Identifying Asset Price Bubbles – An Application to the Jamaican Asset Markets

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Abstract

This paper tests for asset price bubbles in Jamaican asset markets using exchange rate, housing market and stock market data. The bubble periods are identified by estimating the right tailed Generalized Supremum Augmented Dickey Fuller Test developed by Phillips, Shi and Yu (2015) for varying frequencies of asset market data. Strong evidence of explosiveness was found in the exchange rate and the stock market, however no evidence of explosiveness was found in the housing market. This test showed some success in its ability to identify bubble periods and can assist policy makers in serving as a market surveillance tool.

1. Introduction

The creation and maintenance of a healthy, stable and sustainable economic environment is among the major goals of any developing country; this necessitates proper assessment, supervision and regulation of financial systems. In an effort to effectively monitor this system, macro prudential surveillance, which is a broad analytical framework that assesses key threats to the financial system, is required. Managing systemic risks emerging from the procyclicality of the financial cycle and from the structure of the financial system are at the core of this surveillance technique.

A major source of systemic risk which has plagued the global economy surrounds the issue of asset price bubbles. The term asset price bubble refers to large, sustained mispricing of financial or real assets. Though, not every temporary mispricing can be called a bubble, they are often associated with mispricings that have certain features such as explosive valuation periods. More specifically the concept of rational bubbles refers to periods in which the price of an asset exceeds fundamentals because investors believe that they can make a profit by selling at a higher price in the future (Brunnermeier & Oehmke, 2013).

Asset prices are important to the economy not only because they allocate resources across sectors but also because of the role they play in reflecting markets' risk attitudes, in being sources of information concerning market expectations, in being leading indicators of output, inflation and financial distress, and as influencers of the strength of the financial system. "As a result, it has become more important to understand what determines asset price movements, to interpret the message they contain about the future and to incorporate them into policy decisions." (Hördahl and Packer, 2007).

Over the past 40 years, numerous countries have suffered from financial crises followed by serious economic recessions. Among them, the Latin American debt crisis in the early 1980s, the Japanese asset price bubble burst in 1990, the Asian financial crisis in 1997, and the US subprime loan crisis in the late 2000s were the most severe and are all believed to have been associated with the formation and subsequent bursting of some form of asset price bubbles. Jamaica has also endured its own bout of financial crisis beginning with the financial liberalization efforts of the early 1990's. This led to rapid expansion and deepening of the financial sector (see Kirkpatrick and Tennant, 2002 for summary) but also brought with it rapid and risky lending to the private sector at unsustainable rates (Green, 1999). It is possible that the combination of this credit boom, the emergence of large interconnected financial conglomerates and risky investments gave rise to asset price bubbles in the financial and real sector.

In the wake of the latest global crisis, deemed to be "the most severe crisis since the Great Depression" (Caballero & Krishnamurthy, 2009), there has been extensive empirical research and continued development of methods of asset price bubble detection with application across different sectors of the economy including stock markets, real estate markets and the exchange rate. Therefore, understanding the correlation between asset price bubbles and crises has serious implications because bursting asset price bubbles can have detrimental effects on the financial system and give rise to systemic financial crises (Brunnermeier, Rother & Schnabel, 2019).

In an effort to continuously improve macro prudential surveillance techniques, having a firm grasp of the country's macroeconomic position involves adopting new strategies for monitoring factors which may put the economy at risk, including asset price bubbles. This paper therefore, applied a mechanism for detecting and date stamping asset price bubbles in the exchange rate, housing market and stock market in Jamaica. This test developed by Phillips, Shi and Yu (2015a,b) uses a recursive right tailed Augmented Dickey Fuller Test called the Generalized Supremum Augmented Dickey Fuller Test (GSADF) to identify the presence of bubbles and periods of their existence. This paper employed this tool to test for explosiveness in the fundamental value of the exchange rate, stock market prices and housing prices by using the: bilateral real exchange rates for Jamaica against the United States, Canada and Britain, the real effective exchange rate (REER) on a monthly and quarterly basis, the stock market capitalization to GDP ratio on a quarterly and annual basis and Jamaica's residential property price index on a quarterly basis.

Strong evidence of explosive behavior was detected in all bilateral exchange rates and the real effective exchange rates on a monthly basis as well as in the stock market on a quarterly and yearly basis. There was however no explosiveness detected in exchange rates on a quarterly basis and in the housing market. The organization of this paper will proceed as follows: Section 2 will review literature surrounding asset price bubbles and financial system risk as well as methods used for testing asset price bubbles, section 3 will review the methodology of the right tailed tests and look at the data used and sections 4 and 5 will display the results and conclude and give relevant policy implications.

2. Literature Review

Asset price bubbles and rampant credit growth often precede financial crisis with the 2007-2008 global financial crisis being no exception. It has impelled central bank economists and policymakers to implement macro prudential policies including the Basel III accord which works to stabilize the financial system by way of placing guidelines on capital requirements and related measures to control "excessive credit creation." This crisis, and subsequent guidelines, have raised important questions surrounding market surveillance, particularly around the issue of what is considered "excessive", around whether or not asset price bubbles can be properly detected and if properly detected whether or not they should be combatted. (Phillips, Shi & Yu, 2015).

2.1 Asset price bubbles and financial system risk

First referred to as "mania", the earliest signs of an asset price bubble surfaced in the 1600's in the tulips industry of the Netherlands. Bubbles have now become a more common phenomenon that extends beyond commodity markets to all sectors of the economy particularly the financial market. (Jiménez & Vilella, 2011). Brunnermeier and Oehmke (2013) emphasize that a common pattern associated with financial crises includes a period of booming asset prices, typically associated with asset price bubbles initiated by some financial or fundamental innovation, followed by a crash or bust period which is characterized by sharp and persistent reductions in the price of that asset and in economic activity.

There is a plethora of literature that give empirical accounts of financial and debt crises that follow this boom-bust cycle outlined above. A few of these instances include the United States stock market and real estate boom of the 1920's which was followed by a crash in the stock market and real estate valuations leading to the Great Depression (White, 1990), the Latin American debt crisis of the 1980's that originated from a boom in international credit to fund industrialization and subsequent bust due to depreciating domestic currencies and increasing debt burdens (Sturzenegger and Zettelmeyer, 2006). Major financial crisis also plagued the Scandinavian countries of Finland, Norway and Sweden in the early 1990's due to credit market liberalization, which facilitated a lending boom and subsequent asset price boom in the real estate sector and eventual bust (Jonung, Kiander, and Vartia, 2009). Similar patterns of boom bust cycles that had contagion effects that led to crises also occurred in East Asia, Japan and Russia during this era (Brunnermeier and Oehmke, 2013).

Though there is no universally accepted theory about how asset price bubbles are formed or what drives them, empirical evidence points to a few of the common driving forces being: expansionary monetary policy, greater access to specific types of credit/ lending booms, financial innovation or deregulation, asymmetric information between investors and portfolio managers, heterogeneous beliefs that lead to overpricing and highly emotional speculative processes (see Brunnermeir and Schnabel, 2015; French 2009; Brunnermeir and Oehmke, 2013; Allen and Gorton, 1993; Taffler, Obring & Agarwal, 2018).

Scherbina (2013) also notes five common ways bubbles usually burst. Bursts occur when: the uncertainty about an assets value is resolved, the inflow of new capital that keeps a bubble growing slows down and new capital becomes exhausted, positive sentiment is reversed, a strong negative signal emerges or when arbitrageurs attack it by selling short a sufficient amount of the overvalued asset.

Though the effects of a bursting bubble may lead to economic downturn, the seriousness of crisis following such a scenario is linked more closely with how the asset is financed than to the type of asset. (Brunnermeier and Schnabel, 2015) find that crisis are more severe when accompanied by lending booms, high leverage of market players and when financial institutions participate in the buying frenzy. (Brunnermeier et al, 2019) also notes increases in systemic risk are not solely associated with bursting asset price bubbles but are associated with the health of the financial system at the time of the bursting.

The formation and growth of bubbles as explained by the previous paragraph is closely linked to bubbles in the stock market and real estate market but differs slightly for the exchange rate. (Okina, 1984) outlines three causes of the appearance of bubbles in the exchange rate. These include: "excess market reaction" towards news of economic fundamentals, speculative action based on chart analysis[1], and the belief that once deviations from fundamentals surface they will continue which has a self-fulfilling impact. It is difficult to state with certainty the impact a bursting exchange rate bubble may have because each country may define their exchange rate by different fundamentals.

2.2 Methods used for testing asset price bubbles

Before the appropriate policy response to asset price bubbles can be formulated, having the ability to reliably and accurately detect and predict asset price bubbles is essential. The collection of research efforts dealing with bubble detection methods tell of a challenging econometric journey which has led, over time, to the development of robust tests that can aid central banks and policy makers in decision making. This challenge is due to the fact that "asset prices resemble random walks where the direction and magnitude of changes are random so that predicting price change is difficult." (Steenkamp, 2017)

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[1] Speculative chart analysis involves the behavior of the public towards appreciations and depreciations in the exchange rate, that is, when the exchange rate appreciates it should be bought and when it depreciates it should be sold.

(Gurkaynak, 2008) surveys several econometric tests for rational bubbles. Rational bubbles are defined as bubbles that occur when equity prices rise because investors are willing to pay a higher price for a stock than they know is justified by the value of the discounted dividend stream, because the price is expected to continue rising. Gurkaynak concludes that the tests outlined cannot confirm with certainty the presence of bubbles because of the misaligned results given by surveyed tests replicated for the same time periods and data sets. The first tests outlined are the earliest ones developed by (Shiller, 1981) and (LeRoy and Porter, 1981) that focused on using present value models. Present value models define asset prices as the discounted value of expected future dividends, and determinations about the presence of bubbles were constructed by placing variance bounds on asset price series. Bubbles are considered to be present when the variance bound is violated. The null hypothesis is based on the idea that this present value solution forms the basis for prices. When rejected it means that equity prices are not constructed as sums of expected discounted dividend flows. (Blanchard and Watson, 1982) along with (Gurkaynak, 2008) both agreed that the problem with this method is that rejection of the null cannot be solely attributed to the presence of bubbles.

(West, 1987) adopted a new approach to bubbles, testing separately for the presence of bubbles and model misspecification, using the Euler equation and autoregressive processes, he ruled that after specification tests, the price estimates generated by these two processes should be the same unless there is a price bubble. However, West pointed out that the difference might be explained with the variation in discount rates. Despite progress there still proved to be econometric shortcomings and evidence of model misspecifications (Flood, Hodrick and Kaplan, 1994).

Continuing with the application of present value models (Diba and Grossman, 1987 &1988) applied a slightly different approach by focusing on the cointegration of dividends and stock prices. As outlined by (Taipalus, 2012) they defined bubbles as being generated by extraneous events or just explosive dividends and stipulated that in the absence of bubbles, the stationarity of dividends should account for the stationarity of prices no matter how many differences are taken in the data series. He also pointed out that they concluded that rational bubbles must have been present at the initial sale and cannot re-form once they have burst. (Evans, 1991) develops on this deficiency by accounting for periodically collapsing bubbles in his methodology. He created a new model for a bubble process in which bubbles collapse to a nonzero value and starts again with an explosive rate (Taipalus, 2012). His work was followed by a number of other tests for periodically collapsing bubbles such. (see Wu, 1997; Blanchard 1979; and Hall, Psaradakis and Sola 1999).

Recent developments by (Phillips, Wu and Yu, 2011), in econometric detection mechanisms have shown the effectiveness of recursive procedures in identifying and dating financial bubbles by using a right tailed Augmented Dickey Fuller Test known as the Supremum Augmented Dickey Fuller Test (SADF). This procedures however, proved to be deficient in identifying the presence of bubbles over long historical periods due to the complexity of the nonlinear structure and breaks that are inherent in multiple bubble phenomena within the same period. In 2015 Phillips, Shi and Yu developed tests (known at the PSY tests) to augment this detection mechanisms by developing a recursive flexible window method that effectively identifies the presence of multiple bubbles while employing anticipative algorithms that utilize data up to the point of analysis for ongoing assessment that can assist regulators in monitoring the market. The PSY tests proposes a generalized sup ADF (GSADF) and Backward Supremum Augmented Dickey Fuller Test

(BSADF) method to test for the presence of bubbles and allows these bubbles to be date stamped. Similar to the Phillips, Wu and Yu (PWY) tests it uses recursive right-tailed ADF tests but doesn't fix the starting point of the window on the first observation but allows start and end points to change over the range of the sample. Other recently developed tests involve testing for rational bubbles in a co-explosive vector auto regression (see Englsted and Nielsen, 2012).[2]

2.3 Summary

The existing literature makes several things clear, with the main point being that asset price bubbles often precede financial crisis or periods of economic downturn and this has become a major concern for economies worldwide. (Scherbina, 2013) notes that "most bubbles have a compelling and sensible story behind them" with each asset price bubble having its own process of formation, development and bursting. Each bubble has varying degrees of impact on the economy depending on the level at which the market players and financial institutions participate in the purchase of these assets, and on the health of financial systems. Efforts made by economists to identify asset bubbles have resulted in a robust test that not only identifies but also date stamps the origination and termination points of asset price bubbles which will be a useful tool for policymakers and regulators.

[2] Main findings of the application of PWY and PSY tests in the housing market and stock market can be reviewed in. Engsted, Hviid and Pedersen (2015); Yui, Yu and Jin, (2013); Gómez, Ojeda, Guerra, & Sicard (2013); Phillips, Shi and Yu (2015); Harvey, Leybourne, Sollis and Taylor (2015) and Basoglu (2012)). With regard to application to the exchange (Steenkamp, 2018) and (Bettendorf and Chen, 2013) found no evidence of explosiveness.

3. Methodology and Data

3.1 Left- tailed Augmented Dickey Fuller Tests

This paper tests for explosiveness in the Jamaican Dollar by employing methods developed by Phillips, Shi & Yu (PSY) which utilizes right tailed Augmented Dickey Fuller tests applied over recursive sub-samples, however we will briefly review the traditional left tailed test. Augmented Dickey Fuller (ADF) tests are used to test for stationarity in time series data. Stationarity implies that the mean and variance of the time series are constant. The ADF test identifies the presence of a unit root in time series given a simple AR (1) process that regresses the dependent variable y_t on its lagged value y_{t-1} :

$$y_t = \mu + \theta\, y_{t-1} + \varepsilon_t \qquad (1)$$

$$H_0: \theta = 1$$

$$H_1: \theta < 1$$

Where θ is the coefficient on the lagged term, μ is the intercept, and the error term ε_t is a white noise process with zero mean and constant variance. Software packages perform this test using the regression of the change in y_t on its lagged value which is denoted as follows:

$$y_t - y_{t-1} = \mu + (\theta - 1)\, y_{t-1} + \varepsilon_t \qquad (2)$$

$$\Delta y_t = \mu + \delta\, y_{t-1} + \varepsilon_t \qquad (3)$$

$$H_0: \delta = 0$$

$$H_1: \delta < 0$$

Where δ is the new coefficient of model. The traditional ADF test is a left tailed test with the null hypothesis suggesting the time series has a unit root (and is therefore nonstationary) whereas the alternative hypothesis suggests stationarity. The ADF compares the t-statistics of residuals of δ with Dickey-Fuller critical values rather than normal t statistic critical values to determine the presence of a unit root.

The ADF test is applicable for more complex time series such as AR (p) processes seen below:

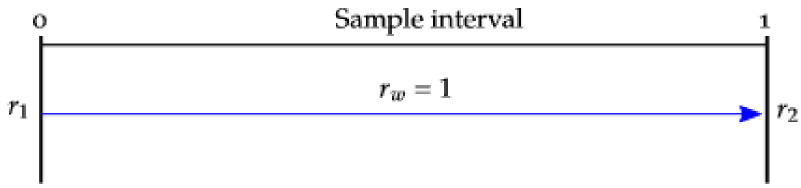
$$y_t = \mu + \delta_1 y_{t-1} + \delta_2 y_{t-2} + \ldots + \delta_k y_{t-p} + \varepsilon_t \quad (4)$$

The regression below is estimated to perform the ADF test on the AR(p) process above.

$$\Delta y_t = \mu + \delta y_{t-1} + \sum_{i=1}^{p} \emptyset_i \Delta y_{t-i} + \varepsilon_t \quad (5)$$

Y_t is the price in question, μ is the intercept, p is the maximum number of lags, $\emptyset_i$ for $i = 1, \ldots, p$ are differenced lags coefficients and ε_t is the error term. The figure below gives a visual depiction of the standard ADF procedure which runs the test over the entire sample:

Figure 1: Augmented Dickey Fuller Test



Source: (Caspi, 2017)

3.2 Right tailed ADF - Supremum Augmented Dickey-Fuller Test (SADF)

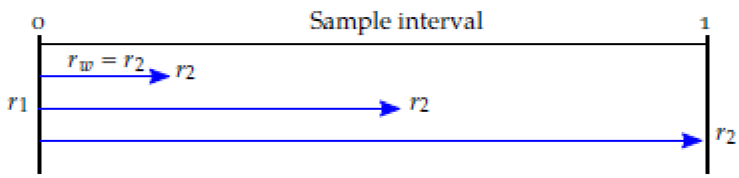
This right tailed ADF test now employs a recursive expanding window approach to ADF style regression implementation. As seen below in equation 6 the null hypothesis remains the same, however the alternative hypothesis is now of a mildly explosive autoregressive coefficient (Capsi, 2017). In addition, suppose the rolling window regression sample starts from the r_1^{th} fraction of the total sample (T) and ends at the r_2^{th} fraction of the sample, where $r_2 = r_1 + r_w$ and $r_w > 0$ is the (fractional) window size of the regression (Phillips, Shi & Yu, 2015). The equation is specified below:

$$\Delta y_t = \hat{\mu}_{r_1,r_2} + \hat{\delta}_{r_1,r_2} y_{t-1} + \sum_{i=1}^{p} \hat{\phi}^{i}_{r_1,r_2} \Delta y_{t-i} + \varepsilon_t \qquad (6)$$

$$H_0 : \delta = 0$$
$$H_1 : \delta > 0$$

The SADF test depicted in figure 2 below detects explosive behavior by applying the right tailed ADF test over an expanding test window (with a fixed starting point) to prevent a period where the series has a unit root from dominating the test result.

Figure 2: Supremum Augmented Dickey Fuller Test



Source: (Caspi, 2017)

In figure two above the starting point of the estimation window, r_1, is the set as the first observation in the sample and the end point of the initial estimation window (which is set by the user), r_2, is set according to some choice of minimal window size, r_0, such that the initial window size is $r_w = r_2$. The regression is then recursively estimated while increasing the window size one observation at a time. Each estimation produces an ADF statistic denoted as ADF_{r_2}. The SADF statistic is defined as the supremum value of the ADF_{r_2} sequence (Caspi, 2017)

$$\text{SADF}\ (r_0) = sup_{r_2 \in [r_0,1]} \ ADF_{r_2}$$

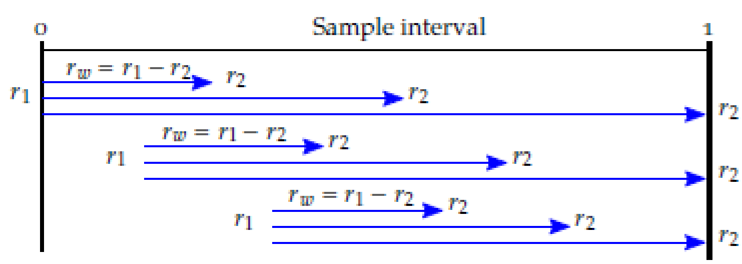
3.3 Generalized Augmented Dickey Fuller Test (GSADF)

In the presence of multiple bubble bursts, however, the SADF test might lose power in identifying bubbles. To overcome this issue, (Phillips et al, 2015b) propose `generalized SADF' (GSADF) test which uses rolling samples of variable window length when conducting unit root tests. (Phillips et al., 2015b) show that their approach is good at discriminating between `bubbles' and `no bubble' periods, even when there are multiple bubbles over the full sample. (Steenkamp 2017).

The GSADF test developed (see figure 3 below) pursues the idea of repeated ADF test regressions on subsamples of the data in a recursive fashion. The subsamples used in the recursion are much more extensive than those of the SADF test because the test not only varies the endpoint of the regression r_2, but also allows the starting point r_1, to change within a feasible range. The GSADF statistic is defined as the largest ADF statistic in this double recursion over all feasible ranges of r_1 and r_2 and we denote this statistic by GSADF (r_0). (Phillips, Shi, Yu, 2015)

$$GSADF\ (r_0) = \ sup_{]r2\in[r0,1]_{r1\in[0,r2-r0]}} \quad \{ADF_{r_1}^{r_2}\}$$

Figure 3: Generalized Supremum Augmented Dickey Fuller Test



Source: (Caspi, (2017)

3.4 Date Stamping

Both the SADF and GSADF tests make it possible for origination and termination points of a bubble to be estimated therefore giving a date stamp for bubbles, if the null hypothesis is rejected. The first date-stamping strategy is based on the SADF test. PWY propose comparing each element of the estimated ADFr_2 sequence to the corresponding right-tailed critical values of the standard ADF statistic to identify a bubble initiating at time Tr_2. The estimated origination point of a bubble is the first chronological observation, denoted by Tr_e , in which ADFr_2 crosses the corresponding critical value from below, while the estimated termination point is the first chronological observation after Tr_e , denoted by Tr_f , in which ADFr_2 crosses the critical value from above. Formally, the estimates of the bubble period (as fractions of the sample) are defined by

Origination Point: $\hat{r}_e = inf_{r_2 \in [r_0,1]} \{r_2: ADF_{r_2} > cv_{r_2}^{\beta_T} \}$

Termination Point: $\hat{r}_f = inf_{r_2 \in [\hat{r}_e,1]} \{r_2: ADF_{r_2} < cv_{r_2}^{\beta_T} \}$

Where $cv_{r_2}^{\beta_T}$ is the 100(1- β_T)% critical value of the standard ADF statistic based on T_{r_2} observations.

Similarly the estimates of the bubble period based on the GSADF are given by

Origination Point: $\hat{r}_e = inf_{r_2 \in [r_0,1]} \{r_2: BSADF_{r_2} > cv_{r_2}^{\beta_{T_{r_2}}} \}$

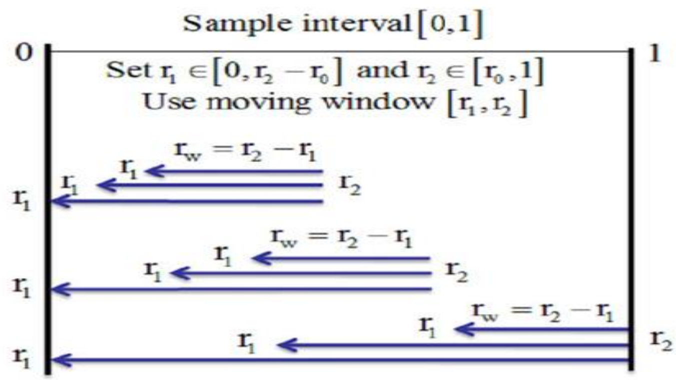
Termination Point: $\hat{r}_f = inf_{r_2 \in [\hat{r}_e,1]} \{r_2: BSADF_{r_2} < cv_{r_2}^{\beta_{T_{r_2}}} \}$

Where $cv_{r_2}^{\beta_T}$ is the 100(1- β_T)% critical value of the sup ADF statistic based on T_{r_2} observations. BSADF (r_0) for $r_2 \in [r_0$, 1], is the backward sup ADF statistic based the sup ADF statistic that relates to the GSADF statistic by the following relation:

$$\text{GSADF}(r_0) = sup_{r_2 \in [r_0,1]} \{ \text{BS}ADF_{r_2}(r_0) \}$$

Figure 4 shows how this test is performed by (Phillips et al.,2015) .

Figure 4: Backward Generalized Supremum Augmented Dickey Fuller Test



Source: Phillips, Shi, Yu (2015)

3.5 Exchange Rate and Bubble Structure

In order to apply this test to the exchange rate, we assume the following present value model in line with (Engel and West, 2005) who suggest viewing the exchange rate as an asset price[3], this means it can be written as a linear combination of current and future economic fundamentals and spot rates as seen below:

$$s_t = (1-\gamma)\sum_{j=0}^{k}\gamma^j E_t[f_{t+j}] + \gamma^{k+1} E_t[s_{t+j+1}] \quad (7)$$

Where s_t is the nominal exchange rate, γ is the discount factor and f_{t+j} is the economic fundamental at time t + j. Imposing the transversality condition, this implies that the exchange rate will only be determined by the sum of discounted expected future fundamentals and $E_t[s_{t+j+1}]$ will therefore tend to zero in the limit as seen below

$$\lim_{k\to\infty} y^k E_t [s_{t+1}] = 0 \quad (8)$$

[3] In viewing the exchange rate as an asset price it is important to note that explosive behavior is associated with a depreciation in the real rate

However if this does not hold then the exchange rate will include a fundamental component (s_f^t) and a bubble component:

$$s_t = s_f^t + bubble_{t-1} + \varepsilon_t \qquad (9)$$

Where

$$bubble_t = \frac{1}{1-\gamma} bubble_{t-1} + \varepsilon_t \qquad (10)$$

The bubble will be an explosive process when the AR(1) coefficient $\frac{1}{1-\gamma} > 0$.

3.6 Description of Data

The equilibrium exchange rate fundamentals used in the examination of explosive behavior in this paper are two measures of the real exchange rate, that is, the bilateral exchange rates for the United States, Canada and Britain adjusted for Purchasing Power Parity and the Real Effective Exchange Rate (REER) for Jamaica's top seventeen trading partners calculated by the Bank of Jamaica. The housing and stock markets were also assessed using Jamaica's Residential Property Price Index and the Stock Market Capitalization to GDP ratio respectively.

An outline of how the fundamental value of each asset price is calculated is given as follows: Purchasing Power Parity (PPP) states that nominal exchange rates should move to equate the price of goods and services across countries, (Stephens, 2004). This means that JMD $1000 should buy just as much goods locally and it does abroad when converted to its foreign counterpart using the nominal exchange rate. The formula used to adjust nominal exchange rates for PPP is shown below:

$$Real\ Exchange\ rate = NER \times \frac{P_t^*}{p_t}$$

Where NER is the nominal exchange rate, p_t^* is the CPI for the foreign equivalent rebased as at the year 2000 and p_t is the CPI for Jamaica.

The REER measures the country's external competitiveness relative to that of its seventeen major trading partners and is calculated by deflating the nominal effective exchange rate (NEER) by domestic consumer prices relative to those of the country's major trading partners. It is calculated by the following formula[4]:

$$\frac{NEER\ Index\ \times\ Relative\ Price\ Index}{100}$$

Jamaica's Residential Property Price Index measures and monitors changes in house prices in Jamaica over time. Separate indices exist for movement in house prices for the major regional markets of Jamaica St. Catherine, St. James and Kingston & St. Andrew. Lastly, Jamaica's stock market capitalization to gross domestic product ratio is a ratio that measures the total value of all publicly traded stocks in the market against the total value of its output. It is calculated by the following formula:

$$\frac{Stock\ market\ capitalization}{Gross\ Domestic\ Product} \times 100$$

Explosiveness in each market was tested using the GSADF and were considered based on the following number of observations: the bilateral exchange rates were considered for JMD: USD and JMD: GBP on a monthly basis from 1990 M1 to 2018 M7 (343 observations each) and JMD:

[4] The NEER index is calculated as follows: $\frac{Domestic\ Exchange\ Rate\ Index}{Foreign\ Exchange\ Rate\ Index} \times 100$ and the Relative Price Index is calculated as follows: $\frac{Domestic\ CPI\ Index}{US\ CPI\ Index} \times 100$

CAN from 1991 M2 to 2018 M7 (330 observations); and on a quarterly basis for JMD: USD and JMD: GBP from 1990 Q1 to 2018 Q2 (114 observations each) and JMD: CAN from 1991 Q1 to 2018 Q2 (110 observations). The REER was considered on a monthly and quarterly basis from 1996 M1 to 2018 M5 (281 observations) and from 1996 Q1 to 2018 Q2 (94 observations) respectively. Jamaica's Residential Property Price Index was considered on a quarterly basis from 2008 Q4 to 2019 Q2 for Kingston, St. Andrew and St. Catherine (43 observations each) and the Stock Market Capitalization to GDP ratio was considered on a quarterly basis from 2010 Q3 to 2019 Q1 (35 observations) and yearly basis from 1969 to 2018 (50 observations)[5]. The GSADF test is estimated on equation 6 where Δy_t represents the asset price in question, that is, the exchange rate, residential property price index and stock market capitalization to GDP.

4. Results

Table one below shows results from the GSADF test applied to monthly exchange rates. All exchange rate measures exceeded their respective 95% right-tail critical values (i.e., 3.277 > 2.172, 3.663 > 2.196, 2.379 > 2.204 and 3.271 > 2.171), giving strong evidence they had explosive sub periods.

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[5] Initial window sizes and lag lengths were selected based on suggestions and rules prescribed by Phillips et al, 2015. The rule for selecting the window size is: $r_0 = 0.01 + 1.8/\sqrt{T}$ where T is the sample size. The lag length selected was p = 0.

Table One : GSADF test on monthly variables

Variable (Monthly)	***GSADF test statistic***	***95% CV***	***P-value***
USD (PPP)	3.277	2.172	0.002
CAN (PPP)	3.663	2.196	0.000
GBP (PPP)	2.379	2.204	0.034
REER	3.271	2.171	0.002

The figures below show date stamps of these explosive sub periods which are labelled and highlighted by grey columns:

Figure 5: Generalized Supremum ADF Test performed on USD (PPP)

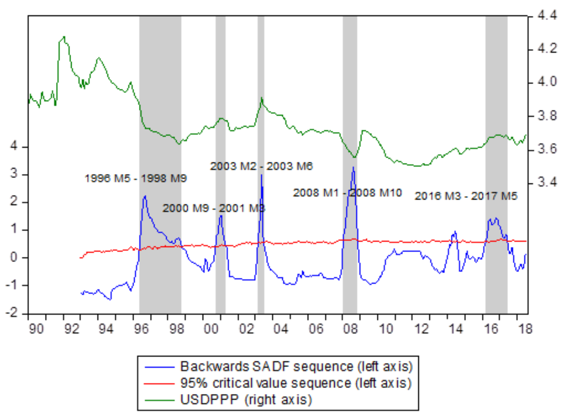


Figure 6: Generalized Supremum ADF Test performed on CAN (PPP)

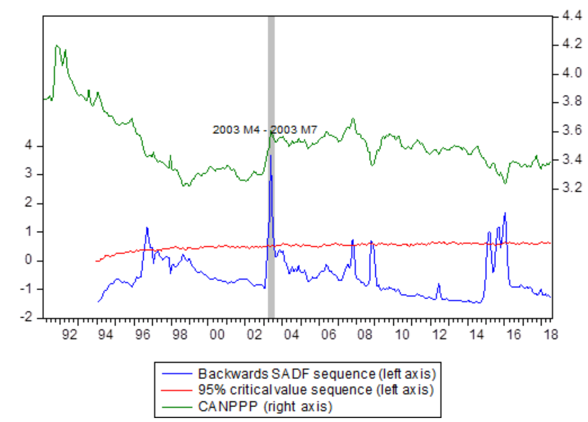


Figure 7: Generalized Supremum ADF Test performed on GBP (PPP)

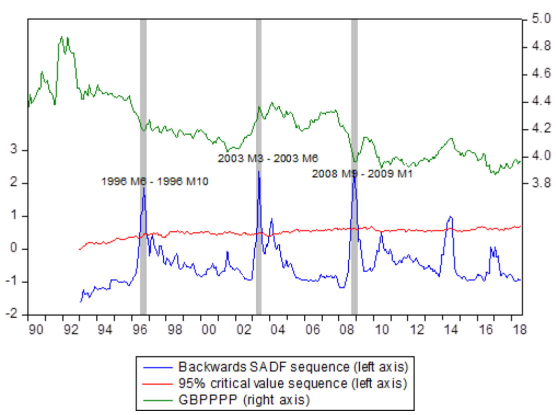
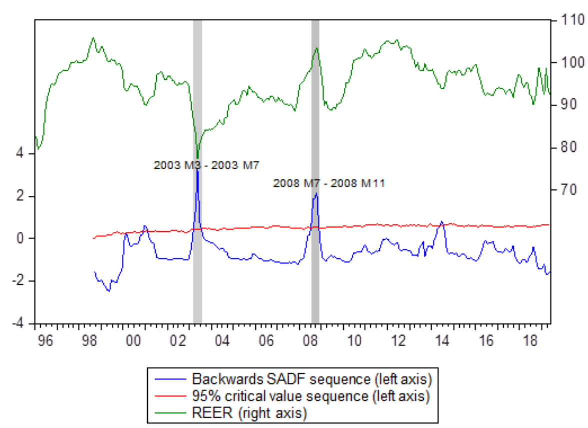


Figure 8: Generalized Supremum ADF Test performed on REER



The REER experienced explosiveness during the period March to July 2003 and July to November 2008 which can be credited to loss of confidence in the country's economic condition (Bank of Jamaica, 2003) and to events surrounding the global financial crisis respectively.

Results were, however, not consistent between monthly and quarterly versions of the exchange rate with the test failing to identify any explosive periods from all four exchange rate methods. The test also failed to identify explosive periods in the housing markets for Jamaica, Kingston and St. Andrew and St. Catherine. Table two and three below display these results with all critical values exceeding their GSADF test statistic.

Table Two : GSADF test on quarterly variables

Variable (Quarterly)	***GSADF test statistic***	***95% CV***	***P-value***
USD (PPP)	1.091	2.015	0.352
CAN (PPP)	0.758	2.017	0.554
GBP (PPP)	1.348	2.054	0.223
REER	0.623	1.981	0.605

Table Three : GSADF test on quarterly variables of HPI

Variable (Quarterly)	***GSADF test statistic***	***95% CV***	***P-value***
Jamaica	0.013	1.957	0.800
Kingston & St. Andrew	-1.085	1.957	0.996
St.Catherine	-1.179	1.957	0.998

The stock market showed signs of explosiveness in both quarterly and annual measures of its fundamental value. Table four below shows both test statistics exceeding their 95% critical values. Quarterly results displays a period of bubble expansion forming around 2018 Q3 into 2019 where it appears to be declining (see figure 9). The test also identified a prolonged period of stock market downturn rather than bubble expansion beginning around 2013 Q3 and improving in the first quarter of 2015. This boom and bust period can be credited to weak domestic economy and low investor confidence and to positive macroeconomic developments and improved consumer confidence respectively (Bank of Jamaica, 2013; 2015)

Table Four : GSADF test on Stock Market Cap to GDP Ratio

Stock Market Cap to GDP Ratio	***GSADF test statistic***	***95% CV***	***P-value***
Quarterly	2.819	1.849	0.008
Annually	4.449	1.893	0.000

Figure 9: Generalized Augmented Dickey Fuller Test for Stock Market (Quarterly)

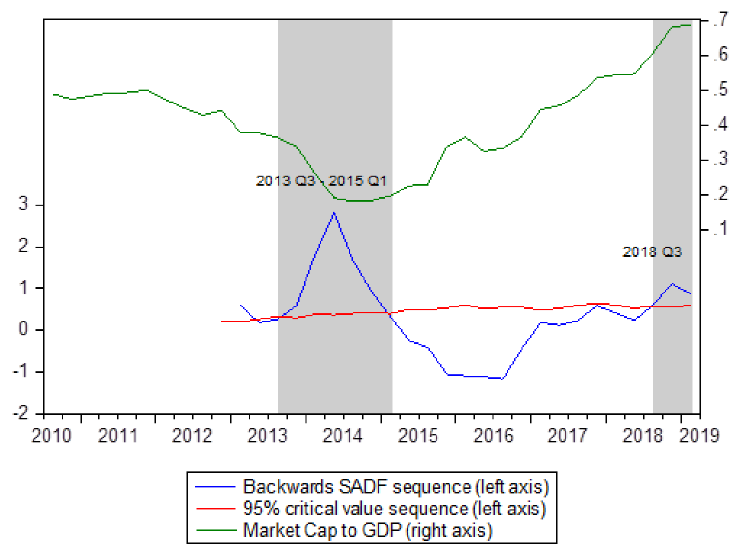
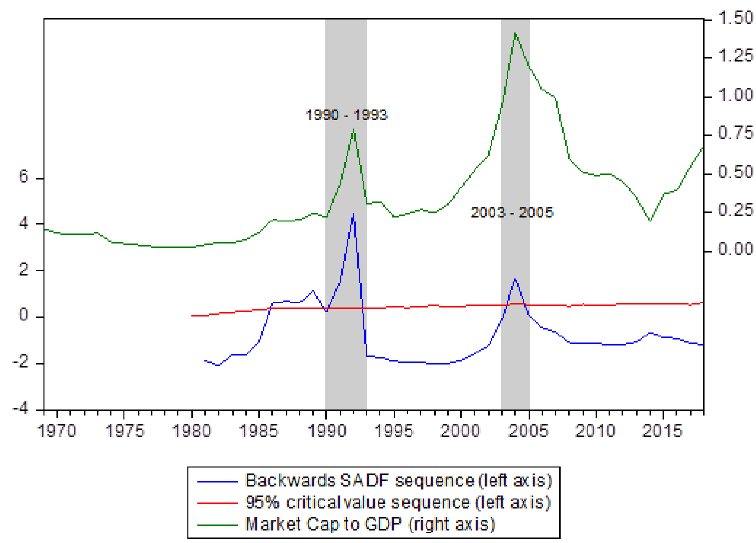


Figure 10: Generalized Supremum Augmented Dickey Fuller Test for Stock market (Annual)



Annual results, as seen figure in 10 above, show periods of explosiveness from 1990-1993 associated with financial liberalization, and in 2003- 2005 which was facilitated by an accommodative macroeconomic environment and strong performance of individual share price. Annual results however failed to identify explosive activity during 2013-2015 and 2018 as displayed by quarterly test results.

5. Conclusion and Policy Implications

This paper adds to the literature by being the first to utilize the right tailed Generalized Supremum Augmented Dickey Fuller Test developed by Phillip, Shi and Yu in 2015 to test for explosive behavior in Jamaica's asset markets. This method of testing for explosiveness was investigated as a test for asset price bubbles. The boom-bust nature of the financial system highlights the importance of this test in macro prudential surveillance as it can serve as an early warning alert that points central banker and regulators towards unusual activity in markets across different sectors.

Results showed that explosiveness was detected in the bilateral real exchange rates adjusted for purchasing power parity and in the real effective exchange rate on a monthly basis but failed to detect explosiveness on a quarterly basis. Results also showed explosiveness in the stock market but found no explosiveness episodes in the housing market. Overall, the results showed that a larger number of explosive periods were identified with higher frequency data. This coupled with (Phillips et al, 2015) suggestion that the test is better suited for practical implementation with long historical time series emphasizes the need for reliable granular monthly data spanning longer time series in order to be more beneficial in identifying explosiveness that can effectively assist policy makers.

5.2 Policy Implications

What does the identification of explosive periods mean for central banks and regulators? Traditionally, monetary policy was considered as the main tool in combatting problems surrounding asset bubbles. There have been long-standing debates over appropriate responses to bubble behavior. On one hand some economists believe central banks should "lean against the wind" [6](Wadhwani, 2008) because of the broad evidence that supports the fact that asset price bubbles do occur from time to time, and that such bubbles may lead to economic distortions as well as financial and real economic instability. Thus, many argue that optimal monetary policy requires monetary policy authorities to react to such bubbles over and above the effects that these bubbles have on current output growth, aggregate spending and expected inflation. They believe central banks should use monetary policy as a tool to detect and prevent rather than simply responding to the aftermath of the crisis caused by the busting of a bubble (Brunnermeier and

[6] "Leaning against the wind" refers to stricter monetary policy for financial stability purposes.

Schnabel 2015). Others are of the view that monetary policy should not react to asset prices or bubbles beyond the effect that such asset price movements directly have on inflation, aggregate spending and economic growth (Roubini, 2006).

Whatever position central banks and policy makers choose to hold, it is important to note that monetary policy is not the only tool that can be considered when addressing the issue of asset bubbles. Macro prudential policies such as the imposition of lending limits, loan to value ratios and counter cyclical capital buffers among an array of other measures can aid in mitigating against risks associated with explosive activity in a more efficient way by targeting specific sectors rather than the economy as a whole. In addition monetary and macro prudential policies should not focus solely on regulating excessive market activity but should aim to continuously improve the health, and solidify the strength of the financial system. This due to the fact that systemic risk rises not only with the bursting of a bubble but also during its build up phase. (Brunnermeier et al, 2019).

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