Testing for explosivity in US-Pak Exchange Rate via Sequential ADF Procedures

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Abstract

Global Financial Crises (GFC) of 2007-08 has disclosed the fact that economists and policymakers were unable to foresee bubble in housing prices in the US and other countries that consequently triggered the economic downturn. However, serious attempts have been made afterwards by researchers towards early identification of asset price bubbles, so that necessary policy measures could be taken to avoid any future mishap. Current study is conducted in similar vein to identify bubbles in nominal Dollar to Pakistani Rs exchange rate, from January 1982 to May 2020. Whether any identified bubble in nominal exchange rate is a rational bubble or otherwise generated by fundamentals, nominal exchange rate is adjusted for traded goods price differential and non-traded goods price differential in two countries as there is growing trend to take underlying fundamentals into account while studying asset prices to get accurate results on bubble detection (Bettendorf and Chen, 2013; Jiang et al., 2015 and Hu & Oxley, 2017). Further to explore whether nature of bubble changes with regime switching from managed floating to flexible floating in Pakistan is an addition of the study. Results of Generalized sup Augmented Dicky-Fuller (GSADF) test show that traded goods fundamental fully explain the movements in exchange rates even when non-traded goods are taken into account. Exchange rates were volatile both in managed floating and flexible floating regimes. However, volatility in only managed floating regime can be attributed to traded goods price difference. Various explosive episodes have been observed during flexible floating regime, which are either collapse or collapse and recovery phases.

Key Words: Multiple Bubbles; Explosive Behavior; GSADF test

JEL Classification: F3, F31, G1, G12

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1. **Introduction**

Today in a globally connected word, economic shocks in one economy can spillover to the rest of the world (Berrospide et al., 2016; Gulzar et al., 2019; Bhattarai et al., 2020). Recently the financial crises of 2007-08 originated in the US, resulted in huge losses not only for the US economy but sparked the global recession. As proclaimed by analysts and researchers, the root cause of the financial meltdown was the crash of US housing bubble in 2007 (see for review Acharya and Richardson, 2009; Claessens et al., 2010). The recent case is not the only crises leaded by real estate bubble, but most of the asset price bubbles had negative consequences when it burst (Merrett, 1989, 1993; Kindleberger, 1996; Murphy, 2005; Dagher, 2018) although exceptions are there when bubbles can be socially useful (White, 1990; Eatwell, 2004; Nicholas, 2007; Janeway, 2018). The intuition underlying positive linkage between financial crises and economic bubble is that when asset prices escalate, investors despite knowing that price of the asset is not justified, still invest in the asset in the hope that in the future, asset value will increase further. Therefore they hold the asset and do not sell Due to high demand, the price of asset reached the level beyond its productive capacity and time changes when no one is willing to buy it further. Consequently price of asset falls drastically, and people start selling the asset even at below the purchased price to avoid further loss that creates panic situation in the market (Kindleberger, 2000).

Economic bubbles have prolonged history that affected commodity markets, financial securities and real estate equally. For example first known bubble, the Tulip Mania extends from 1634 to 1637. Bubble existed since statistics showed that the price of tulips exceeded the price of a luxury home apartment in Amsterdam. Traders were buying bulbs not because they needed it, but they were purchasing the commodity intending to sell it at a higher price to earn profits. After 3 years of price escalation the bubble collapsed in 1637 when new buyers rejected buying the bulbs that resulted in sharp decrease of prices and burst of bubble. Thus various investors suffered loss by selling the commodity lower than purchased price due to unfavorable market conditions. Japanese asset price bubble (1986-1991) is characterized by inflation in the stock and real estate prices. Prices were increased due to high speculation on values of the assets that were further stimulated due to uncontrolled money supply and credit expansion. After overwhelming boom over a period 5 years, finally the bubble burst in 1992 that stagnated Japanese economy. The 1990s was a period of internet. In the era bubble occurred in the stock market of internet related companies known as the dot-com bubble (1990). During the period from 1995 upto 2000, the Nasdaq composite stock market index rose 400 %. The stock market was crashed in 2002 and several companies such as Boo.com, Global Crossing, Pets.com and Worldcom were failed and shut down. Devastations caused by burst of rational bubble in asset prices increases when the asset is closely integrated with other assets and financial institutions (Ali, 2008). One such case can be seen in the shape of the United States housing bubble (2007-2008) which when collapsed, led world into financial crises. The major reason behind the crises were low interest rates and loose lending standards that increased people demand for homes leading to high home prices. Lending banks showing these loans as assets on their financial statements were sold to investment banks, which reshape them into financial instruments such as mortgage-backed securities (MBS) and collateralized debt obligations (CDO). Eventually, home prices started to decline due to decreasing demand as borrowers were reluctant to get loans due rising interest rates in 2004. The collapse of the housing bubble had serious consequences not only for home valuation, but led crises to home builders, real estate, mortgage market, home supply outlets and hedge funds etc.

Detection of bubble at an early stage is more important in the case of economic factors which have become more intertwined together today than even before. Exchange rate (hereafter ER) is one among these factors. For instance, past incidents of ER bubble caused financial crises. Most famous are the Sterling crisis in 1976, Black Wednesday (crisis in UK currency) in 1992, Mexican Peso Crisis in 1994–95, and the Asian Crisis in 1997–98. ER is considered as the most critical policy variable since its fluctuations determine economic performance (Kandil et al., 2006). There is often debate over a currency ER. Economists and policymakers believe that currency depreciation increases competitiveness in the international market, as it makes exports cheaper and imports expensive. Hence exports demand increases, and imports demand decreases, which positively affects trade balance (Baharumshah, 2001; Brahmasrene 2002; Lal and Lowinger 2003; Onafowora 2003; Stucka 2004; and Tochitskaya 2005). Moreover, it positively affects foreign direct investment and remittances; as a result, it stimulates the Gross domestic product (GDP) (Aizenman, 1992; Dollar, 1992; Hausmann et al., 2005; Rodrik, 2008; Di Nino et al., 2011; Habib et al., 2017). However some studies find adverse effects of currency devaluation for trade balance (Upadhyaya and Dhakal 1997; Kale 2001; Shahbaz et al., 2011), for economic growth (Cooper, 1971; Krugman and Taylor, 1978; Kamin, 1988; Edwards, 1989; Lizondo and Montiel, 1989) among others. Apart from unidirectional relationship in which ER affects other macroeconomic variables, Raza and Afsha (2017) find that ER and economic growth have bi-directional relationship. Other factor affecting ER of a country is the United States dollar (US D). US D is the most dominant currency, and most of the assets are denominated in dollars in the global market. Similarly, to build up a foreign reserve and to manage current accounts balance, most of the developing countries align their currencies to the US D. As a result, economies are not only affected by their internal circumstances but also of the US (Zhang & Yao, 2016). However, this put currencies in a very vulnerable situation, as those may be affected by any unanticipated fluctuations in the value of US D.

Bubbles have been successfully detected in ER of various economies in the past (Van Norden, 1996; Jiang et al., 2015; Hu & Oxley, 2017). However, no serious attempt has been made to investigate this phenomenon for Pakistani Rupee (Rs)-US D ER. Pakistan experienced different ER regimes over time, like a fixed ER regime from 1947 to 1981 and afterwards dirty floating ER system upto 2000. These reforms were fruitful for newly established country since fixed ER system stabilizes prices and increases efficiency of monitory policy (Barro and Gordon, 1983; Velasco, 1996; Dornbusch, 2001). Similarly dirty float, an ER system where central bank of a country occasionally intervenes to set currency value, was a world popular ER system after abolishment of Bretton Woods agreement (Garber, 1993). Along with these improvements, unfortunately in 1998 Pakistan faced severe international sanctions in response to its nuclear tests. Later on, Pakistan joined the war on terror, which significantly changed the economic, political, and social position of Pakistan. This may contribute in ER fluctuations as Saeed et al (2012) argue that factors affecting exchange rate may be economic, political and psychological. In 2000 Pakistan adopted flexible ER system and it is maintained to date. In other words, now ER of Pakistan is set according to demand and supply forces, without government intervention. Thus, the country experienced various shifts in policies related to ER that might fluctuated its value (De Grauwe and Vansteenkiste, 2007). However previous ER related studies, conducted in Pakistani context ignore this possibility that only focus on examining determinants and or effects of ER. With these insights Pakistan provides an interesting case to test ER bubbles.

The rest of the paper is organized as follows: Section 2 deals with the literature review, section 3 provides a theoretical background of ER bubbles and section 4 discusses methodology. Empirical results are discussed in section 5, and conclusion of the study is made in section 6.

2. Literature Review

Bubble in asset prices can only be detected if we know intrinsic value of the asset, such as deviation of market price of the asset from its fundamental value is considered as bubble (Reza, 2010). However, measurement of fundamental value is a difficult task. On the other hand, researchers based on various assumptions made about actual price series, proposed several methods to identify bubbles. Among these most well known are "variance bound test (volatility test)" introduced by Shiller (1981), "Hausman specification test" introduced by West (1987a), "unit root and cointegration based test" of Johansen (1988) and Johansen and Juselius (1990), and "two-regime Markov-switching unit root test (MSURT)"of Hall et al., (1999). However, success stories of these tests are mixed and content specific.

Previous literature shows that West (1987b)use volatility test to identify bubble in Dollar-British Pound (D-BP) ER, but he could not find any significant evidence of bubble. However, by using Hausman test he concludes that bubble exists in Dollar-Deutsche Mark (D-DM) ER and D-BP ER (West, 1987a). Moreover, Evans (1986) finds that ER bubbles exist in these currencies in the early 1980s. Similarly, Meese (1986) has used hybrid monetary exchange rate models and Hausman's specification test to investigate bubbles in D-BP, D-DMand Dollar-Japanese Yen (D-JY) ER for the period of 1973 to 1982 and reject the joint null hypothesis of no bubble. However, the main problem with West and Meese methodology is that it does not identify which factor is responsible for the bubble,for instance, it is possible that bubbles may be speculative in nature, or market fundamentals may be misspecified or market agents may behave irrationally etc.

Similarly, MSURT has also certain limitations. As revealed by Shi (2011)these models often lead to false detection or show spurious explosive behavior. Moreover, Funke at al., (1994) and Norden and Vigfusson (1998) note that when regime-dependent error variance is allowed, it is difficult to distinguish between genuine or spurious explosive behavior. In addition to these limitations, Psaradakiset al., (2001) argued that the MSURT with embedded bootstrapping procedure is computationally burdensome. Hence, due to these pitfalls, MSURT seems difficult and unreliable tool of financial inquiry. Furthermore, Wu (1995)has used "Kalman filter technique" and "unit root test" on D-BP and JY-DM ER to investigate the unobservable component of ER. However, he does not find any significant evidence in support of bubbles in ER, which again shed doubts on earlier studies.

Besides the limitations of earlier methods, Diba and Grossman (1988) have observed that explosive series are non-stationary both in levels and after first difference. Moreover, if a series has a bubble component then it follows an "explosive autoregressive process". This implies that it will not become stationary after first difference. Based on the observations they proposed standard "left tailed regression based unit root test" to test the null hypothesis of no explosive behavior. However, the latest bubble detection test is based on the right-tailed Dicky Fuller test to the level of the series. Phillips et al. (2011) have made the first contribution in this field by investigating stock markets for bubbles. They have used "forward recursive right-tailed DF test statistics" to investigate the explosive behavior in NASDAQ composite stock price and dividend index from the period of February 1973 to June 2005. They identify dot-com bubble in the mid of 1995. Phillips et al. (2011) proposed test is extensively used in econometrics and finance literature to identify bubbles, because of its strong power properties and procedural simplicity (see Gilbert, 2010; Homm and Breitung, 2012; Bettendorf and Chen, 2013). Gilbert (2010) has found explosive behavior in the prices of various commodities by using commodity price data from 2000 to 2009. Similarly, Homm and Breitung (2012) have found bubbles in stock prices, commodity prices and house prices using Chow-type test and PWY test. Using sequential unit root test, Bettendorf and Chen (2013) argue that nominal S-D ER has explosive behavior. Furthermore, they investigate the causes of explosiveness by examining underlying fundamentals and conclude that traded goods fundamentals explain the explosive behavior of S-D ER and identified bubbles cannot be regarded as speculative bubbles. However, the PWY test has a serious limitation, that it cannot detect more than one asset price bubble. Jirasakuldechet al., (2006) find no significant evidence of a rational speculative bubble in ER of D-BP, US D and Canadian Dollar (D-CD), D-JY, South African Rand (SAR) and US D by using cointegration analysis. They note that bilateral ER follows AR(1) process and it is cointegrated with US dollar.

Moreover, Jiang et al., (2015) find two bubbles in nominal D-RMB ER using generalized sup ADF (GSADF) test. Whereas the first bubble occurs in 2005-06 and second bubble occur in 2008. They believe that the first bubble is not because of price difference of both traded and non-traded goods in domestic and foreign countries. However, the second bubble is because of traded goods price difference. Similarly, Montasseret al., (2016) have also found that the relative prices of traded goods cause explosive behavior in China-US ER from 2005 onward. They have used right-tailed unit root (sup Augmented Dickey-Fuller (SADF) and GSADF tests to reach this conclusion.Hu and Oxley (2017)investigate ER bubbles in some G10, Asian and BRICS countries from March 1991to December 2014. For this purpose, they use nominal ER, nominal ER deflated by traded goods differential and nominal ER deflated by non-traded differential of the countries. Their study concludes that the US D-Mexican Peso crisis of 1994–95 was a bubble.

Fundamentals of ER are not limited to traded and non-traded goods prices differentials in domestic and foreign countries as previous studies show that other economic factors also determine ER. Mainly, attempts to identify relevant determinants of exchange rate volatility intensified since breakdown of Bretton woods system when currencies were no more pegged with US D, in order to minimize ER risk. In this regard Holden et al., (1979) employing OLS method on a data of 75 countries find that inflation rate differential and GDP significantly positively affect exchange rate volatility, while openness of economy, product concentration and geographical concentration significantly negatively affect exchange rate flexibility. Similarly using least square method for a data of 35 countries, Sarno and Schmeling (2014) find significantly lower future inflation, growth in money balances, GDP growth, and interest rates for countries whose currencies appreciated against US D than those countries whose currencies depreciated. Other strand of literature (e.g., Meese and Rogoff, 1983; Flood and Rose, 1995 and Rose, 1996) suggests that a non-linear relationship exists between ER and fundamentals. Ma and Kanas (2000) use two nonparametric tests to examine non-linear relationship between fundamentals and bilateral ER of three countries that is France, Germany and Netherland, making two pairs namely Netherland-Germany and France-Germany. The first approach, non-linear Cointegration test suggests existence of long run non-linear relationship among money supply, output and Netherland-Germany ER. However they fail to find evidence of non-linear cointegration for France-Germany ER. The second, non-linear Granger-causality test reveals non-linear causality from French money to France-Germany case only. De Grauwe and Vansteenkiste (2007) examine whether relationship between fundamentals and nominal ER (hereafter NER) is non-linear. For this purpose they apply Markov switching model to a sample of low and high inflation countries. Results of the study show that for high inflation countries fundamentals such as change in money supply, change in inflation and change in bond yield have significant stable relationship with ER. However ER of low inflation countries does not show stable relationship with underlying fundamentals. These results are also confirmed by using two non-linear models which are based on the existence of transaction costs and existence of different types of agents using different information to forecast the future ER respectively.

Previously noted studies show that researchers are not in consensus to specify exact factors affecting ER. Also, whether relationship between fundamentals and ER is linear or non-linear, divergence of beliefs exists. On the other hand, theory of purchasing power parity (PPP) states that ER is the ratio of the price levels of goods in two countries. Goods may be traded goods or non-traded goods. Rostom (2007) asserts that if PPP holds, NER only depends on price level in two countries. In such a scenario we only left with constituent variables of ER namely traded goods price differential and non-traded goods price differential in domestic and foreign countries as economic fundamentals of NER (Bettendorf & Chen, 2013; Jiang et al., 2015). Other studies suggest that NER needs to be adjusted for variations in local and international prices to reap the benefits of nominal devaluation policy (see for example

Bahmani-Oskooee, 1998; Bahmani-Oskooee and Gelan, 2007). Ogun (2012) provides evidence that in developing countries inflation rate differential is negatively associated with ER. Various studies on ER predictability are conducted in Pakistani context based on PPP theoretical framework. Among these studies, Zada (2010) using data from 1979 to 2008 empirically show that high inflation rate leads to the depreciation of Pakistani currency. Moreover, Parveen et al. (2012) based on data over a period of 1975 to 2010 provide evidence that inflation decreases ER of Pakistan.

Obstfeld and Rogoff (1986) assert that the NER must be considered as an asset price. To determine true value of an asset previous studies mostly use present value model (Scott, 1985; Campbell and Shiller, 1987; Falk, 1991; Pindyck, 1992; Bohl & Siklos, 2004). Thus, based on the same theoretical foundation we first hypothesize ER and then measure its fundamental components in subsequent section.

3. Theoretical Background

In lines withEngel and West (2005), Bettendorf and Chen (2013) and Jiang et al., (2015), we use following model to measure present value of ER:

$$s_t = (1-\alpha)\sum_{j=0}^{k} \alpha^j E_t(f_{t+j}) + \alpha^{k+1} E_t(s_{t+k+1}) \qquad [1]$$

Where, s_t indicates NER, f_t indicates market fundamental at time period 't' and α indicates discount factor. Similarly, transversality condition is

$$\lim_{k\to\infty} \gamma^k E_t(s_{t+1}) = 0 \qquad [2]$$

This implies that "exchange rate will only depend on future expected fundamentals in the long run". But if this condition failed to hold, then ER may lead to an explosive rational bubble and possess AR(1) process$b_t = \frac{1}{\gamma} b_{t-1} + \varepsilon_t$. Moreover, AR(1) coefficient $\frac{1}{\gamma} > 1$ and $\varepsilon_t \sim \text{NID}(0, \sigma 2)$.

Hence NER can be written as

$$s_t = s_t^f + b_t \text{or } s_t - s_t^f = b_t \qquad [3]$$

Where b_t is bubble component and s_t^f is the discounted sum of all future economic fundamentals and is linearly dependent onf_t, where $f_t$is I(1).

According to PPP economic fundamental for the NERis defined as the price differential between domestic and foreign price indices i.e.,

$$f_t = p_t - p_t^* \qquad [4]$$

Where, p_t indicates log of the domestic price index and p_t^* indicates the log of theforeign priceindex. Engel (1999)demonstrates that price index is a weighted average of traded and non-traded goods prices. Hence for domestic country

$$p_t = (1-\alpha)p_t^T + \alpha p_t^N \quad [5]$$

Where p_t^T indicates a log of the traded goods price index of domestic country, p_t^N a log of the non-traded goods price index of domestic country and α the share of the non-traded goods component.

On the other hand foreign price index

$$p_t^* = (1-\alpha)p_t^{T*} + \alpha p_t^{N*} \quad [6]$$

Asterisks denote foreign country.

Hence equation (4) can be written as

$$f_t = (p_t^T - p_t^{T*}) + \alpha(p_t^N - p_t^T) - \beta(p_t^{N*} - p_t^{T*}) \quad [7]$$

It shows that price differential (f_t) can be decomposed into traded goods component $(p_t^T - p_t^{T*})$ and non-traded goods component $\{\alpha(p_t^N - p_t^T) - \beta(p_t^{N*} - p_t^{T*})\}$.Normally Producer price index (PPI) is used to measure price level of the traded goods. In the case of Pakistan, data on PPI is not available. However, data on Wholesale price index (WPI) is available, which is closely related to PPI. So we will use WPI for Pakistan and PPI for US to calculate traded goods component (f_t^T) as follows:

$$f_t^T = lnWPI_t - lnPPI_t^* \quad [8]$$

The non-traded good component(f_t^N) is constructed from aggregate consumer price index (CPI), Wholesale price index (WPI) and Producer price index (PPI) as follows:

$$f_t^N = \ln(CPI_t) - \ln(WPI_t) - [(\ln(CPI_t^*) - \ln(PPI_t^*)] \quad [9]$$

4. Methodology and Data Sources

4.1 Generalized sup Augmented Dicky-Fuller (GSADF) test

Global financial crises of 2007-08 haveraised the questions on the already existing techniques which are used to identify bubbles. Identification of bubble is a challenging task. A lot of tests have been devised in this field. However, each has certain limitations as we have discussed in the second section. To Phillips et al. (2011) has proposed a sup ADF (SADF) test to investigate the price bubble and its timing.

$$SADF\ (r_0) = \sup_{r_2 \in [r_0, 1]} \{ADF_o^{r_2}\} \quad [10]$$

P. C. Phillips and Yu (2011); P. C. Phillips et al. (2011); P. Phillips et al. (2012) and P. C. Phillips et al. (2015) introduced new techniques to identify bubbles. Their work is based on the idea that random walk behavior is different from explosive behavior and speculative bubbles emerge not just after their collapse. They have devised a new recursive methodology that considers explosive unit roots to detect bubbles. The traditional testrestricts to an autogressive process where $\delta \leq 1$. But the test devised by P. C. Phillips and Yu (2011), they consider δ can exceed unity but it is still in the neighborhood of unity. This helps in calculating recursively right-tailed unit root test (RT-UR) to assess all possible bubbles. The right-tailed test is different from the left tailed test for stationarity.

Homm and Breitung (2012)find that the SADF test is an effective way to detect bubbles. However, the SADF test has certain limitations. In SADF testfirst observation is the starting point which remains fixed. Now if there exist two bubbles and the first bubble is dominant, then the SADF test may fail to detectthe second bubble. To overcome this limitation P. C. Phillips et al. (2011) has introduceda rolling version of SADF test, in which starting window is not fixed, it moves over the sample, however,the size of the starting windowremains same. To overcome this limitation, P. C. Phillips et al. (2015)nested SADF test and rolling SADF test in the GSADF test. It has the ability to detect multiple bubbles.

$$GSADF\ (r_0) = \sup_{r_2 \in [r_0, 1], r_1 \in [0, r_2 - r_0]} \{ADF_{r_1}^{r_2}\} \qquad [11]$$

Here r_2 is enthe d point, which varies fromr_0 to 1, where r_0 is the minimum window size. Similarly, r_1 also varies from 0 to $r_2 - r_0$. Hence the GSADF statistics varies over the range of $r_2 - r_0$. P. C. Phillips et al. (2015) notes GSASDF distribution depend on the minimum window size r_0. If r_0 is too small, then estimation would not be possible and if it is too large, then there is a chance that we might misssome early bubble. Therefore, by following P. C. Phillips et al. (2015)and Hu and Oxley (2017) we use formula for r_0: $r_0 = 0.01 + \frac{1.8}{\sqrt{T}}$, where T is a number of observations. P. C. Phillips et al. (2015)notes that this rule provide satisfactory window size.P. C. Phillips et al. (2015)suggests that over-specified lag order leads to severe size distortion problem, hence the lag length of size zero is used in the study. Similarly, Monte Carlo simulations with 1000 replications are used to find finite critical values.

Finally, following P. C. Phillips et al. (2015)we have used an empiricalmodel with an intercept to investigate the explosive bubble. P. C. Phillips et al. (2015)has used different regression model specifications like with and without intercept, trend and without trend, and conclude that the model with intercept term performs better with real data. However, sometimes inclusion of intercept may lead to false (positive) bubbles when actually there was "collapse" or "collapse and recovery phase"(Hu & Oxley, 2017). This issue can easily be resolved by visual inspection. The backward SADF statistics along with 95% critical value is used to analyze this issue.

4.2 Data and its source

Historically Pakistan has adopted three types of ER policies. First prevailed since independence of Pakistan in 1947 upto 1981 when Rs was initially pegged with British Pound and later on integrated with US D. Second started in 1982 when dirty floating ER system was introduced in Pakistan. Third, brought in force in 2000 in the shape of flexible float that is maintained till date. According to De Grauwe and Vansteenkiste (2007) fixed ER is characterized by stable rates. Therefore, we exclude fixed ER period and use data starting from 1982 to analyze ER volatility due to shift in policy from managed floating to flexible floating. Further to identify bubbles in ER of Pakistan we are expressing Rs in world most dominated currency of the US D through direct quotation. Due to non-availability of a higher frequency prices, only monthly data on nominal Pak-US ER (NER) from January 1982 to May 2020 has been extracted from International Financial Statistics (IFS) on International Monetary Fund (IMF) site. In case of missing values, alternate sourcewww.exchangerates.org.uk site is used. To examine whether any explosive behavior of ER is merely due to economic factors, we follow two steps procedure. First, we construct traded goods fundamental (f^T) and non-traded goods fundamental (f^N) by employing equations 8 and 9 respectively for which CPI (for Pakistan and US), PPI (for the US) and WPI (for Pakistan) are collected from IMF database. Then we adjust the NER to both fundamentals by taking ratios as follows:

$$NERT_t = NER_t/f_t^T \quad (12)$$

$$NERNT_t = NER_t/f_t^N \quad (13)$$

In the above equation NERT stands for the ratio of NER to traded goods fundamental (f^T). NERNT stands for the ratio of NER to non-traded goods fundamental (f^N). Remaining variables are as described in previous lines. Like fundamentals we also convert NER into logged form to make all time series consistent. Second, if NER series exhibits explosive behavior during a period which is also show by both NERT and NERNT, then it is sign of rational bubble as exuberance in NER is not created by traded goods and non-traded goods (Hu & Oxley, 2017).

5. Results

5.1 Descriptive Statistics

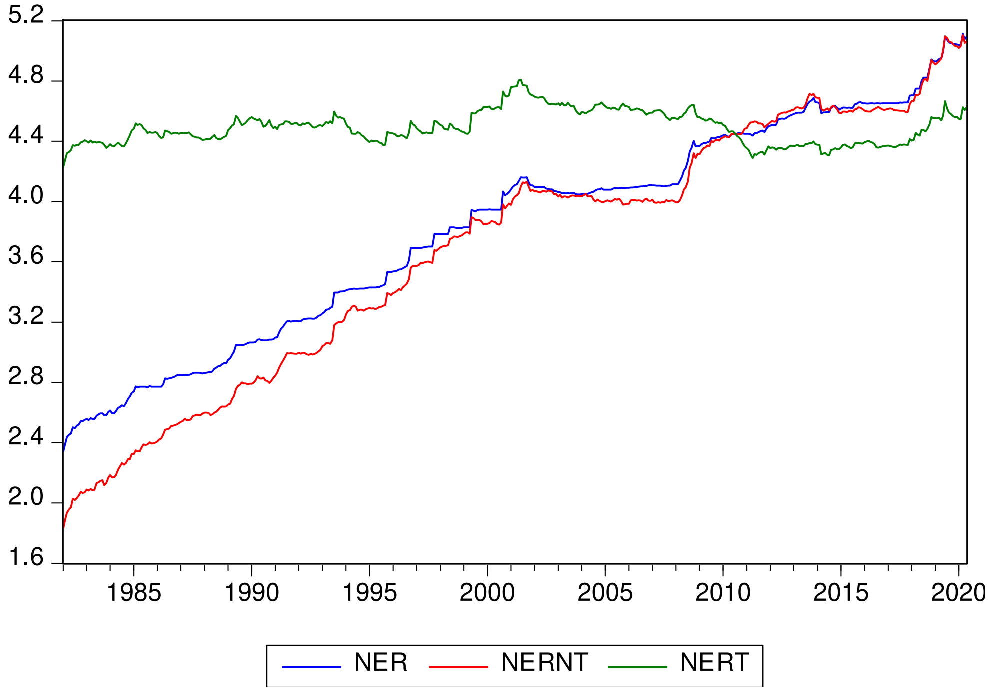
Summary statistics of three time series namely NER, NERT and NERNT are provided in table 1. Mean value of NER (3.817) is greater than that of NERNT ratio (3.682) and less than that of NERT ratio (4.493). These values show that on average, difference in prices of non-traded goods is greater than disparity in prices of traded goods of the two countries. Thus, it can be implied that mostly high prices of non-traded goods in Pakistan depreciate Rs against the US D. Std. Dev of NER (0.723) is close to that of NERNT (0.857) and away from that of NERT (0.108). Thus, prices of non-traded goods cointegrate with NER and any unanticipated change in NER is probably due to prices of traded goods. Similarly graphical presentation of all three series is provided in Fig (1). It shows that both NER NERNT are slopping upward. Thus, NER is almost depreciated during the study period that is accompanied by decreasing non-traded goods price difference in two countries. On the other hand NERT line graph is almost horizontal. Comparing NERT with NER it can be deduced that on average, traded goods price difference in two countries increased during the period. Normality tests statistics depict that data used in analysis is not normally distributed as p value of Jarque-Bera test for each data series is less than 0.05. On the part of skewness, NER and NERNT are skewed left while NERT is skewed right. Similarly, kurtosis shows that all 3 distributions include extreme values. Still normality is not a requirement in our case and analysis can be conducted with non-normal data.

Table 1: Basic Summary Statistics

Statistic	NER	NERNT	NERT
Mean	3.817	3.682	4.493
Median	4.051	3.985	4.483
Maximum	5.114	5.105	4.808
Minimum	2.341	1.830	4.229
Std. Dev	0.723	0.857	0.108
Skewness	-0.257	-0.386	0.373
Kurtosis	1.883	1.962	2.521
Jarque-Bera	29.028	32.169	15.078
Probability	0.000	0.000	0.001

Note: Total number of observations are 461 (Jan 1982—May 2020)

Figure 1: Plot of data series



5.2 Estimation Results

One of the characteristics of GSADF methodology is that it can detect multiple bubbles by examining data series over rolling windows. Similarly, researchers have option to set any suitable window length to perform the analysis. Also, previous studies, conducted in various contexts provide evidence that ER contain multiple bubbles. Due to these facts, we apply the GSADF test on all 3 ER variables (NER, NERT and NERNT) where window size is 161. Results of test statistics are presented in table 2. P value of the statistic for each variable is less than 0.01 significance level which indicates existence of multiple bubbles for these variables. On the other hand results of test statistics of older version of GSADF that is SADF provided in the table do not suggest for bubble existence in the data as p value of the statistic is not less than even 0.10 significance level for any variable. Phillips et al. (2012) show that advanced version of SADF test that is GSADF test outperforms due to its capability of detecting multiple bubbles and compatibility with small size samples. By rolling windows of appropriate size, this test examines for bubbles in more subsamples of the data. Based on this argument, we can conclude that multiple bubbles exist in the Pakistani Rs-D ER.

Table 2: Results of SADF and GSADF Statistics

Nominal Exchange Rate (NER)		
S. No.	**Statistic**	**p-value**
SADF	0.121	0.583
GSADF	12.011***	0.005
Nominal Exchange Rate to Non-Traded Goods Price Differential (NERNT)		
S. No.	**Statistic**	**p-value**
SADF	-0.383	0.813
GSADF	6.360***	0.000
Nominal Exchange Rate to Traded Goods Price Differential (NERT)		
S. No.	**Statistic**	**p-value**
SADF	-1.158	0.975
GSADF	3.298***	0.002

Note: *** indicates significance at 1% significance level.

To specify bubble episodes, we compare Backward SADF statistics with 95% critical value obtained from Monte Carlo simulations with 1000 replications. If observed SADF statistic is more than its calculated value then it is an indication of exuberance in ER series during the period. Based on the criteria we observe multiple bubbles for all three series and their date stamps are provided in table 3 (Panel A-C). To make the picture clearer, bubble date stamps are accompanied by graphical view of original ER series, Backward SADF statistics and its critical values for each variable as presented in fig (2-4). Whenever graph of SADF statistic lies above the line of critical values, it corresponds to exuberance in ER series during that particular period. Hu & Oxley (2017) argue that not every exuberance is bubble but if data series is continuously growing during explosive episode, we call it collapse phase due to home currency devaluation. On the other hand, if data series is continuously declining it is a sign of bubble phase; and if it is initially growing and then declining it indicates collapse and recovery phase.

Results on bubble date stamps of NER are provided in table 3 (Panel A). It shows exuberance for NER during September 1988 to July 2000 as null hypothesis of no bubble is rejected at 0.05 significance level. Also if we look at Fig. 2, Backward SADF sequence (blue line) lies above 95% critical values (red line) during the period. Further actual NER graph shows upward trend which is continuously growing until the end of the period that is July 2000.This behavior corresponds to collapse phase in NER. Duration of collapse phase show that Pakistani Rs depreciated against USD during dirty floating ER which is abandoned in July 2000 and flexible ER system is introduced. Whether the explosive behavior of NER is due to investors' rational speculation or otherwise driven by ER fundamentals, we observe that most of the time during the session, NERNT is also explosive. For example, table 3 (Panel B) shows that NERNT exhibits both short lived bubbles having less than year duration (May 1986-Sep 1986, May 1989-Oct 1989, Mar 1990-May 1990, Mar 1991-Jan 1992, May 1999-Aug 1999) and long-lived bubbles having more than year duration (Jul 1993-Aug 1994, Sep 1996-Aug 1997, Oct 1997-Mar 1999). Thus, non-traded goods have little role in generating NER bubble.

There are other bubble episodes in NER. First one is extended from June 2006 to May 2007 and second one is extended from November 2007 to February 2008.However, NERNT does not show any explosiveness during June 2006 to February 2008. Table 3 (Panel C) does not show any explosiveness for NERTtill end date of the most recent bubble extended from November 2007 upto February 2008 that is evidence that traded goods fully explain all previous bubbles occurred in NER and NERNT. Next bubble in NER is observed during May 2008 to February 2014 while for NERNT it spans from June 2008 to June 2014. On the other hand statistics on NERT show that currency crises exist only from August 2010 to November 2011 and volatility in NER for remaining period is due to traded goods prices. It can be observed from published sources of data that ER is continuously decreasing from August 2010 to November 2011. For example, D is trading for Rs 85.64 Rs on 31 August 2010, Rs 85.73 on 30 September 2010, Rs 86.53 on 31 October 2011 and Rs 86.68 on 30 November 2011. The continuous depreciation of Rs can be regarded as collapse phase of ER. Apart from currency devaluation, during 2010-11 economy was adversely affected by rising oil prices from $70/barrel to $125/barrel. Record floods during the period resulted in nearly $10 billion loss to the economy. Due to destruction of crops, growth in agriculture sector decreased to below zero level. This was accompanied by reduction in manufacture sector production. Growth in services sector was 4.1%, below than target 5.4%.

NER remains bubbly for two more times that is April 2015-February 2018 and April 2018-May 2020. On examining other series, it is evident that corresponding to former bubble, results on NERT and NERNT confirm that bubbly behavior in NER is due to relative prices difference in both traded and non-traded goods. With respect to later bubble, NERNT have almost same episode i.e June 2018 to May 2020. However, NERT have two episodes having short duration i.e Oct 2018- Mar 2019 and May 2019- Jul 2019. Thus, traded goods partially explain exuberance in NER. If we look at Figure 4, the graph for NERT is continuously growing during Oct 2018-March 2019. Similarly, data shows that ER is decreasing as D is trading for Rs 132.54 on 31 October 2018, Rs 134.19 on 30 November 2018, Rs 139.64 on 28 February 2019 and Rs 140.67 on 29 March 2019. This may be regarded as collapse phase for NERT. It is also obvious from Figure 4 that NERT series initially grows and then declines during May 2019 to July 2019. ER is decreased from Rs 146.86 on 31 May 2019 to Rs 163.75 on 30 June 2019 that is increased to Rs 160.75 on 30 July 2019. These fluctuations can be considered as collapse and recovery phase in ER.

The Rs depreciation in 2018-19 may be due to previous government which is said to have kept value of Rs artificially high during its tenure. Similarly, Nomura Holdings Inc, predicted at that time, that Pakistan was one among seven countries which could face exchange rate crises in the near future across thirty emerging markets. Main reasons for the Rs appreciation in July 2019 may be inflows of remittances from overseas Pakistanis ahead of Eid and shirking demand locally as the State Bank had tightened rules and regulations for opening letters of credit for imports. However traded goods fundamental do not justify these factors of appreciation and as a result bubble is emerged.

Table 3: Bubble date stamping for Pakistan Exchange Rates

Panel A - Nominal Exchange Rate (NER)			
S. No.	**Start Period**	**End Period**	**Duration (months)**
1	Sep 1988	Jul 2000	142
2	Feb 2001	Sep 2001	7
3	Jun 2006	May 2007	11
4	Nov 2007	Feb 2008	3
5	May 2008	Feb 2014	69
6	Apr 2015	Feb 2018	34
7	Apr 2018	May 2020	25
Panel B - Nominal Exchange Rate to Non-Traded Goods Price Differential (NERNT)			
S. No.	**Start Period**	**End Period**	**Duration (months)**
1	May 1986	Sep 1986	4
2	May 1989	Oct 1989	5
3	Mar 1990	May 1990	2
4	Mar 1991	Jan 1992	10
5	Jul 1993	Aug 1994	13
6	Sep 1996	Aug 1997	11
7	Oct 1997	Mar 1999	17
8	May 1999	Aug 1999	3
9	Jun 2001	Sep 2001	3
10	Jun 2008	June 2014	72
11	Aug 2014	Oct 2014	2
12	Jun 2018	May 2020	23
Panel C - Nominal Exchange Rate to Traded Goods Price Differential (NERT)			
S. No.	**Start Period**	**End Period**	**Duration (months)**
1	Aug 2010	Nov 2011	15
2	Oct 2018	Mar 2019	5
3	May 2019	Jul 2019	2

Figure 2: Bubbles Date Stamping for nominal exchange rate (NER)

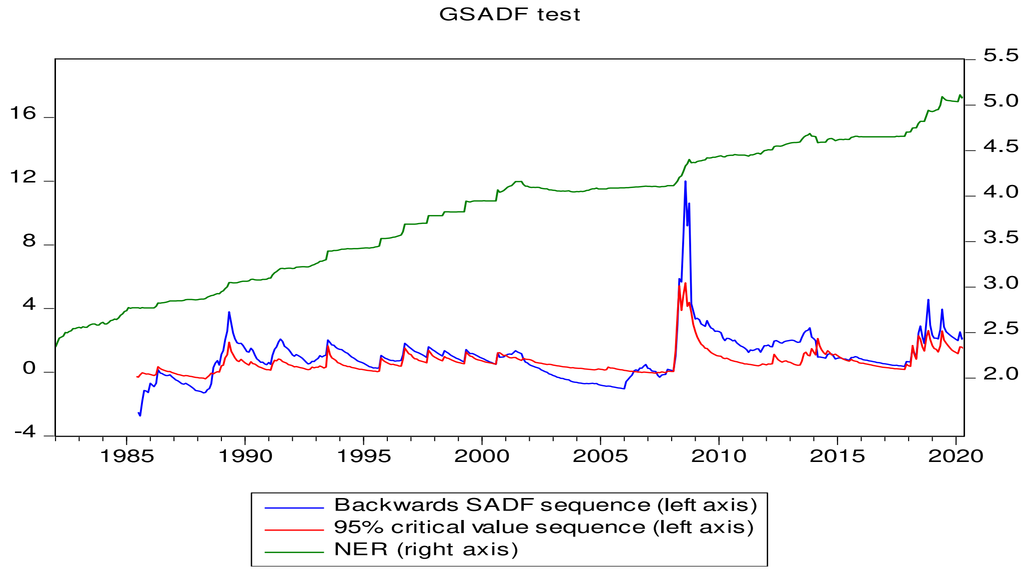


Figure 3: Bubbles Date Stamping for nominal exchange rate to non-traded goods price differential (NERNT)

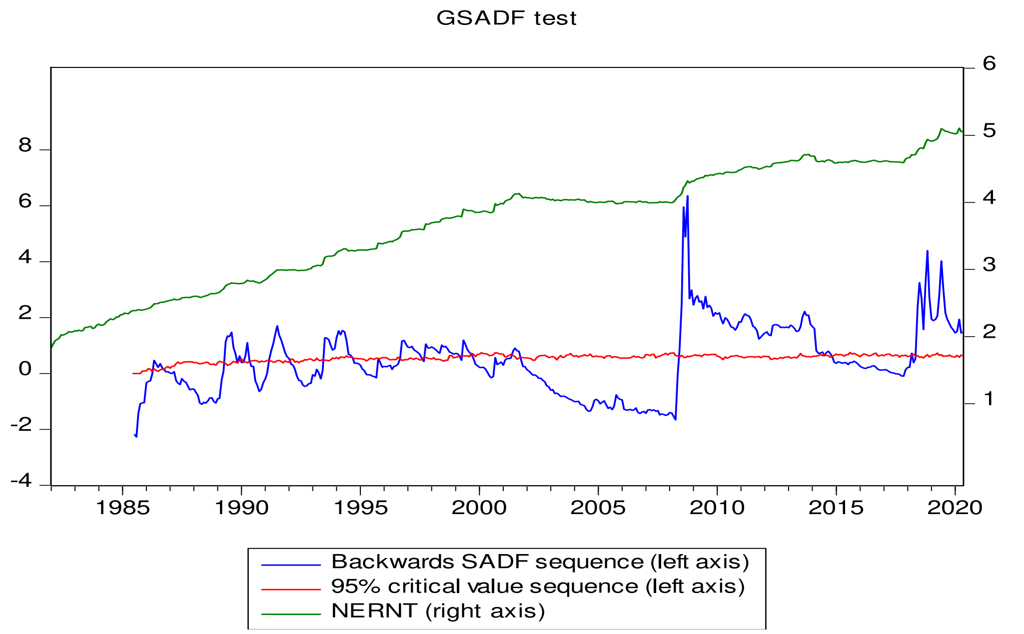
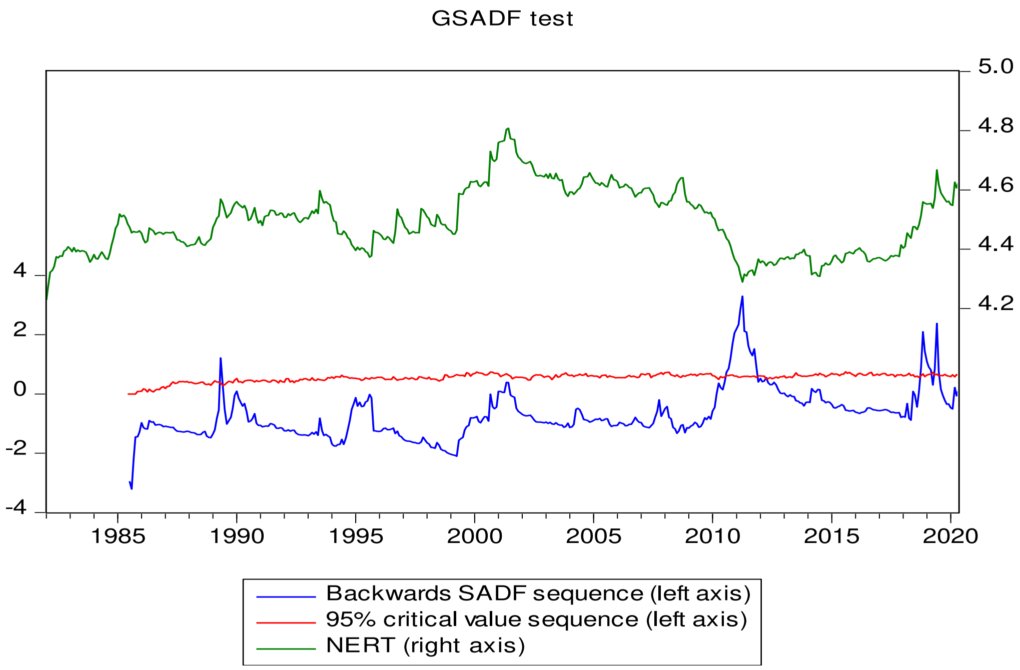


Figure 4: Bubbles Date Stamping for nominal exchange rate to traded good price differential (NERT)



6. Discussion and Conclusion

In this paper, we have used GSADF test developed by Phillips et al., (2015) to investigate the existence of multiple bubbles in D-Rs exchange rates. We have also explored whether regime switching from managed floating to flexible floating have some effects on the Pakistani exchange rate volatility. As identified by Bettendorf and Chen (2013) every explosiveness in asset prices is not a rational bubble and that may be generated by fundamentals as well. Thus replicating previous methods, analysis is carried out on nominal exchange rates along with two other series namely nominal exchanges rates to traded goods prices differential and nominal exchange rates to non-traded goods prices differential to examine nature of explosiveness. Through this procedure we consider only those phases of currency appreciation and or depreciation as rational bubble that is not driven by fundamentals.

Results of the study show that nominal exchange rates are almost decreased during study period with few exceptions when exchange rates are increased. Nominal exchange rates and nominal exchange rates to non-traded goods fundamental are explosive in both managed floating and flexible floating regimes, nominal exchange rates to traded goods fundamental on the other hand is explosive only in flexible floating regime. Thus traded goods prices differential caused the volatility in exchange rates during managed floating.Similarly flexible exchange rate system shows less stability which is not attributed to traded goods price differential.

Although bubble period for nominal exchange rates and nominal exchange rates to non-traded goods fundamental covers era of Asian financial crises (1997), test results on nominal exchange rates to traded goods rejects presence of such crises as we did not find any explosive behavior for nominal exchange rates to traded goods during the period. Pakistan did not face crises possibly due to following reasons. The country used mostly official flows and bank deposits to finance its deficits. These modes of financing remained stable during crises in the 1990s. Private sector was raising capital mostly from local resources. Thus foreign currency exposure of private businesses was low. Similarly to improve credit decision making of banks, banking sector reforms were introduced in early 1997.

Overall nominal exchange rates show highest exuberance during study period followed by nominal exchange rates to non-traded goods. Nominal exchange rates to traded goods series, on the other hand exhibits fewer explosions for limited durations that indicate that most of the explosive behavior in nominal exchange rates and nominal exchange rates to non-traded goods are explained by traded goods price differential. Broadly exuberance in nominal exchange rate to traded goods can be segregated into three periods which are either collapse or collapse and recovery phase. For example, first exuberance is detected during October 2010 to November 2011 when Rs was depreciated against US D and is regarded as collapse phase. It was the period when Pakistani economy was adversely affected by increasing oil prices, floods and low agriculture and manufacture sectors production. Second exuberance is detected during October 2018-March 2019 when Rs was devalued during the period and is regarded as collapse phase. Third exuberance exists for a short duration of three months from May 2019 to July 2019 when Rs is initially weakened and then strengthened against D. This period is considered as collapse and recovery phase.

The Rs depreciation in 2018-19 may be due to previous government which is said to have kept value of Rs artificially high during its tenure. On the other hand, Pakistani rupee appreciation in July 2019 may be due to inflows of remittances from overseas Pakistanis ahead of Eid and shirking demand locally as the State Bank had tightened rules and regulations for opening letters of credit for imports. However traded goods fundamental does not justify these factors of appreciation and as a result bubble is detected.

Results of our study are in line with Bettsand Kehoe (2006, 2008); Bettendorf and Chen, (2013); Jiang et al., (2015) who demonstrate that traded goods price differential is important determinant of exchange rate movements, while non-traded goods price differential have little role in exchange rate volatility. Policy makers should take into account this insight. Similarly various monitory and fiscal ramifications are required to avoid bubbles. Further in future, researchers should include underlying fundamental variables in their studies because explosiveness in asset prices alone is not a sufficient condition for identification of rational bubble.