Long et al. Financ Innov (2021) 7:48
https://doi.org/10.1186/s40854-021-00262-0

Financial Innovation

RESEARCH

Open Access

Do the RMB exchange rate and global commodity prices have asymmetric or symmetric effects on China's stock prices?

Shaobo Long[1,2*], Mengxue Zhang[2], Keaobo Li[3] and Shuyu Wu[4]

*Correspondence: longshbcqu@126.com
[1] Center for Public Economy and Public Policy, Chongqing University, Chongqing, China
Full list of author information is available at the end of the article

Abstract

With the rapid expansion of the RMB exchange rate's floating range, the effects of the RMB exchange rate and global commodity price changes on China's stock prices are likely to increase. This study uses both auto regressive distributed lag (ARDL) and nonlinear ARDL (NARDL) approaches to explore the symmetric and asymmetric effects of the RMB exchange rate and global commodity prices on China's stock prices. Our findings show that without considering the critical variable of global commodity prices, there is no cointegration relationship between the RMB exchange rate and China's stock prices, and the coefficient of the RMB exchange rate is not statistically significant. However, when we introduce global commodity prices into the NARDL model, the result shows that the RMB exchange rate has a negative effect on China's stock prices, that there indeed exists a long-run cointegration relationship among the RMB exchange rate, global commodity prices, and stock prices in the NARDL model, and that global commodity price changes have an asymmetric effect on China's stock prices in the long run. Specifically, China's stock prices are more sensitive to increases than decreases in global commodity prices. Thus, increases in global commodity prices cause China's stock prices to decline sharply. In contrast, the same magnitude of decline in global commodity prices induces a smaller increase in China's stock prices.

Keywords: RMB exchange rate, Global commodity prices, China's stock prices, Asymmetric effects

JEL Classification: F3, G1

Introduction

Modern finance has become an interdependent system (Kou et al. 2019), and the foreign exchange market and stock market are the two primary financial markets. Under open conditions, changes in the exchange rates cause movements in the stock market by affecting the global competitiveness of a country's products (Dornbusch and Fischer 1980). On the other hand, fluctuations in stock prices can also affect the foreign exchange market through capital flows (Branson 1983; Frankel 1992). In recent years, with the widespread adoption of floating exchange rate systems in various countries, a growing number of researchers have tried to identify whether changes in exchange rates impact stock prices. However, the conclusions are still contested.

In studies on the impact of exchange rates on stock prices, an important recent finding is that the omission of global commodity prices, a critical variable, may lead to biased results. Furthermore, it is easy to overlook the relationship between the exchange rates and stock prices. As an essential input for industrial and agricultural production, changes in global commodity prices will inevitably affect the profits of enterprises, and such changes will eventually reflect in the stock market. The impact of global commodity prices on stock prices varies depending on whether a country is a commodity exporter or importer. For global commodity-exporting countries, the rise of global commodity prices brings more profits to their enterprises, leading to an increase in stock prices (Chortareas et al. 2011). However, for global commodity-importing countries, the effect may be the opposite. Higher global commodity prices can lead to higher production costs for domestic firms, weakening their profitability and negatively impacting stock prices (Jones et al. 2004). Meanwhile, as the financial attribute of global commodities strengthens, an increasing number of financial products are designed to target global commodities, which provides an investment alternative to stocks (Enilov et al. 2021). Because some global commodities and the financial products designed to target them are considered safe assets, investors shift investments over to commodities and their financial products when the economy and stocks are not doing well and vice-versa (Jain and Biswal 2016). Thus, there is greater substitutability between global commodity-based financial products and stocks due to the financialization of commodities. Changes in global commodity prices can affect investors' asset allocation, causing changes in demand for stocks and, consequently, stock prices as well.

We examine the impact of exchange rates and global commodity prices on stock prices in China, the largest developing country. Several reasons motivate our focus on the relationships among these variables. First, China's RMB exchange rate has become much more market-oriented, and its impact on the domestic stock market may increase significantly (Tian and Ma 2010; Nieh and Yau 2010; Rutledge et al. 2014). In July 2005, China began to implement a managed floating exchange rate regime, with the RMB exchange rate no longer pegged to the US dollar. The country formed a more flexible RMB exchange rate regime based on market supply and demand, adjusting for a basket of currencies. In 2014, the People's Bank of China expanded the floating range of the RMB exchange rate to US dollar, from 1 to 2%, further enhancing RMB bidirectional floating flexibility. Moreover, China has insisted on an export-oriented strategy for a long time; thus, the external dependence of the Chinese economy is relatively high. The expansion of the fluctuation range of the RMB exchange rate will inevitably affect imports and exports, thereby causing fluctuations in the stock market because of expected changes in companies' profitability.

Second, it is beneficial to study whether there is an asymmetric impact of the RMB exchange rate on stock prices in China. In the ongoing literature, the asymmetric effects of exchange rates on stock prices have been confirmed in many developed countries (Bahmani-Oskooee and Saha 2016). Nonetheless, this type of research on China is scarce. Given that firms may use real options to hedge the risks associated with exchange rate changes (Miller and Reuer 1998), the uncertainty of future cash flows, and the presence of default risk (Bartram 2004), the impact of exchange rates on enterprise performance and stock prices may be asymmetric. Therefore, it is necessary to investigate whether a similar asymmetric effect exists in China to better inform governments and investors' decision-making.

Third, China is a major importer of global commodities. By affecting the production costs and future cash flows of Chinese companies, changes in global commodity prices may indirectly affect company profits and stock prices. The global commodity market has long been monopolized by a small number of oligarchic companies (Meyer and Cramon-Taubadel 2010); however, China's industry concentration ratio is low compared to other developed economies. As such, it is difficult for Chinese companies to possess bargaining power over global commodities companies.[1] Thus, there may exist an asymmetric price transmission from global commodity prices to product costs for Chinese companies (Long and Liang 2018). That is, the impact of global commodity prices on enterprise profits and stock prices may be asymmetric.

As reform of the RMB exchange rate formation mechanism continues to deepen, along with China's high external dependence on global commodities, it is necessary to clarify the asymmetric impacts of the RMB exchange rate and global commodity prices on China's stock prices. Dramatic changes in stock prices not only have an adverse effect on the capital market, but also have a negative effect on the healthy development of the entire economy (Wen et al. 2019). Thus, this study's findings can help investors better understand and forecast changes in stock markets, make more profitable investments, and adopt appropriate hedging strategies when encountering RMB exchange rate and commodity price changes. Moreover, it is also crucial for authorities to more successfully stabilize China's stock market based on asymmetric influence characteristics.

Literature review

The effects of exchange rates on stock prices

The debate about whether there is a relationship between exchange rates and stock prices has been ongoing for some time, but no consensus has been reached. Two main theoretical models attempt to account for the interaction between exchange rates and stock prices. One is the flow-oriented model, developed by Dornbusch and Fischer (1980), which asserts that a movement in a country's currency will change actual output and stock prices through products' global competitiveness and trade balance. The depreciation of domestic currency can lead to an increase in output and export via the dividend-discount model, which translates into a rise in stock prices with investors' optimistic expectations of company profitability. The other is the stock-oriented model, suggested by Branson (1983) and Frankel (1992), which proposes that exchange rates are affected by stock prices through capital mobility. Increasing domestic stock prices attract foreign capital to the domestic stock market, bringing appreciation pressure on domestic currency.

[1] Taking iron ore as an example, three major mining giants control more than 70% of the world's iron ore production and trade volume. Conversely, China's steel industry has low concentration, and the total output of the top nine steel companies accounts for less than 37% of China's steel production, while the top four steel companies in Japan and the EU account for 75% of the total steel production.

In empirical research, the literature on the relationship between exchange rates and stock prices is very extensive but remains controversial. On one hand, numerous empirical studies provide evidence favoring the flow-oriented hypothesis of exchange rates. The earliest study was conducted by Aggarwal (1981), who concluded that there is a positive relationship between the two variables using monthly data from 1974 to 1978 in the United States. Subsequently, many studies have supported the effect of exchange rates on stock prices using various empirical approaches, such as cointegration techniques, the Granger causality test, and so on (Phylaktis and Ravazzolo 2005; Yau and Nieh 2009; Aslam and Ramzan 2013; Lin and Fu 2016; Sui and Sun 2016; Yang 2017). On the other hand, numerous studies support the stock-oriented hypothesis of exchange rates (Soenen and Hennigar 1988; Maysami and Koh 2000; Wongbangpo and Sharma 2002; Kim 2003; Ibrahim and Aziz 2003; Tsai 2012; Inegbedion 2012; Liang et al. 2013). However, other studies either reveal that no apparent relationship exists between exchange rates and stock prices, or their results are ambiguous (Bahmani-Oskooee and Sohrabian 1992; Wu 2000; Nieh and Lee 2001; Smyth and Nandha 2003; Doong et al. 2005; Lean et al. 2005; Rahman and Uddin 2009; Zhao 2010; Kollias et al. 2012; Wickremasinghe 2012).

China has also aroused the interest of scholars on this issue. Several studies have focused on the impact of the RMB exchange rate on China's stock prices. Li and Huang (2008) found a short-run causation effect of the RMB exchange rate on Shanghai stock returns. Nieh and Yau (2010), Zhao (2010), Tian and Ma (2010), and Rutledge et al. (2014) also came to similar conclusions. Nevertheless, these studies on China are more straightforward and mainly examine the linear relationship between these variables. However, under different thresholds, the relationship between variables is usually nonlinear (Tian et al. 2020). Several recent studies have pointed out that the symmetry assumption may underestimate the impact of exchange rates on stock prices (Effiong and Bassey 2019; Wong 2019; Salisu et al. 2020). Ismail and Isa (2009) concluded that a nonlinear model is more appropriate. Applying a nonlinear model, they found a nonlinear relationship between exchange rates and stock prices in Malaysia using monthly data from 1990 to 2005. Bahmani-Oskooee and Saha (2015) also revealed that exchange rate changes have asymmetric effects on stock prices after introducing nonlinearity into the adjustment process. Ding (2021) pointed out that the relationship among exchange rates and stock prices is time-varying, so traditional linear models may not accurately capture the relationship. Therefore, in this study, we employ both the symmetric auto regressive distributed lag (ARDL) model and the asymmetric nonlinear auto regressive distributed lag (NARDL) model to analyze and compare the symmetric and asymmetric effects of the RMB exchange rate on China's stock prices to avoid estimation bias caused by model setting.

The effects of global commodity prices on stock prices

Although much research progress has been made on the effects of exchange rates on stock prices, several aspects remain worthy of further study. First, some studies lack the key variable of global commodity prices. As mentioned, global commodity prices significantly impact the input prices of products and the balance sheets of listed companies and their stock prices. Chaban (2009) discovered a three-way relationship among exchange rates, commodity prices, and stock prices. Basher et al. (2012) studied the dynamic linkage among exchange rates, oil price, and emerging market stock price and found that increases in oil prices tend to drive down emerging market stock prices in the short run. Chortareas et al. (2011) examined the role of oil prices from 1994 to 2006 for a possible link between exchange rates and the stock market for oil-exporting countries, such as Egypt, Kuwait, Oman, and Saudi Arabia. They also noted that, when the oil price is not considered, there is no long-run cointegration relationship between exchange rates and stock prices. However, when the oil price is considered, exchange rates are positively related to stock prices in Egypt and Oman. Groenewold and Paterson (2013) in a study on Australia from 1979 to 2010 revealed that the relationship between exchange rates and stock prices is weak when omitting global commodity prices. Nevertheless, once global commodity prices are added, all three variables are cointegrated in the long run. Roubaud and Arouri (2018) argue that exchange rates, oil prices, and stock markets should be linked theoretically, as oil plays an active role in the effect of exchange rates on stock prices. Akbar et al. (2019) examined and confirmed the dynamic linkages among exchange rates, gold prices, interest rates, and stock prices in Pakistan. Singhal et al. (2019) investigated and found a dynamic relationship among exchange rates, international oil prices, international gold prices, and stock market index in Mexico. Chkir et al. (2020) also studied the relationship among oil prices, exchange rates, and stock prices in Canada, Australia, Mexico, Norway, Britain, France, and Japan.

However, although research has been ample, few studies have focused on major importing countries such as India (Ram 2017; Kumar et al. 2020). Moreover, relatively few studies have examined the impact of the RMB exchange rate on China's stock prices while adding the variable of global commodity prices, which has proven unignorable in more recent studies. Given the high degree of dependence on global commodities imports, China must consider the impact of global commodity prices when investigating the relationship between exchange rates and stock prices.

Moreover, the impact of global commodity prices on stock prices may be asymmetric. Using a regime-switching approach, Roubaud and Arouri (2018) found relationships among oil prices, exchange rates, and stock markets to be nonlinear and asymmetric. Kumar (2019) also examined the asymmetric impact of oil prices on stock prices. The results demonstrated that positive (negative) shocks in oil prices have significant positive (negative) impacts on stock prices. Furthermore, a positive shock has a more pronounced effect than a negative shock. Chang (2020) examined the asymmetric impact of oil prices on stock prices and found that in the short run, oil prices significantly and asymmetrically affect stock prices in Russia, Indonesia, and India. Olayeni et al. (2020) also found that there is a long-run, asymmetric relationship among oil prices, exchange rates, global economic activity index, oil production, and stock market activity in Nigeria.

In general, existing literature on the impact of the RMB exchange rate on China's stock prices either ignores the vital variable of commodity prices or does not consider the asymmetry among these variables. Accordingly, this study attempts to overcome these shortcomings and makes marginal contributions to the previous literature in two aspects. First, we add global commodity prices and other primary macroeconomic variables when studying the relationships between the RMB exchange rate and China's stock prices to prevent omitting key variables. Second, using the NARDL model developed by Shin et al. (2014), we consider the asymmetric effects of the RMB exchange rate and global commodity prices on China's stock prices by relaxing the strict assumption of symmetry to capture a more reasonable and realistic relationship. For comparison, we also employ the ARDL model to investigate the symmetric relationship among these variables.

The remainder of this paper is organized as follows. Section "Methods and models" describes the methodology and data, section "Data and empirical results" presents and interprets the overall results, and section "Conclusion" draws conclusions and implications based on the findings.

Methods and models

We use both ARDL and NARDL models in this study. The ARDL model captures the symmetric relationship among these variables, while the NARDL helps analyze the asymmetric relationship between financial or economic time series (Katrakilidis and Trachanas 2012; Asimakopoulos et al. 2000), such as the exchange rates and stock prices. Compared with other conventional cointegration techniques, the NARDL model exhibits both cointegration and asymmetric nonlinearity in a single equation. Moreover, the model contains a dynamic error correction that captures both short- and long-run asymmetries (Shahzad et al. 2017). Thus, it can identify the asymmetric effects of the rise and fall of the RMB exchange rate and global commodity prices on China's stock prices in the short and long run. Furthermore, unlike standard cointegration techniques, the ARDL and NARDL models are flexible to different orders of integrations in the time series. They are applicable regardless of whether the regression variables are pure I(0), I(1), or mutually cointegrated (Pesaran et al. 2001; Shin et al. 2014).

Symmetry relationship in the linear ARDL framework

According to the number of variables in the estimated equation, existing research can be divided into two categories—the bivariate model, including only stock prices and exchange rate, and the multivariable model, including additional control variables (Bahmani-Oskooee and Saha 2015). According to Bahmani-Oskooee and Saha (2015), the multivariable model can prevent inaccurate estimation stemming from the omission of the main macroeconomic variables as in the bivariate model. As such, we adopt the revised multivariate model of Boonyanam (2014), Moore and Wang (2014), Bahmani-Oskooee and Saha (2015), and Bahmani-Oskooee and Saha (2016), among others, to estimate the relationship between the RMB exchange rate and stock prices:

$$sp_t = \beta_0 + \beta_1 neer_t + \beta_2 fr_t + \beta_3 i_t + \beta_4 ipi_t + \beta_5 m2_t + \mu_t \tag{1}$$

where *sp* denotes an index of China's stock prices, and *neer* denotes the nominal effective exchange rate of RMB[2]; *fr* is the foreign exchange reserve; *i* is the interest rate, representing the price monetary policy instrument; *m*2 is a measure of the broad money supply that represents the quantitative monetary policy instrument and may have

[2] Following Boonyanam (2014), Moore and Wang (2014), and Bahmani-Oskooee and Saha (2015), the nominal effective exchange rate is adopted in this study.

positive effects on the stock market; *ipi* is the industrial production index used as a proxy for domestic economic activities, which may also have a positive impact on stock prices; and μ is the random error term. All the variables are in logarithms except for interest rate i.

For comparison, we add the global commodity prices in Eq. (1) to study its influence on China's stock prices because not including them may make the cointegration relationship between the RMB exchange rate and stock prices seem non-existent (Groenewold and Paterson, 2013). Thus, Eq. (1) can be rewritten as:

$$sp_t = \beta_0 + \beta_1 neer_t + \beta_2 comm_t + \beta_3 fr_t + \beta_4 i_t + \beta_5 ipi_t + \beta_6 m2_t + \mu_t \tag{2}$$

where *comm* refers to global commodity prices and is also expressed in logarithmic form.

According to Pesaran and Shin (1998) and Pesaran et al. (2001), we can also infer both the short- and long-run effects if we rewrite Eqs. (1) and (2) in an error-correction model. The standard linear ARDL error-correction model of Eqs. (1) and (2) can be respectively expressed, as follows:

$$\begin{aligned} \Delta sp_t =& \alpha + \sum_{j=1}^{n1} \beta_{1,j} \Delta sp_{t-j} + \sum_{j=0}^{n2} \delta_{1,j} \Delta neer_{t-j} + \sum_{j=0}^{n3} \varphi_{1,j} \Delta fr_{t-j} \\ &+ \sum_{j=0}^{n4} \theta_{1,j} \Delta i_{t-j} + \sum_{j=0}^{n5} \pi_{1,j} \Delta ipi_{t-j} + \sum_{j=0}^{n6} \rho_{1,j} \Delta m2_{t-j} \\ &+ \lambda_1 sp_{t-1} + \lambda_2 neer_{t-1} + \lambda_3 fr_{t-1} + \lambda_4 i_{t-1} + \lambda_5 ipi_{t-1} + \lambda_6 m2_{t-1} + \mu_t \end{aligned} \tag{3}$$

$$\begin{aligned} \Delta sp_t =& \alpha + \sum_{j=1}^{I1} \beta_{2,j} \Delta sp_{t-j} + \sum_{j=0}^{I2} \delta_{2,j} \Delta neer_{t-j} + \sum_{j=0}^{I3} \tau_{2,j} \Delta comm_{t-j} \\ &+ \sum_{j=0}^{I4} \varphi_{2,j} \Delta fr_{t-j} + \sum_{j=0}^{I5} \theta_{2,j} \Delta i_{t-j} + \sum_{j=0}^{I6} \pi_{2,j} \Delta ipi_{t-j} \\ &+ \sum_{j=0}^{I7} \rho_{2,j} \Delta m2_{t-j} + \lambda_1 sp_{t-1} + \lambda_2 neer_{t-1} + \lambda_3 comm_{t-1} \\ &+ \lambda_4 fr_{t-1} + \lambda_5 i_{t-1} + \lambda_6 ipi_{t-1} + \lambda_7 m2_{t-1} + \mu_t \end{aligned} \tag{4}$$

where Δ is a difference operator $np(p = 1, 2, \ldots, 6)$ and $Ip(p = 1, 2, \ldots, 7)$ are lag orders for the independent variable and dependent variables in Eqs. (3) and (4), respectively.

We can test for the symmetric, long-run cointegration relationship by using two bounds tests. First, following Banerjee et al. (1998), the test is named t_{BDM}, and the null hypothesis is $H_0 : \lambda_1 = 0$. If $\lambda_1 = 0$, Eq. (3) is reduced to a regression involving only first differences, as there are no long-run relationships between these variables. Second, as suggested by Pesaran and Shin (1998) and Pesaran et al. (2001), a modified F-test, denoted by F_{PSS}, can be applied to investigate the cointegration relationships. The joint null hypothesis is that coefficients of the level variables are jointly equal to zero ($H_0 : \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = 0$). If the null hypothesis is rejected, it implies that there are cointegration relationships among these variables. Similar test procedures can also be applied to test the cointegration in Eq. (4).

Pesaran et al. (2001) established the upper and lower bounds for tests of t_{BDM} and F_{PSS}, respectively, to judge the existence of the cointegration relationship. When the calculated statistics of t_{BDM} and F_{PSS} exceed their respective upper critical values, there is evidence of a cointegration relationship among these variables. Conversely, if the calculated statistics t_{BDM} and F_{PSS} are below their respective lower critical values, it is not possible to reject the null hypothesis claiming no cointegration relationship. However, no clear conclusion can be drawn if the statistics lay between the upper and lower bounds.

Asymmetry relationship in the nonlinear ARDL framework

In Eqs. (3) and (4), we assume that the RMB exchange rate and global commodity prices have symmetric effects on China's stock prices; however, they may also have asymmetric effects (Chortareas et al. 2011; Groenewold and Paterson 2013; Roubaud and Arouri 2018). Therefore, we relax the strict restriction of symmetry and apply the asymmetric NARDL model developed by Shin et al. (2014). Following Shin et al. (2014), the NARDL model employs positive and negative partial sum decompositions to investigate the asymmetric relationship in both the short and long run. Furthermore, we obtain the partial sum processes of positive changes ($neer_t^+$) and negative changes ($neer_t^-$) by decomposing $neer_t$ as $neer_t = neer_0 + neer_t^+ + neer_t^-$:

$$neer_t^+ = \sum_{j=1}^{t} \Delta neer_j^+ = \sum_{j=1}^{t} \max(\Delta neer_j^+, 0)$$
$$neer_t^- = \sum_{j=1}^{t} \Delta neer_j^- = \sum_{j=1}^{t} \min(\Delta neer_j^-, 0)$$

where $neer_t^+$ and $neer_t^-$ are partial sum processes of positive and negative changes in $neer_t$, respectively. Then, we introduce $neer_t^+$ and $neer_t^-$ into the symmetric ARDL-ECM model (3), which can then be developed into the NARDL-ECM model, as follows:

$$\begin{aligned}\Delta sp_t =& \alpha + \sum_{j=1}^{n1} \beta_{1,j} \Delta sp_{t-j} + \sum_{j=0}^{n2} \delta_{1,j}^{+} \Delta neer_{t-j}^{+} + \sum_{j=0}^{n2} \delta_{1,j}^{-} \Delta neer_{t-j}^{-} \\ &+ \sum_{j=0}^{n3} \varphi_{1,j} \Delta fr_{t-j} + \sum_{j=0}^{n4} \theta_{1,j} \Delta i_{t-j} + \sum_{j=0}^{n5} \pi_{1,j} \Delta ipi_{t-j} \\ &+ \sum_{j=0}^{n6} \rho_{1,j} \Delta m2_{t-j} + \lambda_1 sp_{t-1} + \lambda_2^{+} neer_{t-1}^{+} + \lambda_2^{-} neer_{t-1}^{-} \\ &+ \lambda_3 fr_{t-1} + \lambda_4 i_{t-1} + \lambda_5 ipi_{t-1} + \lambda_6 m2_{t-1} + \mu_t \end{aligned} \tag{5}$$

where $-\lambda_2^+/\lambda_1$, $-\lambda_2^-/\lambda_1$, $-\lambda_3/\lambda_1$, $-\lambda_4/\lambda_1$,$-\lambda_5/\lambda_1$ and $-\lambda_6/\lambda_1$ are the long-run influence coefficients of$neer^+$,$neer^-$,fr,i,ipi, and $m2$ on China's stock prices. In particular, $-\lambda_2^+/\lambda_1$ and $-\lambda_2^-/\lambda_1$ denote the long-run influence coefficients of the RMB exchange rate's appreciation and depreciation on China's stock prices, respectively.

Similarly, two bounds tests are proposed to investigate the existence of a long-run cointegration relationship in the NARDL. The first is the t_{BDM} test, which is similar to the ARDL suggested by Pesaran et al. (2001). The null hypothesis is $H_0 : \lambda_1 = 0$. If the null hypothesis cannot be rejected, Eq. (5) reduces to the linear regression involving only first differences, implying that there is no long-run cointegration relationship among the levels of sp, $neer^+$, $neer^-$, fr, i, ipi and $m2$. The second is referred to as the F_{pss} test, a joint null of the modified F-test to investigate the long-run cointegration relationships among variables. The joint null hypothesis is $H_0 : \lambda_1 = \lambda_2^+ = \lambda_2^- = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = 0$.

Once the long-run cointegration relationship is identified in Eq. (5), we can obtain the long-run influence coefficients of the RMB exchange rate rising and falling to China's stock prices, which can be expressed as $\beta_{neer^+} = -\lambda_2^+/\lambda_1$ and $\beta_{neer^-} = -\lambda_2^-/\lambda_1$, respectively. To test the long-run symmetry, we use the Wald test, with the null hypothesis being $H_0 : \beta_{neer^+} = \beta_{neer^-}$. If the long-run symmetry hypothesis is not rejected, we can infer that the effects of exchange rate appreciation and depreciation on stock prices are the same in the long run. Thus, Eq. (5) can be simplified as:

$$\begin{aligned}\Delta sp_t =& \alpha + \sum_{j=1}^{n1} \beta_{1,j} \Delta sp_{t-j} + \sum_{j=0}^{n2} \delta_{1,j}^{+} \Delta neer_{t-j}^{+} + \sum_{j=0}^{n2} \delta_{1,j}^{-} \Delta neer_{t-j}^{-} \\ &+ \sum_{j=0}^{n3} \varphi_{1,j} \Delta fr_{t-j} + \sum_{j=0}^{n4} \theta_{1,j} \Delta i_{t-j} + \sum_{j=0}^{n5} \pi_{1,j} \Delta ipi_{t-j} \\ &+ \sum_{j=0}^{n6} \rho_{1,j} \Delta m2_{t-j} + \lambda_1 sp_{t-1} + \lambda_2 neer_{t-1} + \lambda_3 fr_{t-1} \\ &+ \lambda_4 i_{t-1} + \lambda_5 ipi_{t-1} + \lambda_6 m2_{t-1} + \mu_t\end{aligned} \tag{6}$$

We can then check the short-run asymmetric relationship by the null hypothesis in two ways: (1) $H_0 : \delta_{1,j}^{+} = \delta_{1,j}^{-}$, for all $j = 0, 1, ..., \text{n2}$, or (2) $H_0 : \sum_{j=0}^{n2} \delta_{1,j}^{+} = \sum_{j=0}^{n2} \delta_{1,j}^{-}$, $j = 0, 1, ..., \text{n2}$. In the short run, stock prices adjust differently to an appreciation than a depreciation if the sum of each of the dynamic coefficients associated with '+' differs from that associated with '−'. If the short-run symmetry hypothesis cannot be rejected, Eq. (5) can be simplified to Eq. (7), which represents an asymmetric long-run relationship only and yields the following:

$$\begin{aligned}\Delta sp_t =& \alpha + \sum_{j=1}^{n1} \beta_{1,j} \Delta sp_{t-j} + \sum_{j=0}^{n2} \delta_{1,j} \Delta neer_{t-j} + \sum_{j=0}^{n3} \varphi_{1,j} \Delta fr_{t-j} \\ &+ \sum_{j=0}^{n4} \theta_{1,j} \Delta i_{t-j} + \sum_{j=0}^{n5} \pi_{1,j} \Delta ipi_{t-j} + \sum_{j=0}^{n6} \rho_{1,j} \Delta m2_{t-j} \\ &+ \lambda_1 sp_{t-1} + \lambda_2^{+} neer_{t-1}^{+} + \lambda_2^{-} neer_{t-1}^{-} + \lambda_3 fr_{t-1} + \lambda_4 i_{t-1} \\ &+ \lambda_5 ipi_{t-1} + \lambda_6 m2_{t-1} + \mu_t\end{aligned} \tag{7}$$

Similarly, we can also obtain the partial sum processes of the positive changes ($comm_t^{+}$) and negative changes ($comm_t^{-}$) by decomposing $comm_t$ as $comm_t = comm_0 + comm_t^{+} + comm_t^{-}$:

$$\begin{aligned}comm_t^{+} &= \sum_{j=1}^{t} \Delta comm_j^{+} = \sum_{j=1}^{t} \max(\Delta comm_j^{+}, 0) \\ comm_t^{-} &= \sum_{j=1}^{t} \Delta comm_j^{-} = \sum_{j=1}^{t} \min(\Delta comm_j^{-}, 0)\end{aligned}$$

where $comm_t^{+}$ and $comm_t^{-}$ are partial sum processes of positive and negative changes in $comm_t$. Then, we introduce $neer^{+}$, $neer^{-}$, $comm^{+}$, and $comm^{-}$ into the symmetric ARDL-ECM model (4) and get the NARDL-ECM model, presented as follows:

$$\begin{aligned}\Delta sp_t =& \alpha + \sum_{j=1}^{I1} \beta_{2,j} \Delta sp_{t-j} + \sum_{j=0}^{I2} \delta_{2,j}^{+} \Delta neer_{t-j}^{+} + \sum_{j=0}^{I2} \delta_{2,j}^{-} \Delta neer_{t-j}^{-} \\ &+ \sum_{j=0}^{I3} \tau_{2,j}^{+} \Delta comm_{t-j}^{+} + \sum_{j=0}^{I3} \tau_{2,j}^{-} \Delta comm_{t-j}^{-} + \sum_{j=0}^{I4} \varphi_{2,j} \Delta fr_{t-j} \\ &+ \sum_{j=0}^{I5} \theta_{2,j} \Delta i_{t-j} + \sum_{j=0}^{I6} \pi_{2,j} \Delta ipi_{t-j} + \sum_{j=0}^{I7} \rho_{2,j} \Delta m2_{t-j} \\ &+ \lambda_1 sp_{t-1} + \lambda_2^{+} neer_{t-1}^{+} + \lambda_2^{-} neer_{t-1}^{-} + \lambda_3^{+} comm_{t-1}^{+} + \lambda_3^{-} comm_{t-1}^{-} \\ &+ \lambda_4 fr_{t-1} + \lambda_5 i_{t-1} + \lambda_6 ipi_{t-1} + \lambda_7 m2_{t-1} + \mu_t\end{aligned} \tag{8}$$

Table 1 ADF unit root and pp stationarity tests

Variables	Levels		First-order difference	
	ADF	**PP**	**ADF**	**PP**
sp(sh)	− 4.408***	− 3.332**	− 9.386***	− 9.842***
sp(sz)	− 2.503	− 2.683*	− 9.871***	− 10.105***
neer	1.304	1.383	− 10.109***	− 10.166***
m2	− 2.664*	− 4.649***	− 3.109	− 16.132***
ipi	− 0.775	− 0.774	− 4.361***	− 4.361***
i	− 5.076***	− 4.101***	− 12.805***	− 24.365***
fr	− 3.705***	− 2.516	− 4.508***	− 10.974***
comm	− 1.650	0.838	− 2.570**	− 2.570**

(1) The test equation includes both trend and intercept, and the optimal lags are determined using the Schwarz information criterion. The maximum lags are 8. (2) The p-values of the ADF and PP tests adopt MacKinnon's (1996) one-sided p-values. (3) ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. (3) The null hypothesis of both the ADF and PP tests are that the series have a unit root. If the null hypothesis is rejected, we can conclude that the series is stationary

Similarly, we can obtain only the short-run asymmetric NARDL model (Eq. (9)) or only the long-run asymmetric NARDL model (Eq. (10)), concerning global commodity prices, using the short-run (long-run) asymmetric Wald test, as above.[3]

$$\begin{aligned}\Delta sp_t =& \alpha + \sum\nolimits_{j=1}^{I1} \beta_{2,j} \Delta sp_{t-j} + \sum\nolimits_{j=0}^{I2} \delta_{2,j}^{+} \Delta neer_{t-j}^{+} + \sum\nolimits_{j=0}^{I2} \delta_{2,j}^{-} \Delta neer_{t-j}^{-} \\ &+ \sum\nolimits_{j=0}^{I3} \tau_{2,j}^{+} \Delta comm_{t-j}^{+} + \sum\nolimits_{j=0}^{I3} \tau_{2,j}^{-} \Delta comm_{t-j}^{-} + \sum\nolimits_{j=0}^{I4} \varphi_{2,j} \Delta fr_{t-j} \\ &+ \sum\nolimits_{j=0}^{I5} \theta_{2,j} \Delta i_{t-j} + \sum\nolimits_{j=0}^{I6} \pi_{2,j} \Delta ipi_{t-j} + \sum\nolimits_{j=0}^{I7} \rho_{2,j} \Delta m2_{t-j} + \lambda_1 sp_{t-1} \\ &+ \lambda_2^{+} neer_{t-1}^{+} + \lambda_2^{-} neer_{t-1}^{-} + \lambda_3 comm_{t-1} + \lambda_4 fr_{t-1} \\ &+ \lambda_5 i_{t-1} + \lambda_6 ipi_{t-1} + \lambda_7 m2_{t-1} + \mu_t\end{aligned} \tag{9}$$

$$\begin{aligned}\Delta sp_t =& \alpha + \sum\nolimits_{j=1}^{I1} \beta_{2,j} \Delta sp_{t-j} + \sum\nolimits_{j=0}^{I2} \delta_{2,j}^{+} \Delta neer_{t-j}^{+} + \sum\nolimits_{j=0}^{I2} \delta_{2,j}^{-} \Delta neer_{t-j}^{-} \\ &+ \sum\nolimits_{j=0}^{I3} \tau_{2,j} \Delta comm_{t-j} + \sum\nolimits_{j=0}^{I4} \varphi_{2,j} \Delta fr_{t-j} + \sum\nolimits_{j=0}^{I5} \theta_{2,j} \Delta i_{t-j} \\ &+ \sum\nolimits_{j=0}^{I6} \pi_{2,j} \Delta ipi_{t-j} + \sum\nolimits_{j=0}^{I7} \rho_{2,j} \Delta m2_{t-j} + \lambda_1 sp_{t-1} + \lambda_2^{+} neer_{t-1}^{+} \\ &+ \lambda_2^{-} neer_{t-1}^{-} + \lambda_3^{+} comm_{t-1}^{+} + \lambda_3^{-} comm_{t-1}^{-} + \lambda_4 fr_{t-1} + \lambda_5 i_{t-1} \\ &+ \lambda_6 ipi_{t-1} + \lambda_7 m2_{t-1} + \mu_t\end{aligned} \tag{10}$$

Data and empirical results

Data description

In our empirical analysis, we use monthly data from July 2005 to December 2020 of China. Because China began to adopt a managed floating exchange rate regime since July 2005, and the RMB exchange rate fluctuations became more resilient, December

[3] In our empirical analysis, we consider a combination of long-run (short-run) asymmetric effects of global commodity prices and long-run (short-run) asymmetric effects of the RMB exchange rates on China's stock prices. Lastly, we use the Wald test to select the final optimal model.

Table 2 Symmetric and asymmetric estimation results for exchange rates pass through to stock prices

Exchange rate → Shanghai Composite Index				**Exchange rate → Shenzhen Composite Index**			
Symmetric ARDL		**NARDL**		**Symmetric ARDL**		**NARDL**	
sp_{t-1}	− 0.065*** (0.018)	sp_{t-1}	− 0.076*** (0.018)	sp_{t-1}	− 0.068*** (0.019)	sp_{t-1}	− 0.072*** (0.020)
$reer_{t-1}$	0.021 (0.119)	$reer_{t-1}$	0.120 (0.113)	$reer_{t-1}$	0.154 (0.154)	$reer_{t-1}$	0.168 (0.156)
fr_{t-1}	− 0.028 (0.023)	fr_{t-1}	− 0.033 (0.024)	fr_{t-1}	− 0.016 (0.028)	fr_{t-1}	− 0.020 (0.029)
i_{t-1}	0.002 (0.007)	i_{t-1}	− 0.0002 (0.007)	i_{t-1}	− 0.006 (0.009)	i_{t-1}	− 0.007 (0.009)
ipi_{t-1}	0.015 (0.067)	ipi_{t-1}	− 0.006 (0.068)	ipi_{t-1}	0.036 (0.080)	ipi_{t-1}	0.027 (0.082)
$m2_{t-1}$	− 0.007 (0.045)	$m2_{t-1}$	0.006 (0.046)	$m2_{t-1}$	− 0.001 (0.055)	$m2_{t-1}$	0.006 (0.056)
Δsp_{t-1}	0.322*** (0.066)	Δsp_{t-1}	0.309*** (0.067)	Δsp_{t-1}	0.272*** (0.069)	Δsp_{t-1}	0.268** (0.069)
Δsp_{t-4}	0.291*** (0.067)	Δsp_{t-4}	0.293*** (0.068)	Δsp_{t-4}	0.225*** (0.068)	Δsp_{t-4}	0.232** (0.069)
Δfr_{t-3}	− 0.725** (0.365)	Δi_{t-3}	0.005 (0.008)	Δfr_{t-1}	1.099** (0.441)	Δfr_{t-1}	1.084** (0.447)
Constant	0.536 (0.492)	Constant	0.617*** (0.143)	Δfr_{t-3}	− 0.932** (0.439)	Δfr_{t-3}	− 0.921** (0.441)
t_{BDM}	− 3.700	t_{BDM}	− 4.120*	Δi_t	− 0.024** (0.011)	Δi_t	− 0.023** (0.011)
$\mathrm{F}_{\mathrm{PSS}}$	3.770*	$\mathrm{F}_{\mathrm{PSS}}$	3.666*	Constant	− 0.302 (0.622)	Constant	0.482*** (0.123)
β_{neer}	0.317	β_{neer}	1.584	t_{BDM}	− 3.560	t_{BDM}	− 3.658
β_{fr}	− 0.436	β_{fr}	− 0.439	$\mathrm{F}_{\mathrm{PSS}}$	2.860	$\mathrm{F}_{\mathrm{PSS}}$	2.903
β_i	0.030	β_i	0.003	β_{neer}	2.269	β_{neer}	2.325
β_{ipi}	0.230	β_{ipi}	− 0.075	β_{fr}	− 0.233	β_{fr}	− 0.280
β_{m2}	− 0.100	β_{m2}	0.078	β_i	− 0.094	β_i	− 0.090
		$W_{LR,neer}$	–	β_{ipi}	0.529	β_{ipi}	0.374
		$W_{SR,neer}$	–	β_{m2}	− 0.014	β_{m2}	0.085
						$W_{LR,neer}$	–
						$W_{SR,neer}$	–
Diagnostic tests statistics							
R^2	0.293	R^2	0.282	R^2	0.282	R^2	0.277
Adj-R^2	0.255	Adj-R^2	0.244	Adj-R^2	0.236	Adj-R^2	0.238
χ^2_{norm}	7.61** [0.022]	χ^2_{norm}	8.14** [0.017]	χ^2_{norm}	19.33*** [0.0001]	χ^2_{norm}	2.07 [0.356]
χ^2_{SC}	11.958* [0.063]	χ^2_{SC}	11.949* [0.063]	χ^2_{SC}	8.396 [0.211]	χ^2_{SC}	8.946 [0.177]
χ^2_{HET}	7.38*** [0.007]	χ^2_{HET}	0.55 [0.457]	χ^2_{HET}	6.54** [0.011]	χ^2_{HET}	0.000 [0.992]
χ^2_{Ramsey}	0.60 [0.619]	χ^2_{Ramsey}	0.73 [0.533]	χ^2_{Ramsey}	1.99 [0.117]	χ^2_{Ramsey}	1.22 [0.306]
Cusum	Unstable	Cusum	stable	Cusum	Unstable	Cusum	stable

(1)***, ** and * denote significance at the 1%, 5%, and 10% levels, respectively; (2) maximum lag lengths of n_k and l_k are 6, and the general-to-specific approach is used to decide the final specifications by dropping all insignificant variables; (3) β_{neer} indicates the symmetric long-run coefficient of the nominal effective exchange rates to the stock prices; (5)$\mathrm{F}_{\mathrm{PSS}}$ indicates the Paseran-Shin-Smith F test statistic (2001), and following Shin et al. (2014), conservative critical values are adopted, k = 5, and the upper bound test statistics at 10%, 5%, and 1% are 3.35, 3.79, and 4.68, respectively; the upper bound t_{BDM} test statistics at 10%, 5% and 1% are − 3.86, − 4.19 and − 4.79, respectively; (6) χ^2_{norm}, χ^2_{sc}, χ^2_{HET} and χ^2_{Ramsey} denote the test of Normality, the Breusch-Godfrey LM test for serial autocorrelation, the Breusch-Pagan test for heteroskedasticity, and the Ramsey RESET test, respectively; (7)W_{LR} refers to the Wald test for long-run symmetry, the relevant joint null hypothesis is $-\lambda_2^+/\lambda_1 = -\lambda_2^-/\lambda_1$, while W_{SR} refers to the Wald test of short-run symmetry, and the relevant joint null hypothesis is $\sum_{j=0}^{n2}\delta_{1,j}^+ = \sum_{j=0}^{n2}\delta_{1,j}^-$; (8) standard error and p-values are displayed in parentheses and brackets, respectively (9) Cusum denotes the CUSUM test for the stability of parameters

2020 is the latest data available for some variables in the study. The nominal effective exchange rates (*neer*) are obtained from the bank for international settlements. An increase (decrease) in the index indicates an appreciation (depreciation) of the RMB nominal effective exchange rate. The industrial production index (*ipi*) is provided by Bureau van Dijk-Economist Intelligence Unit country data, while the interest rate (i) is the weighted average interbank overnight interest rate obtained from the China Economy Information NET Statistics Database. The foreign exchange reserve (*fr*) and broad money supply (*m*2) are also obtained from the China Economy Information NET Statistics Database. Global commodity prices (*comm*) are obtained from the Global Financial Statistics of the International Monetary Fund database, which are prices of a basket of commodities such as energy, foods, and metal. Currently, China has two stock exchange centers, the Shanghai Stock Exchange and the Shenzhen Stock Exchange. The Shanghai Stock Exchange is the exchange market primarily for large listed companies, while the Shenzhen Stock Exchange includes mostly small- and medium-sized listed companies. Thus, it is necessary to use both the Shanghai Composite Index and the Shenzhen Composite Index to represent China's stock prices. Furthermore, both indexes are obtained from the Wind Database. All the above data have been converted into logarithmic form, except interest rate.

To avoid the spurious regression problem, we adopted the augmented Dickey-Fuller (ADF) test and the Philips-Perron (PP) test to investigate the integration of the variables before the regression. As shown in Table 1, the series are either I(0) or I(1), which conform to the stationarity requirements of the ARDL and NARDL models (Shin et al. 2014).[4] Following Pesaran et al. (2001) and Shin et al. (2014), we can use all variables in level for regressions in the ARDL or NARDL models.

Empirical results

The impact of the RMB exchange rate on China's stock prices

Our empirical analysis is divided into two parts. First, we examine the symmetric effects of the RMB exchange rate on China's stock prices, as expressed in Eq. (3), using the ARDL model. We also analyze the asymmetric impact of the RMB exchange rate on China's stock prices, as described in Eqs. (5), (6), or (7), using the NARDL model, as determined by the aforementioned Wald test. Table 2 shows the symmetric and asymmetric effects of the RMB exchange rate on the Shanghai Composite Index (left side of Table 2) and the symmetric and asymmetric impact of the RMB exchange rate on the Shenzhen Composite Index (right side of Table 2).

On the left side of Table 2, it can be seen that, whether in the ARDL or NARDL model, both F_{PSS} and t_{BDM} tests are unable to reject the null hypothesis of no cointegration relationship at a 5% significance level. Moreover, the long-run coefficient of the exchange rate β_{neer} is not significant at the 10% significance level either. The results indicate no long-run cointegration relationship between the RMB exchange rate and the Shanghai Composite Index. The impact of the RMB exchange rate on China's stock prices is also not significant. To ensure the robustness of the estimation results, we further examine

[4] According to Pesaran et al. (2001) and Shin et al. (2014), when all underlying variables are I (0) or I (1), the level variables are used for the regression in ARDL and NARDL.

Table 3 Symmetric and asymmetric estimation results for exchange rates and commodities prices pass through to stock prices

Exchange rate → Shanghai Composite Index				**Exchange rate → Shenzhen Composite Index**			
Symmetric ARDL		**NARDL**		**Symmetric ARDL**		**NARDL**	
sp_{t-1}	− 0.062*** (0.017)	sp_{t-1}	− 0.085*** (0.017)	sp_{t-1}	− 0.073*** (0.020)	sp_{t-1}	− 0.107*** (0.019)
$neer_{t-1}$	− 0.193 (0.159)	$neer_{t-1}$	− 0.661*** (0.180)	$neer_{t-1}$	− 0.112 (0.189)	$neer_{t-1}$	− 0.547*** (0.205)
$comm_{t-1}$	− 0.170*** (0.051)	$comm^{+}_{t-1}$	− 0.288*** (0.063)	$comm_{t-1}$	− 0.198*** (0.064)	$comm^{+}_{t-1}$	− 0.403*** (0.074)
fr_{t-1}	0.074* (0.039)	$comm^{-}_{t-1}$	− 0.154*** (0.056)	fr_{t-1}	0.095** (0.049)	$comm^{-}_{t-1}$	− 0.232*** (0.069)
i_{t-1}	0.014* (0.007)	fr_{t-1}	0.104*** (0.039)	i_{t-1}	0.016* (0.008)	fr_{t-1}	0.190*** (0.048)
ipi_{t-1}	0.029 (0.066)	i_{t-1}	0.010 (0.007)	ipi_{t-1}	0.052 (0.075)	i_{t-1}	0.001 (0.010)
$m2_{t-1}$	− 0.022 (0.046)	ipi_{t-1}	− 0.067 (0.067)	$m2_{t-1}$	− 0.022 (0.052)	ipi_{t-1}	− 0.006 (0.075)
Δsp_{t-1}	0.235*** (0.065)	$m2_{t-1}$	0.268** (0.114)	Δsp_{t-4}	0.201*** (0.063)	$m2_{t-1}$	0.299** (0.128)
$\Delta comm_{t-3}$	− 0.310*** (0.102)	Δsp_{t-4}	0.318*** (0.064)	$\Delta neer_{t-4}$	− 1.156** (0.451)	Δsp_{t-4}	0.205*** (0.063)
Δfr_{t}	− 0.799** (0.337)	$\Delta neer^{+}_{t-5}$	1.588** (0.619)	$comm_{t-3}$	− 0.289** (0.127)	$\Delta neer^{-}_{t-1}$	2.025*** (0.748)
Δfr_{t-1}	1.003*** (0.350)	$\Delta neer^{-}_{t-1}$	1.689*** (0.637)	$\Delta comm_{t-4}$	− 0.543*** (0.125)	$\Delta neer^{-}_{t-3}$	1.499** (0.706)
Constant	1.730** (0.777)	$\Delta comm^{+}_{t-1}$	0.444*** (0.138)	Δfr_{t-1}	1.570*** (0.390)	$\Delta comm^{-}_{t-1}$	0.405** (0.166)
		$\Delta comm^{+}_{t-3}$	− 0.295* (0.159)	Δfr_{t-2}	0.990** (0.403)	$\Delta comm^{-}_{t-3}$	− 0.372** (0.185)
		$\Delta comm^{-}_{t-4}$	− 0.417*** (0.159)	Constant	1.290 (0.899)	$\Delta comm^{-}_{t-4}$	− 0.599*** (0.181)
		Constant	0.695*** (0.137)			Δfr_{t-1}	1.319*** (0.407)
t_{BDM}	− 3.590	t_{BDM}	− 4.869**			Δfr_{t-2}	1.162*** (0.401)
F_{PSS}	3.640**	F_{PSS}	5.891***			Δi_{t}	− 0.021** (0.010)
β_{neer}	− 3.108	β_{neer}	− 7.772***			Constant	0.653*** (0.124)
β_{comm}	− 2.742***	$\beta_{comm^{+}}$	− 3.386***	t_{BDM}	− 3.750	t_{BDM}	− 5.528***
β_{fr}	1.198**	$\beta_{comm^{-}}$	− 1.815***	F_{PSS}	3.270*	F_{PSS}	6.437***
β_{i}	0.225*	$W_{LR,neer}$	–	β_{neer}	− 1.526	β_{neer}	− 5.104***
β_{ipi}	0.467	$W_{SR,neer}$	0.017	β_{comm}	− 2.697***	$\beta_{comm^{+}}$	− 3.755***
β_{m2}	− 0.350	$W_{LR,comm}$	4.18**	β_{fr}	1.290**	$\beta_{comm^{-}}$	− 2.168***
		$W_{SR,comm}$	1.235	β_{i}	0.218*	$W_{LR,neer}$	–
		β_{fr}	1.227***	β_{ipi}	0.710	$W_{SR,neer}$	10.43***
		β_{i}	0.122	β_{m2}	− 0.306	$W_{LR,comm}$	5.354**
		β_{ipi}	− 0.793			$W_{SR,comm}$	3.932**
		β_{m2}	3.148**			β_{fr}	1.768***
						β_{i}	0.011
						β_{ipi}	− 0.060
						β_{m2}	2.790**
Diagnostic tests statistics							
R^2	0.358	R^2	0.435	R^2	0.427	R^2	0.487
Adj-R^2	0.316	Adj-R^2	0.387	Adj-R^2	0.383	Adj-R^2	0.432

Table 3 (continued)

Exchange rate → Shanghai Composite Index				**Exchange rate → Shenzhen Composite Index**			
Symmetric ARDL		**NARDL**		**Symmetric ARDL**		**NARDL**	
χ^2_{norm}	2.77 [0.250]	χ^2_{norm}	6.07** [0.048]	χ^2_{norm}	9.75** [0.008]	χ^2_{norm}	2.86 [0.239]
χ^2_{sc}	4.011 [0.675]	χ^2_{sc}	11.326* [0.079]	χ^2_{sc}	7.222 [0.301]	χ^2_{sc}	10.259 [0.114]
χ^2_{HET}	0.02 [0.877]	χ^2_{HET}	2.37 [0.124]	χ^2_{HET}	1.35 [0.245]	χ^2_{HET}	0.000 [0.955]
χ^2_{Ramsey}	0.50 [0.684]	χ^2_{Ramsey}	0.98 [0.403]	χ^2_{Ramsey}	2.43* [0.067]	χ^2_{Ramsey}	0.76 [0.517]
Cusum	stable	Cusum	Stable	Cusum	Stable	Cusum	Stable

Notes: (1)***, ** and * denote significance at the 1%, 5%, and 10% levels, respectively; (2) maximum lag lengths of n_k and l_k are 6, and the general-to-specific approach is used to decide the final specifications by dropping all insignificant variables; (3) β_{neer} and β_{comm} indicate the symmetric long-run coefficients of the exchangerates and global commodity prices on China's stock prices; β_{comm+} and β_{comm-} refer to the rising and falling long-run coefficients of global commodity prices on China's stock prices; (5)F_{PSS} indicates the Paseran-Shin-Smith F test statistic (2001), and following Shin et al. (2014), the conservative of critical values is adopted, k = 6, and the upper bound test statistics at 10%, 5% and 1% are 3.23, 3.61 and 4.43, respectively; the upper bound of t_{BDM} test statistics at 10%, 5%, and 1% are − 4.04, − 4.38 and− 4.99, respectively; (6)χ^2_{norm}, χ^2_{sc}, χ^2_{HET}, and χ^2_{Ramsey} denote the test of Normality, the Breusch-Godfrey LM test for serial autocorrelation, the Breusch-Pagan test for heteroskedasticity, and the Ramsey RESET test, respectively; (7)W_{LR} refers to the Wald test for long-run symmetry, the relevant joint null hypotheses are $-\lambda_2^+/\lambda_1 = -\lambda_2^-/\lambda_1$ and $-\lambda_3^+/\lambda_1 = -\lambda_3^-/\lambda_1$ respectively, while W_{SR} refers to the Wald test of short-run symmetry and the relevant joint null hypotheses are $\sum_{j=0}^{l2}\delta_{2,j}^+ = \sum_{j=0}^{l2}\delta_{2,j}^-$ and $\sum_{j=0}^{l2}\tau_{2,j}^+ = \sum_{j=0}^{l2}\tau_{2,j}^-$ respectively; (8) standard error and p-values are displayed in parentheses and brackets, respectively; (9) Cusum denotes the CUSUM and CUSUM squared test for stability of parameters

the symmetric and asymmetric effects of the RMB exchange rate on the Shenzhen Composite Index. Consistent with the above results, in both the ARDL and NARDL models, no long-run cointegration relationship is confirmed between the RMB exchange rate and China's stock prices. Hence, China's stock prices are not sensitive to fluctuations in the RMB exchange rate.

The impact of the RMB exchange rate and global commodity prices on China's stock prices

As discussed, global commodity prices can ultimately impact the stock market by affecting the listed enterprise input costs and profits and changing investor expectations for stock prices. China is a major importer of commodities. With the deepening of the exchange rate system reforms and the expansion of the RMB exchange rate's floating range, China's stock market may be more vulnerable to fluctuations in global commodity prices. Therefore, one plausible explanation for the unidentified relationship between the RMB exchange rate and China's stock prices is the omission of the critical global commodity prices variable. To verify our conjecture, we introduce global commodity prices into the ARDL, as expressed in Eq. (4), and obtain the NARDL model. This is done to further detect the symmetric and asymmetric influences of the RMB exchange rate and global commodity prices on China's stock prices. Applying the short- and long-run Wald test for symmetry, the ultimate models are shown in Table 3.

In the ARDL model, the t_{BDM} test is not statistically significant at the 5% level, which confirms that no cointegration exists among the RMB exchange rate, global commodity prices, and the Shanghai Composite Index.[5] In other words, if asymmetry is not considered, there would seemingly be no long-run cointegration relationship among the RMB exchange rate, global commodity prices, and the Shanghai Composite Index, as before. Moreover, the influence coefficient of the RMB exchange rate on stock prices is similarly not significant at 5%.

On the other hand, when we verify the asymmetric relationship among the RMB exchange rate, global commodity prices, and China's stock prices with the NARDL model, both the F_{pss} and t_{BDM} tests are statistically significant at the 5% level. This statistic confirms a long-run cointegration relationship among the RMB exchange rate, global commodity prices, and the Shanghai Composite Index. Moreover, the long-run coefficients β_{neer}, β_{comm^+}, and β_{comm^-} are all statistically significant at the 1% level. This denotes that China's stock prices respond considerably to changes in the RMB exchange rate and respond to the rise and fall of global commodity prices with varying degrees. On the left of Table 3, we can see a negative correlation between the RMB exchange rate and the Shanghai Composite Index. According to the Wald test, there is no asymmetric effect of the RMB's effective exchange rate on the Shanghai Composite Index both in the long and short run.

Nevertheless, there is an asymmetric impact of global commodity prices on the Shanghai Composite Index in the long run, and the $W_{LR,comm}$ is statistically significant at the 5% level. This demonstrates that the asymmetric impact of global commodity prices on the Shanghai Composite Index is remarkable in the long run. Specifically, the positive (β_{comm^+}) and negative (β_{comm^-}) long-run impact coefficients of global commodity prices on China's stock prices are -3.386 and -1.815, respectively, and both are statistically significant at the 1% level. The absolute value of the negative long-run impact coefficient of global commodity prices is much smaller than the positive one, indicating that China's stock prices are more sensitive to positive changes than negative movements in global commodity prices. In other words, the decline in China's stock prices caused by the rise in global commodity prices is greater than the increase in China's stock prices caused by the decline in global commodity prices.

Moreover, when the critical variable of global commodity prices is added in the NARDL model, the adjusted R-square of the model is bigger than other models, which indicates that the model's explanatory power is enhanced. When considering global commodity prices in the NARDL model, the regression results perform better based on the cointegrations, significances of coefficients, and adjusted R-square, when comparing the outcomes in Table 3 with Table 2.

In diagnostic test statistics, the Breusch-Godfrey LM test (χ^2_{sc}) and the Breusch-Pagan test (χ^2_{HET}) show no serial autocorrelation and heteroskedasticity in the

[5] Following the strict standards of most studies, only when both F_{PSS} and t_{BDM} reject the null hypothesis of no cointegration relationship can we confirm that there is an obvious cointegration relationship among the underlying variables. In the cointegration tests of the ARDL model (left of Table 3), only the F_{PSS} statistic is significant at the 5% level, while cointegration of the t_{BDM} test is not statistically significant at the 5% level. Thus, we conclude that there is no obvious cointegration relationship among these variables.

residual. The CUSUM test (Cusum) and the Ramsey RESET test (χ^2_{Ramsey}) indicate that the estimated parameters are stable, and the NARDL model set is appropriate.

Considering the actual state of China's stock markets, and to ensure the robustness and effectiveness of the empirical results, the Shenzhen Composite Index is used as a proxy for China's stock prices too. We revisit the empirical study above, and the results are shown on the right side of Table 3. It can be seen that the results are consistent with the conclusions from the left side of Table 3, where the Shanghai Composite Index is chosen as the proxy for China's stock prices, indicating that our outcomes and conclusions are robust.

Specifically, in the symmetric ARDL model, the F_{pss} and t_{BDM} tests are not statistically significant at the 5% level. Thus, if asymmetry is not considered, it also shows no long-run cointegration relationship among the RMB exchange rate, global commodity prices, and the Shenzhen Composite Index.

However, if we adopt the NARDL model to investigate the effects of the RMB exchange rate and global commodity prices on the Shenzhen Composite Index, then both the F_{pss} and t_{BDM} tests are statistically significant at the 1% level. The long-run cointegration relations among these underlying variables are substantial, which further indicates that it is necessary to consider the asymmetric effects of exchange rates and global commodity prices on stock prices in China.

In the NARDL model, the long-run influence coefficient of the RMB exchange rate on the Shenzhen Composite Index (β_{neer}) is -5.104; this result indicates that a rise (decrease) in the RMB exchange rate causes the Shenzhen Composite Index to decline (increase). The Wald test demonstrates no asymmetric effect of the RMB exchange rate on the Shenzhen Composite Index in the long run. Nevertheless, the impact of global commodity prices on the Shenzhen Composite Index is significant and asymmetric in the long run because the $W_{LR,comm}$ test is statistically significant at the 5% level. Moreover, the positive (β_{comm^+}) and negative (β_{comm^-}) long-run coefficients of global commodity prices on the Shenzhen Composite Index are -3.755 and -2.168, respectively, both at a statistically significant level of 1%. This indicates that changes in global commodity prices have an asymmetric impact on the Shenzhen Composite Index as well. Additionally, the rise effect on the Shenzhen Composite Index, induced by the decrease in global commodity prices, is much smaller than the decline effect caused by the increase in global commodity prices. Moreover, the results of the diagnostic test statistics indicate that there are no serial autocorrelation and heteroskedasticity in the residual, that parameters estimated are stable, and that the model set is appropriate.

In general, our empirical results show that there is a long-run cointegration relationship between the RMB exchange rate and China's stock prices when global commodity prices are taken into consideration in the NARDL model, and that the RMB exchange rate has a negative effect on China's stock prices. When the RMB appreciates, China's stock prices will decline; otherwise, China's stock prices will increase. As a large emerging economy, China has insisted on its export-oriented development strategy for decades. Thus, a significant number of products exported by enterprises have become fundamental to rapid economic growth. If the RMB appreciates, the products of Chinese exporters priced in foreign currencies will become more expensive, thus weakening the global competitiveness of Chinese exports and inhibiting exports. Such a situation would

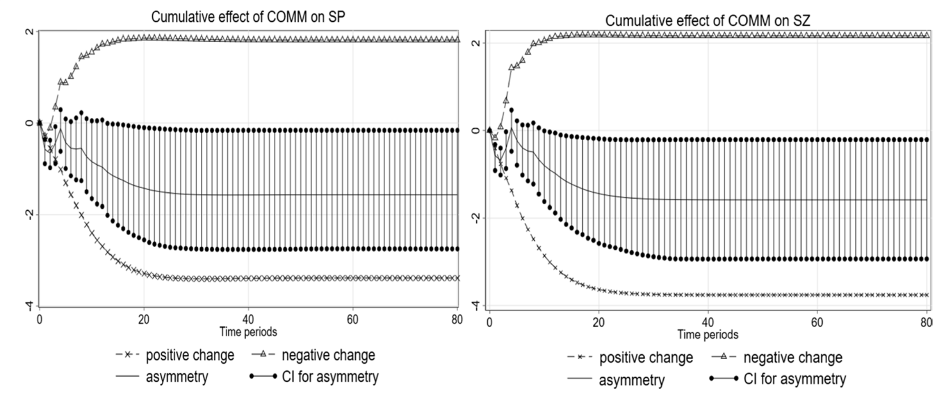

Fig.1 Dynamic multipliers of commodity prices on the Shanghai and Shenzhen Composite Indexes

lead to a decline in earnings and potential earnings of listed companies, ultimately lowering stock prices. Conversely, if the RMB depreciates, Chinese products denominated in foreign currencies will become less expensive, stimulating exports, thereby increasing enterprise earnings. When high earnings result in an increase in projected earnings, stock prices rise. Therefore, the RMB exchange rate is negatively correlated with China's stock prices.

In studying the impact of global commodity prices on stocks, we find an asymmetric relationship. China's stock prices are more sensitive to an increase in global commodity prices than a decrease. The global commodity market has long been monopolized by a small number of oligarchic companies. Simultaneously, China's industry concentration ratio is low compared with other developed economies, so it is difficult for Chinese companies to form price alliances and gain strong bargaining power in the face of commodity oligarchs. Thus, given the low concentration of industry and the dispersion of corporate power, when global commodity prices rise, oligarchs tend to raise their commodity prices sharply. Simultaneously, domestic commodity prices also significantly increase. Moreover, there is excessive competition in China's downstream product market due to an overcapacity problem. To maintain a competitive price advantage and stabilize the market share of products, downstream manufacturers or companies can only slightly raise the selling prices of their products and have to passively accept rising commodity prices. In this case, rising global commodity prices will considerably increase company production costs and drastically reduce their profitability, eventually causing stock prices to fall sharply in anticipation of reduced profitability. However, when global commodity prices fall, relying on their monopoly power in the domestic market, commodity suppliers in the Chinese market maintain relatively high domestic commodity prices. Hence, the production costs of Chinese companies only slightly decline, and in turn, their profits only slightly rise, eventually causing stock prices to increase marginally. Thus, the increase in global commodity prices drive China's stock prices to decline sharply; however, the same magnitude of decline in global commodity prices induces a smaller rise in China's stock prices.

Since the NARDL model confirms the asymmetric cointegration relationship, and the effect of global commodity prices on China's stock prices is asymmetric in the long run, we can draw the asymmetric dynamic trajectories of stock prices by unit increase and falling global commodity prices using asymmetric cumulative dynamic multipliers. The asymmetric cumulative dynamic multipliers of global commodity prices to China's stock prices can be represented as follows:

$$m^{+}_{comm,h} = \sum_{j=0}^{h} \frac{\partial sp_{t+j}}{\partial comm^{+}_{t}}, \quad \text{and} \quad \mathrm{m}^{-}_{\mathrm{comm,h}} = \sum_{\mathrm{j}=0}^{\mathrm{h}} \frac{\partial \mathrm{sp}_{\mathrm{t+j}}}{\partial \mathrm{comm}^{-}_{\mathrm{t}}}. \quad \mathrm{h} = 0, 1, 2 \ldots, \tag{11}$$

when $h \to \infty$, then $m^{+}_{comm,h} \to \beta_{comm^{+}}$ and $m^{-}_{comm,h} \to \beta_{comm^{-}}$, where $\beta_{comm^{+}} = -\lambda_3^{+}/\lambda_1$ and $\beta_{comm^{-}} = -\lambda_3^{-}/\lambda_1$ are the positive and negative asymmetric long-run coefficients of global commodity prices to China's stock prices, respectively.

Figure 1 shows the asymmetric trajectories of the Shanghai and Shenzhen Composite Indexes after the rise and fall of unit global commodity prices. Specifically, both indexes are more sensitive to increases than decreases in global commodity prices. Furthermore, the increase in global commodity prices causes China's stock prices to decline sharply, while the same magnitude of decline in global commodity prices induces a smaller increase in China's stock prices. The asymmetric dynamic multiplier results further support our previous findings that the impact of commodity prices on stock prices is indeed asymmetric in the long run.

Conclusion

This study investigates both the symmetric and asymmetric impact of the RMB exchange rate on China's stock prices using the ARDL and NARDL models. However, all the results indicate that there is no cointegration relationship when the key variable—global commodity prices—is absent. After the inclusion of global commodity prices, the empirical results reveal a long-run cointegration relationship among the RMB exchange rate, global commodity prices, and China's stock prices in the NARDL model. The changes in the RMB exchange rate have a negative effect on China's stock prices. As a large emerging economy, China has long insisted on an export-oriented economic development strategy. Thus, with the rapid expansion of the RMB exchange rate's floating range, fluctuations in the RMB exchange rate will eventually influence China's stock market by affecting the global competitiveness of the listed companies' exports.

We also find that the impact of global commodity prices on China's stock prices is asymmetric, and that China's stock prices are more sensitive to increases than to decreases in global commodity prices. In other words, the rise in global commodity prices causes China's stock prices to decline sharply, while the same magnitude of decline induces a smaller increase in stock prices. Chinese companies have lacked pricing power in global and domestic commodity markets for a long time; thus, Chinese companies are forced to bear high production costs when global commodity prices increase. This results in a sharp reduction in current and expected corporate profits and eventually a significant decline in China's stock prices. When global commodity prices fall, relying on monopoly and higher bargaining power, the commodity monopolists refuse to cut prices significantly. As a result, the production costs of downstream enterprises only decreases minimally, while China's stock prices only slightly rises.

Therefore, with the rapid expansion of the RMB exchange rate's floating range, the exchange rate exposure faced by the Chinese stock market and enterprises has expanded. The government must accelerate RMB globalization and improve its status in global trade. Considering the asymmetric impact of rising and falling global commodity prices on China's stock prices, authorities should adopt asymmetric and precise regulations to achieve the goal of stabilizing the stock market. Meanwhile, China should actively bid for overseas resources, break the monopoly pattern of the global commodity market, and strive for pricing power in global commodities. In addition, China is slated to accelerate improvement of the country's commodity futures markets and create conditions for Chinese companies to use hedging instruments, such as futures and options, to enhance their ability to resist risks and maintain financial stability.

Acknowledgements
We are thankful to anonymous reviewers for their constructive suggestions.

Authors' contributions
SBL was responsible for empirical analysis and the writing of Introduction and Literature Review and provided guidance on full manuscript writing, and was a major contributor in writing the manuscript. MXZ was responsible for the writing of Methods and Model and Data and Empirical Results. KABL was responsible for the writing of Concluding Remarks. SYW collected literature and relevant data. All authors read and approved the final manuscript.

Funding
This research was supported by the Fundamental Research Funds for the Central Universities (2019CDSKXYGG0042, 2018CDXYGG0054, 2020CDJSK01HQ01) and National Social Science Funds (16CJL007).

Availability of data and materials
The datasets used in the study is original and collected by the researchers through primary sources. And the datasets are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Center for Public Economy and Public Policy, Chongqing University, Chongqing, China. [2]Department of Public Economics, School of Public Affairs, Chongqing University, 174 Shazheng Street, Shapingba District, Chongqing 400044, China. [3]A Center for Chinese Economic Practice and Thinking, Tsinghua University, Room 128, Shunde Building, Haidian District, Beijing 100084, China. [4]School of Economics and Resource Management, Beijing Normal University, 19 xinjiekouwai street, Haidian District, Beijing 10084, China.

Received: 7 January 2021 Accepted: 8 June 2021
Published online: 18 June 2021

References
Aggarwal R (1981) Exchange rates and stock prices: a study of the US capital markets under floating exchange rates. Akron Bus Econ Rev 12:7–12
Akbar M, Iqbal F, Noor F (2019) Bayesian analysis of dynamic linkages among gold price, stock prices, exchange rate and interest rate in Pakistan. Resour Policy 62:154–164
Asimakopoulos I, Ayling D, Mahmood WM (2000) Non-linear Granger causality in the currency futures returns. Econ Lett 68(1):25–30
Aslam MT, Ramzan M (2013) Impact of consumer price index, real effective exchange rate index, per capita income and discount rate on Pakistan's stock market index. Int J Res Commerce Econ Manag 3(5):10–14
Bahmani-Oskooee M, Saha S (2015) On the relation between stock prices and exchange rates: a review article. J Econ Stud 42(4):707–732
Bahmani-Oskooee M, Saha S (2016) Do exchange rate changes have symmetric or asymmetric effects on stock prices? Glob Finance J 31:57–72
Bahmani-Oskooee M, Sohrabian A (1992) Stock prices and the effective exchange rate of the dollar. Appl Econ 24(4):459–464
Banerjee A, Dolado J, Mestre R (1998) Error-correction mechanism tests for cointegration in a single-equation framework. J Time Ser Anal 19(3):267–283
Bartram SM (2004) Linear and nonlinear foreign exchange rate exposures of German nonfinancial corporations. J Int Money Finance 23(4):673–699
Basher SA, Haug AA, Sadorsky P (2012) Oil prices, exchange rates and emerging stock markets. Energy Econ 34(1):227–240

Boonyanam N (2014) Relationship of stock prices and monetary variables of Asian small open emerging economy: evidence from Thailand. Int J Financ Res 5(1):52

Branson WH (1983) Macroeconomic determinants of real exchange rates. NBER Work Pap 26(3):20–21

Chaban M (2009) Commodity currencies and equity flows. J Int Money Finance 28(5):836–852

Chang BH (2020) Oil prices and E7 stock prices: an asymmetric evidence using multiple threshold nonlinear ARDL model. Environ Sci Pollut Res 27(35):44183–44194

Chkir I, Guesmi K, Brayek AB, Naoui K (2020) Modelling the nonlinear relationship between oil prices, stock markets, and exchange rates in oil-exporting and oil-importing countries. Res Int Bus Finance 54(12):1–13

Chortareas G, Cipollini A, Eissa MA (2011) Exchange rates and stock prices in the MENA countries: what role for oil? Rev Dev Econ 15(4):758–774

Ding L (2021) Conditional correlation between exchange rates and stock prices. Q Rev Econ Finance 80(5):452–463

Doong SC, Yang SY, Wang AT (2005) The dynamic relationship and pricing of stocks and exchange rates: empirical evidence from Asian emerging markets. J Am Acad Bus 7(1):118–123

Dornbusch R, Fischer S (1980) Exchange rates and the current account. Am Econ Rev 70(5):960–971

Effiong EL, Bassey GE (2019) Stock prices and exchange rate dynamics in Nigeria: an asymmetric perspective. J Int Trade Econ Dev 28(3):299–316

Enilov M, Fazio G, Ghoshray A (2021) Global connectivity between commodity prices and national stock markets: a time-varying MIDAS analysis. Int J Finance Econ 3:1–13

Frankel J A (1992) Monetary and portfolio balance models of exchange rate determination. International Economic Policies & Their Theoretical Foundations 793–832

Groenewold N, Paterson JE (2013) Stock prices and exchange rates in Australia: are commodity prices the missing link? Aust Econ Pap 52(3–4):159–170

Ibrahim MH, Aziz H (2003) Macroeconomic variables and the Malaysian equity market: a view through rolling subsamples. J Econ Stud 30(1):6–27

Inegbedion HE (2012) Macroeconomic determinants of stock price changes: empirical evidence from Nigeria. Indian J Finance 6(2):19–23

Ismail MT, Bin Isa Z (2009) Modeling the interactions of stock price and exchange rate in malaysia. Singapore Econ Rev 54(4):605–619

Jain A, Biswal PC (2016) Dynamic linkages among oil price, gold price, exchange rate, and stock market in India. Resour Policy 49:179–185

Jones DW, Leiby PN, Paik IK (2004) Oil price shocks and macroeconomy: what has been learned since 1996. Energy J 25:1–32

Katrakilidis C, Trachanas E (2012) What drives housing price dynamics in Greece: new evidence from asymmetric ARDL cointegration. Econ Model 29(4):1064–1069

Kim KH (2003) Dollar exchange rate and stock prices: evidence from multivariate cointegration and error correction model. Rev Financ Econ 12(3):301–313

Kollias C, Mylonidis N, Paleologou SM (2012) The nexus between exchange rates and stock markets: evidence from the euro-dollar rate and composite European stock indices using rolling analysis. J Econ Finance 36(1):136–147

Kou G, Chao X, Peng Y, Alsaadi FE, Herrera-Viedma E (2019) Machine learning methods for systemic risk analysis in financial sectors. Technol Econ Dev Econ 25(5):716–742

Kumar S (2019) Asymmetric impact of oil prices on exchange rate and stock prices. Q Rev Econ Finance 72:41–51

Kumar S, Kumar A, Singh G (2020) Causal relationship among international crude oil, gold, exchange rate, and stock market: fresh evidence from nardl testing approach. Int J Finance Econ 3:1–11

Lean HH, Halim M, Wong WK (2005) Bivariate causality between exchange rates and stock prices on major Asian countries. Monash economics working papers, Monash University, Department of Economics

Li Y, Huang L (2008) On the relationship between stock return and exchange rate: evidence on China. In: Chinese Economic Association (UK/Europe) conference papers

Liang CC, Lin JB, Hsu HC (2013) Reexamining the relationships between stock prices and exchange rates in ASEAN-5 using panel Granger causality approach. Econ Model 32:560–563

Lin JB, Fu SH (2016) Investigating the dynamic relationships between equity markets and currency markets. J Bus Res 69(6):2193–2198

Long SB, Liang J (2018) Asymmetric and nonlinear pass-through of global crude oil price to China's ppi and cpi inflation. Econ Res 31(1):240–251

Maysami RC, Koh TS (2000) A vector error correction model of the Singapore stock market. Int Rev Econ Financ 9(1):79–96

Meyer J, De Cramon-Tauba LS (2010) Asymmetric price transmission: a survey. J Agric Econ 55(3):581–611

Miller KD, Reuer JJ (1998) Asymmetric corporate exposures to foreign exchange rate changes. Strateg Manag J 19(12):1183–1191

Moore T, Wang P (2014) Dynamic linkage between real exchange rates and stock prices: evidence from developed and emerging Asian markets. Int Rev Econ Finance 29:1–11

Nieh CC, Lee CF (2001) Dynamic relationship between stock prices and exchange rates for G-7 countries. Q Rev Econ Finance 41(4):477–490

Nieh CC, Yau HY (2010) The impact of renminbi appreciation on stock prices in China. Emerg Mark Finance Trade 46(1):16–26

Olayeni OR, Tiwari AK, Wohar ME (2020) Global economic activity, crude oil price and production, stock market behaviour and the Nigeria-US exchange rate. Energy Econ 92(10):1–13

Pesaran MH, Shin Y (1998) An autoregressive distributed-lag modelling approach to cointegration analysis. Econom Soc Monogr 31:371–413

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Econom 16(3):289–326

Phylaktis K, Ravazzolo F (2005) Stock prices and exchange rate dynamics. J Int Money Finance 24(7):1031–1053

Rahman ML, Uddin J (2009) Dynamic relationship between stock prices and exchange rates: evidence from three south Asian countries. Int Bus Res 2(2):167–174
Ram PS (2017) An empirical study on the interdependence among stock market, commodities market and foreign exchange market. IOSR J Econ Finance 08(4):1–7
Roubaud D, Arouri M (2018) Oil prices, exchange rates and stock markets under uncertainty and regime-switching. Financ Res Lett 27:28–33
Rutledge RW, Karim KE, Li C (2014) A study of the relationship between renminbi exchange rates and Chinese stock prices. Int Econ J 28(3):381–403
Salisu AA, Isah K, Ogbonnaya-Orji N (2020) A firm level analysis of asymmetric response of U.S. stock returns to exchange rate movements. Int J Finance Econ 3:1–20
Shahzad SJH, Nor SM, Ferrer R, Hammoudeh S (2017) Asymmetric determinants of CDS spreads: US industry-level evidence through the NARDL approach. Econ Model 60:211–230
Shin Y, Yu B, Greenwood-Nimmo M (2014) Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In: Festschrift in honor of Peter Schmidt. Springer, New York, pp 281–314
Singhal S, Choudhary S, Biswal PC (2019) Return and volatility linkages among International crude oil price, gold price, exchange rate and stock markets: evidence from Mexico. Resour Policy 60:255–261
Smyth R, Nandha M (2003) Bivariate causality between exchange rates and stock prices in south Asia. Appl Econ Lett 10(11):699–704
Soenen L, Hennigar E (1988) An analysis of exchange rates and stock prices—the US experience between 1980 and 1986. Akron Bus Econ Rev 19(4):7–16
Sui L, Sun L (2016) Spillover effects between exchange rates and stock prices: evidence from BRICS around the recent global financial crisis. Res Int Bus Finance 36:459–471
Tian GG, Ma S (2010) The relationship between stock returns and the foreign exchange rate: the ARDL approach. J Asia Pac Econ 15(4):490–508
Tian XL, Kou G, Zhang W (2020) Geographic distance, venture capital and technological performance: evidence from Chinese enterprises. Technol Forecast Soc Change 158(9):1–12
Tsai IC (2012) The relationship between stock price index and exchange rate in Asian markets: a quantile regression approach. J Int Financ Mark Inst Money 22(3):609–621
Wen F, Xu L, Ouyang G, Kou G (2019) Retail investor attention and stock price crash risk: evidence from China. Int Rev Financ Anal 65(10):1–15
Wickremasinghe G (2012) Stock prices and exchange rates in Sri Lanka: some empirical evidence. Innovations 9:4
Wong HT (2019) Volatility spillovers between real exchange rate returns and real stock price returns in Malaysia. Int J Finance Econ 24(1):131–149
Wongbangpo P, Sharma SC (2002) Stock market and macroeconomic fundamental dynamic interactions: ASEAN-5 countries. J Asian Econ 13(1):27–51
Wu Y (2000) Stock prices and exchange rates in VEC model—the case of Singapore in the 1990s. J Econ Finance 24(3):260–274
Yang SP (2017) Exchange rate dynamics and stock prices in small open economies: evidence from asia-pacific countries. Pac Basin Finance J 46:337–354
Yau HY, Nieh CC (2009) Testing for cointegration with threshold effect between stock prices and exchange rates in Japan and Taiwan. Jpn World Econ 21(3):292–300
Zhao H (2010) Dynamic relationship between exchange rate and stock price: evidence from China. Res Int Bus Finance 24(2):103–112

Publisher's Note