Are there bubbles in the exchange rates? Some evidence from G10 and emerging markets countries.

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Abstract

This paper applies the generalized sup ADF (GSADF) test of Phillips, Shi & Yu (2015, PSY) to examine the existence of bubbles in the exchange rate markets in both G10 and emerging market countries (including some Asian and BRICS countries). In most cases, we could not regard the finding of explosive behavior in the nominal exchange rate as the evidence of rational bubbles. In fact, the explosiveness from the nominal exchange rate may be driven by either exchange rate fundamentals (relative prices of traded goods or nontraded goods) or rational bubbles. Some interesting results are obtained from our study.

Keywords: Bubbles; Rational bubbles; GSADF test; G10 countries; Emerging markets countries; Exchange rates
JEL classification: C12; C15; F31

1. Introduction

The aim of this paper is to apply the generalized sup ADF (GSADF) test of Phillips, Shi & Yu (2015, PSY) to investigate the presence of exchange rate bubbles in G10 and emerging markets countries (including some Asian and BRICS countries). The motivation of this paper comes from two recent papers by Bettendorf & Chen (2013) and Jiang et al. (2015), who empirically examine the explosive behaviour in the Sterling-dollar and Chinese RMB-dollar exchange rates, respectively. Bettendorf & Chen (2013) used the GSADF test to examine the existence of bubbles in the Sterling-dollar exchange rate.

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\textsuperscript{2}Montasser et al. (2016) also apply the sup ADF (SADF) of Phillips, Wu & Yu (2011, PWY) and GSADF tests to the Chinese RMB-dollar exchange rate between October 1996 and August 2014.
rate from January 1972 to June 2012 and they found evidence of explosive behavior in the nominal exchange rate. According to Bettendorf & Chen (2013), the finding of explosive behavior in the nominal exchange rate could not be simply interpreted as the evidence of rational bubbles. The explosiveness in the nominal exchange rate may be driven either by rational bubbles or explosive fundamentals themselves (e.g., the relative prices of traded goods and the relative prices of nontraded goods). Empirical results from Bettendorf & Chen (2013) suggest that the explosiveness in the Sterling-dollar nominal exchange rate is explained by the relative prices of traded goods only. Similarly, Jiang et al. (2015) applied the same bubble-detection test to explore the presence of bubbles in Chinese RMB-dollar exchange rate between July 1995 and October 2013 and they found explosive behavior in the nominal exchange rate. The explosiveness in the nominal exchange rate is explained by both rational bubbles and relative prices of traded goods.

A number of studies have tested for bubbles in the exchange rates. Evans (1986) found evidence to support the presence of bubbles in the Sterling-dollar exchange rate between 1981 and 1984. Similarly, Meese (1986) provided evidence of bubbles for the dollar-deutsche mark and Sterling-dollar exchange rate using the monthly data between 1973 and 1982. Wu (1995) applied the Kalman filter technique to estimate and test for exchange rate bubbles between the US dollar, the British pound, the Japanese yen and the deutsche mark using the monthly data over 1974-1988. However, Wu (1995) found no significant evidence of bubbles in these exchange rates. Van Norden (1996) investigated the existence of speculative bubbles in exchange rates of the Japanese yen, the German mark and the Canadian dollar from 1977 to 1991 by applying a new regime switching test. The presence of bubbles display a particular kind of regime-switching behavior by implying some coefficient restrictions on a simple switching-regression model of exchange rate. Empirical results are sensitive to the choice of exchange rate fundamentals and measurement of exchange rate innovations. Elwood et al. (1999) made use of state-space models and Monte Carlo experiments to explore the presence of a stochastic rational bubble in the Japanese and German exchange rates over the period of December 1984 to November 1998. According to the theory of uncovered interest parity, a series under rational expectation is supposed to be white noise. Elwood et al. (1999) therefore inspected this condition for evidence of bubbles. A finding of a deviation from white noise implies the existence of a stochastic rational bubble. Their results suggest a bubble have burst between the end of March and the end of April of 1990, which is coincided with economic turmoil in Japan and Germany. Jirasakuldech et al. (2006) examined the existence of rational speculative bubbles in the bilateral exchange rates of the British pound, the

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*Diba & Grossman (1988) defined a rational bubble as a belief that an asset’s price depends on a variable (variables) which is not relevant to fundamentals.*
Canadian dollar, the Danish krone, the Japanese yen and the South African rand against the US dollar covering the period from January 1989 to December 2004. Three different bubble detection procedures have been used: the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, the Johansen’s multivariate cointegration test and the duration dependence test of McQueen & Thorley (1993). All three tests provide firm evidence of no rational speculative bubbles in these currency pairs.

There are some well-known examples of currency crises in the literature. Krugman et al. (1999) concluded three regional currency crises in 1990s: the ERM crisis in Europe in 1992-1993, the Latin America crisis of 1994-1995 and the Asian crisis in 1997-1998. Similarly, Summers (2000) mentioned several major crises during the 1990s: Mexico in 1995, Asia in 1997-1998, Russia in 1998 and Brazil in 1999. The first currency crisis example in 1990s was the ERM (European Exchange Rate Mechanism) crisis in 1992-1993. The EMR was established in 1979 as part of the European Monetary System (EMS), which aimed at reducing exchange rate fluctuations. Many empirical studies have attempted to investigate this classic episode of speculative attack (e.g., Rose & Svensson (1994), Dornbusch et al. (1995), Krugman et al. (1999), Volz (2006)). The collapse of the Mexican peso in 1994-95 was widely regraded as one of the exchange rate crises in the 20th century. A number of authors have investigated the cause of the Mexican peso crisis including Calvo & Mendoza (1996), Sachs et al. (1996a), Sachs et al. (1996b), Gil-Díaz & Carstens (1996), Edwards (1998), Fratzscher (1998). The Asian currency crisis in 1997 is another example of exchange rate crises. The crisis began in July 1997 when the Thai baht was forced to float due to the lack of foreign currency to maintain its fixed exchange rate. This crisis then spread to most Southeast Asia countries. Several Asian currencies including Thai Baht, Indonesia Rupiah, Malaysia Ringgit, Philippines Peso, Singapore Dollar and South Korea Won were under attack. There is a large literature that researches on the Asian currency during the 1997-98 crisis, especially what has caused the widespread financial crisis (e.g., Fratzscher (1998), Corbett & Vines (1999), Corsetti et al. (1999), Mishkin (1999), Burnside et al. (2001)). This crisis also spread to other countries outside the region: Russian in 1998, Brazil in 1999 and Argentina in 2001-2002. Russian currency crisis in 1998 was another example of currency crises in the 1990s, which led to the devaluation of the ruble and default of debt (See, Sapid (1999), Desai (2000), Komulainen (2000), Chiodo & Owyang (2002)). Several studies look into the cause of the Brazilian currency crisis in 1999.

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4 One of the most influential papers is by Frankel & Rose (1996), who investigated currency crashes in 100 developing countries from 1971 to 1992 using annual data. They defined a ‘currency crash’ as a nominal depreciation of the currency of at least 25% that is also 10% increase in the rate of depreciation.

5 Glick & Rose (1999) conclude that currency crises tend to be regional. Their evidence also suggests that if a crisis country suffers a speculative attack, then its trading partners and competitors are also likely to be attacked.
The Argentinean currency crisis in 2001-2002 has also received much attention in the literature (e.g., Edwards (2002), Boschi (2005), Boinet et al. (2005), Alvarez-Plata & Schrooten (2006)). Apart from these crises, Turkey also experienced a severe currency crisis during 2000 and 2001 (e.g., Akyüz & Boratav (2003), Ozkan (2005), Akyurek (2006), Kadri Ekinci & Alp Ertürk (2007)).

The approach we have used in this study aims to provide new insight into the existence of bubbles or rational bubbles in exchange rates. In line with Bettendorf & Chen (2013) and Jiang et al. (2015), we will use the same methodology from Engel (1999) to construct exchange rate fundamentals. In order to explore the cause of the explosiveness, we test for the evidence of explosive behavior in the exchange rate fundamentals as well. Several research questions will be addressed in this paper. Are there bubbles in G10 currency pairs? Can we find evidence of bubbles to support the Mexican currency crisis in 1994-95? Are there bubbles in Asian currency during the 1997-1998 crisis? Do relative prices of traded goods or the relative prices of non-traded goods account for the explosive behaviour in the nominal exchange rate?

The remainder of the paper is organized as follows. Section 2 provides a review of the fundamentals for the nominal exchange rate and Section 3 gives a brief description of the GSADF and SADF tests of Phillips et al. (2015) and Phillips et al. (2011). Section 4 describes the data. Section 5 provides empirical results for the G10 and emerging markets countries and Section 6 concludes.

2. Background

The economic fundamental for the nominal exchange rate is the price differential:

\[ f_t = p_t + p_t^* , \]  

where \( p_t \) denotes the log level of the domestic price index. Asterisks denote foreign counterparts. For decomposing the price index into indexes of nontraded and traded goods, Engel (1999) considers a price index for a country as a weighted average of traded and nontraded goods

\[ p_t = (1 - \alpha)p_t^T + \alpha p_t^N , \]  

where \( p_t^T \) denotes the log of the traded goods price index and \( p_t^N \) the log of the nontraded goods price index and \( \alpha \) the share of the nontraded goods component. For the foreign country, one can write:

\[ p_t^* = (1 - \beta)p_t^* + \beta p_t^* , \]  

where
It follows that the price differential \((f_t)\) can be decomposed into two components, the traded goods component \((f_T^t)\), and the nontraded goods component \((f_N^t)\):

\[
p_t - p_t^* = (p_T^t - p_T^*) + \alpha(p_N^t - p_T^t) - \beta(p_N^* - p_T^*).
\]

The producer price index (PPI) is the most broadly available and frequently used index to represent the price level of traded goods. Though there are some producer goods that are not traded, PPI is measured at the production site and thus excludes marketing and other nontraded consumer services. Thus we construct the traded goods component using the PPI following Engel (1999):

\[
f_T^t = \ln(\text{PPI}_t) - \ln(\text{PPI}_t^*).
\]

(5)

The relative nontraded goods component is constructed from the aggregate consumer price indices (CPI) relative to aggregate PPI:

\[
f_N^t = \ln(\text{CPI}_t) - \ln(\text{PPI}_t) - (\ln(\text{CPI}_t^*) - \ln(\text{PPI}_t^*)).
\]

(6)

3. Method

This section overviews the bubble detection tests drawing on the discussion in Phillips et al. (2011) and Phillips et al. (2015), respectively. Phillips et al. (2011) proposed a sup ADF (SADF) test based procedure that can test for evidence of price exuberance and date stamp its origination and collapse of period of exuberance. Such a test procedure makes good use of the a right-tailed unit root and a sup test in a recursive way. The highlight of this new approach is the ability to capture explosive behavior and even periodically collapsing bubbles of Evans (1991). The SADF test is recursively applied to the sample data and is implemented as follows. For each time series \(x_t\), we apply the augmented Dickey-Fuller (ADF) test for a unit root against the alternative of an explosive root (right-tailed). The following autoregressive specification for \(x_t\) is estimated by the least squares:

\[
x_t = \mu + \delta x_{t-1} + \sum_{j=1}^{J} \phi_j \Delta x_{t-j} + \varepsilon_{x,t}, \quad \varepsilon_{x,t} \sim \text{NID}(0, \sigma_x^2),
\]

(7)

for some given value of the lag parameter \(J\), where NID denotes independent and normal distribution. The null hypothesis of this test is \(H_0 : \delta = 1\) and the alternative hypothesis is \(H_1 : \delta > 1\). Equation (7) is estimated repeatedly using subsets of the sample data incremented by one additional observation at each pass in the forward recursive regression. Thus the SADF test is constructed by repeatedly estimating the ADF test. Let \(r_w\) be the window size of the regression. The window size \(r_w\) expands from \(r_0\) to 1, where \(r_0\) is the smallest sample window width fraction and 1 is the largest window fraction (full sample). The staring point point \(r_1\) is fixed at 0, and the end point of each sample \((r_2)\)
equals \( r_w \) and changes from \( r_0 \) to 1. The ADF statistic for a sample that runs from 0 to \( r_2 \) is therefore denoted by \( ADF^2_0 \). The SADF statistic is defined as the sup value of the ADF statistic sequence:

\[
SADF(r_0) = \sup_{r_2 \in [r_0, 1]} ADF^2_0
\]

Unlike the SADF test, the GSADF test is extended by a more flexible window size. The end point \( r_2 \) varies from \( r_0 \) (the minimum window size) to 1. The start point \( r_1 \) is also allowed to vary from 0 to \( r_2 - r_0 \). The GSADF statistic is the largest ADF statistic over range of \( r_1 \) and \( r_2 \). The key difference between the SADF and GSADF is the window size of starting point \( r_1 \). The GSADF statistic is therefore defined as:

\[
GSADF(r_0) = \sup_{r_2 \in [r_0, 1], r_1 \in [0, r_2 - r_0]} ADF^2_{r_1}
\]

According to Phillips et al. (2015), the minimum window size \( r_0 \) needs to be large enough to allow initial estimation but it should not be too large to miss the chance of detecting an early bubble period. We therefore follow Phillips et al. (2015) and let \( r_0 = 0.01 + 1.8\sqrt{T} \), where \( T \) is number of observation. The fixed lag order approach is used in this study as suggested by Phillips et al. (2015) as well. The lag order is chosen at 0 for the following analysis. The finite critical values are obtained from Monte Carlo simulation with 2000 replications.

4. Data

We obtained the time series of the exchange rate from the Wiki Exchange Rates. Following the work of Bettendorf & Chen (2013) and Jiang et al. (2015), the time series of the consumer price index (CPI) and producer price index (PPI) are obtained from the IMF International Financial Statistics and used for constructing the fundamentals of the exchange rates. The monthly sample data from March 1991 to December 2014 is used for our analysis. All series have been transformed into logarithm.

5. Results

We divide our results into four parts. Section 5.1, Section 5.2, Section 5.3, Section 5.4 provide the empirical results for G10, Asian, BRICS and other emerging markets countries, respectively.

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6 The modern Brazilian real was introduced in 1994. The sample data for Brazil from June 1994 to December 2014 is used for our analysis. Due to data availability, the data for the Philippines ranges from January 1993 to December 2014.
5.1. Results for G10 Countries

We firstly test for the existence of exchange rate bubbles in the G10 currencies (e.g., British Pound (GBP), Canada Dollar (CAD), Japanese Yen (JPY), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF)). Results for the nominal exchange rate $s_t$ are presented in Table 1 and Table 2. As the results suggest, we do not find significant evidence of explosive behavior in these currencies except for the Sterling-Swiss Franc and Sterling-Japanese Yen. We will only include the bubble-detection results for these two exchange rates.

GBP/CHF

The second row of Table 1 suggests the existence of explosive behavior in the nominal exchange rate $s_t$ at the 1% significance level, which indicates the existence of explosive subperiods. Figure 1a compares the backward SADF statistic with 95% critical value sequences for the nominal exchange rate. The backward SADF statistic sequences indicate the presence of multiple episodes including 1995M05-1995M07, 2008M02-2008M04, 2008M09-2009M01 and 2011M05-2011M08.

Figure 1b and Figure 1c display the backward SADF statistic sequences for the nominal exchange rate to relative prices of traded goods fundamentals $f^T_t$ and relative prices of nontraded goods fundamentals $f^N_t$, respectively. The relative prices of traded goods have explained some explosiveness in the nominal exchange rate, while the relative prices of nontraded goods play little role in explaining the explosiveness in the nominal exchange rate. Neither $f^T_t$ or $f^N_t$ has explained the explosiveness between 2008M09 and 2009M01, which implies the presence of rational bubbles.

GBP/JPY

Similarly, the third row of Table 1 provides strong evidence of explosive behavior in the nominal exchange rate $s_t$ at the 1% significance level. As shown in Figure 2a, there is an episode between 2008M10 and 2009M03 in the backward SADF statistic sequences, which is likely related to the 2008 global financial crisis.

The exchange rate $s_t$ is still explosive although both the relative prices of traded goods and the relative prices of nontraded goods are taken into account. Results from Figure 2b and Figure 2c suggest that both traded goods fundamentals and nontraded goods fundamentals do not explain the explosiveness in the Sterling-Japanese Yen exchange rate. Our findings therefore indicate the presence of rational bubbles in the nominal exchange rate.
Figure 1: Dating strategy for GBP/CHF nominal exchange rate $s_t$, the relative ratio of the exchange rate to the traded goods fundamental $s_t - f^T_t$ and the relative ratio of the exchange rate to the nontraded goods fundamental $s_t - f^N_t$.

5.2. Results for Asian Countries

We have a look at several emerging market exchange rates in Asia against the US dollar. Such currencies have been considered in our analysis including Indonesian Rupiah (IDR), Korean Won (KRW), Malaysian Ringgit (MYR), Philippine Peso (PHP), Singapore Dollar (SGD) and Thai Baht (THB).

Thai Baht (THB)

The 1997 Asian financial crisis was originated in Thailand. This crisis began in July 1997 when the Thai baht was allowed to float and soon spread to most Southeast Asia countries including Indonesia,
Malaysia, the Philippines, Singapore. South Korea, China, Hong Kong, Taiwan and Vietnam were also affected.

The baht was pegged at 25 to the US dollar between 1986 and 1995. Until May 1997, a massive speculative attack took place against the baht. Due to the lack of foreign currency to defend the baht, the Thai government forced to float the baht to US dollar in July 1997. The baht was depreciated at 55 to the US dollar at the end of January of 1998 and lost more than 50% of its value.

According to the third row of Table 3, the null hypothesis of no explosive behavior is rejected at the 1% significance level for the nominal exchange rate. From Figure 3a, there are two explosive...
bubbles in the nominal exchange rate (1997M07-1998M02 and 2008M01-2008M05). The explosiveness in 1997-1998 is driven by neither the relative prices of traded goods nor nontraded goods. Similarly, neither the relative prices of traded goods nor the relative prices of nontraded goods can explain the explosiveness in 2008. In both cases, the exchange rate remains explosive even if the relative prices of traded goods $f_t^T$ and the relative prices of non-traded goods $f_t^N$ are considered in Figure 3b and Figure 3c, respectively. We therefore conclude that neither the relative prices of traded goods nor nontraded goods could explain the explosiveness in the dollar-baht exchange rate $s_t$, which suggest the existence of rational bubbles.

(a) USD/THB $s_t$  

(b) USD/THB $s_t - f_t^T$

(c) USD/THB $s_t - f_t^N$

Figure 3: Dating strategy for USD/THB nominal exchange rate $s_t$, the relative ratio of the exchange rate to the traded goods fundamental $s_t - f_t^T$ and the relative ratio of the exchange rate to the nontraded goods fundamental $s_t - f_t^N$. 

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**Indonesian Rupiah (IDR)**

Following the collapse of the baht, Indonesia widened the rupiah currency trading band from 8% to 12% to against speculators in July 1997. In August 1997, the managed floating exchange rate was abandoned and the rupiah was allowed to float freely. The nominal exchange rate remained almost constant before the burst of 1997 Asian Financial Crisis and it had some initial falls immediately after the burst. The rupiah was traded at 2600 to the US dollar in July 1997 and it depreciated to 14900 per US dollar in June 1998. Indonesian rupiah was one of the most fluctuated currencies during the East Asian currency crisis as it depreciated to near one-sixth of its pre-crisis level (Ito 2007).

The null hypothesis of no explosive behavior in the nominal Indonesian Rupiah-dollar exchange rate is rejected at the 1% significance level as listed in the second row of Table 3. We find the presence of multiple bubbles in the nominal exchange rate including 1994M08-1996M08, 1996M11-1998M09 and 2013M07-2014M02 from Figure 4a.

The first episode in the nominal exchange rate is driven by the relative prices of traded goods \( f^T_t \) as the nominal exchange rate is no longer explosive once the relative prices of traded goods fundamentals are taken into account. The \( f^T_t \) also explains the part of movements in explosiveness in 1998 and 2013. In line with Engel (1999) and Betts & Kehoe (2005), the relative prices of traded goods have explained the majority of the movements in the nominal exchange rate.

**Korean Won (KWR)**

The null hypothesis of no bubbles is rejected for the nominal exchange rate \( s_t \), the relative ratio of the exchange rate to the traded goods fundamental \( s_t - f^T_t \) and the relative ratio of the exchange rate to the nontraded goods fundamental \( s_t - f^N_t \) at the 1% level and the empirical results are shown in Table 3.

Figure 5a to Figure 5c show the date-stamping bubbles periods in \( s_t \), \( s_t - f^T_t \) and \( s_t - f^N_t \), respectively. Four bubbles periods are identified from Figure 5a including 1995M03-1995M08, 1996M12-1998M02, 2008M08-2008M11 and 2009M01-2009M02.

Firstly, we find the evidence of explosiveness between March 1995 and August 1995 in all three series. The exchange rate \( s_t \) remains explosive after both the relative prices of traded goods \( f^T_t \) and nontraded goods \( f^N_t \) are taken into account. Thus \( f^T_t \) and \( f^N_t \) play no role in explaining the explosive behavior in 1995.

The exchange rate between Korean Won and US dollar was one of the most affected pairs during the 1997 Asian financial crisis. Both \( s_t \) and \( s_t - f^N_t \) report the explosiveness from the late 1996 or early
Figure 4: Dating strategy for USD/IDR nominal exchange rate $s_t$, the relative ratio of the exchange rate to the traded goods fundamental $s_t - f_t^T$ and the relative ratio of the exchange rate to the nontraded goods fundamental $s_t - f_t^N$.

1997 to the early 1998 while $s_t - f_t^T$ suggests a bubble episode starting from September 1997 until the early of 1998. In other words, the relative prices of traded goods have partially explained the explosive behaviour from the early to middle 1997. These bubble episodes correspond to the 1997 Asian financial crisis. The Korean won has depreciated sharply from the precrisis level at 800 per US dollar to 1700 per US dollar at the end of 1997. The IMF provided a $58.4 billion bailout plan to South Korea in December 1997 (Koo & Kiser 2001).

Two more bubbles periods (2008M08-2008M11 and 2009M01-2009M02) identified in the $s_t$ series are likely related to the 2008 global financial crisis. Both $f_t^T$ and $f_t^N$ have no effect in explaining the explosiveness in the nominal exchange rate $s_t$ in 2008 while the relative prices of traded goods can
explain the explosiveness in early 2009.

Unlike the existing studies, our results indicate that the relative prices of traded goods play little role in the movements of Korean won-dollar exchange rate and the relative prices of nontraded goods doesn’t contribute much in explaining the explosiveness either.

(a) USD/KRW $s_t$

(b) USD/KRW $s_t - f_t^T$

(c) USD/KRW $s_t - f_t^N$

Figure 5: Dating strategy for USD/KRW nominal exchange rate $s_t$, the relative ratio of the exchange rate to the traded goods fundamental $s_t - f_t^T$ and the relative ratio of the exchange rate to the nontraded goods fundamental $s_t - f_t^N$.

Malaysian Ringgit (MYR)

We find strong evidence of explosive behavior in the nominal exchange rate $s_t$, the ratio of the exchange rate to the traded goods fundamental $s_t - f_t^T$ and the ratio of the exchange rate to the nontraded goods
fundamental $s_t - f^N_t$ at the 1% level based on the first row of Table 3. As indicated in Figure 6a, there is evidence of multiple bubbles in the nominal Malaysian Ringgit-dollar exchange rate $s_t$ including 1997M08-1998M08, 2003M03-2003M06, 2006M02-2006M06 and 2006M11-2008M08.

The Malaysian Ringgit was traded at 2.5 US dollar before the burst of the 1997 Asian financial crisis and it depreciated sharply to 3.8 US dollar at the end of 1997. There is a bubble period between August 1997 and August 1998 in the nominal exchange rate of Figure 6a and the ratio of the exchange rate to the nontraded goods fundamental $s_t - f^N_t$ of Figure 6c while a shorter bubble episode is detected in the ratio of the exchange rate to the traded goods fundamental $s_t - f^T_t$ starting at August 1997 and ending at February 1998 in Figure 6b. Such bubbles are corresponded to the 1997 Asian financial crisis. The relative prices of traded goods $f^T_t$ have partially explained the explosiveness in $s_t$ while such a explosive behavior is not driven by the relative prices of nontraded goods $f^N_t$.

The Malaysian Ringgit was pegged to US dollar in September 1998 and keeping the exchange rate around 3.8 per US dollar until the end of 2005. Thus we would not expect any explosive behavior during this seven-year period. However, as shown in Figure 6a, there is a spurious bubble episode ranging from March 2003 to June 2003 in the series. We could not explain the reason behind this explosive period. This spurious bubble episode may be an example that the GSADF test fails to detect the correct number of bubbles and seldom gives false alarms. As explained in Phillips, Shi & Yu (2015, PSY), the multiple breaks could potentially diminish the power of the SADF test based procedure of Phillips et al. (2011). If we treat the fluctuation of nominal exchange rates between June 1997 and September 1998 from Figure 6a as the sign of multiple breaks, then the date-stamping results seem to suggest that the breaks could affect the identifiability of explosive behavior for the GSADF test as well. What we learn from this exchange rate pair is that the spurious bubble episode may be caused by the reduction power of the GSADF test.

Our empirical results suggest that the relative prices of nontraded goods have explained the most movements in $s_t$. The exchange rate series is no longer explosive after the nontraded goods are taken into account except the bubble period during the 1997 Asian financial crisis. The relative prices of traded goods also play an important role in explaining the explosiveness in $s_t$ as well, but the explosive behaviours during the 1997 Asian financial crisis and 2008 global financial crisis are not driven by the relative prices of traded goods.

**Philippine Peso (PHP)**

The third row in Table 3 suggests that the null hypothesis of no explosive behavior in the nominal exchange rate $s_t$ is rejected at the 1% significance level for the GSADF test. As shown in Figure 7a,
there is evidence of two bubbles in the US dollar-Philippine peso exchange rate $s_t$ including 1997M08-1998M10 and 2006M12-2008M05. The first explosive episode is clearly related to the 1997 Asian financial crisis. The nontraded goods $f_t^N$ could not explain this explosiveness while the traded goods $f_t^T$ explain some movements in the exchange rates.

As can be seen in Figure 7b, we find no evidence of explosiveness in the $s_t - f_t^T$ series for the second explosive period in 2007-2008, which is likely associated with the 2008 global financial crisis. According to Figure 7c, the exchange rate still remains explosive after the relative prices of nontraded goods are taken into account although the time duration of explosive behaviour in the $s_t - f_t^N$ series is shorter than those from the $s_t$ series. On the other hand, we also observe three additional bubble periods from

Figure 6: Dating strategy for USD/MYR nominal exchange rate $s_t$, the relative ratio of the exchange rate to the traded goods fundamental $s_t - f_t^T$ and the relative ratio of the exchange rate to the nontraded goods fundamental $s_t - f_t^N$. 
the $s_t - f_t^N$ series. Overall, the above results seem to suggest that traded goods play a crucial role in explaining the explosiveness in the nominal US dollar-Philippine peso exchange rate.

(a) USD/PHP $s_t$

(b) USD/PHP $s_t - f_t^T$

(c) USD/PHP $s_t - f_t^N$

Figure 7: Dating strategy for USD/PHP nominal exchange rate $s_t$, the relative ratio of the exchange rate to the traded goods fundamental $s_t - f_t^T$ and the relative ratio of the exchange rate to the nontraded goods fundamental $s_t - f_t^N$.

Singapore Dollar (SGD)

Unlike some Asian currencies, a managed floating exchange rate regime is adopted by the Singapore government in 1973 (Lu & Yu 1999). In 1967, the board of Commissioners of Currency of Singapore (BCCS) is set up to issue currency. The Monetary Authority of Singapore (MAS) established in 1971 manages the Singapore dollar against a trade-weighed basket of currencies. The board of
Commissioners of Currency of Singapore merged with Monetary Authority of Singapore in October 2002.

As can be seen at the second row in Table 3, we find strong evidence of explosive behaviour in nominal exchange rate $s_t$, the ratio of the exchange rate to the traded goods fundamental $s_t - f^T_t$ and the ratio of the exchange rate to the nontraded goods fundamental $s_t - f^N_t$ at the 1% significance level.

As shown in Figure 8a, evidence of multiple bubbles is found in the nominal exchange rate $s_t$ (e.g., 1994M07-1995M08, 1997M09-1998M02, 2007M09-2008M08 and 2011M01-2011M09). The first episode in 1994-1995 is explained by the relative prices of traded goods only. The second explosive period is associated with the 1997 Asian financial crisis. Neither the relative prices of traded goods nor the relative prices of nontraded goods explain the explosiveness during the Asian financial downturn. The explosiveness in the nominal exchange rate during 2007-2008 and 2011 are explained by the relative prices of traded goods.

Overall, as can be seen from Figure 8b, the relative prices of traded goods play an important role in explaining the majority of the movements in $s_t$ as the $s_t - f^T_t$ remains explosive only during the 1997-1998. In contrast, the relative prices of nontraded goods play little role in explaining the explosiveness in $s_t$ based on Figure 8c.

5.3. Results for BRICS countries

We also look for evidence of explosive behavior in the exchange rate of the BRICS countries such as Brazilian Real (BRL), India Rupee (INR) and South African Rand (ZAR) against the US dollar.

Brazilian Real (BRL)

Based on the first row in Table 4, the null hypothesis of explosive behavior in the nominal US dollar-Brazilian Real is rejected at the 5% significance level. We then investigate whether the explosiveness in the nominal exchange rate is driven by rational bubbles or exchange rate fundamentals.

The Brazilian Real was pegged to 1 US dollar as it was initially introduced in July 1994. The real appreciated against the US dollar in the earlier two years. Since July 1996, the real had depreciated against the US dollar. By the end of 1998, the real depreciated slowly against the US dollar at a rate of 1:1.2. The real was allowed to fluctuate within a narrow trading band until early 1999 and so the path

\[7\text{Due to the lack of the PPI data for Russia, we could not test for the explosive behavior in the Russian ruble-dollar exchange rate fundamentals. Jiang et al. (2015) have already investigated the the explosive behavior in the Chinese RMB-dollar exchange rate. We therefore only include the three remaining countries in our analysis.}\]
of real was closely controlled by the government (Gruben et al. 2001). The adoption of the pre-set band provides some flexibility of the exchange rate system, which aims at the inflation problem. The real was then floated in January 1999 as the government unable to hold the peg (Ferreira & Tullio 2002). As a result, the real was further devalued to a rate of 1:2.

The first bubble period between June 1997 and March 1999 is associated with the devaluation of the real. According to Ferreira & Tullio (2002), the price index for non-traded goods increased by 120 per cent, and the price index for traded goods increased by about 27 per cent between July 1994 and the end of 1998.
According to Figure 9b, the relative ratio of the exchange rate to the traded goods fundamentals \( s_t - f^T_t \) suggests no evidence of rational bubbles as the ratio is no longer explosive. Thus the relative prices of traded goods play a vital role in explaining the volatility of the nominal exchange rate. On the contrary, the prices of non-traded goods have little contributions in explaining the explosiveness.

(a) USD/BRL \( s_t \) 

(b) USD/BRL \( s_t - f^T_t \)

(c) USD/BRL \( s_t - f^N_t \)

Figure 9: Dating strategy for USD/BRL nominal exchange rate \( s_t \), the relative ratio of the exchange rate to the traded goods fundamental \( s_t - f^T_t \) and the relative ratio of the exchange rate to the nontraded goods fundamental \( s_t - f^N_t \).

India Rupee (INR)

Results for the nominal US dollar-India Rupee exchange rate are shown in Table 4. The GSADF test suggests strong evidence of bubbles in the nominal exchange rate as the null of no explosive behavior is rejected at the 1% significance level. Figure 10a shows the date-stamping results for

The nominal exchange rate $s_t$ is no longer explosive in Figure 10 once the the relative prices of traded goods are accounted for. Therefore our findings do not support the existence of rational bubbles as the relative prices of traded goods fundamentals have explained the movements in the nominal exchange rate.

![Graph](image)

(a) USD/INR $s_t$

![Graph](image)

(b) USD/INR $s_t - f_t^T$

![Graph](image)

(c) USD/INR $s_t - f_t^N$

Figure 10: Dating strategy for USD/INR nominal exchange rate $s_t$, the relative ratio of the exchange rate to the traded goods fundamental $s_t - f_t^T$ and the relative ratio of the exchange rate to the nontraded goods fundamental $s_t - f_t^N$.

South African Rand (ZAR)
We find strong evidence of bubbles from the nominal US dollar-South African Rand exchange rate at the third row in Table 4 as the null of no bubbles is rejected at the 1% significance level. Multiple bubbles periods are found in Figure 11a including 1994M01-1994M08, 1996M03-1997M01, 1998M04-1998M10, 1998M12-1999M04 and 2000M08-2002M09.

According to Figure 11b and Figure 11c the relative prices of traded goods have explained the majority of the movements in the nominal exchange rate. As both the relative prices of traded goods fundamentals and non-traded goods fundamentals can not explain all the explosiveness in the nominal exchange rate, we therefore conclude the evidence of rational bubbles.

(a) USD/ZAR $s_t$

(b) USD/ZAR $s_t - f_t^T$

(c) USD/ZAR $s_t - f_t^N$

Figure 11: Dating strategy for USD/ZAR nominal exchange rate $s_t$, the relative ratio of the exchange rate to the traded goods fundamental $s_t - f_t^T$ and the relative ratio of the exchange rate to the nontraded goods fundamental $s_t - f_t^N$. 
5.4. Results for Other Emerging Markets Countries

In this section, we test for the existence of exchange rate bubbles in Colombian peso and Mexican peso against the US dollar.

**Colombian Peso (COP)**

As shown in Table 4, the null hypothesis of no bubbles in the nominal dollar-Colombian peso exchange rate $s_t$ is rejected at the 10% significance level. Figure 12a illustrates two episodes (1997M08-2001M09 and 2002M07-2003M04). The first episode is likely related with the Colombian Banking Crisis between late 1990s and early 2000s.

The nominal exchange rate $s_t$ is no longer explosive as the relative prices of traded goods fundamentals explain the explosiveness in Figure 12b, which is consistent with the theory from Engel (1999) and Betts & Kehoe (2005). On the contrary, the relative prices of nontraded goods fundamentals play little role in explaining the exchange rate explosiveness. In addition, we spot another three episodes in Figure 12c.

**Mexican Peso (MXN)**

Mexican peso was pegged to the US dollar and peso was allowed to appreciate or depreciate against the US dollar within a narrow target band. The Mexican central bank maintained the peg by frequently intervening in the exchange rate markets (Whitt Jr, 1996). As can be seen from Table 4, we find little evidence of explosive behavior in the nominal dollar-Mexican peso exchange rate $s_t$. The null hypothesis of no bubbles cannot be rejected at the 10% significance level although we can observe two episodes from Figure 13a (1998M08-1998M11, 2009M01-2009M03). As usual, the relative prices of traded goods fundamentals have explained the two small episodes in Figure 13b.

Most importantly and surprisingly, our results do not support the finding of explosiveness in the nominal exchange rate between 1994 and 1995. The 1994 Mexican currency crisis is one of the most well-known exchange rate crises in the literature. The North American Free Trade Agreement (NAFTA) came into force at the beginning of 1994 and was signed by Canada, Mexico and the US. The agreement aims at encouraging foreign investors to take advantage of Mexican’s access to the US market and lowering trade barriers between two countries (Whitt Jr, 1996). However, less than 12 months, the crisis erupted in December 1994, when the Mexican government suddenly devalued the peso by 15%. Devaluation of the peso led to a deep crisis in Mexico’s financial services sector (Wilson et al., 2000).
Overall, we may conclude that we could not find the significant evidence of bubbles or rational bubbles in the dollar-Mexican peso exchange rate.

6. Conclusion

Following the recent work of Bettendorf & Chen (2013) and Jiang et al. (2015), we use the GSADF test of Phillips, Shi & Yu (2015) PSY to investigate the evidence of exchange rate bubbles for both G10 and emerging markets countries (including some Asian and BRICS countries). The results can be summarized as follows.
Figure 13: Dating strategy for USD/MXN nominal exchange rate $s_t$, the relative ratio of the exchange rate to the traded goods fundamental $s_t - f_t^T$ and the relative ratio of the exchange rate to the nontraded goods fundamental $s_t - f_t^N$.

We have examined the presence of exchange rate bubbles in the G10 countries. Results for the G10 cross rates are presented in Table 1 and Table 2. As the results suggest, we could not find the evidence of bubbles in most pairs. However, there are a few exceptions including the Sterling-Swiss Franc and Sterling-Japanese yen. Not only do we find evidence of explosiveness in the nominal Sterling-Swiss Franc exchange rate but also evidence of rational bubbles. For Sterling-Japanese yen exchange rate, we find significant evidence of rational bubbles as the exchange rate fundamentals cannot explain the explosiveness in the nominal exchange rate.

Some interesting results are obtained from the Asian currencies against the US dollar. Firstly, in line
with the theory of [Engel (1999)] and [Betts & Kehoe (2005)], the relative prices of traded goods play an important role in explaining the majority of the movements in the dollar-Philippine peso, dollar-Indonesian rupiah and dollar-Singapore dollar exchange rates. Secondly, we conclude that neither the relative prices of traded goods nor the relative prices of nontraded goods could explain the explosiveness in the dollar-Thai baht and dollar-Korean won exchange rates, which confirm the presence of rational bubbles. Unlike the existing studies, our empirical results suggest that the relative prices of nontraded goods have explained most movements in the dollar-Malaysian ringgit exchange rate. In other words, our results also indicate that the exchange rate movements between Korea, Malaysia, Thailand and the US cannot be explained by the theory of [Engel (1999)] and [Betts & Kehoe (2005)]. More importantly, we also detect a spurious bubble from the nominal dollar-Malaysian ringgit exchange rate. Due to the presence of multiple breaks, the identifiability of explosive behavior for the GSADF test is affected. This spurious bubble episode may be an example that the GSADF test fails to detect the correct number of bubbles and seldom gives false alarms.

Our results from the three BRICS countries (e.g., Brazil, India and South African) suggest that the relative prices of traded goods account for the majority of the movements in exchange rate, which are in line with [Engel (1999), Betts & Kehoe (2005), Bettendorf & Chen (2013) and Jiang et al. (2015)]. The bubble detection results from Brazil and India suggest the non-existence of rational bubbles while the results from South African provide some evidence of rational bubbles.

Mixed results are found in the nominal dollar-Colombian peso and Mexican peso exchange rates. The explosiveness in the dollar-Colombian peso has been explained by the relative prices of traded goods while we find no significant evidence of explosive behavior in the dollar-Mexican peso exchange rates.

In this paper, we firstly test for the explosiveness in the nominal exchange rate. In order to investigate the cause of the explosiveness, we then explore whether the explosiveness in the nominal exchange rate is driven by rational bubbles or exchange rate fundamentals. If the exchange rate fundamentals play no role in explaining the explosive behavior, we may conclude the finding of rational bubbles. As explained by [Bettendorf & Chen (2013)], explosiveness in the asset price does not imply the existence of rational bubbles. We reach the same conclusion with [Bettendorf & Chen (2013)] that it is necessary to take economic fundamentals into consideration when testing for rational bubbles in asset prices.

References


Table 1: The GSADF test for exchange rate in G10 countries

Sample: 1991M3-2014M12

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<th>Currency</th>
<th>GSADF</th>
<th>Bubble Period</th>
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Table 2: The GSADF test for exchange rate in G10 countries

Sample: 1991M3-2014M12

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Table 3: The GSADF test for exchange rate in emerging markets countries.

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*aThe sample data for the Philippines ranges from January 1993 to December 2014.*
Table 4: The GSADF test for exchange rate in emerging markets countries.

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<td>s_t</td>
<td>2.7861***</td>
<td></td>
</tr>
<tr>
<td>s_t - f_t**</td>
<td>1.3143</td>
<td>98M04-98M07, 07M05-08M04</td>
</tr>
<tr>
<td>s_t - f_t**</td>
<td>0.7890</td>
<td></td>
</tr>
</tbody>
</table>

*The sample data for Brazil ranges from June 1994 to December 2014.