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CAN CHINA'S EXCHANGE RATE AFFECT GLOBAL COMMODITY PRICES?

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Abstract

In the context of the ongoing trade dispute between China and the United States, our study attempts to investigate the sensitivity of global commodity prices to the appreciation and depreciation of renminbi (RMB). Using quarterly data of 1994-2016, we reach three notable findings which are based on linear and non-linear specifications of autoregressive distributed lag (ARDL). First, the global prices of agricultural commodities are sensitive to the appreciation of RMB, exercising a downward pressure on agricultural commodity markets. Second, crude oil prices are found to react negatively to real appreciation of RMB. Third, the prices of several metal commodities particularly aluminum and nickel are found to respond negatively to changes in RMB. The policy implication from our findings is that China would be benefitted if it adopts a trade strategy by setting a one-off appreciation instead of resorting to tariffs on its imports.

Keywords: Renminbi; global commodity prices; asymmetric effect; trade dispute; ARDL

INTRODUCTION

Predicting commodity prices based on the exchange rate plays a role in trade for commodity-importing and exporting countries. Therefore, it is of interest to know how exchange rates would influence commodity prices since speculative pressures on currency values tend to give rise to bubble-type patterns of volatility in commodity markets (Caporale et al., 2017). A change in the movement of exchange rates often results in substantial losses for commodity-importing and exporting countries. Hence, the exchange rate is argued be a more valid proxy for macroeconomic factors in forecasting the commodity price (Campbell & Shiller, 1987; Rogoff, 1992; Clements & Fry, 2008; Chen et al., 2009; Chen et al., 2010; Chen et al., 2014; Roache & Rossi, 2010).

China has emerged to be one of the largest consumers and producers of commodities in recent years. To maintain a dominant position in the global market for its own benefits, the country tends to influence commodity trading through its effective financial markets and institutions. The first benefit is that China would be able to achieve self-sufficiency for meeting the food needs of its vast population. Next, the country could maintain a stable and ready supply of raw material for utilizing its large manufacturing capacity. Additionally, aside being a big consumer and producer of commodities, China is now well recognized as a leading importer and exporter of commodities in the world. Uncertainties in its foreign exchange market are likely to impact the exchange rates in the emerging markets as well.

The objective of our study is to examine to what extent the global commodity prices are sensitive to the appreciation and depreciation of renminbi (RMB) and if so how much the degree of such sensitivity is likely to be. The examination is conducted for the sample period of first quarter of 1994 - fourth quarter of 2016 by resorting to an autoregressive distributed lag (ARDL) approach. Specifically, we contribute to the relevant literature in the following ways. Firstly, aside from agricultural commodities such a cotton, rice, gold, corn, wheat, sugar, and palm oil, we cover energy and metal commodities including aluminum, nickel, copper, zinc, tin, lead, and crude oil. Secondly, we also consider China's exchange rate, both nominal and real exchange rates, with a view to ensuring the robustness of findings. Thirdly, we propose to check the results by using alternative non-linear models and compare them with those of linear model.

Our findings would provide new insights on the role of RMB in influencing the commodity price. For example, Chinese government could forecast price responses of different types of commodity to changes in the external value of RMB by adopting a dynamic exchange rate regime. This would enable government to take appropriate measures for controlling inflationary pressures on agricultural, metal and energy related products. This is not only for the sake of protecting the domestic commodity markets, but it also serves as the basis in designing trade strategies when the country involved in a trade dispute with other countries.

LITERATURE REVIEW

This section provides a review of literature on the structural link between currency values and commodity prices, considering that commodity prices are a function of exchange rates. However, this link is subject to symmetric or/and asymmetric effect. To support the substantial influence of currency fluctuations on prices for traded commodities which have been appropriately labeled as a "currency commodity", the literature offers the following two arguments.

The first argument is initially based on a standard present value model for exchange rates that put forward by Campbell and Shiller (1987). Their model implies that future fundamentals are predicted by current exchange rates. Based on the model, Rogoff (1992) further develops the asset pricing approach to relate the exchange rate to its fundamentals and expected values. He extends the approach by incorporating the expectation about future fundamental value for nominal exchange rate. His finding shows that the exchange rate is expected to Granger cause its fundamental value.

Several studies corroborate that the commodity price is one of fundamentals for the exchange rate. For instance, Chen et al. (2009) find that the short-term appreciation of China's currency leads to dramatic change in the international rice price index. When RMB appreciates by more than 4%, the price index would continue to rise. When the rate is increased to be greater than 8%, China would become the largest rice importer in the world. In view of the nominal exchange rate as a reasonable guide for forecasting commodity prices, Chen et al. (2010) assert that commodity exporting countries' currencies should be relevant predictors for commodity prices. To test this, they use quarterly data of currencies and commodity price indices for selected 5 commodity-exporting countries (Australia, New Zealand, Canada, Chile and South Africa) to estimate linear predictive regressions. Their results in support of their argument are certainly of interest.

In a subsequent study, Chen et al. (2014) extend the sample period of data by taking the 2008/09 global financial crisis into account. Using a factor-based model, their estimation results provide evidence of price predictability for 51 tradable commodities are based on the United States nominal exchange rate. To further examine the robustness of alternative non-linear model specifications, Lof and Nyberg (2017) consider a non-causal autoregressive model to accommodate non-linear effects of omitted variables. Surprisingly, their estimation results show that the predictability of changes in commodity prices does not come from exchange rates.

The second argument is backed by Clements and Fry (2008) who provide a theoretical underpinning to support the commodity price as a proxy for macroeconomic news which hinges on currency values. In other words, exchange rates would contain forward-looking information beyond which is reflected in commodity prices. The tendency for exchange rates and commodity prices to move in line with the theoretical framework is believed to be applicable for the countries that depend heavily on commodity exports. For those countries, changes in their currency fluctuation substantially influence short-term supply and demand imbalance. To meet the supply expectation, commodity exporters need to have the capacity to reflect their economic expectations that embed within currency values. Thus, expectations regarding the future condition of currency markets could motivate more hedging and hoarding activities in the commodity markets, as well as to place pressure on the world's commodity prices. If countries are large, they can act as price makers with absolute market power. For example, Nazlioglu and Soytas (2012) state that a change in the relative strength of United States dollar is important in examining prices for predominately traded commodities. Using monthly data of January 1980 - February 2010, their results of panel cointegration and Granger causality methods demonstrate a weak dollar positively influences global prices for 24 agricultural commodities.

It is also of interest to note that some studies indicate currency values do not directly influence commodity prices. For instance, Schuh (1974) finds that the overvaluation of United States dollar after the World War II to undervaluation of agricultural prices. The author also notes that the occurrence of devaluation of United States dollar constituted an important structural change in the United States agricultural markets. Concerning commodity-exporting countries, Adams and Vial (1988) consider structural supply and demand responses into their model. Based on the model, they find that diverse exchange rate movements and structural supply-demand adjustments explain the fall in metal prices in the first seven years of the decade in their sample period. Sjaastad and Scacciavillani (1996) find the absence of asymmetric effect of exchange rates on the gold price in the case of the European currency bloc that dominates the world's gold market. Besides that, they also find that both appreciation and depreciation for other currencies contribute to strong effects on gold prices, in addition to the dissolution on Bretton Woods International monetary system and floating exchange rate that cause instability of global prices for gold.

To examine the ability of forecasting commodity prices, Roache and Rossi (2010) consider currency depreciation as a proxy for macroeconomic news. They demonstrate that such a proxy could not enhance ability of forecasting in a daily basis. Several extraordinary events such as weak currency values in most of the countries during the period of 2007-2008 typically signal rising food prices. Following this food crisis, agricultural commodity prices raise with energy prices in the world. Subsequently, currency and commodity markets experience episodes of heightened instability and risk during the 2008/09 global financial crisis. Although a significant large number of boom and bust periods have been identified, there is a tendency for the exchange rate to exhibit an asymmetric effect on the change of persistence of commodity price levels.

In sum, most studies on commodity prices rely upon the estimate of elasticities and symmetric effects. These studies are limited to linking currency values and commodity prices in the context of emerging countries, especially China as these countries are thought to have rich natural resources. Since China emerges to be a large consumer and supplier of globally traded commodities, the sensitivity of commodity prices to the appreciation and depreciation of RMB is rarely examined in the literature. To fill this gap, our study contributes to the literature in two important ways. The first way is to look at the effect of appreciated and depreciated RMB that provides a broader view for price responses of commodity rather than looking either a change of RMB individually. Then, the second way is to look at the effect in regard to different types of commodity, namely agriculture, energy and metal.

DATA AND PRELIMINARY ANALYSIS

This study uses quarterly data of China’s exchange rates (nominal and real values of RMB) and global commodity prices over the period of first quarter of 1994 - fourth quarter of 2016 that consists of 92 observations. The global prices for different commodities are obtained from the United Nations Conference on Trade and Development (UNCTAD).

China started to move toward more managed float relative to the U.S. dollar and other currencies after July 2005. However, a change of China’s exchange rate may reflect from other fundamentals. In order to capture its effect on commodity prices during the sample period, we use China’s nominal effective exchange rate (NEER) as a proxy for other fundamentals. NEER is expressed as the weighted average of bilateral nominal exchange rates of China in terms of other foreign currencies according to trade with each country. To capture inflation differentials between China and its major trading partners, China’s real effective exchange rate (REER) is used as the weighted average of nominal exchange rates, adjusted for inflation. REER would capture movements in cross-currency exchange rates and reflect the degree of external competitiveness of China’s commodity-related products. Both NEER and REER are obtained from the Bank for International Settlements.

To capture the effects of changes in RMB on the global prices for different commodities, we disaggregate commodity prices into three types: (i) agriculture; (ii) energy; and (iii) metal. We use corn, palm oil, rice, sugar and wheat prices for calculating the price index for agriculture; the crude oil price as the price index for energy; and aluminum, gold, lead, nickel, silver, tin and zinc prices as the price index for metal. To enhance the robustness of results of a commodity-specific analysis, both NEER and REER are incorporated into separated models. To comprehend inherent symmetric and asymmetric effects of China’s exchange rate on the price for various types of commodity in line with the principle of parsimony, we incorporate China’s income level which is measured by GDP to represent a relevant economy activity in each our model (Bahmani-Oskooee et al., 2017; Bahmani-Oskooee & Motavallizadeh-Ardakani, 2018). The quarterly data for this series are retrieved from the National Bureau of Statistics of China. All series are plotted and shown in Figure 1 and Figure 2

INSERT FIGURE 1

INSERT FIGURE 2

Given that the bounds testing approach requires absence of any I(2) variable in the model, we perform the augmented Dickey-Fuller (ADF) and Philips-Perron (PP) unit root tests to check for the stationarity properties in each series. As shown in Table 1, the test statistic values from both ADF and PP indicate that the null hypothesis of non-stationarity is not rejected at the level form, except GDP in the PP test. When the variables are transformed into the first difference, both unit root tests consistently reject the null hypothesis. It can be concluded that all variables are stationary at I(1). This fulfills the requirement of the use of autoregressive distributed lag **(**ARDL) bounds testing.

INSERT TABLE 1

AUTOREGRESSIVE DISTRIBUTED LAG (ARDL)

To examine the symmetric and asymmetric effects of China’s exchange rates on commodity prices, linear and non-linear ARDL models are used. To enhance the robustness of results, NEER and

REER of China's exchange rate are further incorporated separately. The estimation of both linear and non-linear models is performed for each selected commodity (agriculture, energy and metal). To begin with the analysis, the following long-run model is constructed:

$$CP_t = C_0 + C_1 EX_t + C_2 GDP_t + e_t \quad (1)$$

where CP_t denotes global commodity price, EX_t denotes China's exchange rate (NEER or REER) and GDP_t denotes China's gross domestic product. C_0 is an intercept which captures all other exogenous factors such as linear trend and structural break if any. C_1 and C_2 are parameters to be estimated and e is a disturbance term with a mean of zero and a finite variance. All series are expressed in natural logarithm.

To differentiate the short-run effects of exchange rate and GDP on commodity prices from their long-run effects, we specify an error correction version of the ARDL model as shown in Eq. (2).

$$\Delta CP_t = \alpha_0 + \alpha_1 CP_{t-1} + \alpha_2 EX_{t-1} + \alpha_3 GDP_{t-1} + \sum_{p=1}^{n1} \theta_1 \Delta CP_{t-p} + \sum_{p=0}^{n2} \theta_2 \Delta EX_{t-p} + \sum_{p=0}^{n3} \theta_3 \Delta GDP_{t-p} + e_t \quad (2)$$

Based on the dynamic adjustment mechanism in Eq. (2), the short-run effects are reflected in the estimated coefficients assigned to first differenced variables ($\theta_1, \theta_2, \theta_3$). In contrast, the long-run effects are indicated by the estimated coefficients of lagged variables $(\alpha_1, \alpha_2, \alpha_3)$.The maximum lag length is set to be 8 since our study uses the quarterly data. The optimum lag length is obtained by minimizing the Akaike Information Criterion (AIC).

To discern the long-run relationship between the concerned variables, we adopt the ARDL bounds testing by Pesaran et al. (2001) and use the Wald F test to impose restrictions on the estimated parameters of lagged level of variables (CP_t, EX_t, GDP_t) in Eq. (2). The null and alternative hypotheses of the test are stated as follows:

$H_0: \alpha_1 = \alpha_2 = \alpha_3 = 0$ (There is no long-run relationship)
$H_1: \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq 0$ (There is a long-run relationship)

Pesaran et al. (2001) develop a statistical table that consists of two sets of critical value for the F-statistic at the 1%, 5% and 10% of significance level.[1] With an integrated order of a series whether zero or one, lower critical bound (LCB) is used for explanatory variables that follow an integrated order zero process *I*(0), while upper critical bound (UCB) is used for explanatory variables that follow an integrated order one process *I*(1). If the F test statistic exceeds the UCB, the null hypothesis of no long-run relationship is rejected. If the F test statistic below the LCB, the null hypothesis cannot be rejected. If the F test statistic falls within the two bounds, the test will be inconclusive.

Other than the F test, a lagged one of the error correction term (ECT_{t-1}) which is generated from Eq. (1) can be used as an alternative way of examining the cointegration relationship. Specifically, we estimate another new specification by replacing the linear combination of lagged variables in Eq. (2) by ECT_{t-1} and imposing the same optimum lag length as before. The significance of ECT_{t-1} along with its negative coefficient value appears to be an additional support for the long-run or cointegration relationship (Bahmani-Oskooee and Aftab, 2017).

As aforementioned, China's exchange rates may contribute to an asymmetric effect on global commodity prices. To capture a dynamic adjustment mechanism of exchange rates, asymmetric adjustments of changes in the exchange rate are decomposed into appreciation and depreciation. POS denotes the partial sum of positive changes which represent appreciation in China's exchange rate, while

[1] Refer to Table CI from p.300 to p.301 in the article by Pesaran et al. (2001).

NEG denotes the partial sum of negative changes which represent depreciation of China's exchange rate. Both positive and negative changes in exchange rates are defined as follows:

$$POS_t = \sum_{j=1}^{t} \Delta EX_j^{\,+} = \sum_{j=1}^{t} \max(\Delta EX_j, 0) \quad (3)$$

$$NEG_t = \sum_{j=1}^{t} \Delta EX_j^{\,-} = \sum_{j=1}^{t} \min(\Delta EX_j, 0) \quad (4)$$

To capture the asymmetric effect, we incorporate appreciation and depreciation of the currency (*POS*, *NEG*) as independent variables into a long-run model (Bahmani-Oskooee and Saha, 2015; Cheah et al., 2017). Hence, Eq. (1) is rewritten as Eq. (5) below:

$$CP_t = \beta_0 + \beta_1 POS_t + \beta_2 NEG_t + \beta_3 GDP_t + \varepsilon_t \quad (5)$$

where β_1, β_2 and β_3 are parameters to be estimated and ε is an error term. β_0 is the intercept which captures all other exogenous factors such as linear trend and structural break if any. Other variables remain as defined earlier.

The long-run effect of China's exchange rates on global commodity prices can be examined by evaluating β_1 and β_2. If β_1=β_2, it can be concluded that an asymmetry relationship does not exist between RMB and commodity price. To support the existence of an asymmetric relationship, $\beta_1 \neq \beta_2$ or at least one of β should not equal to zero. For example, both $\beta_1$and β_2 have non-zero value with an opposite sign or either $\beta_1$or β_2 has non-zero value with regardless expected signs.

The expected signs of β_1 and β_2 can be supported by twofold explanations. First, a negative value of β_1 and a positive value of β_2 are consistent with the view of traditional flow-oriented model, which explains that currency depreciation would improve the trade competitiveness of domestic exporters. Second, a positive value of β_1 and a negative value of β_2 indicate that China is the main importer for a particular commodity type. In short, the movement of exchange rate might have a negative or positive effect on prices for different commodity types. Lastly, the sign of β_3 is expected to be positive as higher income level is associated with higher inflation and thus higher commodity prices.

To allow for a dynamic adjustment mechanism of exchange rate, POS and NEG are incorporated in the ARDL model as the asymmetry property. In turn, the model becomes an asymmetric error correction version of the ARDL model which is written as Eq. (6).

$$\Delta CP_t = \beta_0 + \beta_1 CP_{t-1} + \beta_2 POS_{t-1} + \beta_3 NEG_{t-1} + \beta_4 GDP_{t-1} + \sum_{p=1}^{n1} \theta_1 \Delta CP_{t-p} + \sum_{p=0}^{n2} \theta_2 \Delta POS_{t-p} + \sum_{p=0}^{n3} \theta_3 \Delta NEG_{t-p} + \sum_{p=0}^{n4} \theta_4 \Delta GDP_{t-p} + \mu_t \quad (6)$$

Again, the Wald F test is used to impose restrictions on the estimated parameters of lagged level of variables $(CP_t, POS_t, NEG_t, GDP_t)$ in Eq. (6). The null and alternative hypotheses of testing are stated as follows:

$H_0{:}\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$ (There is no long-run relationship)
$H_1{:}\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq 0$ (There is a long-run relationship)

Once Eq. (6) is estimated, we resort to testing for two asymmetric hypotheses. The first hypothesis testing is to detect the existence of short-run asymmetry. This can be done by examining the size and significance of coefficient estimates which are attached to first-differenced variables. Other than this, the Wald test is used to impose restrictions on the estimated parameters of lagged first difference of variables $(\Delta POS_t, \Delta NEG_t)$ in Eq. (6). The computed test statistic is distributed as chi-squared with one degree of freedom. If the test statistic value is greater than the critical value from the chi-squared distribution, there is an indication of short-run asymmetry when ΔPOS_t takes different lag orders than ΔNEG_t. The null and alternative hypotheses of testing are stated as follows:

$H_0: \sum \theta_2 = \sum \theta_3$ (There is no short-run asymmetry)
$H_1: \sum \theta_2 \neq \sum \theta_3$ (There is a short-run asymmetry)

The second hypothesis testing is to detect the existence of long-run asymmetry. Once cointegration is established, we normalize β_2 and β_3 in order to obtain long-run effects and examine their size and significance level. After this, the Wald test is repeated. The computed test statistic which is distributed as chi-squared with one degree of freedom would be used to perform the hypothesis testing. We can reject the following null hypothesis if the test statistic value is greater than the critical value, thereby supporting that the existence of long-run asymmetry.

$H_0: \beta_2/-\beta_1 = \beta_3/-\beta_1$ (There is no long-run asymmetry)
$H_1: \beta_2/-\beta_1 \neq \beta_3/-\beta_1$ (There is a long-run asymmetry)

EMPIRICAL RESULTS AND DISCUSSIONS

Effect of China's exchange rates on global prices for agricultural and energy commodities

In Panel C of Table 2, our cointegration analysis based on the bounds test or ECT_{t-1} with a significant negative coefficient highlights the existence of cointegration relationship among variables for all selected agricultural and energy commodities. The coefficient value of ECT_{t-1} represents the speed of adjustment to the long-run equilibrium, which must have the value between -1 and 0. This significant negative value indicates a convergence of the dynamics towards to the long-run equilibrium. For example, the value of -1 signifies perfect and instantaneous convergence, while the value of 0 means no convergence after a shock in the process.

Three notable findings are noticed from the linear ARDL models. First, GDP has a significant positive effect on palm oil, rice, sugar, wheat and crude oil prices in the long run. Second, the exchange rate significantly contributes to a negative effect on palm oil, sugar and crude oil prices. Third, other than the long-run effect, GDP and exchange rate (NEER and REER) also contribute to the short-run effect on prices for agricultural and energy commodities, except for rice. As shown in Panel D of Table 2, diagnostic checking through LM, ARCH, JB, RESET tests, as well as CUSUM and CUSUMSQ indicate that some linear models are not adequate.

The inadequacy of linear ARDL models could be due to ignoring asymmetric effects of exchange rate on commodity prices. Hence, we perform a non-linear analysis to capture such effects by disaggregating the exchange rate into appreciation (*POS*) and depreciation (*NEG*). The results are summarized in Table 3. It's noteworthy that exchange rates and global prices for all selected commodities are cointegrated. This finding is similar to the linear counterpart, supporting that the highest speed of adjustment on wheat prices. Surprisingly, the change from NEER to REER by considering an asymmetric effect of exchange rates into account increases the adjustment on wheat prices by 65.05%. Then, it is followed by 20.18% for palm oil prices. Lastly, 8.68% and 4.60% are recorded for rice and corn prices, respectively. However, there is no change in the adjustment on sugar prices.

When the non-linear ARDL specification is applied, both short-run and long-run impacts of changes of nominal and real exchange rates (appreciation and depreciation) on commodity prices are observed in all selected agricultural commodities. The results of estimation reveal a negative, long-run causal effect from appreciation to agricultural commodity prices, indicating that an appreciation in China's exchange rate contributes to a negative shock in the price movement.

Among selected agricultural commodities, corn and rice prices are seen to be more sensitive to the appreciation of RMB. This is revealed in the magnitudes of long-run coefficients for nominal *POS* and real *POS*. These coefficients indicate that an increase in nominal appreciation by 1% would decrease corn prices by 4.41% and rice prices by 4.68%. An additional real appreciation would decrease 4.03% of corn prices and 4.16% of rice prices.

Besides, the prices for wheat are influenced by both appreciation and depreciation. When nominal and real currency values appreciate by 1%, the price decreases by 1.72% and 2.36%, respectively. An addition of 1% nominal and real depreciations increases the price by 2.25% and 4.27%, respectively. In sum, the price of wheat is found to be more sensitive to RMB depreciation. In the context of sugar, we find that 1% of nominal and real appreciations in RMB reduce the price of sugar by 3.47% and 2.84%, respectively.

Based on our findings, we also find that 1% nominal appreciation of RMB decreases price of palm oil by 3.88%. In terms of real exchange rate, while 1% of currency appreciation of RMB reduces the price by 3.47%, while 1% of real depreciation of RMB increases the price by 2.84%. In regard to crude oil, we find that its price only responds to real appreciation of RMB. Our results show that the real exchange rate appreciation by 1% decreases the global crude oil price by 7.05%.

We conduct several diagnostic tests to check the robustness of our results. As shown in Panel D of Table 3, these tests reveal that most of the models do not suffer from serious econometric problems. To detect the existence of short-run and long-run asymmetries, we perform the Wald test and summarize the results in Panel E of Table 3. As observed, the results indicate that the long-run asymmetry effect of exchange rate on the price is present in the case of all commodities, except for sugar, while the short-run asymmetric effect of exchange rate on the commodity price only exists in the case of crude oil. Specifically, a long-run asymmetry only exists in agricultural commodities, namely corn, palm oil, rice, sugar and wheat. In regard to crude oil prices, both short-run and long-run asymmetries are significant.

INSERT TABLE 2

INSERT TABLE 3

Effect of China's exchange rates on global prices for metal commodities

Table 4 presents the results of linear ARDL for metal commodities. As shown in Panel C, the cointegration relationship is established and supported by either bounds test or significant ECT_{t-1}. It is found that GDP has a significant positive effect on commodity price, whereas the exchange rate has an opposite effect. In Panel D, diagnostic tests show that most of linear models are free from econometric problems.

To better characterize the effect of China's exchange rates on commodity prices, we extend linear models into a non-linear framework. The results of non-linear ARDL models are summarized in Table 5. Again, the bounds test or significant negative coefficient of ECT_{t-1} supports convergence towards the long-run equilibrium. As the coefficient value measures the speed of adjustment, the results reveal that the corrected deviation from the long-run equilibrium path for aluminum is between 34% and 40.2%. This highest percentage of adjustment implies that China's production of aluminum provides alternative markets. Other than that, the percentage of corrected deviation for zinc is recorded to be the lowest around 5.7% - 11%, suggesting that the steel industry in China imposes some restrictions on the future growth of consumption and production for zinc.

We establish the long-run models and summarize the results in Panel B of Table 5. We find significant downward pressure on the prices of aluminum, silver and nickel regardless of the changes in the value (appreciation/depreciation) of RMB. This implies a weak asymmetry between the global price of nickel and RMB, the global price of silver and RMB, and the global price of aluminum and RMB. However, it is still worth highlighting that the price of aluminum is more sensitive to appreciation of RMB, the price of nickel fluctuates more when there is change in the nominal value of RMB, and the price of silver is more vulnerable to nominal depreciation of RMB.

Turning to gold, when RMB depreciates by 1%, the global price of gold would drop by 2.62%. In contrast, the appreciation of RMB does not seem to impact the global gold price. Besides, we note that the price of lead only responds to the nominal appreciation of RMB. When the RMB appreciates by 1% nominally, the price of lead would decrease by 4.93%. There is no significant relationship found between real exchange rate changes and global prices of lead. Meanwhile, the values of RMB do not significantly influencing the global prices of zinc.

Based on our empirical results, we find that both nominal and real appreciations of RMB would contribute to a fall in the global price by 3.69% and 5.11%. Although the results from the linear model in Table 4 consistently point out that exchange rate has a negative impact on commodity prices, the Wald test indicates that asymmetry exists either in the short run or long run as shown in Panel E of Table 5. We also observe that the diagnostic tests fail to detect any econometric problems, though not in all models.

INSERT TABLE 4

INSERT TABLE 5

POLICY IMPLICATION AND CONCLUSION

This paper attempts to provide useful insights into understanding of the commodity price predictability based on exchange rate regimes. We focus on RMB to evaluate how sensitive are global commodity prices to changes in its value. By using quarterly data of 1994-2016, our results based on ARDL model specifications show that the effect of RMB changes is asymmetric in regard to most of the tradable commodities, meaning that the global price of commodities responds differently to RMB appreciations and depreciations. We argue that asymmetry is mostly due to different expectations of traders and consumers associated with changes in value of RMB.

Our results provide the following notable findings and implications. Global prices of most agricultural commodities respond to the appreciation of RMB, exercising downward pressure on agricultural commodity markets. This finding is relatively new, but does not support the argument that a stronger RMB would increase global agricultural commodity prices. This implies that China with declared goal of self-sufficiency could buy more corn and rice to satisfy domestic demand at a lower price when RMB appreciates. This is also true in the context of sugar where China has been one of the top importers of sugar despite being a key producer. This implies that the country is facing problem with its declared goal of self-sufficiency as the domestic production of sugar is unable to fulfill its domestic demand. This empirical finding unveils a new trade strategy that can be helpful in realizing its self-sufficiency by setting a one-off appreciation.

Besides, only the price of wheat is found to be sensitive to the depreciation of RMB. The result of depreciation in RMB causing an increase in global price of wheat is more due to Chinese policy of supporting farmers' income and reaching the goal of self-sufficiency in food as well as building up sufficient stock for food security. For palm oil, being one of the top importers due to the rapid expansion of food industry, China would find itself in a beneficial position by setting a one-off appreciation as it lowers the price of palm oil. However, this reduction in palm oil price could also be attributed to the argument in recent decade that the consumption of palm oil increases cholesterol level (Sun et al., 2015), which reduces the global demand of palm oil.

On the other hand, global crude oil prices are found to react negatively only to real appreciation of RMB. This finding seems to be in favor to China as China is among the top countries which consume the most energy in the world. Though our finding reveals a significant relationship between RMB and global oil price, the price mechanism of oil price is also subjected to the Organization of Petroleum Exporting Countries (OPEC) which is mainly responsible for global oil price and supply. Moreover, China's efforts to reduce dependency on crude oil as a solution to reduce pollution and increase the use of renewable energy sources like solar power could also be determining factors for global oil price. Third, the prices of several metal commodities appear to be negatively associated with appreciation or/and depreciation. This suggests that China does not have much influence to change the prices of rare-earth commodities, particularly for aluminum and nickel.

In sum, the appreciation of RMB leads to the reduction in global commodity prices, where agricultural commodities have the highest price elasticity when the RMB appreciate. Based on this commodity-specific finding, China would do well if it keeps inflation low and insulate domestic agricultural markets by appreciating RMB. In order to prevent the fluctuation of commodity prices from macroeconomic instability, our findings lend support to the trade strategy of China's government in setting a one-off appreciation instead of tariff on imported commodities.

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Figure 1: China's nominal, real, positive and negative exchange rates, 1994Q1 - 2016Q4

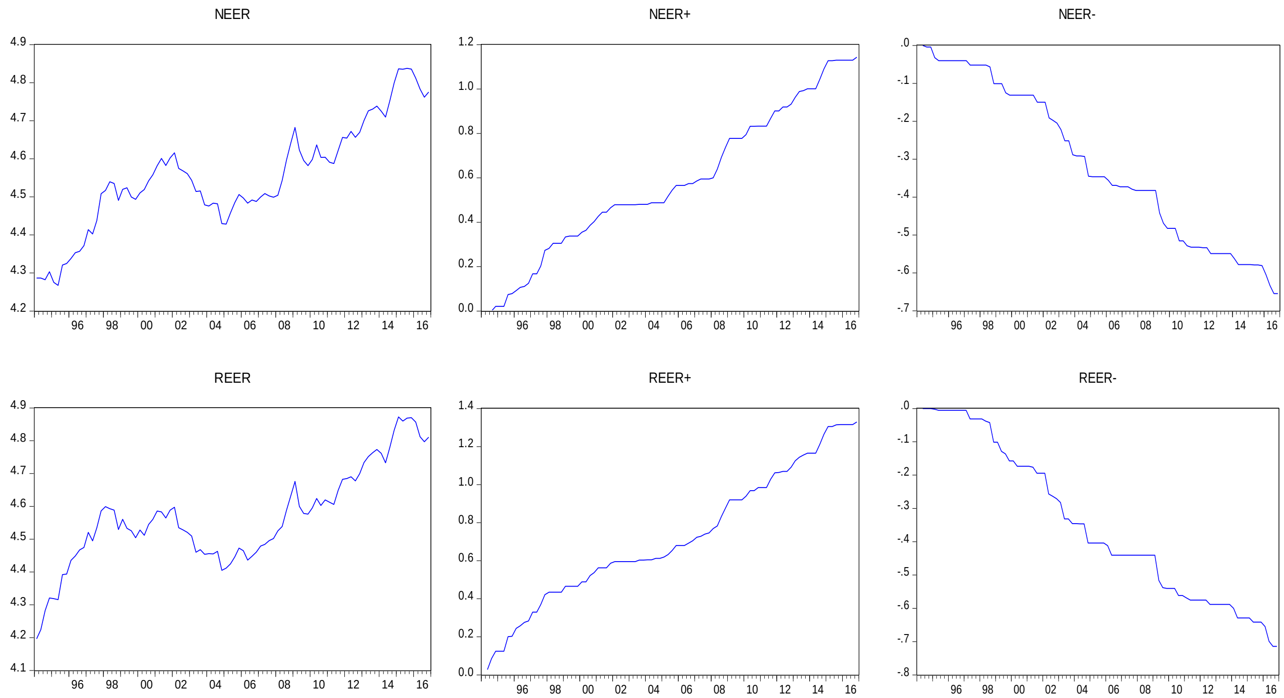
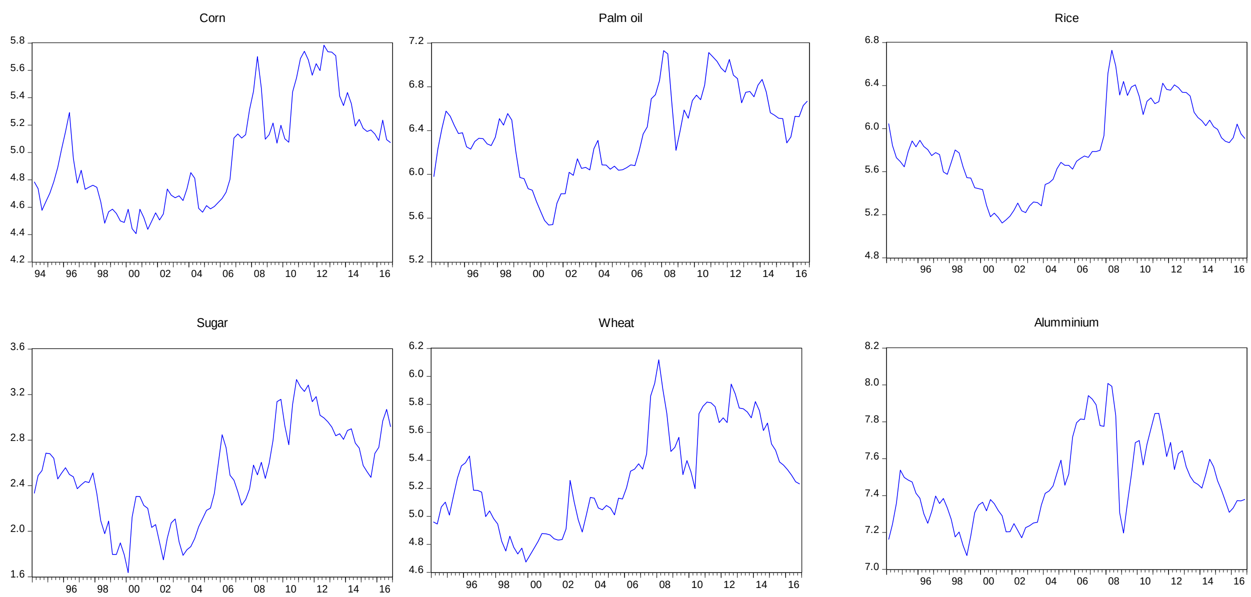


Fig 2: Global prices for corn, palm oil, rice, sugar wheat, crude oil, aluminum, gold, lead, nickel, silver, tin and zinc, 1994Q1 - 2016Q4



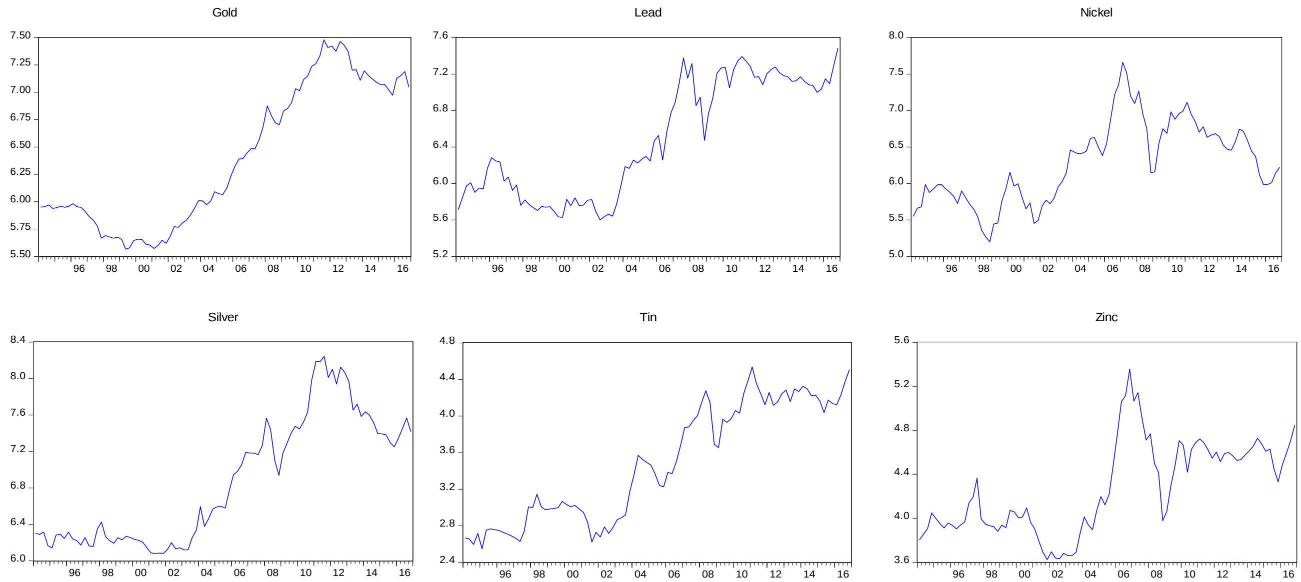


Table 1. Results of unit root tests.

	Exogenous	ADF	PP
Panel A: Level			
Aluminum	*c*, *t*	-2.400 (2)	-2.446
Gold	*c*, *t*	-2.646 (7)	-1.592
Lead	*c*, *t*	-2.662 (2)	-2.026
Nickel	*c*, *t*	-2.196 (1)	-1.950

Silver	*c*, *t*	-2.436 (7)	-1.697
Tin	*c*, *t*	-2.910 (1)	-2.720
Zinc	*c*, *t*	-3.026 (2)	-2.538
Corn	*c*, *t*	-2.399 (6)	-2.106
Palm	*c*, *t*	-2.701 (1)	-2.258
Rice	*c*, *t*	-2.050 (6)	-2.122
Sugar	*c*, *t*	-2.680 (1)	-2.204
Wheat	*c*, *t*	-1.928 (0)	-2.077
Oil	*c*, *t*	-1.483 (2)	-1.777
GDP	*c*, *t*	-2.143 (5)	-6.688***
NEER	*c*, *t*	-2.358 (1)	-2.076
REER	*c*, *t*	-2.150 (0)	-2.209
Panel B: First difference			
ΔAluminum	*c*	-7.317*** (2)	-7.264***
ΔGold	*c*	-3.244** (3)	-7.704***
ΔLead	*c*	-5.163*** (4)	-10.484***
ΔNickel	*c*	-7.316*** (0)	-7.304***
ΔSilver	*c*	-4.429***(3)	-8.369***
ΔTin	*c*	-8.392*** (0)	-8.353***
ΔZinc	*c*	-7.951*** (0)	-7.935***
ΔCorn	*c*	-5.093*** (2)	-8.526***
ΔPalm	*c*	-6.849*** (1)	-7.222***
ΔRice	*c*	-3.063** (5)	-7.429***
ΔSugar	*c*	-7.185*** (1)	-7.661***
ΔWheat	*c*	-9.069*** (0)	-9.069***
ΔOil	*c*	-7.788*** (1)	-8.525***
ΔGDP	*c*	-3.348** (4)	-24.014***

ΔNEER	*c*	-7.366*** (0)	-7.391***
ΔREER	*c*	-8.301*** (0)	-8.277***

Notes: ADF stands for an augmented Dickey-Fuller unit root test. PP stands for a Philips-Perron unit root test. *c* indicates a constant. *t* represents a trend. Lag length selections for ADF test are based on AIC and the maximum lag length allowed is 11. Optimal lag lengths of ADF are reported in ( ). The bandwidth selections and the spectral estimations in PP test are based on Newey-West and Bartlett kernel approach. The probability values are reported in parentheses. *** and ** represent the rejection of null hypothesis of a unit root at significance level of 1% and 5%, respectively.

Table 2. Results of linear ARDL models for agriculture and energy commodities.

	Corn		Palm oil		Rice		Sugar		Wheat		Crude oil	
	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER
ARDL(p,d,q)	(5,6,5)	(5,6,5)	(2,1,2)	(2,2,2)	(7,5,0)	(7,5,0)	(2,0,3)	(3,0,0)	(1,4,4)	(5,4,4)	(4,5,0)	(4,6,0)
Panel A: Short-run estimates												
D(y(-1))	0.987*	0.112	0.753*	0.304*	0.330*	0.330*	0.242*	0.232*	-	0.081	0.042	0.146
	(8.542)	(1.081)	(5.220)	(3.130)	(3.296)	(3.276)	(2.411)	(2.287)		(0.855)	(0.410)	(1.343)
D(y(-2))	-0.394*	-0.308*	-	-	-0.289*	-0.296*	-	-0.149	-	-0.071	-0.210*	-0.139
	(-2.556)	(-2.950)			(-2.747)	(-2.832)		(-1.469)		(-0.744)	(-2.135)	(-1.353)
D(y(-3))	0.446*	0.159	-	-	-0.090	-0.090	-	-	-	0.043	0.183*	0.195*
	(2.820)	(1.466)			(-0.850)	(-0.845)				(0.447)	(1.837)	(1.931)
D(y(-4))	-0.525*	-0.381*	-	-	0.027	0.035	-	-	-	-0.267*	-	-
	(-3.248)	(-3.581)			(0.244)	(0.318)				(-2.767)		
D(y(-5))	0.385*		-	-	-0.170	-0.164	-	-	-	-	-	-
	(3.255)				(-1.652)	(-1.592)						
D(y(-6))	-	-	-	-	0.317*	0.339*	-	-	-	-	-	-
					(3.149)	(3.330)						
D(GDP)	1.287	1.726*	0.002	0.084	-1.677*	-1.469*	0.199*	0.147	1.232*	1.494*	2.685*	2.974*
	(1.160)	(1.757)	(0.022)	(0.796)	(-2.509)	(-2.203)	(1.853)	(1.310)	(4.794)	(5.436)	(2.553)	(2.595)
D(GDP(-1))	-1.616	-0.358	-	0.297*	0.589*	0.870*	-	-	1.189*	1.688*	-0.764*	-1.902
	(-1.044)	(-0.382)		(2.460)	(4.201)	(4.513)			(4.962)	(6.169)	(-2.541)	(-1.603)
D(GDP(-2))	2.480*	2.549*	-	-	0.669*	0.934*	-	-	0.991*	1.262*	-0.730*	0.073
	(2.422)	(5.118)			(4.686)	(4.874)			(3.984)	(4.558)	(-2.562)	(0.438)
D(GDP(-3))	-0.260*	2.385*	-	-	0.618*	0.872*	-	-	1.127*	1.552*	-0.226	0.561*
	(-2.125)	(4.803)			(4.219)	(4.510)			(4.556)	(5.656)	(-0.850)	(3.502)
D(GDP(-4))	-1.410	0.415	-	-	2.092*	2.134*	-	-	-	-	-3.218*	-2.763
	(-1.268)	(0.445)			(3.095)	(3.120)					(-3.205)	(-2.475)
D(GDP(-5))	1.790	2.843*	-	-	-	-	-	-	-	-	-	1.899*
	(1.182)	(2.947)										(1.690)
D(GDP(-6))	-2.277*	-	-	-	-	-	-	-	-	-	-	-
	(-2.305)											
D(EX)	-1.197*	-1.036*	-1.658*	-1.060*	-0.155	-0.083	-1.465*	-0.731	-1.311*	-0.887*	-1.980*	-1.338*
	(-2.052)	(-2.002)	(-3.203)	(-1.980)	(-0.361)	(-0.192)	(-2.615)	(1.424)	(-2.612)	(-1.753)	(-2.799)	(-1.861)
D(EX(-1))	1.402	-0.404	1.091*	1.341*			0.833	-	0.986*	1.261*	-	-
	(1.580)	(-0.734)	(2.045)	(2.858)			(1.369)		(1.897)	(2.483)		
D(EX(-2))	-0.695	-1.079*	-	-	-	-	0.862	-	0.321	0.054	-	-
	(-0.793)	(-2.032)					(1.493)		(0.600)	(0.106)		
D(EX(-3))	1.848*	0.724	-	-	-	-	-	-	0.890*	1.154*	-	-
	(2.191)	(1.412)							(1.673)	(2.306)		
D(EX(-4))	-1.722*	-0.879*	-	-	-	-	-	-	-	-	-	-
	(-1.980)	(-1.735)										
D(EX(-5))	0.780	-	-	-	-	-	-	-	-	-	-	-
	(1.336)											

Notes: * denotes the 10% significance level. Test statistics are reported in ( ).

Table 2. **(Continued).**

	Corn		Palm oil		Rice		Sugar		Wheat		Crude oil	
	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER
ARDL(p,d,q)	(5,6,5)	(5,6,5)	(2,1,2)	(2,2,2)	(7,5,0)	(7,5,0)	(2,0,3)	(3,0,0)	(1,4,4)	(5,4,4)	(4,5,0)	(4,6,0)
Panel B: Long-run estimates												
GDP	-0.061	0.053	0.718*	0.504*	0.613*	0.424	0.823*	0.751*	0.515*	0.387*	1.648*	1.174*
	(-0.085)	(0.168)	(3.896)	(2.516)	(2.189)	(1.564)	(4.306)	(2.571)	(3.098)	(2.836)	(4.030)	(6.947)
EX	4.118	3.605	-3.053*	-1.423	-1.741	-0.197	-3.285*	-2.678	-1.221	-0.351	-8.167*	-4.111*
	(0.679)	(1.244)	(-2.660)	(-1.146)	(-0.811)	(-0.096)	(-2.780)	(-1.486)	(-0.953)	(-0.316)	(-2.292)	(-2.881)
Constant	-15.354	-14.102	12.550*	7.337*	6.594	1.299	8.508*	6.603	4.705	1.934	23.696*	9.784*
	(-0.702)	(-1.276)	(3.449)	(1.794)	(0.897)	(0.185)	(2.285)	(1.151)	(1.067)	(0.482)	(1.889)	(1.881)
Panel C: Cointegration analysis												
ECT(-1)	-0.101*	-0.137*	-0.167*	-0.136*	-0.139*	-0.125*	-0.175*	-0.107*	-0.261*	-0.255*	-0.167*	-0.249*
	(-3.700)	(-4.549)	(-3.630)	(-3.220)	(-4.578)	(-4.571)	(-3.748)	(-2.751)	(-4.476)	(-5.480)	(-3.790)	(-3.912)
Bounds F test	3.272	4.952*	3.178	2.499	5.312*	5.146*	3.000	1.825	4.817*	7.204*	3.094	4.150*
Panel D: Diagnostic statistics												
JB	1.457	1.034	0.936	4.331	107.374*	110.943*	11.319*	6.553*	9.585*	5.087*	2.642	9.494*
	[0.483]	[0.596]	[0.626]	[0.115]	[0.000]	[0.000]	[0.003]	[0.038]	[0.008]	[0.079]	[0.267]	[0.009]
LM	0.412	0.690	1.018	1.012	0.694	0.842	0.230	0.046	0.243	0.161	0.597	0.940
	[0.664]	[0.505]	[0.366]	[0.368]	[0.503]	[0.435]	[0.795]	[0.955]	[0.785]	[0.852]	[0.553]	[0.396]
ARCH	0.048	0.026	2.273	4.411*	0.090	0.024	0.161	0.163	0.602	0.773	0.003	0.002
	[0.828]	[0.871]	[0.135]	[0.039]	[0.765]	[0.878]	[0.689]	[0.687]	[0.440]	[0.382]	[0.955]	[0.961]
RESET	3.411*	3.765*	1.130	1.966	0.045	0.269	1.306	0.004	4.254*	5.903*	0.077	1.539
	[0.069]	[0.057]	[0.291]	[0.165]	[0.832]	[0.605]	[0.257]	[0.952]	[0.043]	[0.018]	[0.782]	[0.219]
CUSUM	S	S	S	S	S	S	S	S	S	S	S	S
CUSUMSQ	S	S	S	U	U	U	S	S	S	S	U	U

Notes: * denotes the 10% significance level. Test statistics are reported in ( ). Bounds F test is used for detecting a cointegration relationship. JB is the Jarque-Bera test of a normality of error term. LM is the Lagrange Multiplier test of residual serial correlation. ARCH is the Autoregressive Conditional Heteroskedasticity test of heteroscedasticity problem. RESET is the Ramsey regression equation specification error test of a model misspecification. CUSUM and CUSUMSQ are cumulative sum of error and its square to measure the stability of estimates. The probability values are reported in [ ].

Table 3. Results of non-linear ARDL models for agriculture and energy commodities.

	Corn		Palm oil		Rice		Sugar		Wheat		Crude oil	
	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER
ARDL(p,d,q,r)	(5,2,1,0)	(5,2,1,0)	(2,1,2,0)	(2,1,1,0)	(7,2,0,0)	(7,2,0,0)	(2,0,2,0)	(2,0,0,0)	(5,4,5,1)	(8,4,2,1)	(3,5,5,0)	(5,5,1,1)
Panel A: Short-run estimates												
D(y(-1))	0.244*	0.246*	0.266*	0.318*	0.299*	0.322*	0.247*	0.253*	0.177	0.310*	-0.059	0.140
	(2.467)	(2.468)	(2.738)	(3.379)	(3.089)	(3.324)	(2.468)	(2.556)	(1.600)	(2.765)	(-0.587)	(1.347)
D(y(-2))	-0.132	-0.150	-	-	-0.153	-0.148	-	-	-0.043	0.218*	-0.342*	-0.188*
	(-1.271)	(-1.429)			(-1.503)	(-1.454)			(-0.396)	(1.951)	(-3.331)	(-1.807)
D(y(-3))	0.203*	0.208*	-	-	-0.044	-0.044	-	-	0.099	0.226*	-	0.198*
	(1.991)	(2.020)			(-0.442)	(-0.439)			(0.985)	(2.203)		(2.042)
D(y(-4))	-0.183*	-0.176*	-	-	0.150	0.156	-	-	-0.256*	-0.125	-	0.158
	(-1.855)	(-1.778)			(1.468)	(1.502)			(-2.536)	(-1.358)		(1.587)
D(y(-5))	-	-	-	-	-0.147	-0.139	-	-	-	0.084	-	-
					(-1.460)	(-1.362)				(0.909)		
D(y(-6))	-	-	-	-	0.271*	0.290*	-	-	-	0.252*	-	-
					(2.778)	(2.943)				(2.627)		
D(y(-7))	-	-	-	-	-	-	-	-	-	0.209*	-	-
										(2.140)		
D(GDP)	0.076	0.085	0.188*	0.227*	-0.025	-0.021	0.255*	0.259*	1.698*	1.793*	2.743*	1.927*
	(0.644)	(0.728)	(1.719)	(1.963)	(-0.281)	(-0.225)	(2.240)	(2.154)	(5.372)	(6.224)	(2.609)	(1.874)
D(GDP(-1))	-0.266*	-0.249*	-	-	-0.273*	-0.285*	-	-	1.207*	1.217*	-1.211*	-1.344*
	(-2.141)	(-1.853)			(-2.587)	(-2.536)			(5.878)	(5.961)	(-2.200)	(-2.668)
D(GDP(-2))	-	-	-	-	-	-	-	-	1.108*	0.987*	-1.122*	-1.255*
									(4.585)	(4.325)	(-2.162)	(-2.890)
D(GDP(-3))	-	-	-	-	-	-	-	-	1.462*	1.432*	-0.661	-0.698*
									(5.374)	(5.766)	(-1.346)	(-1.725)
D(GDP(-4))	-	-	-	-	-	-	-	-	-	-	-	-2.713*
												(-2.767)
D(POS)	-1.414*	-1.906*	-3.012*	-2.241*	-1.001*	-0.836	-2.017*	-0.837	-2.681*	-1.516	-4.932*	-4.470*
	(-2.290)	(-2.839)	(-3.965)	(-3.395)	(-1.970)	(-1.504)	(-2.467)	(-1.362)	(-3.320)	(-1.667)	(-4.494)	(-4.267)
D(POS(-1))	-	-	0.848	-	-	-	1.623*	-	1.674*	1.961*	-0.144	-
			(1.110)				(1.879)		(2.109)	(2.162)	(-0.132)	
D(POS(-2))	-	-	-	-	-	-	-	-	-1.153	-	-2.530*	-
									(-1.452)		(-2.468)	
D(POS(-3))	-	-	-	-	-	-	-	-	1.422*	-	1.176	-
									(1.825)		(1.175)	
D(POS(-4))	-	-	-	-	-	-	-	-	-2.085*	-	-3.434*	-
									(-2.779)		(-3.369)	
D(NEG)	-1.321	-0.017	-0.381	0.115	0.409	0.416	-1.212	-0.846	-0.780	-0.724	0.205	1.322
	(-1.498)	(-0.022)	(-0.414)	(0.151)	(0.599)	(0.728)	(-1.194)	(-1.005)	(-0.775)	(-0.889)	(0.157)	(1.209)

Notes: * denotes the 10% significance level. Test statistics are reported in ( ).

Table 3. (Continued).

	Corn		Palm oil		Rice		Sugar		Wheat		Crude oil	
	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER
ARDL(p,d,q,r)	(5,2,1,0)	(5,2,1,0)	(2,1,2,0)	(2,1,1,0)	(7,2,0,0)	(7,2,0,0)	(2,0,2,0)	(2,0,0,0)	(5,4,5,1)	(8,4,2,1)	(3,5,5,0)	(5,5,1,1)
Panel B: Long-run estimates												
GDP	2.378*	2.479*	2.329*	2.400*	2.693*	2.653*	1.459*	1.724*	2.259*	1.617*	4.770	2.796*
	(4.264)	(5.265)	(3.636)	(5.210)	(5.694)	(6.676)	(2.070)	(2.900)	(5.170)	(6.596)	(1.387)	(4.136)
POS	-4.409*	-4.032*	-3.882*	-3.465*	-4.679*	-4.164*	-3.468*	-2.844*	-2.360*	-1.718*	-16.543	-7.045*
	(-4.311)	(-3.710)	(-4.056)	(-4.151)	(-5.140)	(-4.581)	(-2.890)	(-2.404)	(-2.556)	(-2.690)	(-1.425)	(-3.992)
NEG	1.581	2.093	2.345	2.844*	2.497*	2.610	-0.888	0.925	4.274*	2.251*	-7.015	-2.254
	(0.868)	(1.950)	(1.139)	(2.604)	(1.728)	(2.984)	(-0.357)	(0.558)	(2.463)	(4.647)	(-0.827)	(-1.640)
Constant	-17.663*	-18.094*	-15.745*	-16.008*	-19.734*	-18.884*	-11.607*	-13.816*	-16.833*	-10.497*	-37.753	-21.570*
	(-3.357)	(-4.233)	(-2.614)	(-3.778)	(-4.441)	(-5.219)	(-1.746)	(-2.501)	(-4.106)	(-4.937)	(-1.279)	(-3.640)
Panel C: Cointegration analysis												
ECT(-1)	-0.261*	-0.273*	-0.218*	-0.262*	-0.219*	-0.238*	-0.180*	-0.180*	-0.392*	-0.647*	-0.100*	-0.230*
	(-4.420)	(-4.562)	(-4.471)	(-4.710)	(-5.309)	(-5.167)	(-3.750)	(-3.570)	(-4.145)	(-6.090)	(-4.000)	(-3.957)
Bounds F test	3.274*	4.392*	4.166*	4.473*	5.125*	5.174*	2.201	1.794	3.243*	6.989*	3.098	3.770*
Panel D: Diagnostic statistics												
JB	0.040	0.317	1.955	0.582	60.835*	107.887*	10.441*	11.682*	2.877	15.166*	1.929	14.574*
	[0.980]	[0.854]	[0.376]	[0.748]	[0.000]	[0.000]	[0.005]	[0.003]	[0.237]	[0.001]	[0.381]	[0.001]
LM	0.911	0.342	1.354	0.710	0.207	0.296	0.312	0.450	0.045	0.308	0.445	0.377
	[0.407]	[0.711]	[0.264]	[0.495]	[0.813]	[0.744]	[0.733]	[0.639]	[0.956]	[0.736]	[0.643]	[0.687]
ARCH	0.306	0.019	7.289*	1.755	0.090	0.079	0.196	0.061	0.506	1.069	0.001	0.002
	[0.582]	[0.892]	[0.008]	[0.132]	[0.765]	[0.779]	[0.659]	[0.805]	[0.479]	[0.304]	[0.973]	[0.967]
RESET	0.869	0.299	0.983	2.061	0.110	0.001	0.394	0.018	3.446*	2.745	1.255	0.545
	[0.354]	[0.586]	[0.325]	[0.155]	[0.741]	[0.971]	[0.532]	[0.894]	[0.068]	[0.103]	[0.267]	[0.463]
CUSUM	S	S	S	S	S	S	S	S	S	S	S	S
CUSUMSQ	S	S	S	S	U	U	S	S	S	S	S	U
Panel E: Short-run and long-run asymmetries												
WALD-S	0.107	0.756	0.314	2.559	0.864	0.377	1.143	0.002	1.206	0.400	11.861*	10.461*
	[0.743]	[0.385]	[0.575]	[0.110]	[0.353]	[0.539]	[0.285]	[0.967]	[0.272]	[0.528]	[0.001]	[0.001]
WALD-L	3.451*	4.770*	4.976*	7.163*	8.425*	9.343*	0.955	2.663	3.469*	2.162	1.292	3.881*
	[0.063]	[0.029]	[0.026]	[0.007]	[0.004]	[0.002]	[0.329]	[0.103]	[0.063]	[0.142]	[0.256]	[0.049]

Notes: * denotes the 10% significance level. Test statistics are reported in ( ). Bounds F test is used for detecting a cointegration relationship. JB is the Jarque-Bera test of a normality of error term. LM is the Lagrange Multiplier test of residual serial correlation. ARCH is the Autoregressive Conditional Heteroskedasticity test of heteroscedasticity problem. RESET is the Ramsey regression equation specification error test of a model misspecification. CUSUM and CUSUMSQ are cumulative sum of error and its square to measure the stability of estimates. WALD-S is the Wald test of detecting a short-run asymmetry. WALD-L is the Wald test of detecting a long-run asymmetry. The probability values are reported in [ ].

Table 4. Results of linear ARDL models for metal commodities.

	Aluminum		Gold		Lead		Nickel		Silver		Tin		Zinc	
	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER
ARDL (p,d,q)	(6,8,2)	(3,1,0)	(5,1,6)	(1,2,1)	(6,1,0)	(6,2,0)	(2,8,0)	(2,8,0)	(1,1,1)	(1,2,1)	(2,8,0)	(2,1,0)	(1,5,1)	(1,4,1)
Panel A: Short-run estimates														
D(y(-1))	0.111	0.327*	0.061	-	-0.109	-0.100	0.156	0.193*	-	-	0.153	0.192*	-	-
	(1.022)	(3.668)	(0.620)		(-1.095)	(-0.976)	(1.572)	(1.993)			(1.341)	(1.968)		
D(y(-2))	-0.265*	-0.164*	0.096	-	0.150	0.140	-	-	-	-	-	-	-	-
	(-2.326)	(-1.806)	(0.973)		(1.517)	(1.365)								
D(y(-3))	-0.178	-	-0.112	-	-0.105	-0.129	-	-	-	-	-	-	-	-
	(-1.474)		(-1.078)		(-1.032)	(-1.221)								
D(y(-4))	-0.218*	-	0.250*	-	-0.153	-0.209*	-	-	-	-	-	-	-	-
	(-1.873)		(2.371)		(-1.542)	(-1.992)								
D(y(-5))	0.169*	-	-	-	-0.238*	-0.215*	-	-	-	-	-	-	-	-
	(1.808)				(-2.407)	(-2.105)								
D(GDP)	1.455*	-0.007	-0.033	-0.045	0.017	0.035	0.249	0.522	-0.162*	-0.163*	1.007	0.098	-0.463	-1.192*
	(2.221)	(-0.105)	(-0.676)	(-0.913)	(0.149)	(0.295)	(0.236)	(0.506)	(-1.943)	(-1.708)	(1.081)	(1.061)	(-0.611)	(-3.135)
D(GDP(-1))	0.215	-	-	0.091	-	0.282*	-0.400	-0.298	-	0.161	-1.091	-	-1.873*	-1.001*
	(0.315)			(1.563)		(2.065)	(-0.374)	(-0.283)		(1.403)	(-1.236)		(-4.197)	(-2.402)
D(GDP(-2))	-0.674	-	-	-	-	-	-4.072*	-3.647*	-	-	-1.592*	-	-1.920*	-1.201*
	(-0.966)						(-3.962)	(-3.629)			(-1.884)		(-4.527)	(-3.171)
D(GDP(-3))	1.066	-	-	-	-	-	1.820*	1.943*	-	-	1.553*	-	-1.772	-1.079*
	(1.544)						(1.897)	(2.060)			(1.990)		(-4.299)	(-2.867)
D(GDP(-4))	-2.346*	-	-	-	-	-	-2.495*	-1.868*	-	-	-1.868*	-	-1.397*	-
	(-3.578)						(-2.390)	(-1.865)			(-2.191)		(-1.863)	
D(GDP(-5))	-1.128	-	-	-	-	-	-1.645	-0.807	-	-	0.122	-	-	-
	(-1.650)						(-1.598)	(-0.812)			(0.146)			
D(GDP(-6))	-0.345	-	-	-	-	-	2.102*	2.574*	-	-	0.733	-	-	-
	(-0.499)						(2.042)	(2.606)			(0.876)			
D(GDP(-7))	-1.942*	-	-	-	-	-	-3.605*	-2.834*	-	-	-2.407*	-	-	-
	(-2.823)						(-3.818)	(-3.154)			(-3.197)			
D(EX)	-0.845*	-0.531*	-1.497*	-0.968*	-1.562*	-0.740	-2.805*	-1.638*	-1.790*	-1.410*	-1.036*	-0.702*	-2.713*	-2.023*
	(-2.077)	(-1.699)	(-5.954)	(-4.165)	(-2.977)	(-1.380)	(-4.603)	(-2.700)	(-4.085)	(-3.142)	(-2.113)	(-1.705)	(-5.382)	(-3.907)
D(EX(-1))	0.954*	-	0.565*	-	-	-	-	-	-	-	-	-	-	-
	(2.109)		(2.084)											
D(EX(-2))	-	-	-0.018	-	-	-	-	-	-	-	-	-	-	-
			(-0.069)											
D(EX(-3))	-	-	0.495*	-	-	-	-	-	-	-	-	-	-	-
			(1.885)											
D(EX(-4))	-	-	-0.365	-	-	-	-	-	-	-	-	-	-	-
			(-1.407)											
D(EX(-5))	-	-	0.675*	-	-	-	-	-	-	-	-	-	-	-
			(2.790)											

Notes: * denotes the 10% significance level. Test statistics are reported in ( ).

Table 4. **(Continued).**

	Aluminum		Gold		Lead		Nickel		Silver		Tin		Zinc	
	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER
ARDL (p,d,q)	(6,8,2)	(3,1,0)	(5,1,6)	(1,2,1)	(6,1,0)	(6,2,0)	(2,8,0)	(2,8,0)	(1,1,1)	(1,2,1)	(2,8,0)	(2,1,0)	(1,5,1)	(1,4,1)
Panel B: Long-run estimates														
GDP	0.766*	0.396*	1.274*	1.724*	1.346*	1.449*	1.950*	1.264*	1.420*	1.453*	1.226*	0.907*	2.187*	2.179
	(2.538)	(6.624)	(7.790)	(2.779)	(7.827)	(3.178)	(2.780)	(4.457)	(5.667)	(3.303)	(5.667)	(8.914)	(2.477)	(1.220)
EX	-5.453*	-2.255*	-3.915*	-7.146*	-4.681	-5.454*	-12.990*	-7.337*	-5.144*	-5.722*	-4.011*	-1.388*	-14.930*	-15.287
	(-2.065)	(-5.553)	(-3.553)	(-1.692)	(-3.996)	(-1.691)	(-2.154)	(-2.958)	(-3.102)	(-1.800)	(-2.353)	(-2.198)	(-2.074)	(-1.015)
Constant	24.561*	13.503*	10.519*	20.755	13.347*	15.871	46.190*	26.800*	15.157*	17.560*	9.075	0.061	51.067*	53.367
	(2.646)	(9.810)	(2.979)	(1.575)	(3.576)	(1.538)	(2.167)	(2.978)	(2.863)	(1.665)	(1.538)	(0.029)	(2.062)	(1.007)
Panel C: Cointegration analysis														
ECT(-1)	-0.231*	-0.318*	-0.107*	-0.043*	-0.233*	-0.110*	-0.152*	-0.228*	-0.121*	-0.076*	-0.234*	-0.241*	-0.105*	-0.057*
	(-5.113)	(-5.522)	(-4.205)	(-4.639)	(-5.078)	(-3.486)	(-4.650)	(-5.063)	(-4.353)	(-3.303)	(-3.872)	(-4.266)	(-4.965)	(-3.434)
Bounds F test	6.248*	7.797*	4.242*	5.192*	4.922*	2.976	3.693*	7.465*	4.576*	2.633	3.542*	4.193*	5.932*	2.841
Panel D: Diagnostic statistics														
JB	11.291*	182.426*	3.863	4.790*	4.721*	7.331*	2.871	0.849	11.493*	10.495*	2.883	2.997	0.614	4.417
	[0.004]	[0.000]	[0.145]	[0.091]	[0.094]	[0.026]	[0.238]	[0.654]	[0.003]	[0.005]	[0.237]	[0.224]	[0.736]	[0.110]
LM	0.549	1.158	0.038	0.057	1.355	0.772	0.516	0.439	0.231	0.467	0.311	0.300	1.017	2.224
	[0.580]	[0.854]	[0.963]	[0.945]	[0.264]	[0.456]	[0.599]	[0.647]	[0.794]	[0.628]	[0.734]	[0.742]	[0.366]	[0.115]
ARCH	0.361	0.344	0.009	0.001	0.006	0.001	1.508	0.044	0.004	0.116	1.256	0.554	6.142*	0.382
	[0.550]	[0.559]	[0.923]	[0.975]	[0.938]	[0.980]	[0.223]	[0.835]	[0.952]	[0.734]	[0.266]	[0.459]	[0.015]	[0.538]
RESET	2.578	0.892	0.704	0.519	0.125	0.858	2.025	2.661	1.498	0.271	0.001	0.001	0.096	2.396
	[0.113]	[0.348]	[0.404]	[0.473]	[0.725]	[0.357]	[0.159]	[0.107]	[0.224]	[0.604]	[0.997]	[0.997]	[0.758]	[0.126]
CUSUM	S	S	S	S	S	S	S	S	S	S	S	S	S	S
CUSUMSQ	S	U	U	U	U	S	S	U	U	U	S	S	U	U

Notes: * denotes the 10% significance level. Test statistics are reported in ( ). Bounds F test is used for detecting a cointegration relationship. JB is the Jarque-Bera test of a normality of error term. LM is the Lagrange Multiplier test of residual serial correlation. ARCH is the Autoregressive Conditional Heteroskedasticity test of heteroscedasticity problem. RESET is the Ramsey regression equation specification error test of a model misspecification. CUSUM and CUSUMSQ are cumulative sum of error and its square to measure the stability of estimates. The probability values are reported in [ ].

Table 5. Results of non-linear ARDL models for metal commodities.

	Aluminum		Gold		Lead		Nickel		Silver		Tin		Zinc	
	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER
ARDL(p,d,q,r)	(2,1,1,0)	(2,1,0,0)	(1,5,6,5)	(1,5,6,5)	(6,1,1,0)	(6,2,0,0)	(1,8,0,0)	(2,8,0,0)	(1,1,4,0)	(1,1,0,1)	(2,8,0,1)	(2,8,0,3)	(1,4,1,0)	(3,4,7,0)
Panel A: Short-run estimates														
D(y(-1))	0.294*	0.326*	-	-	-0.099	-0.096	-	0.216*	-	-	0.197*	0.239*	-	-
	(3.501)	(3.905)			(-0.998)	(-0.934)		(2.289)			(1.771)	(2.040)		
D(y(-2))	-	-	-	-	0.144	0.140	-	-	-	-	-	-	-	0.235*
					(1.466)	(1.359)								(2.223)
D(y(-3))	-	-	-	-	-0.105	-0.132	-	-	-	-	-	-	-	-
					(-1.033)	(-1.235)								
D(y(-4))	-	-	-	-	-0.171*	-0.211*	-	-	-	-	-	-	-	-
					(-1.720)	(-1.997)								
D(y(-5))	-	-	-	-	-0.244*	-0.211*	-	-	-	-	-	-	-	-
					(-2.480)	(-2.042)								
D(GDP)	0.039	0.087	-0.494	-0.652	0.109	0.059	-0.074	0.737	-0.247*	-0.131	1.513*	2.084*	-2.079*	-1.542*
	(0.580)	(1.234)	(-1.117)	(-1.441)	(0.904)	(0.470)	(-0.070)	(0.728)	(-2.764)	(-1.358)	(1.783)	(2.370)	(-5.125)	(-3.763)
D(GDP(-1))	-	-	0.544*	0.471*	-	0.284*	-0.722	-0.724	-	-	-1.171	-0.692	-1.783*	-1.495*
			(5.059)	(4.679)		(2.031)	(-0.667)	(-0.695)			(-1.390)	(-0.811)	(-4.735)	(-3.179)
D(GDP(-2))	-	-	0.504*	0.281*	-	-	-4.313*	-3.930*	-	-	-1.529*	-1.058	-1.936*	-1.620*
			(4.421)	(2.776)			(-4.137)	(-3.974)			(-1.881)	(-1.292)	(-5.198)	(-3.689)
D(GDP(-3))	-	-	0.579*	0.395*	-	-	1.041	1.966*	-	-	1.744*	2.796*	-1.888*	-1.730*
			(4.708)	(4.033)			(1.086)	(2.138)			(2.367)	(3.708)	(-4.986)	(-3.974)
D(GDP(-4))	-	-	1.038*	0.939*	-	-	-2.585*	-2.744*	-	-	-2.672*	-2.318*	-	-
			(2.394)	(2.088)			(-2.656)	(-2.686)			(-3.243)	(-2.711)		
D(GDP(-5))	-	-	-	-	-	-	-1.536	-1.394	-	-	-0.509	-0.058	-	-
							(-1.538)	(-1.422)			(-0.619)	(-0.070)		
D(GDP(-6))	-	-	-	-	-	-	2.105*	1.970*	-	-	0.100	0.462	-	-
							(2.050)	(1.992)			(0.120)	(0.554)		
D(GDP(-7))	-	-	-	-	-	-	-3.142*	-3.622*	-	-	-3.021*	-3.120*	-	-
							(-3.420)	(-4.035)			(-4.053)	(-4.092)		
D(POS)	-1.711*	-1.072*	-1.633*	-1.078*	-2.619*	-0.952	-2.136*	-1.882*	-1.782*	-0.979*	-1.013	-1.246	-2.666*	-3.917*
	(-4.205)	(-2.897)	(-3.716)	(-2.360)	(-3.583)	(-1.379)	(-2.190)	(-1.836)	(-2.601)	(-1.818)	(-1.278)	(-1.431)	(-3.746)	(-3.525)
D(POS(-1))	-	-	0.409	-0.042	-	-	-	-	0.068	-	-	-	-	-0.135
			(0.907)	(-0.097)					(0.094)					(-0.135)
D(POS(-2))	-	-	0.246	0.451	-	-	-	-	0.558	-	-	-	-	2.623*
			(0.595)	(1.092)					(0.778)					(2.962)
D(POS(-3))	-	-	0.711*	0.542	-	-	-	-	1.409*	-	-	-	-	-0.824
			(1.719)	(1.322)					(2.125)					(-0.953)
D(POS(-4))	-	-	0.328	0.544	-	-	-	-	-	-	-	-	-	-0.189
			(0.723)	(1.305)										(-0.223)
D(POS(-5))	-	-	1.125*	1.060*	-	-	-	-	-	-	-	-	-	0.076
			(2.740)	(2.686)										(0.090)
D(POS(-6))	-	-	-	-	-	-	-	-	-	-	-	-	-	2.086*
														(2.442)
D(NEG)	-0.443	-0.443	-1.103*	-1.207*	-0.437	-0.456	-3.782*	-1.735*	-1.969*	-1.749*	-1.667*	-1.168	-2.655*	-1.182
	(-0.741)	(-0.884)	(-2.273)	(-2.926)	(-0.456)	(-0.559)	(-3.406)	(-1.874)	(-2.322)	(-2.573)	(-1.860)	(-1.518)	(-2.974)	(-1.223)
D(NEG(-1))	-	-	0.133	0.273	-	-	-	-	-	-	-	-0.037	-	-
			(0.272)	(0.667)								(-0.049)		

Notes: * denotes the 10% significance level. Test statistics are reported in ( ).

Table 5. (Continued).

	Aluminum		Gold		Lead		Nickel		Silver		Tin		Zinc	
	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER	NEER	REER
ARDL(p,d,q,r)	(2,1,1,0)	(2,1,0,0)	(1,5,6,5)	(1,5,6,5)	(6,1,1,0)	(6,2,0,0)	(1,8,0,0)	(2,8,0,0)	(1,1,4,0)	(1,1,0,1)	(2,8,0,1)	(2,8,0,3)	(1,4,1,0)	(3,4,7,0)
Panel A: (Continued)														
D(NEG(-2))	-	-	-0.825	-0.490	-	-	-	-	-	-	-	-1.821*	-	-
			(-1.642)	(-1.202)								(-2.378)		
D(NEG(-3))	-	-	-0.069	0.060	-	-	-	-	-	-	-	-	-	-
			(-0.136)	(0.137)										
D(NEG(-4))	-	-	-1.597*	-1.398*	-	-	-	-	-	-	-	-	-	-
			(-3.121)	(-3.383)										
Panel B: Long-run estimates														
GDP	0.485	0.765*	1.580*	1.288	1.913*	1.554	-0.419	2.782*	0.769	2.405*	2.640*	2.772*	-2.736	2.732
	(1.661)	(4.209)	(1.960)	(1.152)	(3.308)	(0.953)	(-0.193)	(3.168)	(0.803)	(2.808)	(4.403)	(4.907)	(-0.614)	(1.489)
POS	-2.400*	-2.419*	-2.121	-2.913	-4.929*	-5.350	-16.444*	-9.541*	-5.477*	-5.632*	-5.110*	-3.690*	-20.167	-11.701
	(-5.588)	(-7.278)	(-1.603)	(-1.572)	(-4.139)	(-1.575)	(-1.669)	(-3.556)	(-3.459)	(-3.001)	(-3.425)	(-2.777)	(-1.197)	(-1.659)
NEG	-2.203*	-1.144*	-0.077	-2.615*	-2.696	-4.889	-27.637*	-4.796*	-8.245*	-2.063	0.169	2.340*	-43.149	-8.200
	(-2.213)	(-2.392)	(-0.030)	(-0.712)	(-1.057)	(-0.549)	(-1.582)	(-2.556)	(-2.005)	(-0.811)	(0.104)	(2.270)	(-1.077)	(-1.142)
Constant	2.971	0.554	-10.171	-7.085	-12.031*	-8.035	14.682	-17.663*	-0.791	-15.739*	-21.469*	-22.832*	36.786	-17.983
	(1.077)	(0.328)	(-1.361)	(-0.697)	(-2.192)	(-0.512)	(0.676)	(-2.377)	(-0.087)	(-1.982)	(-3.946)	(-4.604)	(0.776)	(-1.161)
Panel C: Cointegration analysis														
ECT(-1)	-0.340*	-0.402*	-0.151*	-0.110*	-0.260*	-0.119*	-0.102*	-0.275*	-0.131*	-0.128*	-0.325*	-0.343*	-0.057*	-0.110*
	(-5.502)	(-6.444)	(-4.540)	(-4.554)	(-5.150)	(-3.492)	(-5.238)	(-5.467)	(-4.474)	(-3.988)	(-4.798)	(-4.516)	(-5.588)	(-4.905)
Bounds F test	7.026*	7.720*	3.880*	3.903*	6.051*	2.388	3.913*	6.627*	4.258*	2.571	4.210*	3.600*	6.029*	3.879*
Panel D: Diagnostic statistics														
JB	67.813*	179.327*	0.817	1.294	3.067	7.305*	2.158	0.593	5.262*	10.331*	4.957*	4.559	0.181	1.060
	[0.000]	[0.000]	[0.665]	[0.524]	[0.216]	[0.026]	[0.340]	[0.744]	[0.072]	[0.006]	[0.084]	[0.102]	[0.914]	[0.589]
LM	0.666	0.740	0.253	0.580	0.641	0.887	0.843	0.185	0.325	0.610	1.205	0.604	0.512	0.195
	[0.517]	[0.480]	[0.777]	[0.563]	[0.530]	[0.416]	[0.435]	[0.831]	[0.724]	[0.546]	[0.306]	[0.549]	[0.602]	[0.824]
ARCH	0.551	0.428	0.378	0.925	0.026	0.001	1.148	0.031	0.246	2.332	1.989	1.041	3.624*	0.004
	[0.460]	[0.515]	[0.540]	[0.339]	[0.872]	[0.975]	[0.287]	[0.860]	[0.622]	[0.130]	[0.162]	[0.311]	[0.060]	[0.982]
RESET	7.161*	3.100*	4.214*	3.410*	0.206	0.853	3.385*	1.709	5.904*	0.861	0.519	1.935	0.126	0.490
	[0.009]	[0.082]	[0.044]	[0.070]	[0.651]	[0.359]	[0.070]	[0.196]	[0.018]	[0.356]	[0.474]	[0.169]	[0.724]	[0.487]
CUSUM	S	S	S	S	S	S	S	S	S	S	S	S	S	S
CUSUMSQ	U	U	U	U	S	U	S	S	U	U	S	S	U	S
Panel E: Short-run and long-run asymmetries														
WALD-S	1.802	0.709	6.679*	5.035*	2.181	0.837	0.687	0.008	2.687	0.010	0.313	0.796	0.010	0.663
	[0.180]	[0.400]	[0.010]	[0.025]	[0.140]	[0.360]	[0.407]	[0.927]	[0.101]	[0.921]	[0.576]	[0.372]	[0.922]	[0.416]
WALD-L	0.032	2.976*	0.396	0.006	0.607	0.004	3.174*	3.171*	0.654	1.090	4.636*	6.472*	6.717*	0.395
	[0.858]	[0.085]	[0.529]	[0.941]	[0.436]	[0.950]	[0.075]	[0.075]	[0.419]	[0.297]	[0.031]	[0.011]	[0.010]	[0.530]

Notes: * denotes the 10% significance level. Test statistics are reported in ( ). Bounds F test is used for detecting a cointegration relationship. JB is the Jarque-Bera test of a normality of error term. LM is the Lagrange Multiplier test of residual serial correlation. ARCH is the Autoregressive Conditional Heteroskedasticity test of heteroscedasticity problem. RESET is the Ramsey regression equation specification error test of a model misspecification. CUSUM and CUSUMSQ are cumulative sum of error and its square to measure the stability of estimates. WALD-S is the Wald test of detecting a short-run asymmetry. WALD-L is the Wald test of detecting a long-run asymmetry. The probability values are reported in [ ].