Economic Research-Ekonomska Istraživanja

ISSN: 1331-677X (Print) 1848-9664 (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

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To cite this article: Chi-Wei Su, Kai-Hua Wang, Ran Tao & Oana-Ramona Lobonț (2019) Does the covered interest rate parity fit for China?, Economic Research-Ekonomska Istraživanja, 32:1, 2009-2027, DOI: 10.1080/1331677X.2019.1642780

To link to this article: https://doi.org/10.1080/1331677X.2019.1642780

Published online: 06 Aug 2019.

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2019, VOL. 32, NO. 1, 2009–2027
https://doi.org/10.1080/1331677X.2019.1642780

Does the covered interest rate parity fit for China?

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ABSTRACT

This paper aims to investigate whether the covered interest rate parity (C.I.P.) holds or not through examining the dynamic link between nominal interest rate differential (N.I.R.D.) and nominal exchange rate (N.E.R.) in China. With economic transitions and structural changes existing, we find that the C.I.P. condition using full-sample data does not always hold. Consequently, we apply a time-varying rolling-window approach to revisiting the dynamic causal relationship, and the results show that N.I.R.D. has both positive and negative impacts on N.E.R. in several sub-periods, and in turn, N.E.R. has the same effects on N.I.R.D. for China. Exchange regime reform, currency-specific market risk and capital control are considered in explaining the deviations in some sub-sample periods. Therefore, empirical results have important implications for distinguishing factors that bring about the C.I.P. deviations and further offers policy suggestions for the Chinese monetary authority.

ARTICLE HISTORY
Received 8 November 2017
Accepted 15 February 2019

KEYWORDS
Interest rate differential; exchange rate; rolling window; bootstrap; time-varying causality

JEL CLASSIFICATIONS
C32; E4; F31

1. Introduction

The objective of this paper is to examine whether the covered interest rate parity (C.I.P.) condition fits for China. The C.I.P. is one of the fundamental tenets of international finance and indicates nominal exchange rate (N.E.R.) forward premiums or discounts offset the nominal interest rate differentials (N.I.R.D.) between two sovereigns (Dekle et al., 2002; Pinnington and Shamloo, 2016; Skinner and Mason, 2011). Therefore, the C.I.P. plays an important role in explaining the foreign exchange market efficiency. From the standpoint of the C.I.P., a long-run relationship between N.I.R.D. and N.E.R. represents a unity and N.I.R.D. across countries should be an unbiased predictor of N.E.R. However, N.E.R. always deviates from the C.I.P. (Yang, 2010). Cavoli (2009) indicates that emerging markets (e.g., China) have weaker macroeconomic fundamentals (e.g., more volatile economic conditions, shallow financial markets and incomplete institutional reforms), making them more vulnerable to

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exchange rate shocks. In China, with the deepening of internationalisation of Renminbi (R.M.B.) in a decade, the volatility of the R.M.B. exchange rate may severely affect the development of the economy. Fan and Xiang (2006) show that the fluctuation in the exchange rate has a significant influence on producer price and consumer price through import. Vieira et al. (2013) suggest that highly fluctuated exchange rates have negative impacts on economic growth. Su et al. (2016) evidence the impact of the exchange rate on inflation during the economic crisis. Therefore, People's Bank of China (P.B.O.C.) prefers discrete interest rate policy when decreasing the negative influence from deviations (Dhamotharan and Ismail, 2015). The C.I.P. condition between N.I.R.D. and N.E.R. forward premiums or discounts not only provides a basis for the evaluation of the effectiveness of interest rate policy, but also offers suggestions to promote N.E.R. mechanism reform.

Since 2005, China has experienced the following striking shocks both from inside and outside. The P.B.O.C. launched the reform of the R.M.B. exchange rate regime by switching from the dollar peg to a basket of currencies in 2005:M07. Meanwhile, the P.B.O.C. also allowed the bilateral exchange rates to float within a daily band from 0.3% to 2% through four times adjustments. Yu (2005) indicated the reform increased the flexibility of the R.M.B. exchange rate. The effects of the global financial crisis were widespread (Taylor, 2010), which certainly impacted the Chinese economy, affecting exports, N.E.R. and structural adjustments (Kayani et al., 2014). R.M.B. was included in Special Drawing Rights (S.D.R.) by the International Monetary Fund (I.M.F.) in 2016, denoting substantial progress in internationalisation and liberalisation of the R.M.B. (Xu et al., 2016). To maintain N.E.R. stability and continue the momentum of rapid development, the P.B.O.C. has implemented low interest rate policies. Consequently, there is imminent concern regarding how the interest rate policy would stabilise N.E.R. for China. According to Jin and Chen (2012), the C.I.P. focused on the idea that N.E.R. would fluctuate when facing a constant domestic–foreign N.I.R.D. If the C.I.P. fits for China, the higher domestic interest rate will result in R.M.B. exchange rate depreciation in the future. In response to this, we are greatly motivated to pursue an investigation related to the C.I.P. condition between N.I.R.D. and N.E.R. in China. Combining with corresponding results, we provide suggestions for reforming the N.E.R. mechanism and implementing interest rate policy.

This paper intends to be a valuable addition to the existing literature through taking into account the time variation in the C.I.P. condition between N.I.R.D. and N.E.R. Commonly, previous research has only investigated the causal link under the full sample, which is liable to produce inaccurate conclusions because the parameters may present instability when meeting structural changes. China has experienced obvious economic reconstruction and structural changes from 2005 to 2016 which have greatly influenced its economic fundamentals. Overholt (2010) indicates that prior to the global financial crisis of 2008, China underwent a paradoxical combination of rapidly rising inflation and spreading bankruptcies. Li (2012) shows that under the influence of the European debt crisis of 2011, terms of trade in China became better but asset prices and inflation increased modestly. Ho et al. (2014) argue there are obvious responses of Chinese N.E.R. and interest rate to U.S. shocks, such as quantitative easing policy in 2008, 2010 and 2012 separately. Qin et al. (2015) find the first R.M.B. regime reform, undertaken in 2005:M07, had a significant impact on the exchange market in the short term. All have led to structural changes in the domestic interest rate and N.E.R., which indicates that such dynamic linkage exists among the two series, and would clearly display instability varying across sub-samples. Therefore, the bootstrap Granger full-sample causality test and sub-sample rolling-window estimation are applied to revisit the C.I.P. condition between N.I.R.D. and N.E.R. The bootstrap rolling-window method is different from previous methods that cannot distinguish full-sample and sub-sample relationship changes over time. When meeting structural changes, the causal linkage between these two variables may be not accurate in previous studies (Balcilar and Ozdemir, 2013). This can be solved by assuming the causal link is time varying and the single causality holds in every sub-interval. The time-varying character may exist in the causal nexus, which has been taken into account in this paper. The test for causality on the full sample is under the assumption that the causal relationship is fixed. This approach tests for causality on the rolling sample, which captures structural changes in the model and the evolution of causality between sub-periods. The results show that there are bidirectional causal relationships between N.I.R.D. and N.E.R. with the sub-sample rolling-window estimation. N.I.R.D. has both positive and negative impact on N.E.R. in several sub-periods, and N.E.R. has same effects on N.I.R.D. When suffering external and internal shocks, the C.I.P. does not always hold. Therefore, it is critical for policymakers to pay attention to specific backgrounds (e.g., economic situation, monetary policies) and further make use of interest rate policy moderately, which reduces negative influence from N.E.R. on the Chinese economy.

The rest of this paper is organised as follows: Section 2 shows literature review. Section 3 presents covered interest rate parity. Section 4 provides the methodology. Section 5 describes the corresponding data. Section 6 presents the empirical results and policy implications, and Section 7 concludes.

2. Literature review

Substantial studies have been undertaken with a focus on the C.I.P. Models of foreign exchange rate behaviour often assume that C.I.P. supports as a valid approximation. Thus it is not surprising that a lot of studies have been devoted to examine the validation of this condition. Taylor (1987) uses high-frequency data to test the C.I.P. and finds it is effective. Byrne and Nagayasu (2010) indicate the sizeable forward premium is found to be offset by interest rate differentials, which means C.I.P. is valid. However, other studies have identified significant deviations from the C.I.P. and give the corresponding reasons. Frenkel and Levich (1977) observe deviations from the C.I.P. can occur without yielding any profit after netting out transactions costs. Atkins (1993) suggests that deviations from the C.I.P. in Euromarket are, in general, eliminated within two days, with this time decreasing as one moves from the 1970s to 1980s. Baba and Packer (2009) consider that the sharp and persistent deviations observed during financial turmoil are found to be significantly associated with differences in the counterparty risk. Fong et al. (2010) analyse the positive C.I.P. arbitrage deviations including a compensation for liquidity and credit risk. Skinner and Mason (2011) find that the C.I.P. holds for large and small triple A-rated economies, but it holds for emerging markets only for a three-month maturity, and credit risk is the source of violation. Du et al. (2016) show that the C.I.P. condition is violated among G10 currencies, which leads to significant arbitrage opportunities in currency and funding markets. Pinnington and Shamloo (2016) argue on how the reduced liquidity in the foreign exchange market can explain the sustained deviations from the C.I.P. Fukuda (2016) suggests the existence of a structural break in the determinants of the C.I.P. deviations between the global financial crisis and European debt crisis.

Because China's ever-growing economy under strictly managed exchange rate policies also shows an 'immunological strength' to contagion, the R.M.B. exchange regime and its timely reforms have attracted a great deal of attention from researchers, investors and the wider public (Qin et al., 2015). Yang (2010) indicates the C.I.P. does not hold in China with international capital and foreign exchange control. Fan and Zhou (2010) find international speculative capital chases increasing asset price instead of N.I.R.D., which results in deviations from the C.I.P. Zhang (2011) contributes the C.I.P. deviations to non-market interest rate and exchange rate formation mechanism. Zhang (2013) ascribes the deviations to the exchange rate policy and inefficient foreign exchange market. However, some researchers have contrary standpoints about the C.I.P. Jiang and Liu (2007) show the C.I.P. fits for China gradually with the liberalisation of interest rate and currency convertibility. Li et al. (2009) revisit the relationship between N.I.R.D. and N.E.R., which can support the C.I.P. to some extent. Wang and Sheng (2015) also argue the C.I.P. has played an increasingly important role in forwarding exchange rate formation. Thus, China needs to focus on the deviations and find corresponding reasons to make sure that the C.I.P. condition holds.

C.I.P. is regarded as an equilibrium link between the interest rates of two currencies and their spot and forward exchange rates for no-arbitrage opportunities. It has been widely investigated in different ways. Holms and Wu (1997) examine the C.I.P. by employing a panel-data unit root test, and the results show that the relaxation of the remaining capital controls in the European Union in 1990 did not lead to the C.I.P. achievement. Bhar et al. (2004) apply Markov regime shifting models to generate time series of volatility regime probabilities, and these were used to explain daily deviations from the C.I.P. condition. Moosa and Bhatti (1996) find cointegration and coefficient restriction tests are more favourable for investigating C.I.P. Baba and Packer (2009) examine C.I.P. between the U.S. dollar and the Euro through Exponent Generalised Auto Regressive Conditional Heteroscedasticity (E.G.A.R.C.H.) model, and discover persistent deviations during the turmoil in 2007-2008. Fong et al. (2010) investigate C.I.P. arbitrage violations using tick-by-tick firm quotes for all financial instruments and find that positive C.I.P. arbitrage deviations include a compensation for liquidity and credit risk. Ferreira et al. (2010) use Augmented Dickey Fuller (A.D.F.) test, univariate approach and Generalised Maximum Entropy to investigate C.I.P., finding that since the adoption of the Euro, it cannot be used to measure financial integration among E.U. countries. Ferreira (2011) uses on C.I.P. condition and cointegration method to compare the situation of the new members with the

Eurozone, and discovers that Hungary and Poland do not show any evidence of monetary integration. Skinner and Mason (2011) find that while C.I.P. holds for large and small triple A-rated economies, it holds for emerging markets only for a three-month maturity in regression analysis. Filipozzi and Staehr (2013) indicate that deviations from C.I.P. can be described as the annualised forward premium minus the interest rate spread, and demonstrate it holds for Czech Republic, Hungary, Poland, but not for Romania. Ferreira and Dionisio (2015) use a detrended cross-correlation analysis (D.C.C.A.) approach to analyse C.I.P., and indicate that it does not hold for countries that adopted the Euro before joining the Eurozone. Ferreira et al. (2016) also use the D.C.C.A. approach, and point to confirmation of C.I.P. in Central European countries, while Southern countries show more evidence of its violation. Fukuda (2016) explain that the Sterling pound and the Danish kroner show asymmetric deviations from C.I.P. through ordinary least square (O.L.S.) regression. Ferreira and Kristoufek (2017) employ two novel regression methods based on D.C.C.A. and detrended moving-average cross-correlation analysis (D.M.C.C.A.), and find that the Southern European countries, as well as other new Eurozone countries, show little evidence of C.I.P. verification. Chen et al. (2017) demonstrate that C.I.P. does hold between New Taiwan dollar and U.S. dollar in Dickey Fuller–Generalise Least Square (D.F.-G.L.S.) and Ng-Perron (N.P.) unit root tests and cointegration analysis.

3. Covered interest rate parity

Du et al. (2016) let $i^*_{t,t+n}$ and $i_{t,t+n}$ denote the n-year risk-free interest rates in U.S. dollar and foreign currency, respectively. The spot exchange rate S_t rate is expressed in units of foreign currency per U.S. dollar: an increase in S_t thus denotes a depreciation of the foreign currency and an appreciation of the U.S. dollar. Likewise, $F_{t,t+n}$ denotes the n-year outright forward exchange rate in foreign currency per U.S. dollar at time t. The C.I.P. condition states that the forward rate should satisfy:

$$\left(1+\ i^*_{t,t+n}\right)^n = \left(1+i_{t,t+n}\right)^n \frac{S_t}{F_{t,t+n}} \tag{1}$$

In logs, the forward premium $\rho_{t,t+n}$ is equal to the interest rate difference between interest rate in the two currencies:

$$\rho_{t,t+n} \equiv \frac{1}{n}\left(F_{t,t+n}-S_t\right) = i_{t,t+n} - \ i^*_{t,t+n} \tag{2}$$

The intuition behind the C.I.P. condition is simple: an investor with one U.S. dollar in hand today would own $\left(1+\ i^*_{t,t+n}\right)^n$ U.S. dollar n years from now by investing in U.S. dollars. But the investor may also exchange his U.S. dollar for S_t units of foreign currency and invest in foreign currency to receive $\left(1+i_{t,t+n}\right)^n S_t$ units of foreign currency n years from now. A currency forward contract signed today would convert the foreign currency earned into $\left(1+i_{t,t+n}\right)^n \frac{S_t}{F_{t,t+n}}$ U.S. dollars. If both domestic and foreign notes are risk-free aside from the currency risk, and the forward contract has no counterparty risk, the two investment strategies are equivalent and should thus deliver the same payoffs. All contracts are signed today. The C.I.P. condition is thus a simple no-arbitrage condition (Sener et al. 2011). It is also central in understanding financial markets, international trade and monetary policy (Fong et al. 2010).

Meanwhile, this paper defines the cross-currency basis, denoted $\vartheta_{t,t+n}$, as the deviation from the C.I.P. condition:

$$\left(1+\ i^{*}_{t,t+n}\right)^{n}=\left(1+i_{t,t+n}+\vartheta_{t,t+n}\right)^{n}\frac{S_{t}}{F_{t,t+n}} \tag{3}$$

Taking logarithm for both sides of Equation (3), and currency basis can be written as:

$$\vartheta_{t,t+n}=i^{*}_{t,t+n}-\left(i_{t,t+n}-\rho_{t,t+n}\right) \tag{4}$$

The cross-currency basis measures the difference between U.S. dollar interest ($i^{*}_{t,t+n}$) and synthetic dollar interest rate ($i_{t,t+n}-\rho_{t,t+n}$). When C.I.P. holds, the comparison of Equations (1) and (3) immediately implies that the currency basis is zero. If C.I.P. does not set up, cross-currency basis is not equal to zero and arbitrage opportunities appear. In the case of a negative basis, $\vartheta_{t,t+n}<0$, the dollar arbitrageur can earn risk-free profits equal to an annualised $|\vartheta$ percent of the trade notional. They can borrow at the direct dollar risk-free rate and invest at the foreign currency risk-free rate. Meanwhile, arbitrageurs would sign a forward contract to convert back the foreign currency into U.S. dollars. In the case of a positive basis, $\vartheta_{t,t+n}>0$, the opposite arbitrage strategy of funding in the synthetic dollar risk-free rate and investing in the direct U.S. dollar interest rate would get an annualised profit equal to ϑ percent of the trade notional.

Many studies have examined what happens when C.I.P. fails. Balke and Wohar (1997) demonstrate that when C.I.P. does not hold, hedging practices for financial decisions cannot be used. Sener et al. (2011) find C.I.P. deviations can be regarded as proxy for disruptions in law of one price, that two assets with equal returns have equal values. Raja and Jaweed (2014) indicate that the violation of the C.I.P. would imply no or a weakly efficient form of the exchange market, which is central in understanding financial market, international trade, monetary and fiscal policies. Akram et al. (2009), Mancini and Ranaldo (2009) and Fong et al. (2010) show that C.I.P. is systematically and persistently violated, which would lead to significant arbitrage opportunities in currency and funding markets. Furthermore, the systemic pattern of the C.I.P. violations point to the key interaction between costly financial intermediation and global imbalances in funding supply and investment demand across currencies (Du et al., 2016).

4. Methodology

4.1. Bootstrap full-sample causality test

The stationarity of time series is the foundation of the Granger causality statistics. If the precondition cannot hold, the time series may not follow standard asymptotic distributions, which makes it difficult to evaluate the vector autoregression (V.A.R.) models (Sims et al., 1990; Toda and Phillips, 1993, 1994). The modified Wald test is estimated by using Monte Carlo simulations (Shukur and Mantalos, 1997a), but the result is not good especially in small- and medium-sized samples. Comparing with the modified Wald test, critical values can be improved by using the residual-based bootstrap (R.B.) method (Shukur and Mantalos, 1997b). Meanwhile, the R.B. method has been proven to perform well in standard asymptotic tests through Monte Carlo simulations (Mantalos and Shukur, 1998). However, Shukur and Mantalos (2000) further show that the likelihood ratio (L.R.) test performs better still in small samples. Combining the above conclusions, this paper chooses the R.B.-based modified-L.R. statistic to revisit the causal relationship between N.I.R.D. and N.E.R.

In terms of the R.B.-based modified-L.R. causality test, the bivariate V.A.R. (p) process can be constructed as follows:

$$\begin{bmatrix} NIRD_{1t} \\ NER_{2t} \end{bmatrix} = \begin{bmatrix} \varphi_{10} \\ \varphi_{20} \end{bmatrix} + \begin{bmatrix} \varphi_{11}(L)\varphi_{12}(L) \\ \varphi_{21}(L)\varphi_{22}(L) \end{bmatrix} \begin{bmatrix} NIRD_{1t} \\ NER_{2t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}, \quad t = 1, \ 2 \cdots T \tag{5}$$

where$\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})$ is a zero mean, independent, white noise process with nonsingular covariance matrix Σ . Schwarz Information Criteria (S.I.C.) is selected to determine the optimal lag length p in this paper. $\varphi_{ij}(L) = \sum_{k=1}^{p+1} \varphi_{ij,k} L^k, \ i, \ j = 1, \ 2$ and L is the lag operator defined as $L^k X_t = X_{t-k}$.

From Equation (5), N.E.R. does not Granger cause N.I.R.D. is the null hypothesis, and is tested with the restriction, $\varphi_{12,k} = 0$ for $k = 1, \ 2 \cdots p$. In the same way, the null hypothesis that N.I.R.D. does not Granger cause N.E.R. is tested with the restriction, $\varphi_{21,k} = 0$ for $k = 1, \ 2 \cdots p$. As previously debated, the R.B.-based modified-L.R. statistic is utilised to investigate the causal link under the full-sample. The rejection of one of the null hypotheses will show that there is a unidirectional causality. When both hypotheses are rejected, the two variables can affect each other. However, no causal link would exist while the hypotheses are received.

4.2. Parameter stability test

The assumption that parameters in the V.A.R. model are fixed may be violated when meeting structural changes in the full sample. The assumption failing would lead to the causal link showing instability (Balcilar and Ozdemir, 2013). Granger (1996) has stressed that how to solve the precondition that parameters are constant is key in recent research. Based on this, Andrews and Ploberger (1994) utilise *Sup-F*, *Mean-F* and *Exp-F* to investigate the short-term parameters in every sub-interval. In generally, the V.A.R. model can only be constructed by underlying variables that are cointegrated in levels. Regardless, it has been noted that when underlying variables are cointegrated in levels, the first difference in the V.A.R. model is incorrectly specified unless it allows for error correction. Therefore, it is important to take cointegration and parameter stability into consideration. The parameter of cointegration regression is estimated by either modified ordinary least square (F.M.-O.L.S.) (Hansen, 1992) or L_c test (Nyblom, 1989; Hansen, 1992). Parameter stability can also be examined by L_c test.

These methods are proposed to verify whether structural breaks exist or not in time series and lead to parameters unstabilising. Andrews and Ploberger (1994) utilise parametric bootstrap procedure to estimate critical values and p-values. Andrews (1993) also points out that statistics require 15 percent trimming from both ends of the sample to test the stability of parameters in the short run; the fraction of the sample in (0.15, 0.85) is needed.

4.3. Sub-sample rolling-window causality test

In terms of the above analysis, it is necessary to use the rolling-window bootstrap method proposed by Balcilar et al. (2010). Two advantages of using this method should be noted. First, a rolling window is applicable when the casual link between variables is time varying. Second, since structural changes exist, a rolling method is unstable in different sub-samples. The rolling-window bootstrap method is grounded on fixed-size sub-samples rolling unceasingly from start to end of the full sample. In particular, when given a fixed-size rolling window including m observations, the full sample is constituted with T-m sub-samples that includes τ -$m+1$, τ -m, $\ldots$, T for τ $=m$, $m+1$, $\ldots$, T. Then, every sub-interval can be investigated by the R.B.-based modified-L.R. causality test. Potential changes can be distinguished through computing the p-values of observed L.R. statistics. $N_b^{-1}\sum_{k=1}^{p}\varphi_{21,k}^{*}$ and $N_b^{-1}\sum_{k=1}^{p}\varphi_{12,k}^{*}$ represent influence from N.I.R.D. and N.E.R., separately. $\varphi_{21,k}^{*}$ and $\varphi_{12,k}^{*}$ are bootstrap estimates from Equation (3). N_b shows the bootstrap repetitions. The 90% confidence intervals are also estimated, for which the lower and upper limits equal the 5th and 95th quantiles of each of the $\varphi_{21,k}^{*}$ and $\varphi_{12,k}^{*}$, respectively.

Two contradictory aims exist in the bootstrap rolling-window method. One is accuracy, which needs a large window size. The other is representativeness, which needs a small window size. Since the two objectives cannot be handled simultaneously, it is essential to choose a suitable number of observations to achieve a balance between these two objectives. The optimal window size should depend upon the persistence and size of the structural breaks (Pesaran and Timmermann, 2005). They indicate that the window size should include at least 20 observations.

5. Data

This paper uses monthly data covering the period from 2005:M07 to 2016:M12 because the P.B.O.C. moderately appreciates R.M.B. against the U.S. dollar by about 2%. At the same time, the N.E.R. regime was changed from a de facto peg to the U.S. dollar to a more flexible peg to a basket of currencies with narrow fluctuation bands. First, spot R.M.B. exchange rates per U.S. dollar on behalf of N.E.R. are used, and data from the National Bureau of Statistics of China (Cheung and Qian, 2010) extracted. Second, the benchmark one-year deposit rate for domestic interest rate is used, which is one of the main interest rate policy variables in China, and the data are taken from the P.B.O.C. (Yang, 2010). Third, this paper uses the one-year Fed fund interest rate, being tightly related to U.S. monetary policies, for the foreign interest rate (Liu and Wu, 2010) and the data are extracted from Thomson Reuters Datastream. N.I.R.D. indicates changes in the interest spread level between home and

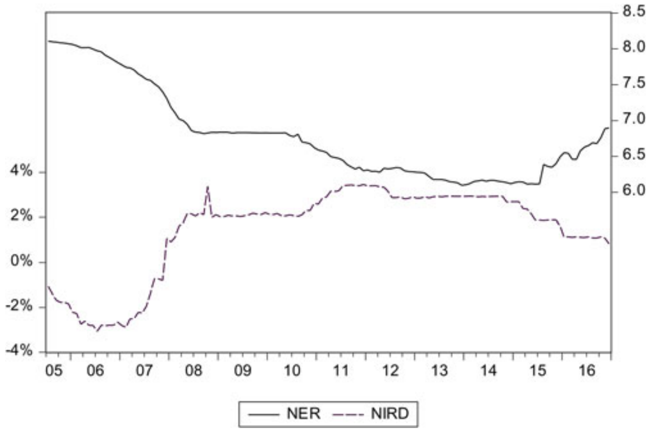

Figure 1. N.I.R.D. and N.E.R. trend. Source: Authors' calculations.

abroad. N.E.R. is the price of another country's currency, and its fluctuation shows depreciation or appreciation in the domestic currency.

Figure 1 indicates that N.I.R.D. and N.E.R. have different trends and both have significant structural changes. The N.I.R.D. decreases in the period 2005:M07–2006:M11, 2011:M12–2012:M06, 2014:M10–2015:M12. In the first sub-interval, the Federal Open Market Committee (F.O.M.C.) increases its target interest rate separately in M08, M09 and M11 of 2005, finally reaching 4%. In the second sub-interval, the P.B.O.C. reduces the bank reserve requirement ratio by 0.5% separately in 2011:M12 and 2012:M02. At the same time, the F.O.M.C. announces it will keep the interest rate range from 0% to 0.25% until the end of 2014. In the last sub-interval, the P.B.O.C. further reduces the one-year deposit and lending interest rate to 2.75% and 5.6%. N.I.R.D. increases in the period 2006:M12–2008:M10 and 2010:M08–2011:M11. In the first sub-interval, a financial crisis breaks out in the U.S. Fannie Mae and Freddie Mac, the top two largest U.S. real estate companies, are taken over by the U.S. government and Lehman Brothers file for bankruptcy protection, sparking market panic. The F.O.M.C. implements the first round of a quantitative easing policy. All the above brings the U.S. interest rate down and increases N.I.R.D. In the second sub-interval, the F.O.M.C. implements the second round of the quantitative easing policy. Meanwhile, the P.B.O.C. raises the one-year deposit and lending interest rate by 0.25%, which contributes to N.I.R.D. becoming bigger. N.I.R.D. keeps stable for the period 2008:M11–2010:M07, 2012:M07–2014:M09 and 2016:M01–2016:M12. In the first sub-interval, the P.B.O.C. reduces the bank reserve requirement ratio two times separately in 2008:M12. At the same time, the F.O.M.C. also cuts the Federal funds target rate and discount rate. In the second sub-interval, the F.O.M.C. implements the third and fourth round of quantitative easing policy. The P.B.O.C. reduces the one-year deposit and lending interest rate by 0.25% and 0.31%. At last sub-interval, with recovery from the financial crisis, the major objective of the F.O.M.C. and the P.B.O.C. is to maintain monetary policy stability. By comparing the shocks and trends in N.I.R.D. and N.E.R., it is found that these two variables do not always change in the same direction and the relationship may not support the C.I.P. in the whole sample.

Table 1. Unit root tests.

	A.D.F.	P.P.	K.P.S.S.	Flexible Fourier test
N.I.R.D.	−2.484(5)	−1.428(8)	0.406[9]*	3.499**
N.E.R.	−1.963(4)	−0.764(8)	1.169[9]***	7.642***

Note: *, ** and *** indicate significance at 10%, 5% and 1% level. The null hypothesis for the tests of A.D.F., P.P. and Flexible Fourier is that the time series have unit root. The null hypothesis for K.P.S.S. is that the time series do not have unit root. The number in parentheses indicates the select lag order of the A.D.F. model. Lags are chosen based on A.I.C. The number in brackets indicates the lag truncation for the Bartlett Kernel, as suggested by the New-West test (Newey & West, 1987).
Source: Authors' calculations.

Table 2. Full-sample Granger cause Tests.

	H_0: N.I.R.D. does not Granger cause N.E.R.		H_0: N.E.R. does not Granger cause N.I.R.D.	
Tests	Statistics	*p*-value	Statistics	*p*-value
Bootstrap L.R. test	11.245	0.219	7.056	0.105

Source: Authors' calculations.

6. Empirical results

The stationarity of variables is regarded as the foundation of the Granger causality statistics. Therefore, the tests of Augmented Dickey and Fuller (1981, A.D.F.), Phillips and Perron (1988, P.P.) and Kwiatkowski et al. (1992, K.P.S.S.) are applied in this study. Table 1 shows that both variables are nonstationary. However, when meeting external structural breaks, these traditional unit root tests would lose power (Liu et al., 2013). Hence, the Flexible Fourier test (Enders and Lee, 2012) is employed, which can capture structure breaks and increase capacity to testing null hypothesis of unit root. The result indicates N.I.R.D. and N.E.R. are 3.499 and 7.642, that can reject the unit root hypothesis at 5% and 1% levels, which provides a base for the next analysis. Following Equation (5), the bivariate V.A.R. model is constructed by N.I.R.D. and N.E.R. The optimal lag length of the V.A.R. model is 2 based on S.I.C. Table 2 shows the full-sample causality results from the R.B.-based modified-L.R. method. N.I.R.D. does not Granger cause N.E.R., and vice versa, through bootstrap *p*-values. That is to say, the movements in N.I.R.D. cannot lead to N.E.R. fluctuation, and N.E.R. has no influence on N.I.R.D. based on the full-sample causality test. This finding is consistent with some of the existing literature that finds no causal link between these two variables (Dhamotharan and Ismail, 2015; Zhao et al., 2013). However, the conclusion is contentious because other researchers take the opposite view, specifically that N.I.R.D. and N.E.R. can affect each other (Sarno, 2005).

Nevertheless, the above conclusion is based on a default assumption. It does not take structural changes into consideration and believes the causal link exists or does not exist in the full-sample (Balcilar et al., 2010). When structural breaks emerge, the parameters of the V.A.R. model are no longer constant. They change with passing time, which shows that the causal linkage between these two variables is unstable. The assumption that the parameters are constant and no structural changes exist is easily violated, hence the corresponding results are no longer reliable (Zeileis et al., 2005). Because of this, the present paper continues to test for parameter stability and pursues the purpose of confirming or denying the existence of structural breaks. As mentioned before, the *Sup-F*, *Mean-F* and *Exp-F* tests are applied to examine whether the parameters are stable or not in the V.A.R. model constructed by N.I.R.D. and

Table 3. Parameter Stability Tests.

	N.I.R.D. Equation		E.R.D. Equation		V.A.R. System	
	Statistics	*p*-value	Statistics	*p*-value	Statistics	*p*-value
Sup-F	33.677***	0.000	38.259***	0.000	63.921***	0.000
Mean-F	18.929***	0.000	11.595***	0.008	49.671***	0.008
Exp-F	12.748***	0.000	14.558***	0.000	28.942***	0.000
L_c^b					7.432***	0.005

Note: *p*-values are calculated using 10,000 bootstrap repetitions. Hansen–Nyblom Parameter stability test for all parameters in the V.A.R. jointly. *** denotes significance at the 1% level.
Source: Authors' calculations.

N.E.R. L_c test has also been employed here in testing for all parameters in the overall V.A.R. system. Table 3 shows the results according to the above tests. For the *Sup-F* test, the null hypothesis is that parameters have no one-time sharp shift. The hypothesis is rejected on the basis of *p*-values in the first row, which means one-time sharp shift exists in the N.I.R.D., N.E.R. and V.A.R. system at the 1% level. For *Mean-F* and *Exp-F* tests, the null hypothesis is that parameters follow a Martingale process. The hypothesis is also rejected in light of *p*-values in the second and third row, which indicates equations from the N.I.R.D., N.E.R. and V.A.R. system might evolve gradually. That the parameters follow a random walk process is the null hypothesis for the L_c statistics test, which is indicative of parameter non-constancy in the overall V.A.R. model estimated. Consequently, parameters in the above V.A.R. model formed by N.I.R.D. and N.E.R. are not stable in the long-run relationship; in other words, the parameters change with time.

According to the results estimated from the parameter stability tests, the conclusion is no longer dependent on that the linear link between N.I.R.D. and N.E.R. is stable. These results indicate that the C.I.P. condition between N.I.R.D. and N.E.R. is not credible in the full-sample period. Considering structural changes, the rolling-window bootstrap method is applied to revisit the causality between N.I.R.D. and N.E.R. Being different from the full-sample causality test, this approach takes the time-varying character into account and provides better accuracy. The R.B. bootstrap based on the L.R. causality is used to re-examine the causal relationship between these two variables in sub-intervals. The hypotheses for these tests are rejected; this means that N.I.R.D. does not Granger cause N.E.R. and vice versa. After several repeats, 20 months is selected as the optimal window size. The *p*-values of L.R. statistics can be estimated from the V.A.R. models in Equation (5) using this window size. When cutting 20 observations from the beginning, the remaining samples cover from 2007:M03 to 2016: M012.

Figure 2 points out that the null hypothesis that N.I.R.D. does not Granger cause N.E.R. is rejected at the 10% significance level in several sub-sample periods, including 2007:M07–2007:M11, 2008:M02–2008:M03, 2012:M04–2013:M07 and 2015:M08–2015:M12. Figure 3 shows that in 2007:M07–2007:M11, 2008: M02–2008:M03 and 2012:M07–2013:M07, N.I.R.D. has a negative impact on N.E.R., while in 2012:M04–2012:M06 and 2015:M08–2015:M12, N.I.R.D. has a positive impact on N.E.R. As we can observe from Figure 1, in the period 2012:M04–2012:M06 and 2015:M08–2015:M12, N.I.R.D. decreases and this change has a negative impact on N.E.R., which is consistent with the C.I.P. In the first period, the P.B.O.C. reduces the benchmark of R.M.B. deposit and lending rate of financial institutions by 0.5% and 0.56%, separately. The falling interest rate reduces

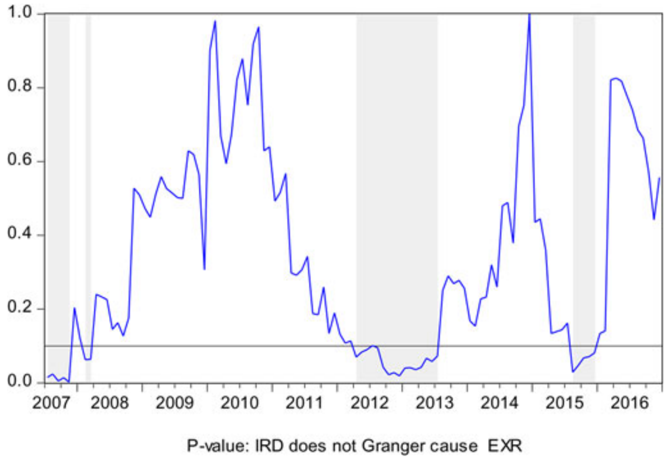

Figure 2. Bootstrap *p*-value of rolling test statistic testing the null that N.I.R.D. does not Granger cause N.E.R. Source: Authors' calculations.

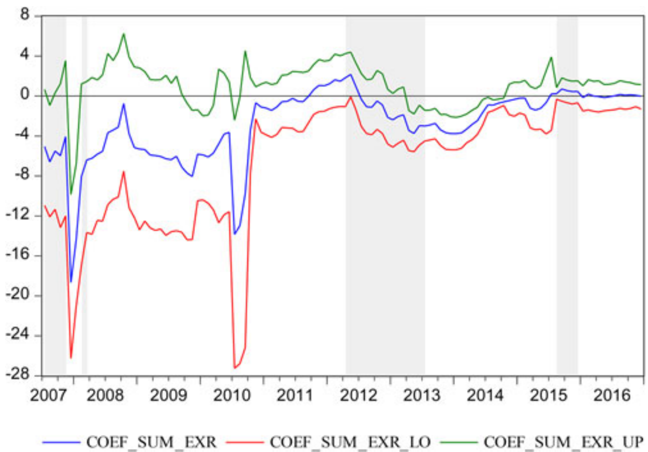

Figure 3. Bootstrap estimates of the sum of the rolling-window coefficients for the impact of N.I.R.D. on N.E.R. Source: Authors' calculations.

arbitrage opportunity. Thus the R.M.B. exchange rate begins to depreciate. In the second interval, the P.B.O.C. reduces the deposit interest rate by 0.25% and U.S. starts to raise its interest rate, which further narrows the interest spread at home and abroad and results in the R.M.B. exchange rate depreciating (Zeng and Xie, 2009). N.I.R.D. increases, and this change has a positive impact on N.E.R. in the following three periods. During 2007:M07–2007:M11, the P.B.O.C. increases the one-year deposit and lending interest rate to 3.87% and 7.29%, which widens N.I.R.D. and has a positive influence on N.E.R. (Zhang, 2013). The financial crisis spreads to the whole world in 2008:M02–2008:M03, China returns to peg to U.S. dollar at 6.83 and has no sign of depreciation (Xu et al., 2016). In 2012:M07–2013:M07, Federal Reserve implements quantitative easing policies separately in 2012:M09 and 2012:M12, which weakens the U.S. dollar (Lim and Mohapatra, 2016). However, in other periods N.I.R.D. deviates from the C.I.P. condition, which can be explained by the time-varying risk

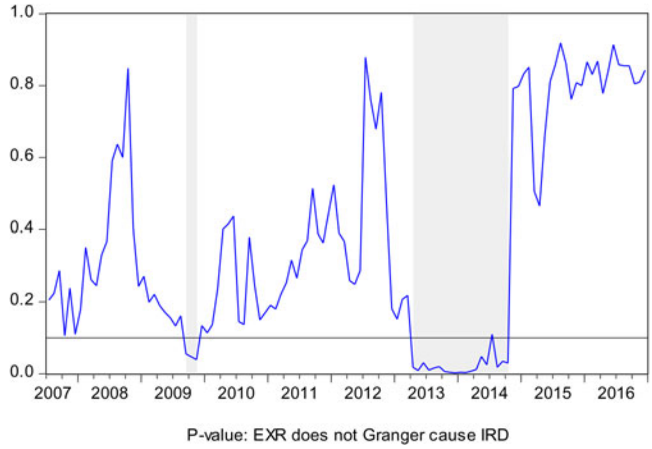

Figure 4. Bootstrap *p*-value of rolling test statistic testing the null that N.E.R. does not Granger cause N.I.R.D. Source: Authors' calculations.

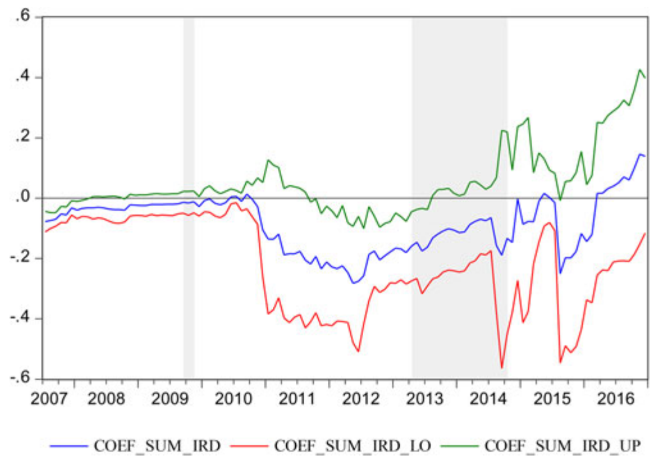

Figure 5. Bootstrap estimates of the sum of the rolling-window coefficients for the impact of N.E.R. on N.I.R.D. Source: Authors' calculations.

premium. The price of oil reaches its highest point at the end of 2007; the variation in oil prices brings about uncertain macroeconomic consequences (Frías-Pinedo et al., 2017), which has a significant impact on N.E.R. (Bal and Rath, 2015). In 2008:M04–2012:M01, the F.O.M.C. implements quantitative easing policies separately in 2008 and 2010, which weaken the U.S. dollar (Michel and Sylvie, 2013). From 2013:M08 to 2014:M07, the F.O.M.C. begins to exit from the quantitative easing policies and Federal funds rates are expected to increase from 0%. At the end of 2013, the Dow Jones, NASDAQ and Standard & Poor rebound strongly, which have an influence on R.M.B. exchange rate (Chen, 2012). Finally, during 2016:M01–2016:M12, the improving U.S. economy, interest rate hike expectations, and Britain falling out of the European Union, result in an intense fluctuation in foreign exchange market and appreciation in the U.S. dollar.

Figure 4 reports the rolling bootstrap *p*-values of the L.R. statistics with the null hypothesis that N.E.R. does not Granger cause N.I.R.D. Figure 5 presents the rolling estimates of the magnitude of the effect that N.E.R. has on N.I.R.D. According to Figure 4, it can clearly be seen that the null hypothesis is rejected significantly in some periods, 2009:M09–2009:M11 and 2013:M04–2014:M10. In Figure 5 the negative effect from N.I.R.D. to N.E.R. can be observed. In the first period 2009:M09–2009:M11, R.M.B. is in the process of appreciating, attracting a mass of international speculative capital flowing into China, and resulting in excess liquidity and lowering domestic interest rate that further narrows N.I.R.D. (Guo et al., 2009). In the second interval 2013:M04–2014:M10, the appreciation of the R.M.B. is expected to strengthen, which will in turn reduce the price of imported goods, improving the domestic real interest rate (Zhao and Li, 2013). However, N.E.R. has no significant impact on N.I.R.D. in the following periods. During 2007:M07–2009:M08, the P.B.O.C. implements more stringent capital control on short-term international capital flow, which influences the mechanism between N.E.R. and N.I.R.D. The F.O.M.C. and the P.B.O.C. continue to implement losing monetary policy from 2009:M12 to 2013:M03, which creates inertia of N.I.R.D. and influence on N.I.R.D. (Wang and Sheng, 2015). In 2014:M11–2016:M12, the F.O.M.C. quits the quantitative easing policy, and the I.M.F. raises a forecast of economic growth for the U.S. Meanwhile, China suffers structural reforms and faces great policy uncertainty. All this leads to international capital flow out of China, which influences N.E.R., violating the C.I.P. condition (Jin and Hong, 2015).

In this paper, the bootstrap Granger full-sample causality test and sub-sample rolling-window estimation provide additional insight into the dynamic relationship between N.I.R.D. and N.E.R. in China. In general, the linkage between N.I.R.D. and N.E.R. is not always consistent with the C.I.P. It can support the C.I.P. for the period 2012:M04–2012:M06 and 2015:M08–2015:M12. However, in other time periods, the same conclusion cannot be achieved. The nexus between N.I.R.D. and N.E.R. in China is not stable over time and even shows a short-term deviation from the positive link (Tang and Ma, 2014). It is actually suitable as in the past few decades China has experienced domestic economic restructuring and global economic fluctuation (Jiang et al., 2015). The P.B.O.C. implemented exchange rate regime reform, which ended the peg of R.M.B. to the U.S. dollar and created a managed float on a basket of currencies (Chen, 2012). Since the financial crisis in 2007, there has been a significant influence on Chinese economic environment at home and abroad. More than a decade ago, China began its interest rate liberalisation, removed the interest ceiling of deposit rates and entered the final stage (Wang, 2016). In 2015, the Central Economic Working Conference proposed supply-side structural reforms, which could be regarded as major strategic innovations. All these internal and external events may have had a temporary impact on the C.I.P. condition between N.I.R.D. and N.E.R. in China, and may even have led to an inaccurate conclusion. Therefore, the bootstrap rolling window that was used to investigate the C.I.P. condition is reasonable and considers the specific backgrounds to obtain a more accurate conclusion for China.

7. Conclusions

This paper re-examines the C.I.P. condition between N.I.R.D. and N.E.R., using a bootstrap full-sample Granger causality test and sub-sample rolling-window causality estimation for China. Considering the structural changes present in the full-sample data, parameter stability tests find that in the short run, the C.I.P. condition does not always hold. Therefore, the bootstrap sub-sample rolling-window causality test was used, finding that N.I.R.D. has both positive and negative impact on N.E.R., and the C.I.P. condition only fits for China in some sub-periods. Although the C.I.P. condition in China is not stable over time and even exhibits short-run deviations from the positive link, it actually fits well with the fact that China has experienced economic transition and structural changes over the past decade. This provides some implications for the P.B.O.C. First, the Chinese government should continue to promote the internationalisation of the R.M.B., which lays the foundation for the C.I.P. Second, the Chinese monetary authority should notice the structural changes from home and abroad that may result in deviations from the C.I.P. Finally, monetary policy should be made under specific economic situations (Taylor, 2010) and reduce the negative influence from the C.I.P. deviations. Through the above, the C.I.P. can act as a foreign exchange market 'stabiliser' and enable a better understanding of financial markets, international trade and monetary policy.

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