\ TS_{2t} \end{bmatrix} = \begin{bmatrix} \phi_{10} \\ \phi_{20} \end{bmatrix} + \begin{bmatrix} \phi_{11}(L) & \phi_{12}(L) \\ \phi_{21}(L) & \phi_{22}(L) \end{bmatrix} \begin{bmatrix} ERE_{1t} \\ TS_{2t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}, \tag{8}$$

where $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ atisfies the condition of zero mean, independent, white noise process with the non-singular covariance matrix; p represents optimal lag length which is calculated by the Akaike information criterion (AIC). $\phi_{ij}(L) = \sum_{k=1}^{p} \phi_{ij,k} L^k$ and L are the lag operator and is expressed as $L^k x_t = x_{t-k}$.

The unrestricted VAR(p) model can be written as:

$$\begin{bmatrix} \mathrm{ERE}_{1t} \\ TS_{2t} \end{bmatrix} = \begin{bmatrix} \varphi_{10} \\ \varphi_{20} \end{bmatrix} + \begin{bmatrix} \varphi_{11}(L) & \mu_{11}(L) & \varphi_{12}(L) & \mu_{12}(L) \\ \varphi_{21}(L) & \mu_{21}(L) & \varphi_{22}(L) & \mu_{22}(L) \end{bmatrix} \begin{bmatrix} ERE_{1t} \\ ERE_{1t-p+1} \\ TS_{2t} \\ TS_{2t-p+1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}, \quad (9)$$

where $\hat{\delta}_U$ stands for the matrix of residuals from equation (9), while $\hat{\delta}_R$ is the equivalent residuals with restricted regression (equation 8). Hence one can obtain $\mathrm{LR} = T \ln \frac{\det S_R}{\det S_U}$, and $S_U = \hat{\delta}'_U \hat{\delta}_U$, $S_R = \hat{\delta}'_R \hat{\delta}_R$. A simple small sample correction was to replace T, this modified LR statistic is given as $\mathrm{LRE} = \Delta_E \ln \frac{\det S_R}{\det S_u}$, where $\Delta_E = \Delta + \frac{1}{2}\left[k(G-1)-1\right]$, G is restrictions $\phi_{12,k} = 0$ and $\phi_{21,k} = 0$ for k = 1,2, …, p, respectively. The causality of the variables in this paper was tested by the bootstrap p-value and the modified LR statistic. It tested whether there was Granger causality relationship between ERE and TS. When the null hypothesis is rejected, this means that TS has a significant causal relationship with ERE, and vice versa.

4.2. Parameter stability test

In the VAR model, the full-sample causality test assumes that the parameters are required to be constant. The VAR model in the whole sample interval usually has a structural change, which may lead to unreliable causal results for the whole sample (Balcilar and Ozdemir, 2013). In order to overcome the instability of parameters in the short term, the authors adopted the *Sup-F*, *Mean-F* and *Exp-F* tests (Andrews, 1993; Andrews and Ploberger, 1994). *Sup-F* can test for a sudden structural change, *Mean-F* and *Exp-F* can test whether the parameters have gradually evolved along the time trajectory or not. Then the *Lc* test (Nyblom, 1989; Hansen, 1992) was applied, which could judge whether there existed long-term parameters' instability (*Lc* statistics were calculated from the *LR* statistic sequence). Moreover, by the parameter bootstrap, one can obtain p-values and critical values (Andrews, 1993; Andrews and Ploberger, 1994). The study used these tests to check the parameters' stability, and examine whether there was a structural or fault change at a certain time.

4.3. Sub-sample rolling-window causality test

Following Balcilar *et al*. (2010), the mechanism of rolling window technology is to make the window roll continuously in full sample from beginning to the end under the condition of a fixed-size sub-sample. When the rolling window width is fixed to l, the whole of the sample data can be divided into $T - l$ sub-samples, i.e. $\tau - l + 1, \tau - l, \ldots, T \;\; \tau = l,\ l+1,\ \ldots, T$, where T is the time length of the total sample.

Each sub-sample can obtain a causality test result by using the *RB*-based modified-*LR* test. One can easily identify the possible structural changes in these two series by the bootstrap *p*-values using the obtained *LR* statistics rolling from $T - l$ sub-samples. $N_b^{-1}\sum_{k-1}^{p}\hat{\phi}_{12,k}$ describes the influence of ERE on TS and vice versa. N_b is the bootstrap repetitions, and $\hat{\phi}_{12,k}$ is the bootstrap estimator in the VAR model. The authors adopted a 90% confidence interval, and uniformly removed 5% of the first and end values of $\hat{\phi}_{12,k}$ and $\hat{\phi}_{21,k}$ calculated by the bootstrap (Yuan *et al.*, 2022).

5. DATA

The study employed monthly data covering the period from 2005M07 to 2019M12. China's economic policy and the situation have undergone a series of major changes. In July 2005, China reformed the RMB exchange rate formation mechanism which led to a 21% appreciation of the RMB against the dollar over the next three years. This change in foreign exchange policy determined the overall trend of the exchange rate in the future and had a profound impact on China's trade. The data used to calculate ERE came from the People's Bank of China (PBC) and the *Wind database*. ERE is defined as the sensitivity of Chinese exporters' asset values to the fluctuation of the exchange rate of RMB against the US dollar (Jacque, 1981). Therefore, the capital-market method is considered to be a relatively good method that can accurately capture the abnormal fluctuations of ERE when the foreign exchange market is affected by global economic changes, and intuitively simplify the results (Fang *et al*., 2018). A higher ERE in Sino-US relations means the degree of foreign exchange risk is high, and vice versa. TS indicates that China's monthly exports to the USA exceed its imports, which can intuitively express the level of trade flows between the two countries (Shen, 2005). The data of TS in Sino-US relations were taken from *General Administration of Customs, P.R. China* to explore the issue of causality between TS and ERE.

From Figure 1, it can be found that the overall trend of TS and EPE tended to be consistent from 2005 to 2019. The size of bilateral trade between China, as the world's largest developing country, and the USA which is the world's largest economy, has gradually expanded. However, while Sino-US trade is rapidly expanding, the trade imbalance is also gradually increasing. Since 2003, the US has applied the pressure on China on the issue of exchange rate, which has become one of the main frictions in Sino-US trade. In July 2005, China launched the reform of the RMB exchange rate system, and implemented the management of a floating exchange rate system based on a basket currency. This is equivalent to relaxing the volatility of the RMB exchange rate, and thereafter, the RMB began to rise against the US dollar. On the day of the reform's implementation, the RMB appreciated by 2%, and the minimum reached 6.0703:1 in the next few years. A trade surplus will help the currency face the pressure of appreciation (Parsley and Popper, 2006), therefore one can see that

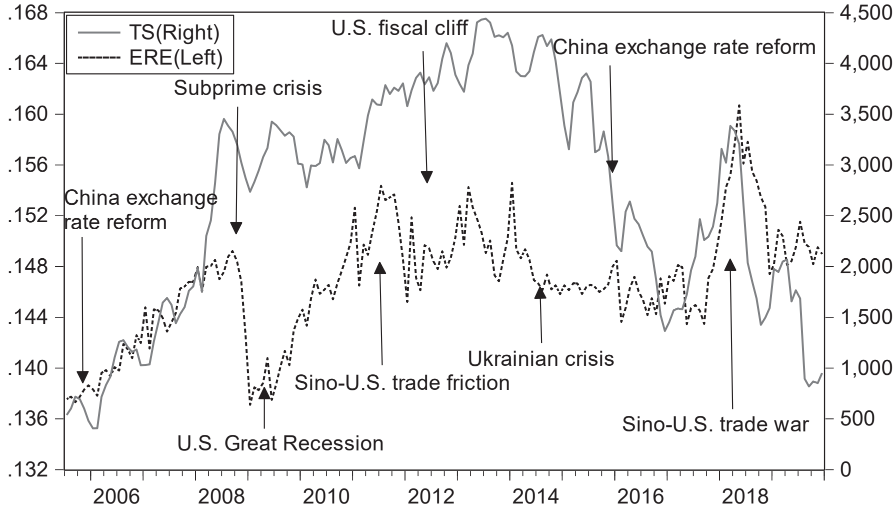

Fig. 1. The trends of TS and ERE

Source: The data of ERE is taken from the People's Bank of China (PBC) and the Wind database while the TS in Sino-US relations comes from General Administration of Customs.

the trend of TS and ERE was similar in most periods. Until the repeated exchange rate reform in 2015, the exchange rate tended to depreciate, the main reason being the slowdown of macroeconomic growth in China. The decline in exchange rate means that export goods are cheaper, thus enhancing the competitiveness of goods (Forbes and Warnock, 2012). This is conducive to exports, thus TS will increase. In March 2018, the trade friction between China and the USA continued to intensify, and the setting of tariff barriers was an important factor in causing exchange rate fluctuations. The increase in trade barriers (increasing tariffs) exacerbated exchange rate rises and expectations of RMB depreciation. The exchange rate has gradually emerged as an inhibitor of trade revenue, hence the scale of the trade was reduced due to the risk of uncertainty (ITO *et al.*, 2018). However, the trade surplus did not change significantly, but gradually increased. Hence, TS and ERE are believed to have a dynamic association, and this can be even reversed under certain circumstances.

The descriptive statistical results of ERE and TS are illustrated in Table 1. Firstly, it can be observed that the kurtosis value of ERE is 3.198 and the standard deviation is 0.009,which means that ERE is relatively concentrated and has few extreme values, but often changes dramatically in a short time. The kurtosis value of TS is 2.891 and the skewness is 0.49, which indicates that the values of TS are relatively scattered and asymmetrically distributed. The mean (median) value of ERE is 0.153 (0.156), suggesting that there are large individual extreme values in ERE. Furthermore, both of the two variables are all skewed to the right, which indicates that few variables have a large value. Due to the influence of the changing global economic operational environment, the Jarque-Bera test also proves the results that the data of ERE and TS approximate non-normal.

Table 1

Descriptive statistics of the sequences of ERE and TS

Statistics	ERE	TS
Mean	0.153	1,765.452
Median	0.156	1,754.356
Maximum	0.168	3,587.897
Minimum	0.135	636.635
Std. Dev.	0.009	581.995
Skewness	1.021	0.490
Kurtosis	3.198	2.891
JB statistics	71.472***	6.559**

Note: *** and ** denote significance at the 1% and 5% level, respectively.

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.

Table 2

The results of unit root test

		ADF	PP	KPSS
Levels	TS	–0.683 (1)	–0.168 [3]	1.753[10]***
	ERE	–1.823 (1)	–1.690 [2]	1.414 [10]***
First differences	TS	–6.474 (0)***	–.445 [4]***	0.057[4]
	ERE	–9.709 (0)***	–9.703 [4]***	0.293 [4]

*** denote significance at the 1% level.

Notes: The number in parenthesis indicates the lag length based on the SIC. The number in the brackets indicates the bandwidth using Bartlett Kernel by the Newey-West test (1987).

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.

In order to eliminate possible heteroscedasticity and the uniform dimensions, the original data were taken from the logarithm (Su *et al.*, 2022b). The parameter stability was verified by the Augmented Dickey-Fuller test (ADF, 1981), Phillips-Perron (PP, 1988) tests, and Kwiatkowski-Phillips-Schmidt-Shin (KPSS, 1992) tests. Table 2 shows that TS and ERE failed to reject the null hypothesis in the ADF and PP tests, indicating that the two variables are unstable. However, after a first-order difference, they became a stable variable. The null hypothesis of the KPSS test is opposite to the ADF and PP tests, and therefore, the result of the unit root tests was that *TS* and *ERE* were both *I*(1) series, hence the original data obtained a stationary series by differentiating. Moreover, the seasonal reduction of TS can be obviously observed in the annual Spring Festival. The non-stationary time series needed to eliminate cyclicity and tendency, thus the authors used the method of difference to eliminate monthly periodicity (Wagman *et al.*, 2015). Then, the two-variable VAR model of TS and ERE was taken as the logarithm's first difference to perform a Granger causality test, which could effectively avoid the deviation of results.

6. EMPIRICAL RESULTS

Let us take TS and ERE as the research variables of the bivariate VAR model shown in equation (8). The optimal lag length was selected as 1, based on AIC. A low order of VAR may result in autocorrelation, and the LM test was applied to show that there is no autocorrelation to damage the properties of the procedure used in testing for causality; the results can be seen in the Appendix. Table 3 presents the results of the full-sample Granger test based on the modified-*LR* causality test. According to the bootstrap *p*-values, one can note that TS and ERE have a one-directional relation. TS does Granger cause ERE, but the opposite hypothesis does not hold. The result is in accordance with the export-oriented model under the premise of profit maximization (Bodnar *et al*., 2002). As the short-term causal relationship can be easily neglected (Zeileis *et al*., 2005), the parameters' stability test was needed to confirm whether there were structural changes.

Table 3

Full-sample Granger-causality tests

	H0: ERE does not Granger cause TS		**H0: TS does not Granger cause ERE**	
Tests	Statistics	*p*-value	Statistics	*p*-value
Bootstrap LR test	0.711	0.3411	0.971***	0.007

Notes: The null-hypothesis is that no-causal relationship exists between the variables. The parameter of bootstrap repetitions is set to 10,000 to calculate p-value.

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.

Equation (8) estimated using full-sample data, the parameters were fixed values, and the whole sample period had only one causal relationship. However, the parameters were not constant due to the structural changes. One should use the parameters' stability test to check the possible ignorance of short-term causality (Balcilar and Ozdemir, 2013; Su *et al*., 2022). *Mean-F*, *Exp-F*, *Sup-F* and *Lc* tests were performed to examine the stability of the VAR model parameters constituted by TS and ERE. Table 3 shows the results of the parameter stability test. The *Sup-F* test was used to check the stability of the parameters, the statistics reported that TS and ERE can reject the null hypothesis of stability at 1% level. The *Mean-F* and *Exp-F* tests were able to verify whether the parameters have a slow change process, the results confirmed that ERE, TS and the VAR model all rejected the null hypothesis that the parameter would not evolve over time at 5% and 1% level, respectively. The *Lc* test was able to check the stability of the long-term relation between the parameters, and the result demonstrated that VAR models rejected the null hypothesis of cointegration at 1% level. In other words, the variable followed the random walking process, which means that the parameters during the whole sample period (long-term) showed instability. Thus, the results revealed that the parameters estimated from the above VAR model showed a significant short-term instability. Based on the above parameter stability test, the short-term parameters established in the VAR model were unstable because there was a structural mutation. In addition, the test also suggested that there was a lack of effective cointegration relation between TS and ERE, indicating that the established VAR model can be treated as the foundation framework for a rolling causal relationship analysis.

Table 4

Parameter stability tests

	ERE equation		TS equation		VAR model	
	Statistics	***p*-value**	**Statistics**	***p*-value**	**Statistics**	***p*-value**
Sup-F	36.780***	0.000	41.093***	0.000	12.708	0.409
Mean-F	7.0128**	0.024	11.412**	0.016	23.641**	0.031
Exp-F	15.106***	0.000	15.899***	0.000	32.094***	0.000
L_c					6.0439**	0.016

Notes: The parameter of bootstrap repetitions is set to 10,000 to calculate p-value. *, **, ** denote significance at the 1% and 5% level, respectively. Hansen-Nyblom parameter stability test for all parameters in the VAR jointly. The tests used R software; the *vars*, *urca* and *strucchange* packages need to be installed in advance.

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.

China has experienced many monetary policies which explain the structural changes (Jiang *et al*., 2015). In addition, parametric stability tests also show that there existed great structural changes in the sub-period. Hence, the VAR model's framework in equation (8) can keep using the rolling-window causality test. The *RB*-based modified-*LR* causality tests based on equation (8) can estimate the bootstrap *p*-values in a rolling-window test. When selecting the rolling-window width, there is no uniform standard (Balcilar *et al*., 2010; Su *et al*., 2022d). A large window period could improve the validity of the estimation, but then the existence of heteroscedasticity would lead to a large error in the result. While a small window period can reduce the impact of potential heteroscedasticity, the estimated variance will be larger and therefore the effectiveness will be weakened. In particular, the bootstrap *p*-values of LR were estimated as a rolling model with a fixed sub-sample width of 24[1] owing to the sample size (Su *et al.*, 2022a).

Figures 2 and 3 show the bootstrap probability value and the direction and size of the influence of TS on ERE, respectively. The null hypothesis that TS does Granger cause ERE can be accepted in 2009M09-2010M10 at the 10% significance level, shows positive effect from TS to ERE. The other of time in 2019M08-2019M12 also shows a negative effect.

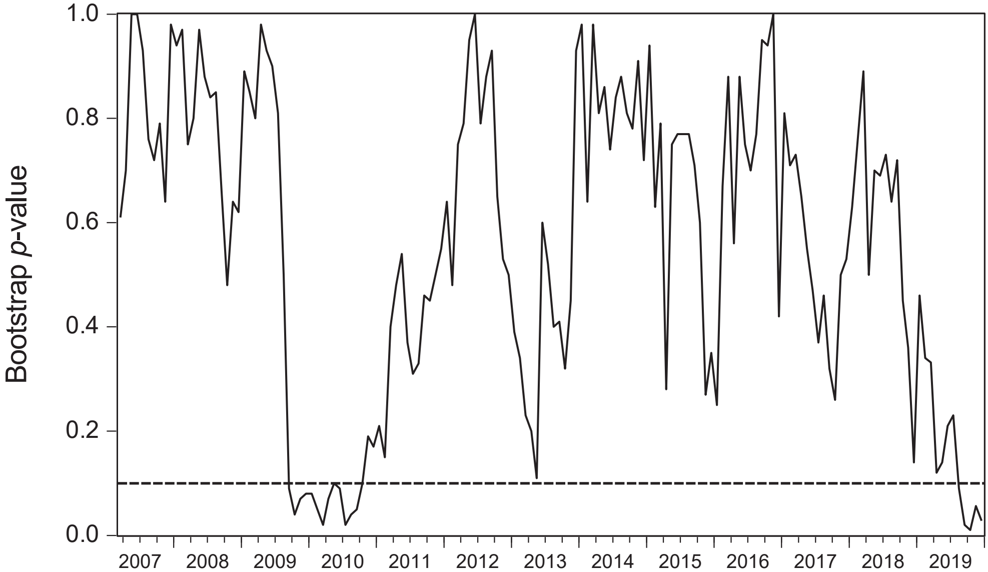

Fig. 2. Bootstrap *p*-value of rolling test statistic testing the null that TS does not Granger-cause ERE

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.

After the financial crisis in 2008, the Chinese government quickly implemented the "Four Trillion (RMB) Stimulus Programme", and China recovered rapidly from the financial crisis (Zhang, 2009; Perkins, 2012; Li, 2013). China is the largest source of the trade deficit in the US, and it manifests a tendency to continue expanding it (Woo, 2008). The expanding trade activities with the US have led to massive capital inflows into China (Sun, 2013). Moreover, persistent TS damages the benefits for foreign importers (Lau, 2018). The increase in TS has slowly evolved into trade

[1] When choosing the window size, the authors also respectively used the rolling-window widths of 20, 28 and 32 months to verify the accuracy. The results show that all these had little impact on the conclusion.

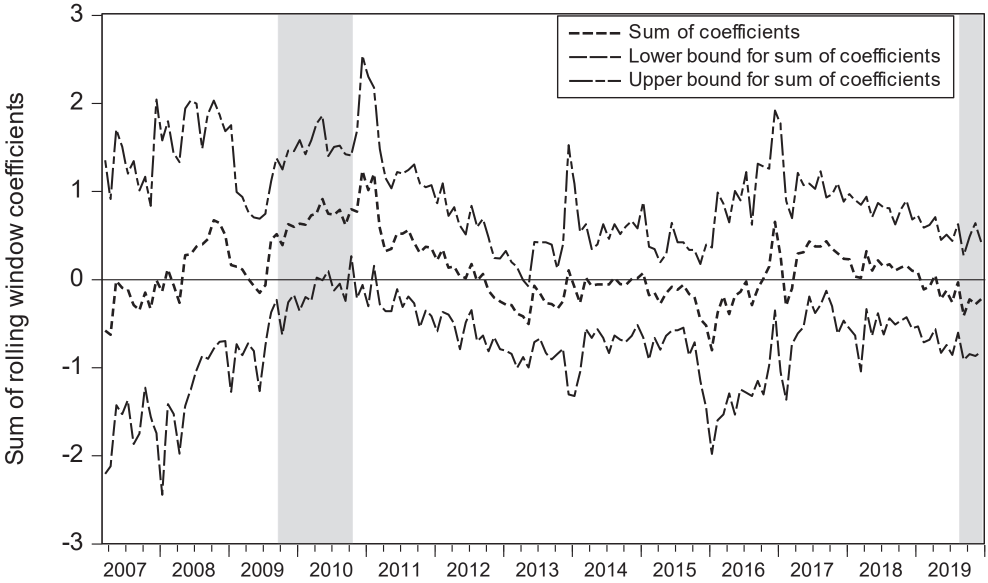

Fig. 3. Bootstrap estimates of the sum of the rolling window coefficients for the impact of TS on ERE

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.

friction with the USA (Rodrik, 2010). Even if increasing trade generates a common interest through comparative advantage, it also adds to the instability of the foreign-exchange markets (Lee, 2005). When the policy effect ended, the RMB exchange rate showed an upward trend and the market expectations became more volatile, which increased ERE (Cavallino, 2017). In general, the performance of exporters is sensitive to exchange rate fluctuations. Investors prefer to move assets into stable income products rather than continue expanding trade activities (Feenstra *et al*., 2013) because it greatly increases the cost of exchange for exporters. During the period 2009M09-2010M10, the expanding TS led to serious unstable market expectation, which increased ERE with the US. The empirical result is consistent with the theory of the export-oriented model (Bodnar *et al*., 2002).

In turn, the period 2019M08-2019M12 showed the negative effect between TS and ERE. The Sino-US relations seemed less friendly in these years. The outbreak of the trade war has spread to various fields such as foreign trade and finance, and the continuously increasing tariff barriers have greatly reduced the operation scale of traditional foreign trade industries (Kwan, 2020). On the one hand, intellectual property disputes have made it more difficult for China to export high-tech products (Chi and Qiao, 2020). On the other hand, there is no substitute for agricultural products and high-tech services from the USA for the time being (Itakura, 2020). In the first 11 months of 2019, exports to the US fell by 8.4% to 2.64 trillion yuan, including TS with the US of 1.88 trillion yuan, narrowing by 3%. At this time, the narrowing and increasing of TS instead stimulated the increase of ERE, which can be found from the recent intensive policy changes in Sino-US trade. The US has put pressure on Hong Kong, while at the same time as imposing trade restrictions. As the largest market for China's foreign exchange transactions, Hong Kong continues to burst with news of foreign capital withdrawing from China, and fears in the Hong Kong foreign exchange market have risen (Petri and Plummer, 2020). As ERE is very sensitive to capital flows in the foreign exchange market, the decline in TS caused by changes in trade policy intensifies risks in the capital market.

Figures 4 and 5 show the bootstrap probability value and the direction and size of the influence of ERE on TS, respectively. The alternative hypothesis that ERE does Granger cause TS can be accepted in 2008M01-2008M10, 2010M05-2010M09, 2012M01-2012M10, 2016M12-2017M01 and 2019M06-2019M12 at the 10% significance level. During these periods, both positive (2010M05-2010M09) and negative (2008M01-2008M10, 2012M01-2012M10, 2016M12-2017M01 and 2019M06-2019M12) effects exist from ERE to TS.

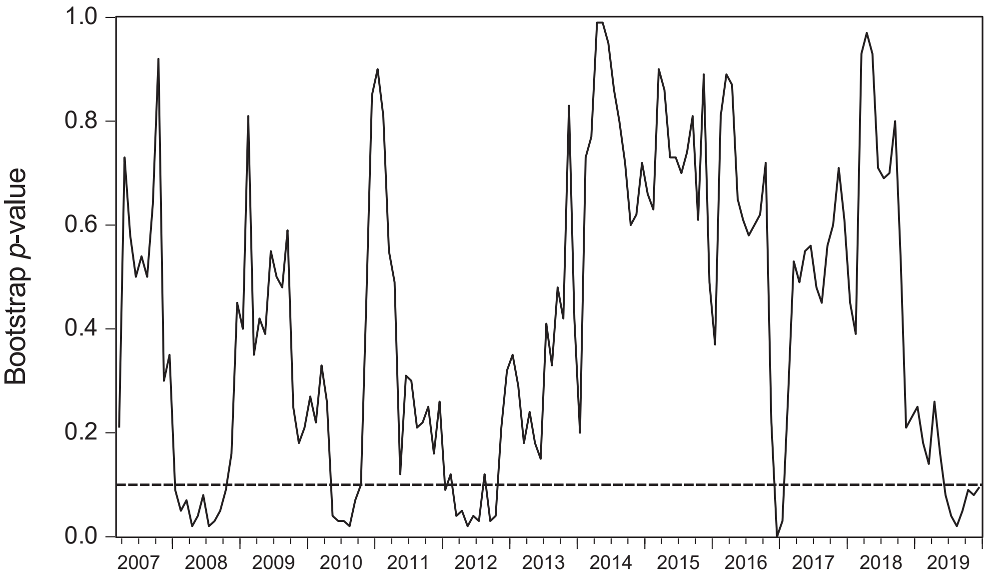

Fig. 4. Bootstrap p-value of rolling test statistic testing the null that ERE does not Granger-cause TS

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.

First, let us consider the negative effects (2008M01-2008M10). From July 2005, China scrapped the US dollar peg, which allowed RMB appreciation and increased the accumulation of ERE (Fidrmuc, 2010). In July 2008, the international financial

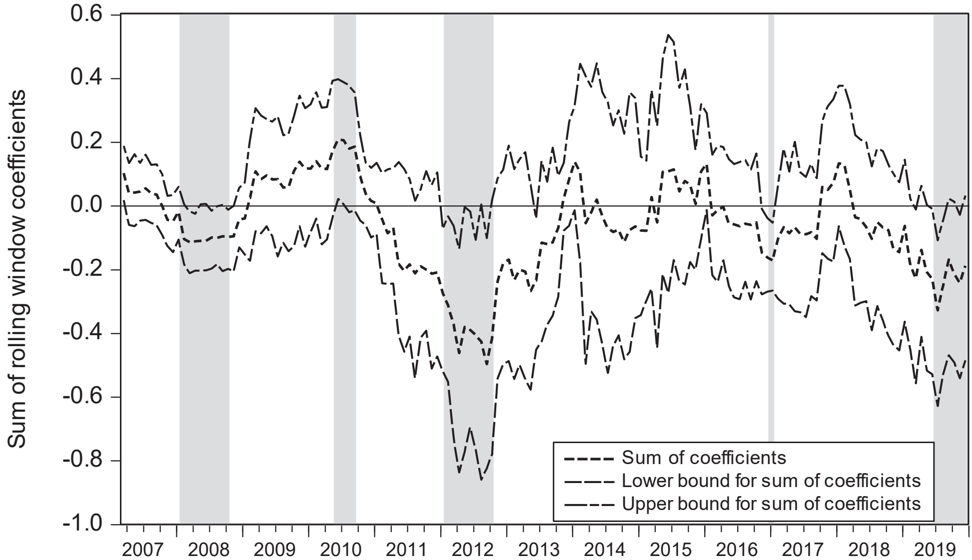

Fig. 5. Bootstrap estimates of the sum of the rolling window coefficients for the impact of ERE on TS

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.

crisis began to influence China and stimulate the rise of ERE (Yuan *et al*., 2010). The increasing exchange loss and higher cost had a negative effect on TS with the USA. (Hsu and Chiang, 2011). Meanwhile, higher ERE dented investor confidence, making exporters more sensitive to price changes (Goldberg and Campa, 2010). On the conservative side, reducing TS immediately is the general way to decrease ERE (Héricourt and Poncet, 2013). During this period, with the increase of ERE, the amount of TS to the USA decreased significantly, which confirmed the common view that the financial crisis has a potential impact on China's trade (Baldwin, 2009).

Another negative impact period was 2016M12-2017M01 and 2019M06-2019M12, during which the relations have experienced a similar international environment. Global political instability is also considered as one of the transmission mechanisms that affect bilateral trade activities and ERE (Elbahnasawy *et al*., 2016). The ongoing US presidential election at the end of 2016 influenced the exchange rate of the RMB against the US dollar (Bown *et al*., 2019). This is because potential trade friction increases the ERE fluctuation in the foreign exchange market (Dominguez and Tesar, 2001). The political instability has indirectly contributed to the appreciation of the RMB, and the rising cost of imported raw materials has dampened TS with the USA (Miao *et al*., 2013). In a politically unstable environment, the impact of ERE on TS is even more significant (Doidge *et al*., 2006). Therefore, investors' persistent cautious attitude led to the relative decrease of TS in the context of the increase of ERE. In 2019, the trade war between China and the USA gradually escalated, while geopolitical conflicts also intensified in China, which greatly stimulated the level of unease in the foreign exchange market. The decline in investor sentiment directly stimulated ERE growth (Vlados, 2020). By the end of 2019, tariffs and trade agreements between the two countries had still not been reached, and malicious economic sanctions even directly hit many Chinese high-tech companies. This led to a continuous decline in China's total imports and exports to the USA, while the decrease in TS also gradually appeared in the second half of the year.

In order to restrain the rapid economic growth and promote the upgrading of the domestic industrial structure (Chunding and Whalley, 2012), the Chinese government proposed the policy that reduced net exports from 5.8% of Gross Domestic Product (GDP) to 4% in 2012. Therefore, exporters have shifted their focus from simply expanding exports to upgrading industrial structures. In response to the possible employment pressure and decreasing market confidence caused by slowing economic growth, the Central Bank also adopted a loose monetary policy (He *et al*., 2013). Moreover, the flexible exchange rate system allowed the RMB to float in a wider band, which led to the high ERE in the foreign exchange market (Dixon *et al*., 2016). The general reduction of market expectations makes imports and exports to the USA inevitably appear to be on a downward trend (Li *et al*., 2015). In 2012M01-2012M10, China's TS with the U.S. was shrinking under the dual pressure of shifting trade centres and increasing ERE (Kang and Jiang, 2012).

Finally, the authors discussed the positive effects of the period (2010M05-2010M09). After the great recession of 2008-2009, the USA mainly adopted a quantitative easing monetary policy, which greatly increased the money supply (Bagis, 2017; Su et al., 2021a). The depreciation of the US dollar and the sharp rise in global primary commodity prices greatly reduced China's import volume within a short time. Following 2010, the goal of monetary policy of the PBC was to maintain stable economic development (Zhang *et al*., 2012). The steady appreciation trend of the RMB exchange rate makes investors' expectations of ERE in the market relatively optimistic. In the context of the gradual internationalization of the RMB, the relatively stable and sustained low level of ERE also stimulated the short rise of TS (McCauley, 2013).

To sum up, the causal relationship analysis between TS and ERE proves that the bootstrap sub-sample rolling-window causality test is effective when the parameters are not stable. The results are robust and can been seen in the Appendix. The results prove that TS has a short-term positive impact on ERE which is consistent with the export-orient model (Bodnar *et al*., 2002). Furthermore, there also existed a negative relationship at the end of 2019, which was due to the complex Sino-US trade policy changes. In another sub-period, there was also a bidirectional influence between ERE and TS. These structural changes were caused by the domestic economic transformation and global economic changes (Jiang *et al*., 2015). The expanding TS with the USA has accelerated the accumulation of foreign exchange reserves and facilitated the increase in ERE (Caporale *et al.*, 2015). To reduce the economic pressure that the financial crisis may bring to China, the Chinese government implemented a four-trillion stimulus plan including the policy of expanding exports, which rapidly increased TS with the USA (McCauley, 2013). Next, moderate monetary policies were proposed to stabilise the foreign exchange market (Li *et al*., 2016). The development of the foreign exchange market also relies on systematic monetary policy adjustments. The monetary authorities should strengthen precautionary controls and restrict abnormal international currency flows.

CONCLUSION

This paper examines the causality between TS and ERE in Sino-US trade relations by using rolling-window bootstrap test. Next, the authors studied the structural changes by parameter stability test across the sub-periods. The results prove the robust evidence that ERE has significant time-varying positive effects on TS, which is consistent with the conclusion of the export-oriented model (Bodnar *et al*., 2002). In turn, the study found that there was an effective bidirectional time-varying relation between ERE and TS with the USA during a few periods (such as the subprime crisis, China's economic reform in 2012, and especially the trade war in 2019, and other times of economic uncertainty). The time-varying causality is closely related to macro-economic conditions and different fiscal policies. These findings prove the value of a loose monetary policy in maintaining stable foreign exchange markets, especially in terms of structural economic changes. The research results can capture effective market information for investors and provide suggestions for them to reduce foreign exchange market risk, crucial to stabilise the impact of exchange rate shock on foreign exchange market. Consequently, in order to minimise ERE in foreign exchange markets and reduce trade frictions with the USA, it is vital to restrict the abnormal flow of international capital from Sino-US trade relations, and promote multilateral trade cooperation.

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APPENDIX I

The LM test can be applied to test whether the regression equation residual sequence is a high-level autocorrelation (Anselin, 1988). Moreover, in the case of a hysteresis due to variables, the LM test is still valid. The value of F statistics is 1.30377, corresponding *p*-value is 0.308, which points to accept the null hypothesis that the lagged residuals does not have sequence autocorrelation.

Table a

Breusch-Godfrey serial correlation LM test

F-statistic	1.304	Prob. F	0.308
Obs*R-squared	13.116	Prob. Chi-Square	0.157

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.

APPENDIX II

In order to examine the robustness of the empirical results, the authors conducted a robustness test by applying the quantile-on-quantile (QQ) method to reveal the time-varying relation between TS and ERE. The scale of the coloured bar indicates the coefficients between TS and ERE based on QQ estimates. The dark blue and dark red indicate the lowest and highest values of the coefficients, respectively. As for the result shown in Figure a, the positive response of ERE to TS appears in the medium quantile of ERE (0.35-0.45), with a lower quantile of TS (0.00-0.05). The lowest coefficient of -40 observed in the medium quantile implies that the exchange rate has shown inhibitory effects on trade when the trade surplus is in an intermediate state. Meanwhile, the impact of TS on ERE changes between negative and positive, which is shown in Figure b. TS positively affects ERE in the medium quantile (0.35-0.40). The most significant impact (the coefficient is 0.6) indicates the greater increase of ERE due to the trade surplus. The coefficients become negative when TS and ERE range in the quantiles of [0.45, 0.50] and [0.00, 0.05], respectively. Compared with the empirical tests, the results also prove the dynamic correlation ability between TS and ERE, and the impacts are both negative and positive when the variables evolve over time. Therefore, the empirical results have good robustness.

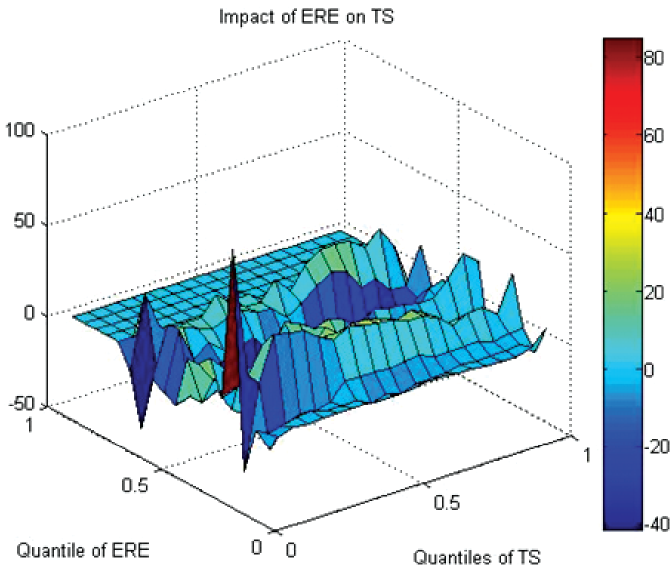

Fig. a. The impact of ERE on TS

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.

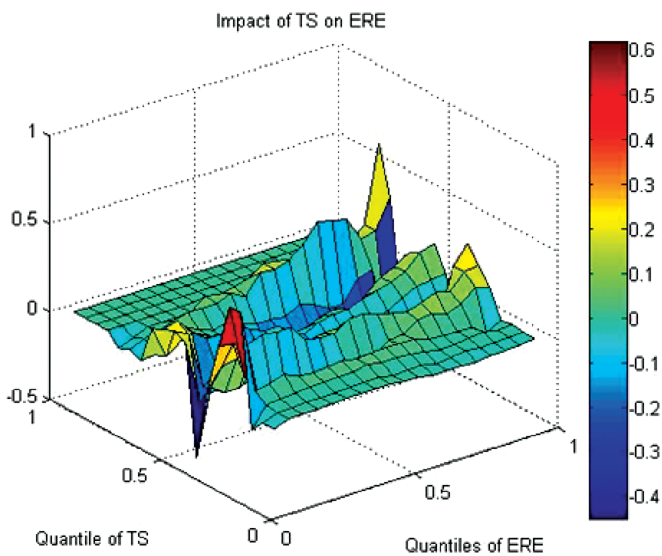

Fig. b. The impact of TS on ERE

Source: The data of ERE is taken from the People's Bank of China (PBC) and Wind database while the data of TS comes from General Administration of Customs.