

An Empirical Time Series Econometric Study of the J-curve Effect of Exchange Rate in Trade Balance between China and the US

ABSTRACT

Background and Aims: With the tensed relationship between China and the US, investigating the trade relationship between the two big countries has received more attention than before. This paper is just towards that direction to empirically examine the relationship between China's real effective exchange rate (REER) and trade balance with the US in both the long-run and short-run, which may exhibit the J-curve effect – currency depreciation deteriorates trade balance in the short-run but promotes trade balance in the long-run – in China's international trade with the US.

Data and Methodology: Quarterly data on China's REER, trade balance and gross domestic product (GDP, for income) and the US GDP from 2001 to 2017 are retrieved from relevant official websites for the current study. Unit-root test is first conducted on each modeling variable and its first difference to examine the stationarity of the variables. Autoregressive distributed lag (ARDL) approach with error-correction modeling (ECM) cointegration is then adopted to test the popular hypothesis of J-curve effect using the available quarterly data.

Results and Conclusion: The modeling results reject the J-curve effect in the short-run but show a long-lasting positive effect of Chinese yuan's depreciation in China's trade balance with the US. Also, the US GDP has a positive and much stronger effect than Chinese GDP on China's trade balance. As such, it is suggested that China should maintain a good relationship with the US and a stable exchange rate for long-run trade balance and economic growth at an appropriate level or rate.

Keywords: Autoregressive distributed lag model; Chinese yuan; cointegration; error-correction model; exchange rate; gross domestic product; J-curve effect; trade balance.

1. INTRODUCTION

Economic growth, either in the short-run or in the long-run, is a common and important issue faced by all people and countries. In simple terms, this refers to the growth of gross domestic product (GDP) or, seemingly more popularly, GDP per capita. Generally economic growth studies need to consider part or all of GDP's major components, namely consumption (private and/or government), investment, and trade balance (or net exports) with other countries. Of particular interest is the study of the long-run prospects (e.g., convergence or not) of GDP in total and/or in parts [1,2]. This paper was just originated from investigating the past experience and future trend of one important component of GDP, trade balance, and the special attention was in China's trade balance with one of its major trade partner, the US.

To start, it is worth mentioning the traditional belief that real effective exchange rate (REER) – weighted average of a country's currency in relation to a basket of other currencies, somewhat similar to the ratio of local currency over US dollar in real terms – has important

impact on the trade balance of a country: increasing exchange rate (implying depreciation of local currency) tends to promote exports and restrain imports, and a decline in exchange rate (corresponding to appreciation of local currency) tends to restrain exports and promote imports. And the influence of exchange rate change on local prices is that increasing exchange rate will cause domestic price levels to rise in general and declining exchange rate is helpful to curb local inflation. However, the classical Marshall-Lerner (M-L) condition (of the famous British economist Alfred Marshall and American economist Abba Lerner) should be well noticed, i.e., currency devaluation has a positive effect on trade balance when price elasticities of exports and imports are bigger than 100% in sum [3,4]. It is commonly accepted that the M-L condition is a fundamental principle of international economics, which has attracted the attention of many researchers, see for example [5] for a literature review of many studies on the topic.

Assuming the M-L condition holds as it should be, then a possible and practically interesting case is that the depreciation of a country's local currency, as reflected by the increase of its

exchange rate (REER), would not increase its trade balance immediately but show a lagged effect for producers and consumers to adjust and adapt for the changes in relative prices. Hence, the depreciation of local currency would lead to reduction of trade balance in the short-run but in the long-run will result in increase of trade balance. The phenomenon, resembling a titled J in shape and thus called the J-curve effect, was first recognized in [6] which observed the continuous reduction in the US trade balance despite a 15% devaluation of the dollar in 1971, and was also noticed for some other industrial economies [7]. One formal explanation for the J-curve phenomenon is that the short-run negative effect of currency depreciation in trade balance is due to the increase in unit price or value of imports and the long-run positive effect is due to the increased price competitiveness of local products which will lead to increased exports and declined imports [8].

How about the relationship between exchange rate and trade balance in the case of China which started its influential economic reform and opening-up policies in late 1978, especially after its entry into World Trade Organization (WTO) in December 2001? According to the official data from National Bureau of Statistics of China (<http://data.stats.gov.cn/>), China's GDP grew from 11.086 trillion (Chinese) yuan in 2001 to 82.712 trillion yuan in 2017, a nominal increase of 6.46 times! The trade balance increased even faster from 22.545 billion (US) dollars to 419.578 billion dollars during the same period from 2001 to 2007, an increase of 17.61 times! In this period of fast growth for Chinese economy, the impact of value changes in Chinese yuan was of course noticeable, partly because exchange rate is an essential factor of trade balance which greatly affects China's opening-up economy. According to China's official data, its yearly-average exchange rate against the US dollar (yuan/dollar) decreased from 8.277 during 2001-2002 to the lowest point of 6.143 in 2014, and then rose steadily to 6.752 in 2017. It is noticed that, during the period from 2001 to 2017, China's exchange rate policy changes could be divided into three sub-periods. Firstly from 2001 to 2004, Chinese yuan was pegged to US dollar (roughly at a rate of 8.277 yuan per US dollar), and China's trade balance increased but not by too much (from 22.545 to 32.097 billion dollars). Then from 2005 to 2014, a more flexible policy was adopted for Chinese yuan's steady appreciation (declining exchange rate) in accordance with market supply and demand, and China's trade balance increased greatly (to 383.085 billion dollars). Finally from 2015,

affected by the raised interest rate in the US and the increase in China's export costs, Chinese yuan got depreciated (exchange rate increased) again, and the trade balance continued to increase sharply to 593.904 billion dollars in 2015, then decreased quickly to 419.578 billion dollars in 2017. From the above empirical observations it seems that the J-curve effect does not fit well to China's relevant data.

Of course, trade balance is not only affected by exchange rate, but also by other policies, actions or variables [9,10]. Recently the relationship between China and the US has become more and more tensed, and the Donald Trump government has put lot of pressure on China economically and politically, including adding more tariffs on Chinese goods and restricting the transfer of key technologies to China, which will certainly affect the normal relationship between China's exchange rate and trade balance. And thus it is necessary more than before to carefully re-study the impact of exchange rate change on trade balance between China and the US, which not only is of academic interests, but also has practical value for China to form appropriate trade policies, especially in well dealing with the trade pressures from the US.

The current paper is aimed at analyzing if there is a J-curve effect in the case of China for the relationship between exchange rate and trade balance with the US. The special while popular error correction model (ECM) cointegrated autoregressive distributed lag (ARDL) approach is used to support the analysis based on 17 years' relevant quarterly data from 2001 to 2017. The analysis focuses on both the long-run and short-run effects of exchange rate on China's trade balance with the US. As usual, a relevant literature review will be conducted in the next section, followed by methodology and data description, modeling results and analysis, and finally some concluding remarks.

2. LITERATURE REVIEW

Examining the impact of (real effective) exchange rate (REER) on trade balance has been a popular research topic in international trade for long time. Many such studies focus on the Marshall-Lerner (M-L) condition [3,4,5,11] and then on the J-curve effect [6,7]. Especially, there have been a large amount of researches analyzing the impact of exchange rate on trade balance by using and exploring the J-curve effect [12,13,14,15], see for example [16] for an earlier while comprehensive literature review on the topic. But the research results are somewhat

different for different countries, industries and time periods, and the effects are also not the same in the long-run and short-run.

Firstly, there are many bilateral trade researches supporting the J-curve phenomenon in both the long-run and especially the short-run. For example, in an earlier study using quarterly data from 1973 to 1980, [17] finds empirical evidence for the J-curve pattern for the then developing countries of Greece, Korea, India, and Thailand. [18] verifies in the case of Serbia that, while supporting the J-curve effect in the short-run, exchange rate depreciation does improve its trade balance in the long-run. [19] finds that decline in Egypt's exchange rate from 1989 to 2010 deteriorated its trade balance in the short-run, but increased its trade balance in the long-run, exactly consistent with the J-curve effect. Using time series modeling approaches on monthly data from 1999 to 2013, [20] demonstrates that currency depreciation in Brazil had the J-curve effect in the short-run, although the long-run improvement in its trade balance with the US depended on more factors. Similarly, applying a number of time series analysis methods (such as unit-root and cointegration tests and impulse-response functions) to Turkey's monthly data from 2013 to 2016, [21] also shows the validity of the M-L condition and J-curve effect for Turkey, especially in the long-run.

In relation to Chinese trade, an earlier study in [22] explains China's trade balance using its exchange rate as well as domestic and foreign output and money supply, and finds strong support for (the short-run) J-curve effect in China. A comprehensive study in [23] tests Chinese exchange rate's short-run J-curve effect and long-run trade balance hypothesis with its 18 major trading partners using panel data time series methods, and the empirical results support the inverted short-run J-curve hypotheses. But in the long-run, [23] finds decreasing effect of real appreciation of Chinese yuan on China's trade balance with only three of the 18 trading partners and increasing long-run effect with only five of the 18 trading partners, leading to the conclusion of no overall long-run impact of real appreciation on China's trade balance. In another recent study, [24] uses time series models and annual data for 19 industries traded between China and Australia from 1990 to 2016 to estimate the short-run and long-run J-curve effect. The results show the short-run J-curve effect for 13 of 19 industries but only reveal the long-run effect for four of 19 industries, reaching the similar conclusion as in [23] of little or no long-run

effects of Chinese yuan's devaluation on China's trade balance (with Australia). Yet in another more recent and comprehensive study for 97 commodities traded between China and the US, [25] finds strong support for the short-run asymmetric J-curve effect for 2/3 of the commodities and for long-run asymmetric J-curve effect for 1/3 of the commodities.

However, there are also many studies finding no or even opposite evidence of the J-curve effect in the whole time period under consideration. For example, [14] detects no statistically significant evidence of a stable J-curve after careful checks of the American data. [10] concludes that India's trade balance is not cointegrated with exchange rate and some other variables and there is no J-curve effect for India. [26] applies a reduced-form trade balance model and an error-correction model (ECM) to examine the J-curve effect for China but fails to find any support. [27] adopts the ARDL approach to cointegration for estimation with quarterly data from 1989 to 2005 and finds no J-curve evidence for US forest products trade with Canada. Applying the ECM based long-term cointegration and impulse responses, [28] shows for Vietnam's case that local currency devaluation fails to improve its trade balance or the J-curve effect is not valid for it. In the case of Nigeria, [29] fails to verify the M-L condition for Nigeria and also fails to identify the J-curve effect using the cointegration approach in data analysis.

In this connection, a special possibility of interest is that there is no short-run J-curve effect but there is clear long-run desirable cointegration between trade balance and exchange rate. For example, in an earlier study, [30] applies a separate trade balance model from [31] to examine the J-curve effect for China with its 13 major trade partners including Australia, Canada, Germany, Japan, UK, and the US, and finds support for the long-run effect but no evidence for the short-run effect. In another study, [32] uses the bounds testing approach of cointegration on monthly data from November 1979 to September 2002, and finds that a real devaluation of Chinese yuan improved its trade balance with the US in both the long-run and short-run, suggesting no evidence of a short-run J-curve type adjustment. And in a recent study, [33] investigates the short-run and long-run relationships of exchange rate and trade balance between China and the US using data during the period from 1985 to 2014, and the research results also support the J-curve effect in the long-run but not in the short-run.

Typically, there are many researchers who study the relationship between exchange rate and trade balance for some pairs of countries, but the J-curve effect may only appear with certain pairs of countries. For example, [34] finds that, in the case of Korea with Japan and the US, the results reveal some J-curve effect; but for Singapore and Malaysia (with Japan and the US), the findings suggest no significant impact of exchange rate on trade balance and hence no evidence for the J-curve. In the case of the Western world, [35] tests the J-curve effect for UK with its 20 major trading partners using data from 1973 to 2001 and finds no support for the J-curve hypothesis in the short-run, and only in 5 cases exchange rate changes have significant impact on UK's trade balance in the long-run. In the case of Eastern Europe, a study in [36] shows the J-curve effect for three of the 11 countries (including Bulgaria, Croatia and Russia); and the short-run effect of exchange rate depreciation is found in six of the 11 countries but fails to last into the long-run. In the case of Taiwan, [37] demonstrates that there is no specific evidence for the J-curve effect with its trade partners except the US, but the relationship between real exchange rate and trade balance is shown to be clear with all its trading partners other than Japan in the long-run. And in the case of Africa, [38] finds no support for the short-run J-curve effect for the nine African countries under study with available quarterly data, and the positive and significant long-run impact of real depreciation in trade balance exists only in Egypt, Nigeria, and South Africa.

Since trade data at country level may have aggregation bias and hence may not clearly reveal the underlying relationship between trade balance and exchange rate, there are also many studies that study the trade balance of different industries to analyze the J-curve effect. For example, [39] analyzes the imports and exports of 88 industries between the US and its trade partner China using cointegration analysis and finds that the US trade balance reacts positively to dollar's depreciation for at least 34 of the industries and the J-curve effect is found to be with 22 industries. [40] considers 47 industries traded between China and UK and differentiates their trade flows by commodities, and the results show that China's trade balance is affected favorably by exchange rate depreciations in most industries, but in only seven industries the short-run effects last into the long-run. Similarly, [41] disaggregates Korean trade flows with all other countries by commodity and considers the response of its trade balances in 148 industries to its exchange rate changes, and finds that the

trade balance of 91 industries are affected by exchange rate changes in the short-run, but these short-run effects only last into favorable long-run in 26 industries. Using Turkey's monthly data in 58 industries from 1990-2012, [42] detects the J-curve effect in only 13 industries. In a more recent study, [43] finds that the short-run J-curve effect is with 17 out of 45 industries traded between Pakistan and the US from 1972 to 2011, and 15 of them also have long-run significant relationship between trade balance and exchange rate change.

3. METHODOLOGY

3.1 Empirical Models

This study aims at determining if real effective exchange rate (REER) has significant effect in China's trade balance with one of its major trade partner, the US. A time series modeling approach is adopted from the literature [14,27] for the purpose. And naturally trade balance is the dependent variable in the relevant models.

The starting point of the models is the simple point that the quantity of imported goods demanded depends on real income and the relative price of imported goods:

$$M_{CN} = M_{CN}(P_{M,CN}, Y_{CN}) \text{ and } M_{US} = M_{US}(P_{M,US}, Y_{US}) \quad (1)$$

where M_{CN} is China's imports from the US, which is also the US's exports to China (X_{US}), Y_{CN} is China's income level measured by its GDP, and $P_{M,CN}$ is the relative price of China's imported goods (from the US) to domestically produced goods; M_{US} is the US's imports from China, which is also China's exports to the US (X_{CN}), Y_{US} is the US GDP (for income), and $P_{M,US}$ is the relative price of the US imported goods (from China) to domestically produced goods in the US.

Likewise, the supply of exported goods in China or the US can be similarly determined as:

$$X_{CN} = X_{CN}(P_{X,CN}, Y_{US}) \text{ and } X_{US} = X_{US}(P_{X,US}, Y_{CN}) \quad (2)$$

where X_{CN} is China's exports to the US, which is also the US imports from China (M_{US}), $P_{X,CN}$ is the relative price of China's exported goods (to the US) to domestically produced goods; X_{US} is the US exports to China, which is also China's imports from the US (M_{CN}), $P_{X,US}$ is the relative price of the US exported goods (to China) to domestically produced goods in the US.

Also, assuming the law of one price (for the same goods or services) holds in a perfectly competitive market, the following relationships should hold:

$$P_{M,CN} = P_{M,US} \cdot REER \text{ and } P_{X,CN} = P_{X,US} \cdot REER \quad (3)$$

where REER is China's real effective exchange rate (similar to the ratio of Chinese yuan per US dollar). The simple equilibrium conditions of the imports and exports in the market are:

$$M_{CN} = X_{US} \text{ and } M_{US} = X_{CN} \quad (4)$$

Then, combining the above eqs. (1)-(4) and taking the local and foreign price levels as given or externally controllable, a simple and direct equation for China's trade balance (TB) with the US, the difference between China's exports and imports, can be derived as follows:

$$TB = X_{CN} - M_{CN} = X_{CN}(P_{X,CN}, Y_{US}) - M_{CN}(P_{M,CN}, Y_{CN}) \equiv TB(REER, Y_{CN}, Y_{US}) \quad (5)$$

Finally, as in many studies (Hurley and Papanikolaou 2018, Petrović and Gligorić 2010, Siklar and Kecili 2018), the similar but somewhat more convenient measure of relative trade balance (RTB) is used in the following part of this paper, which is the ratio of China's exports over its imports:

$$RTB = X_{CN} / M_{CN} = X_{CN}(P_{X,CN}, Y_{US}) / M_{CN}(P_{M,CN}, Y_{CN}) = RTB(REER, Y_{CN}, Y_{US}) \quad (6)$$

As well noticed, practical reason to adopt the ratio format in eq. (6) is because it has certain technical advantages over the difference format in eq. (5) such as, (i) ratios are positive and can easily take logarithms, and (ii) ratios are in small numbers and hence tend to be more stable and normal and less sensitive to outliers [44].

3.2 Model Specification

For practical purposes, especially for empirical estimation using the ARDL modeling approach, eq. (6) can be expressed in a log-linear form as follows to show the long-run effect [14,18,21,33]:

$$\ln RTB_t = \alpha + \beta_1 \ln REER_t + \beta_2 \ln Y_{CN,t} + \beta_3 \ln Y_{US,t} + \varepsilon_t \quad (7)$$

where β_1 , β_2 and β_3 are parameters for the relationships between the dependent variable ($\ln RTB_t$) and the independent variables ($\ln REER_t$, $\ln Y_{CN,t}$ and $\ln Y_{US,t}$) in the long-run. As already explained and also for clarity, here the

variable LTB_t is defined as China's exports divided by its imports, and $REER_t$ is defined as the weighted average of Chinese yuan in relation to a basket of other currencies (something similar to the amount of Chinese yuan per US dollar). Then β_1 can be expected to be positive, because increasing REER (or depreciation of Chinese yuan) tends to increase exports and decrease imports and hence improve the (relative) trade balance, especially in the long-run, although in the short-run the J-curve hypothesis implies a negative effect of REER on trade balance. It is also expected that β_2 is negative but β_3 is positive because an increase in Chinese (the US) income leads to a rise in Chinese imports (exports), thus decreasing (increasing) Chinese trade balance [27,33]. But as also pointed out in some studies [33,45], the hypothesized directions of the income effects or signs of β_2 and β_3 are empirical only since, for example, an increase in Chinese (the US) income may also promote Chinese exports (imports), thus increasing (decreasing) Chinese trade balance.

Because the J-curve phenomenon is largely a short-run concept, so ARDL-type models with differences and/or lags are needed for analysis. When using the ARDL approach, the short-run dynamics should be included based on the long-run equilibrium or cointegration model (7) [27,31,33], thus with a general format as shown below,

$$\begin{aligned} \Delta \ln RTB_t = & \alpha_0 + \sum_{i=1}^p \theta_i \Delta \ln RTB_{t-i} + \sum_{i=1}^p \pi_i \Delta \ln REER_{t-i} \\ & + \sum_{i=1}^p \varphi_i \Delta \ln Y_{CN,t-i} + \sum_{i=1}^p \gamma_i \Delta \ln Y_{US,t-i} \\ & + \lambda_1 \ln RTB_{t-1} + \lambda_2 \ln REER_{t-1} + \lambda_3 \ln Y_{CN,t-1} + \\ & \lambda_4 \ln Y_{US,t-1} + u_t \end{aligned} \quad (8)$$

Here in the above model (8), Δ is the difference operator (i.e., $\Delta y_t = y_t - y_{t-1}$), p is the lag order, and random error u_t is assumed to be serially uncorrelated. The dependent variable ($\ln RTB_t$) and independent variables ($\ln REER_t$, $\ln Y_{CN,t}$ and $\ln Y_{US,t}$) would deviate from equilibrium in the short-run even if these four variables are cointegrated in the long-run as in model (7). An ECM term, formed by replacing the lagged level variables with λ -coefficients in model (8) by a lagged cointegration relationship as estimated from eq. (7), can correct for any disequilibrium that exists during the previous period, and restrict the model's unstable endogenous variable to converge to cointegration relationship in the long-run,

$$\begin{aligned} \Delta \ln RTB_t = & \alpha_0 + \sum_{i=1}^p \theta_i \Delta \ln RTB_{t-i} + \sum_{i=1}^p \pi_i \Delta \ln REER_{t-i} \\ & + \sum_{i=1}^p \varphi_i \Delta \ln Y_{CN,t-i} + \sum_{i=1}^p \gamma_i \Delta \ln Y_{US,t-i} + \lambda_5 ECM_{t-1} + u_t \end{aligned} \quad (9)$$

Here specifically, the terms within the summation symbols (Σ) represent the short-run dynamics (i.e., the J-curve effect) while the terms with λ_1 , λ_2 , λ_3 and λ_4 represent the long-run relationship between the dependent variable and independent variables, and λ_5 shows the speed of adjustment back to equilibrium. Hence the null hypothesis is $H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$ for model (8), or $H_0: \lambda_5 = 0$ for model (9), which implies no long-run cointegration or equilibrium relationship in the model.

As well noticed in the literature, using ARDL models like eq. (8) or (9), formally called ARDL bounds testing approach developed in [31], for analyzing the cointegration relationship like eq. (7) has a number of advantages over directly evaluating model (7) using standard cointegration methods [46,47,48]. These include the freedom in using lags for variables to better capture the data-generating process using more flexible models with more robust and better small sample properties [27,31,33]. Another advantage is more attractive in that a lagged ECM term is available in the ARDL method to adjust deviations from long-run equilibrium back, thus allowing for short-run dynamics while maintaining or restricting the long-run relationships [27,31,33,38].

4. EMPIRICAL RESULTS AND ANALYSIS

This study aims at determining if the real effective exchange rate (REER) has significant effects in trade balance in China from 2001 to 2017. Quarterly data are used for the study to be closer to real world changes and also for having an appropriately larger sample size. The relevant quarterly data on the four modeling variables, i.e., China's REER, trade balance and GDP (for income) and the US GDP, are collected online from the National Bureau of Statistics of China, US Bureau of Labor Statistics, US Bureau of Economic Analysis, and International Monetary Fund. Especially, China's trade balance and GDP data are retrieved from <http://data.stats.gov.cn/easyquery.htm?cn=G0101> and <http://data.stats.gov.cn/english/easyquery.htm?cn=C01>, China's REER data are retrieved from <http://data.imf.org/regular.aspx?key=61545862>, and finally the US GDP data are retrieved from <https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=2#reqid=19&step=2&isuri=1&1921=survey>.

Several quantitative time-series econometric approaches are applied to analyze the short-run and long-run relationships between the

dependent variable of trade balance and the independent variables of REER and China's and the US income levels. Data analysis and model estimation are performed using the professional EViews software. To be simple and clear, standard level of 5% will be used throughout the study when evaluating the significance of the modeling results.

4.1 Unit Root Tests

Firstly, the augmented Dickey and Fuller (ADF) method is used to check the stationarity of each of the four modeling variables with the popular unit-root test [49]. For the current study, this is even necessary since the variables are all in logarithm form and hence are more likely to have unit-root [50]. The main purpose of doing the unit-root test is to check and avoid or remove the variables' non-stationarity (if any) so that the regression is not spurious. This is especially of value for vector autoregression (VAR), ARDL, cointegration and error correction models [51,52]. To do the test, the following null hypothesis is evaluated against the alternative one for each of the four modeling variables for both the initial level variable and its first difference,

H_0 : The variable has a unit root.

H_1 : The variable does not have a unit root.

According to the test results shown in Table 1, the test statistics for the four level variables ($\ln RTB$, $\ln REER$, $\ln Y_{CN}$ and $\ln Y_{US}$) are all much larger than the 5% critical value of -2.90, hence the null hypothesis cannot be rejected and the conclusion is that all four variables have a unit root and are not stationary. Then the same test is done for their first differences, and the results show that the test statistics for the four first-difference variables ($\Delta \ln RTB$, $\Delta \ln REER$, $\Delta \ln Y_{CN}$ and $\Delta \ln Y_{US}$) are all much smaller than the 5% critical value of -2.90. So the four modeling variables are stationary at their first-difference levels, or they are I(1) series, and the proposed ARDL model (8) is appropriate for examining the relevant relationships.

4.2 Autoregressive Distributed Lag (ARDL) Model

An ARDL model like the above eq.(8) or (9) involves many lagged terms and generally needs to be "optimized" by, e.g., removing some insignificant terms. For this purpose, the model's (lagged) variables are selected using the Akaike information criterion (AIC) or the largely equivalent Schwarz criterion (SC) as in most

studies. A maximum lag of four for each of the four first-differenced variables in the model (i.e., $p = 4$) appropriate for quarterly data is imposed, leading to different combinations of the lagged terms with a total of $4^4 = 256$ possibilities. Then the “best” model with the best lags for the variables is selected as the one with the smallest SC value among all possibilities under the condition of cointegration. Eventually the ARDL(2,0,0,0) model turns out to be the choice, with 2, 0, 0, and 0 being the best lags for the four modeling variables ($\Delta \ln \text{RTB}$, $\Delta \ln \text{REER}$, $\Delta \ln Y_{\text{CN}}$ and $\Delta \ln Y_{\text{US}}$) respectively.

Then according to [31], the bounds test is done to see if there is a level cointegration or equilibrium relationship like eq. (7) among the variables, which makes the major difference between the standard VAR model and the ARDL model (8) or (9) which includes the lagged *level* variables (with coefficients λ_1 , λ_2 , λ_3 and λ_4 respectively) to be the lagged ECM term. Hence as mentioned in section 3.2, it is necessary to test whether the lagged level variables should be kept in the ARDL model (8) to be cointegrated by testing the null hypothesis $H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$. Similar to testing the joint significance of these four parameters in traditional multiple regression models, this can be done with the bounds test by evaluating the calculated sample F-statistic, which turns out to be as big as 16.396, much larger than the 5% upper bound critical value (around 4.00) as supplied in [31]. Therefore, the above null hypothesis is clearly rejected and the four level variables ($\ln \text{RTB}$, $\ln \text{REER}$, $\ln Y_{\text{CN}}$ and $\ln Y_{\text{US}}$) have a significant (long-run) cointegration or equilibrium relationship as eq. (7).

Then the long-run relationship, i.e., the level eq. (7), is estimated, and the estimated coefficients are reported in Table 2. From these results it can be seen that exchange rate (REER) has a

positive effect on trade balance as expected and, in the long-run, a 1% increase in REER or a 1% depreciation in Chinese yuan leads to a 0.301% increase in trade balance ratio (RTB). Also as expected, China’s GDP has a negative effect and the US GDP has a positive effect on China’s trade balance, supporting the general expectations for the associations between trade balance and domestic and foreign incomes [27,33]. It is noticed that a 1% increase in China’s GDP is estimated to decrease China’s trade balance ratio by 0.161%, while a 1% increase in the US GDP is estimated to increase China’s trade balance ratio by 1.067%, a much larger effect than China’s own GDP. It is also noticed that the long-run coefficient estimates are all highly significant, implying a highly stable long-run cointegration relationship as follows,

$$\ln \text{RTB} = -8.420 + 0.301 \ln \text{REER} - 0.161 \ln Y_{\text{CN}} + 1.067 \ln Y_{\text{US}} + u_t \quad (10)$$

Finally, the ARDL model (9) with an ECM term is estimated to capture the short-run effects of currency depreciation in trade balance. This is done by re-estimating the optimal ARDL(2,0,0,0) model (8) after replacing the lagged level variable part “ $\lambda_1 \ln \text{RTB}_{t-1} + \lambda_2 \ln \text{REER}_{t-1} + \lambda_3 \ln Y_{\text{CN},t-1} + \lambda_4 \ln Y_{\text{US},t-1}$ ” by the above already-estimated long-run cointegration relationship (10) as a lagged ECM term, ECM_{t-1} . It is hoped to obtain a negative and significant coefficient for ECM_{t-1} so as to reflect the adjustment of the modeling relationship towards the long-run equilibrium (10) and the cointegration among the variables. The estimation results are given in Table 3 and summarized by the following equation, from which it can be found that the ECM term (-0.399) is indeed negative and highly significant, confirming the existence of the long-run cointegration relationship among the four modeling variables.

Table 1. ADF unit-root tests for the four variables and their first differences.

Variable	Test Statistic	Probability	Variable	Test Statistic	Probability
$\ln \text{RTB}$	-0.898	0.783	$\Delta \ln \text{RTB}$	-7.470	0.000
$\ln \text{REER}$	-1.107	0.708	$\Delta \ln \text{REER}$	-4.350	0.001
$\ln Y_{\text{CN}}$	0.783	0.993	$\Delta \ln Y_{\text{CN}}$	-8.133	0.000
$\ln Y_{\text{US}}$	1.330	0.999	$\Delta \ln Y_{\text{US}}$	-6.687	0.000

Table 2. Coefficient estimates for the long-run level model (7).

Variable	Coefficient	Std. Error	t-Statistic	Probability
C	-8.420	1.489	-5.655	0.000
$\ln \text{REER}$	0.301	0.071	4.247	0.000
$\ln Y_{\text{CN}}$	-0.161	0.035	-4.564	0.000
$\ln Y_{\text{US}}$	1.067	0.184	5.800	0.000

Table 3. Short-run optimal ARDL(2,0,0,0) model results with the ECM term.

Variable	Coefficient	Std. Error	t-Statistic	Probability
C	0.002	0.002	0.922	0.361
$\Delta \ln \text{RTB}_{t-1}$	-0.536	0.092	-5.850	0.000
$\Delta \ln \text{RTB}_{t-2}$	-0.437	0.091	-4.805	0.000
$\Delta \ln \text{REER}_t$	0.353	0.128	2.757	0.008
$\Delta \ln Y_{\text{CN},t}$	-0.029	0.008	-3.410	0.001
$\Delta \ln Y_{\text{US},t}$	0.237	0.172	1.378	0.174
ECM_{t-1}	-0.399	0.081	-4.935	0.000

$$\begin{aligned} \Delta \ln \text{RTB}_t = & 0.002 - 0.536 \Delta \ln \text{RTB}_{t-1} - 0.437 \\ & \Delta \ln \text{RTB}_{t-2} + 0.353 \Delta \ln \text{REER}_t \\ & - 0.029 \Delta \ln Y_{\text{CN},t} + 0.237 \Delta \ln Y_{\text{US},t} - 0.399 \text{ECM}_{t-1} \\ & + u_t \end{aligned} \quad (11)$$

As for the short-run results, the existence of the J-curve effect requires that an increase in REER or a depreciation of local currency should decrease trade balance temporarily (reflected by, e.g., a negative and significant coefficient of $\Delta \ln \text{REER}_t$) and increase trade balance in the long-run (reflected by, e.g., a positive and significant coefficient of $\Delta \ln \text{REER}_{t-1}$ and/or a positive and significant coefficient of the level $\ln \text{REER}_{t-1}$ in a confirmed cointegration relationship). In the estimated short-run ARDL model (11), $\Delta \ln \text{REER}$ only has significant effect at the current level which, to be worse, is positive. So there is no J-curve effect in the current study for the relationship between exchange rate and trade balance in the case of China, consistent with the previous no J-curve results of some studies on China [26,32] and on some other countries [27,28,29]. It is also noticed that Chinese GDP has negative effect in China's balance trade while the US GDP has positive and much bigger impact in China's trade balance, similar to those in the long-run cointegration eq. (10).

5. DISCUSSIONS AND CONCLUDING REMARKS

This paper tests whether the J-curve effect exists in China's trade with the US. The ECM-cointegrated ARDL model is applied with the relevant quarterly data from 2001 to 2017 for China's trade balance with the US (measured by the ratio of China's exports over imports), China's real effective exchange rate (REER), as well as China's GDP and the US GDP, to evaluate the hypothesis. Logarithms are taken over the variables to increase their stability and normality as suggested and used in the literature. The unit-root test shows that the variables (after taking logarithms) are not stationary at level, but stationary at first difference. Then the ARDL modeling approach is used over the first-

differenced (log) variables to examine the long-run and short-run effects of exchange rate in China's trade balance with the US.

The modeling results show that the J-curve effect is absent in China's trade with the US in the short-run but present in the long-run. In the short-run, instead of an expected initial decline in trade balance after the depreciation of Chinese yuan, the model reveals an increasing trade balance caused by depreciation and hence rejects the short-run J-curve effect. In the long-run, depreciation of Chinese yuan or increasing exchange rate will lead to increasing exports and/or decreasing imports and thus increasing trade balance (ratio), which is the expected and favorable result. The negative and significant lagged ECM term also supports the long-run effect. The reason why the results differ from the expected (short-run) J-curve effect could be that trade balance may respond to changes in exchange rate quickly without a time lag or without a turning point in China's case (i.e., without the initial decrease in trade balance and then turn to increase, but just increase after the depreciation of local currency).

Moreover, in both the short-run and long-run, Chinese GDP has a negative and relatively small effect in its trade balance while the US GDP has a positive and much larger impact, implying that the US economic conditions play a more crucial role than China's domestic growth in promoting its trade balance with the US.

A number of policy implications and suggestions can be drawn from the modeling results to the government and relevant business sectors to well manage exchange rate changes for achieving appropriate level of trade balance and avoiding trade conflicts between China and the US. Firstly, China's opening-up policies in the first three decades since 1978 had mainly targeted at exporting more to the rich economies led by the US. This had resulted in the long-standing and increasing trade surplus of China with the US, showing that China's resources had been more distributed to the US, which had

certain negative effects on the development of Chinese economy and trade including the high dependence of China's economic growth on exports to the US. After the 2008 global financial crisis, world-wide economic conditions and policies changed a lot, and China also started to expand local demand and increase imports to make resource and income distributions more and more domestically skewed, which helps (partly) explain the hypotheses that China's trade balance depends positively on the US GDP ($\beta_3 > 0$) but negatively on China's own GDP ($\beta_2 < 0$). This is also the right direction because in the long-run appropriate trade balance between two countries can be maintained only when both countries can benefit from the trade roughly equally. Therefore, it is desirable for China to keep on its recent years' policies to increase the quantity and quality of domestic consumption so as to make domestic consumption contribute more towards its overall economic growth. Having more imports, especially from the US which provides a whole range of higher quality goods and services, is an effective way for the purpose of stimulating domestic consumption, which can help improve the living standards of Chinese people not only, but reduce the big surplus of China's trade with the US and hence remove some barriers in the two big countries' bilateral relationships as well.

Secondly, Chinese industries need to be transformed and upgraded to reduce the reliance on manufacturing and exporting labor and resources intensive products. It is time and more beneficial for Chinese economy to focus more on promoting science and technology development to manufacture and export high-tech and high value-added products. This will help improve China's economic structure and international trade pattern, especially maintain its trade balance at a more reasonable level to avoid the negative feelings for and potential sanctions against Chinese exports from Western countries, especially from the US. For example, Chinese government can give more administrative and financial supports to encourage local enterprises especially high-tech industries to have more independent innovations, because many core technologies of domestic products are still heavily depending on those of the US. Only in this way can China avoid the technological monopolies of the US and make its economic development more independent, helping resolve the trade problems between China and the US.

Thirdly, both China and the US should make great efforts to achieve a better trade balance between them. As the above analysis shows, trade balance between China and the US will

show an upward trend in both the short-run and long-run, implying that the change of exchange rate will likely make the trade balance change immediately and last for longer time in the same direction. Therefore, China and the US should maintain good economic relationships because any change in exchange rate would reflect on the trade balance for longer time. For instance, Chinese government can do more to create a better and more standardized investment environment, which can help attract more investment from American enterprises; and Chinese government can also give preferable treatments to the US investors in China in terms of company and personal taxes for the same purpose. On the other hand, the US should also put aside the prejudice about (investment in) China and invest more in China for more benefits since China is still full of opportunities. Working in these ways, it is expected that appropriate levels of trade balance and exchange rate can be better maintained for China.

Finally, the severe on-going global pandemic of coronavirus disease 2019 (COVID-19, first identified in December 2019) has very negatively affected Chinese economy and especially the US economy, and also has been unfortunately making the already affected relationship between China and the US even worse. It is thus more challenging for the two countries to recover their economies and their mutually dependent relationships, both economically and politically. Hopefully the situations, especially in the US, could get improved soon, which, as implied by this study, will also be beneficial to China's trade balance and hence China's economic growth and restructuring in the short-run and long-run as well.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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