ESSAYS ON ECONOMIC BUBBLES

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy (Economics)

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2020

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ABSTRACT

Title of Dissertation	ESSAYS ON ECONOMIC BUBBLES
Author	Pichet Kaytanyaluk
Degree	Doctor of Philosophy (Economics)
Year	2020

The aim of this dissertation is to study the bubbles in the economy. There are two separated studies which are 1) "Testing the bubbles and the crashes of the asset prices: The evidence from the southeast Asian countries." and 2) "Can government bond replace rational bubbles? The empirical investigation on Singapore and Thailand." combined in this dissertation.

For the long period of time, many economists try to find the detector for the existense and the crashes of the bubble. However, many of econometric models might distinquish the explosive bubbles from the non-stationary series. In the first study, which is presented in chapter two of this dissertation, the new algorithm known as right-tail augmented Dickey-Fuller test is applied for evaluating the asset prices. By this tool, it can stamp the start and the end date of the bubbles episode. In this study, in many asset prices such as stock indices, gold prices, rubber prices, and the real estate within the southeast Asian countries. The results show that these models can detect the bubble episodes as recorded in history such as the Black Monday stock market crash (1987) and the subprime crisis (2007 – 2008) in some countries, but fails to detect the collapse of the stock market during Asian financial crisis (1997). Not only the econometric point of view, but also macroeconomic theories of bubbles are taken into account for the study. There are some variables such as the real interest rate, real GDP, real consumption, real investment, and capital flow that have a relationship with the bubbles. These macroeconomic variables may have the differnt values during the different state of the economy (with bubble and without bubble). The tests of difference in mean have been performed to recheck the performance of the new algorithm. The results show that the algorithm may not catch well Thailand's data because it fails to reject null hypothesis and the mean of the macroeconomic variables are the same for the different state of the economy. However, the algorithm may work for Indonesia, Philippines, and Singapore

because there are the different of the average value of macroeconomic variables for the different bubble status in the economy.

For the second study, which is presented in chapter three of this dissertation, it aims to test the theoretical policy implication on rational bubbles that the government bonds can be replaced the rational bubbles in the asset market. The study is scoped down to the bubbles in the stock markets and selected Singapore and Thailand as a representative for the investigation. We apply the Fourier transformation technique to construct our own bubble index. Then, we utilize this bubble index to find out the relationship with each country's government bonds. We found the empirical support of the theory in the case of Singapore, but not in the case of Thailand. For the case of Singapore, the credibility in an ability to collect tax and the appropriate yield of government bonds are keys to the effectiveness of such the anti-bubble policy. Moreover, we also found that expansionary fiscal policies empirically accelerate the growth of bubbles.

ACKNOWLEDGEMENTS

In writing this dissertation, I have received a lot of support and assistance from many people. This dissertation might not happen without their warm support and guidance.

First, I would like to thank to my advisor, Assistant Professor Athakrit Thepmongkol, for his guidance along my way of developing this dissertation. He has supported me in every stage of this writing, from topic selection until publication. I was enlighten by his expertise in Macroeconomics, especially economic bubbles, to formulate the research questions and methodologies. I could learn a lot from his feedback and advice.

I would like to also thank to my co-advisor, Associate Professor Yuthana Sethapramote, for suggesting the second topic to fulfill my dissertation. From this guidance, I could learn the new econometrics technique in more advance level.

Next, I would like to acknowledge to all of my committees who gave me invaluable comments during dissertation defense. This dissertation might not be shaped in the right direction without their mentions.

I am also appreciated to all of my friends in Ph.D. Economics Batch #9 class. They helped and encouraged me to finish this dissertation.

Finally, I would like to thank to my parents for always encouraging me during the development of this dissertation. They always come to cheer up me when I am tired with the writing. This success cannot be happened without their support.

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December 2020

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CHAPTER 1

AN INTRODUCTION

1.1 Overview

Being an investor in one market, either in financial or real physical assets, one of the most important objectives is to gain the returns of holding those assets. The returns that all investors are expecting might be from the income that generates from those assets themselves or the rise in the assets' prices. The latter is known as capital gain which is realized at the time that investor sells his asset in excess of the buying price (or capital loss if the cost of asset is higher than the selling price). From this point of view, every investor is expecting their asset prices to increase over time.

For example, let us consider the holding of a common stock. If we ignore the right to manage (vote) in the company, the returns that investor can earn from investing in the common stock are dividend (which may in the form of cash, stock) and the change in the stock price. Therefore, the return of the stock can be expressed in the following equation:

$$R_{i,t} = \frac{D_{i,t}}{P_{i,t-1}} + \frac{(P_{i,t} - P_{i,t-1})}{P_{i,t-1}} \qquad (1.1)$$

where $R_{i,t}$ is the return of holding stock i at time t, $D_{i,t}$ is the dividend of stock i given in time t, $P_{i,t-1}$ is the price of stock i in period $t-1$, and $P_{i,t}$ is the price of stock i in period t. The first term in Equation (1.1) is known as a dividend yield which represents the earning proportion from a dividend payout by the company. This first element can be zero in the case that there is no dividend payout at that period. The second term is called a capital gain (or loss). It shows the change in the stock price over the holding period. This term can be positive (gain), negative (loss), or zero.

How the stock price is determined? Like other kind of goods, the price is determined by demand and supply for the stock. If the demand of one stock increases given that the other things are unchanged, there will be the excess demand for stock and the stock price will increase. In the case that supply for stock increases exogenously, there will be an excess supply and finally the price will fall. However, whether we should buy or sell the stock depends on our evaluation of the expected benefit of the stock, the buyers (or sellers) have to evaluate its benefit.

As being described in Blanchard and Watson (1982), economists initially believed that the asset price, like stock for example, is purely determined by the intrinsic value or namely the fundamental value which is defined as the discounted stream of all its future dividends. However, market investors think differently. In particular, they believe that apart from the fundamental value there is an additional value generated by the pure market sentiment. Later on, economists acknowledge this concept and develop the theory of bubbles to explain this phenomenon. In particular, the incremental value of asset that is consistent with the rational expectation general equilibrium framework is called rational bubbles.

Because the bubbles are the additional part of the asset price, it becomes that the asset is always overpriced as long as the market is expecting the price to be increased. This overpriced asset will mislead the investors to have more demand for the asset. Once bubbles burst, the assets prices revert back to their fundamental values and it causes the wealth of investors to drop. The effect of the burst of bubbles can be harmful to the economy. There are many cases in the history concerning with bubble boom-bust episodes and their catastrophic consequences.

Specifically, the price of tulip bulbs in the Netherland during the 1630s, the South Sea bubble from the British South Sea company during the early 1720s, and the Japanese bubble crisis during the late 1990s are good example of the bubble crises. These three events have the story in common which is the sharp increase of the asset prices (tulip bulbs, South Sea stock, and real estate respectively) followed by the sudden sharp drop.

By this common formation of the bubble, Minsky (1986) proposed the characteristic of the cycle of the bubble. In the cycle of the bubble, there are five stages occurred in the cycle. Those five stages are 1) displacement, 2) boom, 3) euphoria, 4) profit taking, and 5) panic. The description of each stage can be shown as the following:

1) Displacement. This is the starting point. It happens once the economy reveals an exogenous shock such as a new financial innovative or a new technology. The agents will form the expectation about the higher profit and the high growth in the economy. The smart person who finds out this exogenous shock will join in the market and buy the stock. At this stage, the stock price starts to increase.

2) Boom. More new market participants cause the price to gain the upward momentum slowly. At this stage, the price becomes more attractive to the public. It begins to have speculators joining in the market. Consequently, the prices are getting higher than their fundamental values.

3) Euphoria. At this stage, the price grows exponentially right after the boom stage. The investors have the willingness to purchase their assets even they are overvalued as they expect the price to rise even more. As a result, the value of the assets becomes extremely high and reach its peak.

4) Profit taking. The smart investor starts to take a profit by selling. The information of the existence of the bubble is now spreading in the market. Because no one can predict the exact date of the bubble burst, there is still the trading in the market. The price of the asset begins to drop in this stage.

5) Panic. At some point in the profit taking stage, the price is sharply reduced. This sudden decrease in price intimidates all investors. They will keep selling out their assets and hence the price keeps falling. This situation will become even worse if there are many investors who use the margin account in trading. Because the decreased price in this stage affects the investors' portfolio value to be smaller, they will face the margin calls or even the forced sales. These forced sales create huge amount of supply in the market and cause the sharp drop of the price.

Another example of bubbles is the house price boom in the United States during the 2000s. This house price bubble was one of causes to the global financial crisis during 2007 to 2009. Based on the research of Robert J. Shiller and his famous book, *Irrational Exuberance* (Shiller, 2015), the trend of the real price of the house in the United States has been increased since 1997 and reached the peak in 2006 which was about 85% increase in the real house price. Figure 1.1 shows the U.S. home prices with some other related factors. This figure is from Shiller's website.

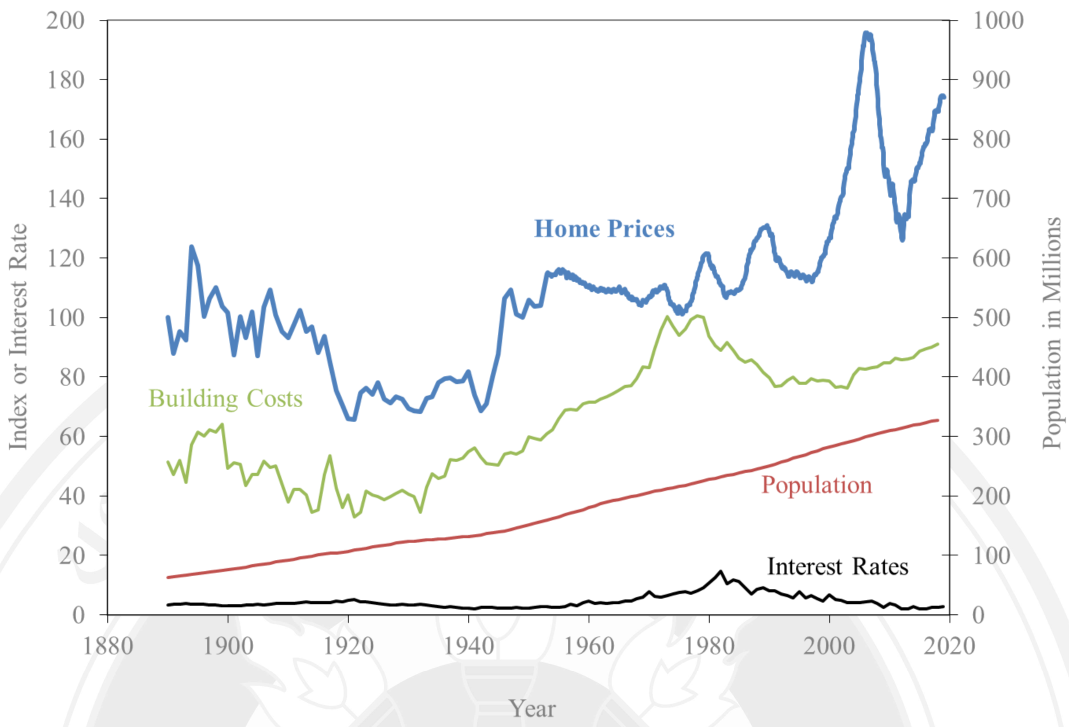

Figure 1.1 The U.S. Home Prices, the Costs of Building, the Population, the Interest Rates during 1890 – 2019. (Source: Shiller (2015))

The presence of bubble boom-bust episode is also evident in the emerging county. In 1997, the Asian financial crisis took place from the Southeast Asia and contagiously affected the world's economy. At the late 1980s, there was a great economic boom in this region and it attracted the investors to allocate their money for the expected high returns from these markets. At that time, there was huge amount of capital inflow flooding into the stock market in Thailand and other emerging markets within the region. The following graph shows the movement of the stock price indices of Thailand and Malaysia from 1985 to 1999.

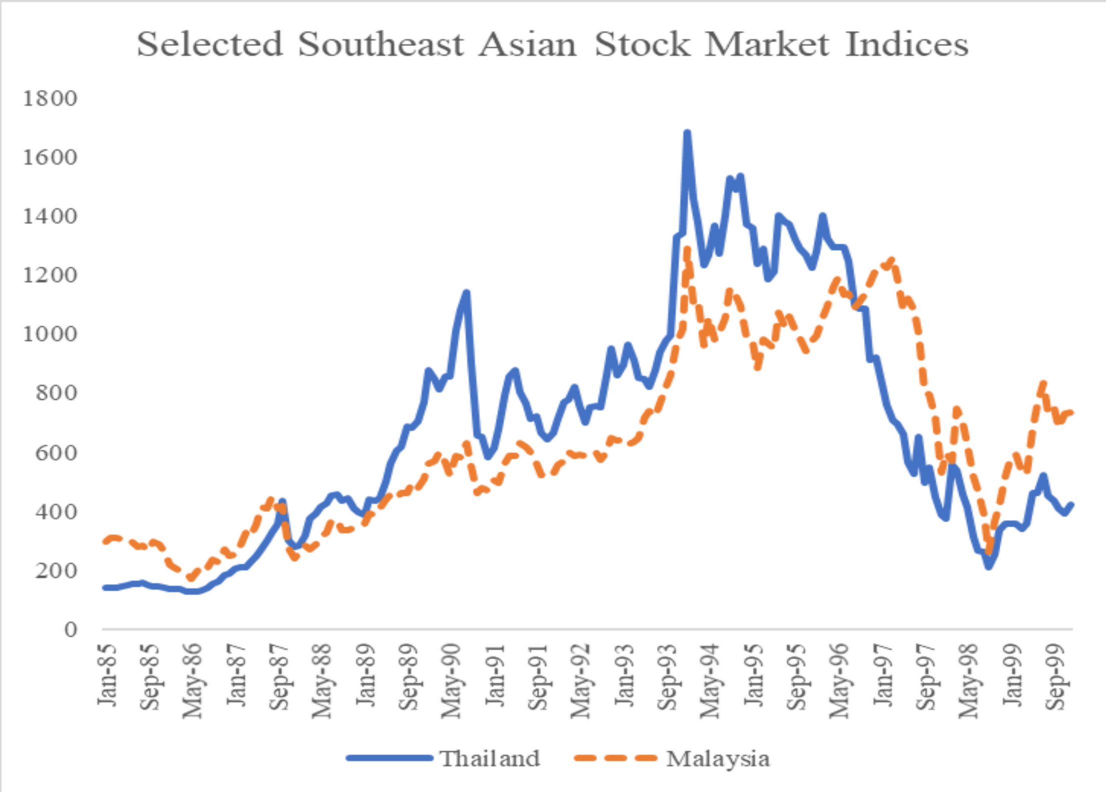

Figure 1.2 Thailand’s and Malaysia’s Stock Market Indices

From the history of bubbles, we learn that bubbles can emerge in the price of any asset (commodities, real estate, or financial assets) within either developed countries or emerging countries. We also know that the bubble bursting costs the severe consequences on not only the bubble-originated country but also others that are related to it. Therefore, the study of bubbles is important and the bubble literature has indeed been growing substantially over past few decades.

1.2 Research Questions

For this thesis, there are two research questions to be answered as follows:

1) Can we detect the time of the formation of the rational bubble and its crash?

2) Can the rational bubble be replaced by government bond?

Therefore, the rest of this thesis is divided into two main chapters to answer these two different research questions.

CHAPTER 2

TESTING THE BUBBLES AND THE CRASHES OF THE ASSET PRICES, THE EVIDENCE FROM THE SOUTHEAST ASIAN COUNTRIES

2.1 Abstract

This study aims to test the existence of bubbles in asset prices. It is a challenge task to test whether there are bubbles in the asset prices. In the early literature, many tests have been proposed mostly through the stationarity testing. Some examples of those tests can be found from Shiller (1981), Diba and Grossman (1988), West (1988). However, there is a critique from Evans (1991) that testing of the bubbles by showing that the fundamental factor from one asset is more stationary than the market price may not be a correct way. The main reason that those tests might not apply for observing the existence of bubble is that the standard unit root test or cointegration test cannot capture for more complex characteristics of bubbles. More specifically, it is difficult to distinguish between a stationary process and a periodically explosive bubble by using the standard unit root test or cointegration test.

Phillips, Wu, and Yu (2011) initiated a new test that can overcome the critique of Evans. They applied the recursive augmented Dickey-Fuller (ADF) test to test the asset price data. The model has been extended to be a generalized model by Phillips, Shi, and Yu (2015). Not only the prediction of the bubble existence, but also the date stamping for bubbles to be started and ended can be explained by these two models.

This study applies these two models to analyze bubbles in many asset prices such as stock indices, gold prices, rubber prices, and the real estate within the southeast Asian countries. The results show that these models can detect the bubble episodes as recorded in history such as the Black Monday stock market crash (1987)

and the subprime crisis (2007 – 2008) in some countries, but fails to detect the collapse of the stock market during Asian financial crisis (1997).

Based on the macroeconomic theories of bubbles, there are some variables that have the relationship with the bubbles such as the real interest rate, real GDP, real consumption, real investment, and capital flow. These variables may decrease (increase) during the bubble periods. So, the tests, that are performed in this section, involve the test of the different mean during the different status (bubble or non-bubble) of the economy. The status of bubble or non-bubble came from the date stamping algorithm performed in the beginning of this paper.

The results show that the algorithm may not catch well Thailand’s data because it fails to reject null hypothesis and the mean of the macroeconomic variables are the same even, they are in the different status of bubbles in the economy. However, the algorithm may work for Indonesia, Philippines, and Singapore because there are the different of the average value of macroeconomic variables for the different bubble status in the economy.

2.2 Introduction

One of the most important explanations of the occurrence of most crises is the existence of bubbles which is the phenomenon that the asset price becomes higher than its fundamental. It would be considerably benevolent if one was able to pinpoint the timing of bubble formation and bursting. This study is another attempt on this regard.

From the Minsky’s theory of the financial instability, the five stages of the bubbles which are displacement, boom, euphoria, profit taking and panic are described for the life cycle of the bubbles. Even we have known the characteristics of bubbles, it is still difficult to find the exact date of their life cycles, specifically the beginning and the end of bubbles. Interestingly, there are many researches trying to find the appropriate ways to timestamp the bubble boom-bust episode.

The famous tests are of Shiller (1981) and West (1988) which focus on determining fundamental values of assets. Alternatively, the studies such as Diba and Grossman (1988) and Hamilton and Whiteman (1985) rely on the test of nonstationarity of the asset price to specify bubbles. Regarding these works, Evans (1991) criticizes that such tests of the bubbles cannot be accurate if the fundamentals (dividends) are more stationary or less explosive than the asset prices (stock prices).

Gürkaynak (2008) surveyed existing econometric tests in the literature during that time, namely the variance bounds tests, cointegration tests, and Markov switching tests. Apparently, the performances of these tests are not quite satisfactory. They fail to distinguish asset price bubbles out of the fundamental price.

In 2011, there was a proposal of a new test for the bubbles in the asset prices. Phillips et al. (2011) and Phillips and Yu (2011) introduced the time series technique to detect and to make the time stamp for asset price bubbles. The test utilizes the recursive method of the right-tail augmented unit root to measure the explosive process in the asset prices.

Since then, there are many studies utilizing the recursive method to check the explosive and the dating of the bubbles. Homm and Breitung (2012) compare the method of Phillips et al. (2011) with the various methods of econometric tests for the bubbles. The results show that the time stamping method of Phillips et al. (2011) can capture well the existence of the bubbles in Nasdaq index during the late 1990s.

Phillips et al. (2015) generalized the model of Phillips et al. (2011) to capture the multiple-cycle of the asset prices bubbles for the long historical data. The test in this study use the long historical data of the S&P 500 stock index from the period of January 1987 until December 2010. The results from utilizing this generalized model can capture all of the well-known bubbles happened in the long testing period while the dating method of Phillips et al. (2011) gives the inconsistency of the time stamp of the bubbles.

Not only is the stock price used for bubble testing, but also many other assets were investigated. Homm and Breitung (2012) have tested the house prices and found the explosive dynamics identifying bubbles in the United States, United Kingdom, and Spain before the financial crisis at the late 2000s. There are also the studies in the agricultural commodities prices applied the same method to find bubbles. Gutierrez (2013) utilized the right-tail augmented Dickey-Fuller test to find the bubble processes in the prices of corn, wheat, and rice. From the testing results, the authors found the explosive price paths being consistent with the peak price timing in agricultural commodities during the period of 2007 and 2008. Another study in agricultural commodity price bubbles is the research of Areal, Balcombe, and Rapsomanikis (2016). They applied the generalized model of Phillips et al. (2015) to the food and beverage price indices, the agricultural raw material price indices, and the 28 single agricultural product prices. Among the 28 individual agricultural commodity prices, the price of wheat, rice, soybean oil, and rapeseed oil were found to have bubbles during the beginning of 2008. This is consistent with the findings from the study of Gutierrez (2013).

This study applies the method of Phillips et al. (2011) and Phillips et al. (2015). Various assets are tested: stock indices, real estate prices, gold prices, and the rubber prices. The study mainly focuses on Thailand's market but other Southeast Asian countries are also considered given the availability of the data.

The remaining of this chapter is organized as follows. Section 2.3 explains the asset pricing model and the econometric methods using for testing the bubbles. Section 2.4 shows the data set. Section 2.5 exhibits the empirical results and some discussions. Section 2.6 uses the theory of rational bubbles to compare that the econometric results are the same as the behavior explained in the theory. Finally, section 2.7 provides the summary of the study in testing the bubbles.

2.3 Tests for Asset Price Bubbles

2.3.1 The Asset Pricing Model

Recall the model of Phillips et al. (2011). Under the efficient market hypothesis or the no arbitrage condition, the price of an asset, mentioned as a stock throughout the text, is determined by the sum of the present value of the future cash flow. It can be described as the following equation:

$$P_t = \frac{1}{R} E_t(P_{t+1} + D_{t+1}) \tag{2.1}$$

where P_t is the stock price at time t, R is the discount rate which is assumed to be a positive constant, E_t is the conditional expectation, and D_{t+1} is the dividend received from holding the stock in period t to $t+1$. Equation (2.1) shows that the current price

(P_t) is the discounted value from the resale value plus the dividend at time $t+1$. Recursively, P_{t+1} is determined in the exact same fashion.

By the analysis of Campbell and Shiller (1988), a log-linear approximation yields the below price equation:

$$p_t = \frac{\kappa-\gamma}{1-\rho} + (1-\rho)\sum_{i=0}^{\infty}\rho^i E_t(d_{t+i+1}) + \lim_{i\to\infty}\rho^i E_t(p_{t+i}) \qquad (2.2)$$

where the lower-case variable is defined as the natural logarithm form, $\gamma = \ln(1+R)$, $\rho = 1/\left(1+e^{\overline{d-p}}\right)$, and $\overline{d-p}$ is the average of the log of dividend to price ratio or the dividend yield in the asset pricing model and $\kappa = -\log(\rho) - (1-\rho)\log\left(\frac{1}{\rho}-1\right)$ is the constant. Equation (2.2) can be simplified as follows.

$$p_t = p_t^f + b_t \qquad (2.3)$$

where

$$p_t^f = \frac{\kappa-\gamma}{1-\rho} + (1-\rho)\sum_{i=0}^{\infty}\rho^i E_t(d_{t+i+1}) \qquad (2.4)$$

and

$$b_t = \lim_{i\to\infty}\rho^i E_t(p_{t+i}). \qquad (2.5)$$

Equation (2.3) shows the stock price (p_t). It consists of two components which are the fundamental value (p_t^f) and the bubbles (b_t) as denoted in Equation (2.4) and (2.5) respectively.

In the rational expectation general equilibrium framework, the transversality condition traditionally rules out bubbles by imposing the terminal restriction of the expected value of all holding assets must be zero at the end of rational agent's life and hence the fundamental price prevails. However, in the presence of the bubbles, the stock price is greater than its fundamental value by its bubble component. Because the investors expect to receive the higher price in the next period, they are willing to pay extra money on the stock. As this behavior does not break the rational expectation framework, this bubble component is rational. Furthermore, Equation (2.5) implies that such bubbles follow the submartingale process. The submartingale process is the process that the conditional expected value of the random variable at time $t+1$ has the value greater than or equal to its value at time t. The submartingale process that implied by equation (2.5) can be shown as

$$E_t(b_{t+1}) = \frac{1}{\rho}b_t + \varepsilon_t = \left(1 + e^{\overline{d-p}}\right)b_t + \varepsilon_t$$

where ε_t is the martingale difference. Because $e^{\overline{d-p}}$ is greater than zero, the rational bubble is expected to be exploded. Hence, Equation (2.3) says that p_t is also explosive.

In the literature, there are many tests to find out the explosive bubbles. The next section describes some of the tests in details.

2.3.2 The Econometric Methods Using for Testing the Bubbles

In this section, there will be two methods that are applied in testing the bubbles. The first method is proposed by Phillips et al. (2011) denoted as PWY. The second method is the model developed by Phillips et al. (2015) denoted as PSY. The brief explanation of each method will be described in the sub-section 2.3.2.2 and 2.3.2.3 respectively.

For both models, they apply one general test for most of macroeconomic and financial data which is called augmented Dickey-Fuller test. In short, the test is known as ADF test. Before going to the details of PWY model and PSY model. I explain the ADF test to get the concept before go to the extended version of the test.

2.3.2.1 Augmented Dickey-Fuller Test

In the econometrics, the data that has a time series characteristic, which are mostly found in the macroeconomic and financial variables, may face a non-stationary problem. There are several reasons that why the non-stationary data is unpreferable in econometrics analysis. The following are the results of using non-stationary data in the analysis.

1) When there is a shock or the unexpected change in the model, the shock in the non-stationary data will not die out when the time passed by. The data are lost their mean reversion ability and cannot be used for forecast.

2) By using the non-stationary data in the regression analysis, it can lead to wrong relationship between the variables. This situation is known as spurious regression. This situation happens when we regress the two or more unrelated random variables and one or more variables have the non-stationary characteristic. The result from running this regression model may have a high

goodness of fit, or (adjusted) R^2, and the coefficients estimated from the model is statistically significant difference from zero. This kind of the regression in econometrics is valueless and cannot be used for explain the economic phenomenon. However, there is a case that unrelated non-stationary random variables can have the true long run relationship. That case can happen when those variables have a cointegrating relationship. This cointegration analysis will be left here as it is not concerned in the following sub-section.

In the econometrics, we call the data have a stationary process when the variable has a constant mean, variance, and covariance depends on time difference i.e. in the same time elapse covariance should be identical. For a series, y_t, we can say that this series is a weakly stationary or covariance stationary when it passes the following three conditions

(a) $E(y_t) = \mu, \forall t$

(b) $Var(y_t) = \sigma^2 < \infty, \forall t$

(c) $Cov(y_{t_1}, y_{t_1+k}) = Cov\left(y_{t_2}, y_{t_2+k}\right) = \gamma_k, \forall t_1, t_2, \forall k$

The condition (a) shows the constant mean, (b) shows the constant variance, and (c) shows the constant covariances between the time difference k (depends only on k not on t).

According to the above definition, many time series are non-stationary. For example, consider the following specification of autoregressive process of lag 1 or AR(1):

$$y_t = \mu + \phi y_{t-1} + \varepsilon_t \tag{2.6}$$

where μ is a constant, ϕ is an autocorrelation coefficient, and ε_t is a random disturbance with mean equal to zero and constant variance (σ_ε^2). For $|\phi| < 1$, the process is stationary; otherwise, it becomes non-stationary process. For example, a random walk with drift process results when $\phi = 1$. In contrast, when $|\phi| > 1$, it is the explosive process and it is not defined in AR process. However, in this study, we are interesting to test on the explosive bubble which is considered as temporarily explosive process. We will see later in the empirical test.

To test the stationarity, we generally perform the test called the unit root test. There are several methods using for testing the unit root such as Dickey-Fuller (DF) test or Phillips-Perron (PP) test. To be aligned with the tests that are performed in the sub-section 2.3.2.2 and 2.3.2.3, augmented Dickey-Fuller (ADF) test will be briefly explained.

Starting from Dickey-Fuller (DF) test, this test is determined whether the interesting process follows unit root (or being random walk process) or not. Referring back to equation (2.6), there exists unit root when $\phi = 1$. By subtracting y_{t-1} for both side of equation (2.6), we get:

$$\Delta y_t = \mu + (\phi - 1)y_{t-1} + \varepsilon_t \tag{2.7}$$

where Δ is the difference operation. Defining $\psi = (\phi - 1)$, the null hypothesis of DF test is to check $\psi = 0$ against the alternative hypothesis of $\psi < 0$. The test is applied *t* statistic test. However, its distribution is not the standard *t* distribution but known as Dickey-Fuller distribution.

Under Dickey-Fuller test, it has a limitation in testing for the complicated structure of the time series. As shown in equation (2.7), Dickey-Fuller test examines time series which follow AR(1) process. There is an extension version of Dickey-Fuller test which is called augmented Dickey-Fuller test or ADF test.

The ADF test examines the null hypothesis of a series having a unit root. The test is conducted under the following equation:

$$\Delta y_t = \mu + \psi y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta y_{t-i} + \varepsilon_t \tag{2.8}$$

where Δ is the difference operation, which is, for example $y_t - y_{t-1}$, ψ is used for calculating the test statistic, α_i is the coefficient for lag order *i* and *i* can vary from 1 to *p* which is the last lag used in the model.

Like DF test, ADF test examines the null hypothesis of a series has a unit root against the alternative of no unit root in a series.

For the ADF test in which the equation (2.8) is to perform, we still use the coefficient of y_{t-1}or ψ for the test. Again, ψ in the equation (2.8) is modified from ϕ in the equation (2.7) and $\psi = \phi - 1$. Therefore, the ADF test is the test of the null hypothesis of $\psi = 0$ versus the alternative hypothesis of $\psi < 0$. The test statistic for ADF can be calculated by the following formula

$$ADF\ test\ statistic = \frac{\hat{\psi}}{Standard\ Error\ (\hat{\psi})} \tag{2.9}$$

Like the other statistical tests, we have to compare the test statistic with the critical value at our decided significant level. As the data generated process in

ADF model is nonstandard like *t* distribution, the value from standard *t* distribution table cannot be used for the critical value in this test. For the critical value for ADF test, it is needed to be simulated and luckily most of statistic programs provide the critical value for ADF test.

If the test statistic is less than critical value, we reject the null hypothesis and accept the alternative hypothesis of no unit root in the series. Conversely, if the test statistic is greater than critical value, it fails to reject null hypothesis and the series is considered to have a unit root or non-stationary process.

This econometric method is applied in the following sub-section. It is used to determine that the asset price series have the explosive bubbles ($\psi > 0$ or $\phi > 1$) or not.

2.3.2.2 The PWY Model

The basic idea to this model is o test for the explosive process in y_t by using the right-tail ADF test. The one-tail test is based on Equation (2.8) where ε_t is the error term with the normally independent distribution: $\varepsilon_t \sim NID(0, \sigma_x)$.

We are going to test whether the autoregressive coefficient, ψ, is explosive. The null hypothesis of the test is that the process y_t has a unit root (H_0: $\psi = 0$) against the alternative hypothesis that the process is mildly explosive (H_1: $\psi > 0$).

The PWY model performs the right-tail ADF test over many sub-samples. To illustrate this, let us normalize the entire sample size T to the unit mass. All sub-samples are hence within the range of [0,1]. Equation (2.8) is estimated over each sub-sample $[r_1, r_2]$, see Figure 2.1. The autoregressive coefficient and the ADF statistic are denoted as ψ_{r_1,r_2} and $ADF_{r_1}^{r_2}$ respectively. The fraction of the sample size is defined by $r_w = r_2 - r_1$. The smallest fraction is denoted as $r_0 = 0.01 + {}^{1.8}/_{\sqrt{T}}$. Here, r_1 is fixed at zero to be the starting point while $r_2 = r_w \in [r_0, 1]$ is the ending point. Moreover, the supremum ADF (SADF) is defined as follows:

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} \left\{ADF_0^{r_2}\right\}$$

We use this SADF statistic to test the existence of explosive process which would imply asset price bubbles.

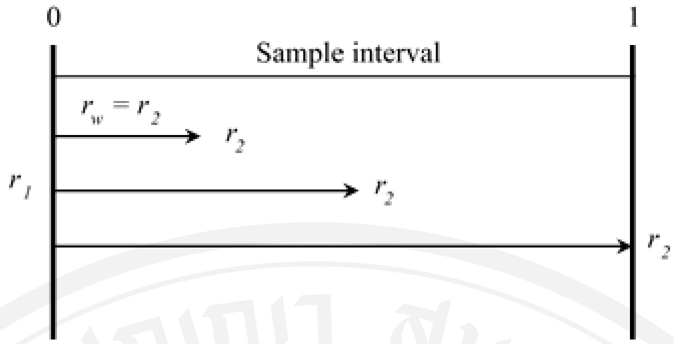

Figure 2.1 The Process of Sample Selection for the Regression in the PWY Model
(Source: Reproduce from Caspi (2013))

We use this SADF statistic in the hypothesis testing. If we are able to reject the null hypothesis, the time-series data of the interested asset price have the bubble. More interestingly, under the PWY model, we can know the beginning and the end of the bubble(s). To find the date-stamping by using the PWY model, we need to compare each calculated $ADF_0^{r_2}$ with its corresponded critical value. The initial date of the bubble, T_{r_e}, is the point where the calculated $ADF_0^{r_2}$ is greater than the critical value and the bursting date of the bubble, T_{r_f}, is the point where the calculated $ADF_0^{r_2}$ is lower than the critical value after T_{r_e}. The condition for date-stamping in PWY can be written mathematically as the following.

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

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

where $cv_{r_2}^{\beta_T}$ is the $100(1 - \beta_T)\%$ critical value with the significance level of β_T. In the empirical test, the significant level of β_T usually set at the certain level such as 5 percent.

2.3.2.3 The PSY Model

This model is modified from the PWY model and it is more flexible in varying the sample period. It is called this generalized SADF (GSADF). Instead of fixed r_1 = 0, in this model r_1 can be any value which are in the range of $[0, r_2 - r_0]$. The following figure shows the image of the GSADF test.

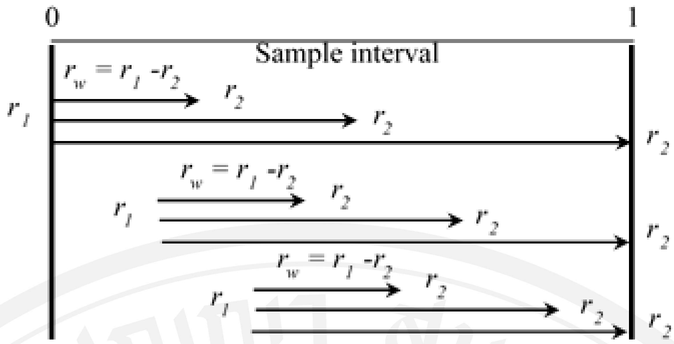

Figure 2.2 The Process of Sample Selection for the Regression in the PSY Model
(Source: Reproduce from Caspi (2013))

The calculated GSADF statistic can be obtained as follows.

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \left\{ ADF_{r_1}^{r_2} \right\} \tag{2.10}$$

The result from Equation (2.10) will be used for the hypothesis testing whether the bubble(s) exist or not. The null hypothesis and the alternative hypothesis are the same as in the PWY model.

The PSY model is able to find the date-stamping for the bubble. The strategy for date-stamping utilizes a backward SADF (BSADF) test. Instead of fixing the starting point r_1, this method fixes the end point r_2 equal to one. The starting point is varied in the range of $[0, r_2 - r_0]$. The recursive regression returns the series of the ADF value as $\left\{ ADF_{r_1}^{r_2} \right\}_{r_1 \in [0, r_2 - r_0]}$. Then the calculated BSADF statistic can be obtained from the following.

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_1]} \left\{ ADF_{r_1}^{r_2} \right\}$$

In PSY, we use BSADF statistics to determine the initial date and bursting date of the bubble.

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) > scv_{r_2}^{\beta_T} \right\}$$

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) < scv_{r_2}^{\beta_T} \right\}$$

where $scv_{r_2}^{\beta_T}$ is the $100(1 - \beta_T)\%$ critical value of the SADF with β_T significance level.

For the testing procedure, I follow the instruction that is given by Caspi (2013). The empirical results from the test in both PWY and PSY model are shown in Section 2.5. The empirical findings in the existence of the bubbles and the date stamping for boom and bust episode are reported in the details.

2.4 Data

In this research, the main country to be studied for the asset price bubbles is Thailand. The assets include both financial assets and physical commodities. The assets that are covered in the study are stock prices (stock index and price-to-dividend ratio), gold price, rubber price, and real estate price. In some assets, there are other southeast Asian countries to be studied. Most of the asset prices are tested by using the real term except for the price-to-dividend ratio and all are monthly data. To make the nominal value to be the real asset prices, the Consumer Price Index (CPI) is used to be the adjusted factor by using it as a denominator. The details on data is presented below.

Table 2.1 Data Set for Dating the Bubbles Test

Variable	Proxy	Source	Selected Data Range
a) Thailand			
CPI	Thailand CPI (not seasonal adjusted)	Datastream	Jan 1976 - Mar 2019
Stock Index	SET Index	Datastream	May 1975 - Mar 2019
Price-to-Dividend	The inverse of SET Index's Dividend Yield	Datastream	May 1975 - Mar 2019
Gold Price	Thai Baht Gold 99.9% Spot - DS Mid Price	Datastream	Dec 1989 - Mar 2019
Rubber Price	Rubber, RSS 3 1-Pos FOB Songkla T/KG	Datastream	Dec 1994 - Mar 2019
Real Estate Price			
▪ House	House with Land Price Index	Bank of Thailand	Mar 2008 - Feb 2019
▪ Townhouse	Townhouse with Land Price Index	Bank of Thailand	Mar 2008 - Feb 2019
▪ Condominium	Condominium Price Index	Bank of Thailand	Mar 2008 - Feb 2019
▪ Land	Land Price Index	Bank of Thailand	Mar 2008 - Feb 2019
b) Indonesia			
CPI	Indonesia CPI (not seasonal adjusted)	Datastream	Jan 1996 - Mar 2019
Stock Index	IDX Composite Index	Datastream	Jan 1996 - Mar 2019
c) Malaysia			
CPI	Malaysia CPI (not seasonal adjusted)	Datastream	Feb 1980 - Feb 2019
Stock Index	FTSE Bursa Malaysia KLCI	Datastream	Feb 1980 - Feb 2019
Rubber Price	Rubber (MRE) SMR GP FOB Sen/Kg	Datastream	Feb 1990 - Feb 2019
d) Philipines			
CPI	Philippines CPI (not seasonal adjusted)	Datastream	Feb 1986 - Mar 2019
Stock Index	PSE Index	Datastream	Feb 1986 - Mar 2019
e) Singapore			
CPI	Singapore CPI (not seasonal adjusted)	Datastream	Sep 1999 - Feb 2019
Stock Index	Singapore Straits Times Index	Datastream	Sep 1999 - Feb 2019

2.5 Empirical Results

In this section, the analysis of the asset prices bubbles is presented by using the data set as described in the previous section. In the first analysis, the explosive bubble test, right tail ADF test, is performed. The test statistics come from the calculation by using PWY and PSY model. After there is a confirmation of the explosive bubble by the rejection of null hypothesis, the second step of the analysis is to find the time stamp for the initial and bursting dates of the bubbles.

First, the real stock price and the price-to-dividend ratio are studied.

In this test, instead of using the single stock price, I choose the stock index to see the overall market movement. The results of the real stock prices are shown in the Table 2.2

Table 2.2 The Right-tail ADF Test of the Real Stock Price Indices

Countries	PWY				PSY			
	SADF	Critical Value			GSADF	Critical Value		
	t-statistic	99%	95%	90%	t-statistic	99%	95%	90%
Thailand	3.7858	1.9406	1.4303	1.2082	11.2156	2.8051	2.2309	2.2309
Indonesia	0.2603	2.0249	1.4405	1.1672	3.3867	2.8300	2.1202	1.9242
Malaysia	1.3997	1.9117	1.4544	1.2129	3.4172	2.8679	2.2307	2.0031
Philippines	0.9586	2.0143	1.4709	1.2267	2.3203	2.9097	2.2319	2.0028
Singapore	0.7504	1.8673	1.4054	1.1201	2.7555	2.6931	2.1483	1.8912

From Table 2.2, the results show that all countries experience the explosive bubbles once we use the PSY method in testing. All countries except Philippines can reject the null hypothesis at 99% of the confidence level while Philippines can reject at 95%. In contrast, when using the PWY method, it fails to reject the null hypothesis even 90% of confidence level except for Thailand and Malaysia. In particular, Thailand accepts the alternative hypothesis of having the explosive of the stock price bubbles at 1% significant level while Malaysia does at 10% significance level. From these results, the second step is to determine the birth and crash of the bubbles in the stock markets of these five countries. The results of date-stamping the bubbles are summarized in Table 2.3 and Figure 2.3 illustrate one example.

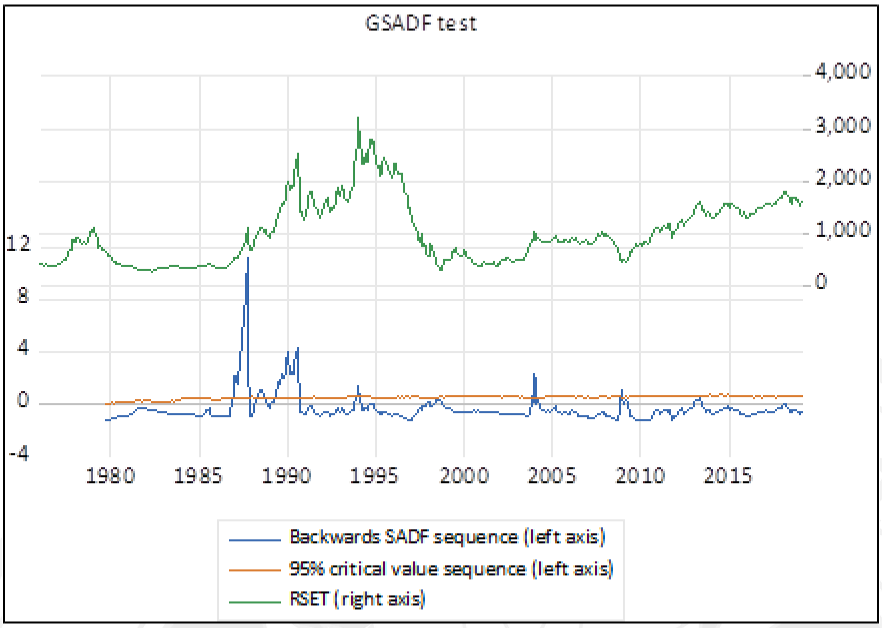

Figure 2.3 The Time Stamping of the Real SET Index Using PSY Algorithm

Table 2.3 Time Stamping of the Stock Price Bubbles

		Thailand		Indonesia		Malaysia		Philippines		Singapore	
		PWY	PSY	PWY	PSY	PWY	PSY	PWY	PSY	PWY	PSY
Sub-period 1	Start	Oct-87	Dec-86	-	Dec-04	Jan-94	May-86	-	Dec-93	-	Jul-05
	End	Nov-87	Nov-87	-	Sep-05	Feb-94	Jun-86	-	Feb-94	-	Sep-05
Sub-period 2	Start	Jun-89	May-88	-	May-06	-	Nov-93	-	Nov-06	-	Feb-06
	End	Oct-90	Nov-88	-	Jun-06	-	Feb-94	-	Feb-08	-	Jun-06
Sub-period 3	Start	Nov-93	May-89	-	Oct-06	-	Dec-97	-	Feb-13	-	Nov-06
	End	Mar-94	Oct-90	-	Jul-08	-	Jan-98	-	Sep-13	-	Feb-08
Sub-period 4	Start	-	Jan-94	-	Oct-10	-	Aug-98	-	Feb-15	-	Dec-08
	End	-	Feb-94	-	Feb-11	-	Oct-98	-	Jun-15	-	Jan-09
Sub-period 5	Start	-	Jan-04	-	Apr-11	-	Apr-07	-	-	-	Mar-09
	End	-	Feb-04	-	Sep-11	-	Mar-08	-	-	-	Apr-09
Sub-period 6	Start	-	Dec-08	-	May-13	-	-	-	-	-	
	End	-	Jan-09	-	Jun-13	-	-	-	-	-	

In Table 2.3, we observe that the PWY model predicts the time stamps in the same period as the PSY model like in Phillips et al. (2015) but the PSY model predicts more time stamps than the PWY model. What we can see in common from the results in Table 2.3 are that the bubbles happened in the Southeast Asian countries are quite the same as the bubbles happened globally. For instance, the stock markets crash during the latest global financial crisis during 2007 – 2009 can be observed as the bubble period for these countries. The bubble in Southeast Asia tends to be concurrent with the subprime crisis.

Surprisingly, there is only Malaysia that can capture the bubbles during the Asian financial crisis in 1997 but the time stamp is quite short period which is between December 1997 to January 1998. From this dataset, both PWY and PSY cannot catch up the bubble episode for this "Tom Yum Kung crisis" which is one of the most impact crisis in Southeast Asia.

To be consistent with the test by Phillips et al. (2015), the price to dividend ratio is used for testing in this study as the other indicator for bubbles. Intuitively, the bubble is the main reason causing the asset price to rise without the increase in its dividend. The test is performed by using Thailand's data set and the results are shown in Table 2.4 and Table 2.5 for the existence of the bubbles and the date stamping respectively.

Table 2.4 The Right-tail ADF Test of the Price to Dividend Ratio

	PWY				PSY			
Countries	SADF	Critical Value			GSADF	Critical Value		
	t-statistic	99%	95%	90%	t-statistic	99%	95%	90%
Thailand	4.2562	2.0592	1.4950	1.2446	7.3711	2.9062	2.2259	2.0232

Table 2.5 Time Stamping of the Price to Dividend Ratio

	Sub-period 1		Sub-period 2		Sub-period 3		Sub-period 4	
	Start	End	Start	End	Start	End	Start	End
PWY	Jul-87	Nov-87	Jul-89	Sep-90	Apr-99	Mar-00		
PSY	Aug-83	Jan-84	Oct-86	Nov-87	Jul-89	Sep-90	Apr-99	Mar-00

From Table 2.4, we find that even when using the price to dividend ratio, we can reject null hypothesis for both the PWY and the PSY model at 1% significant level. This means that in the sub-period of the test data, there exist the explosive bubbles. In the Table 2.5, it shows all sub-periods of the explosive bubbles. Again, the time stamping using the PSY algorithm can capture all of the dating that is detected by the PWY model but the PSY shows one more sub-period. The results are quite different compared with when we use the real stock price to test. The time stamping of the price to dividend ratio is shown in the Figure 2.4.

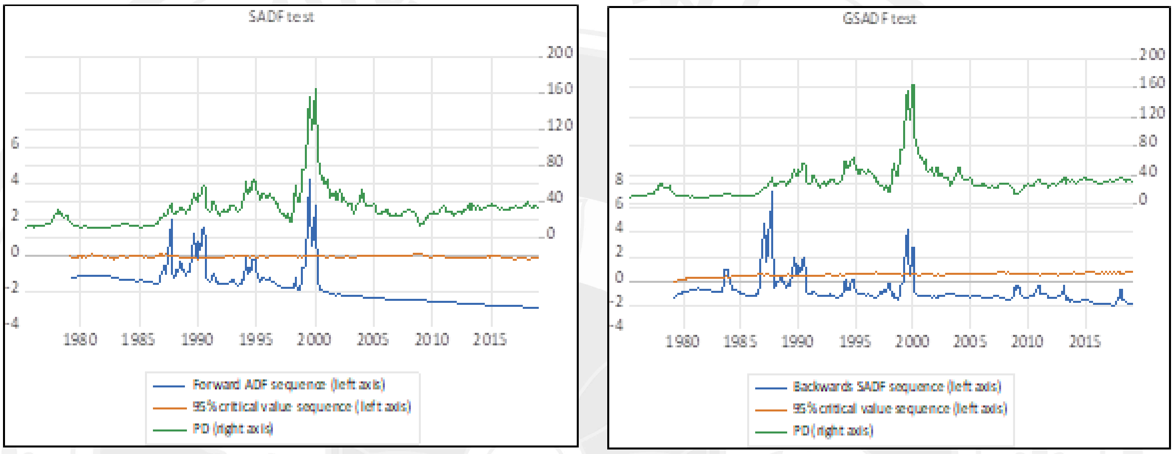

Figure 2.4 The Time Stamping of the Price to Dividend Ratio Using PWY and PSY Algorithm

Next, the test of the real gold price is performed. The results are shown in Table 2.6 and Table 2.7 for the existence of the bubbles and the date stamping respectively and the illustration of the date stamping is shown in Figure 2.5.

Table 2.6 The Right-tail ADF Test of the Real Gold Price

	PWY				PSY			
Countries	SADF	Critical Value			GSADF	Critical Value		
	t-statistic	99%	95%	90%	t-statistic	99%	95%	90%
Thailand	2.2787	2.0789	1.5294	1.1878	2.3073	2.9797	2.2529	1.9898

Table 2.7 Time Stamping for the Real Gold Price

		Thailand	
		PWY	PSY
Sub-period 1	Start	Mar-08	Jun-97
	End	Apr-08	Aug-97
Sub-period 2	Start	Mar-09	Feb-98
	End	May-09	Mar-98
Sub-period 3	Start	Nov-09	Feb-03
	End	May-13	Mar-03
Sub-period 4	Start	-	May-06
	End	-	Jun-06
Sub-period 5	Start	-	Mar-08
	End	-	Apr-08
Sub-period 6	Start	-	Dec-09
	End	-	Jan-10
Sub-period 7	Start	-	Mar-11
	End	-	Jan-13

Both SADF test and GSADF test show that the real gold prices have the explosive bubbles as we reject the null hypothesis at 1% and 5% significance level respectively. For the time stamping, the bubbles in the real gold prices in the range between November 2009 and May 2013. The PSY algorithm can detect more relatively short sub-periods.

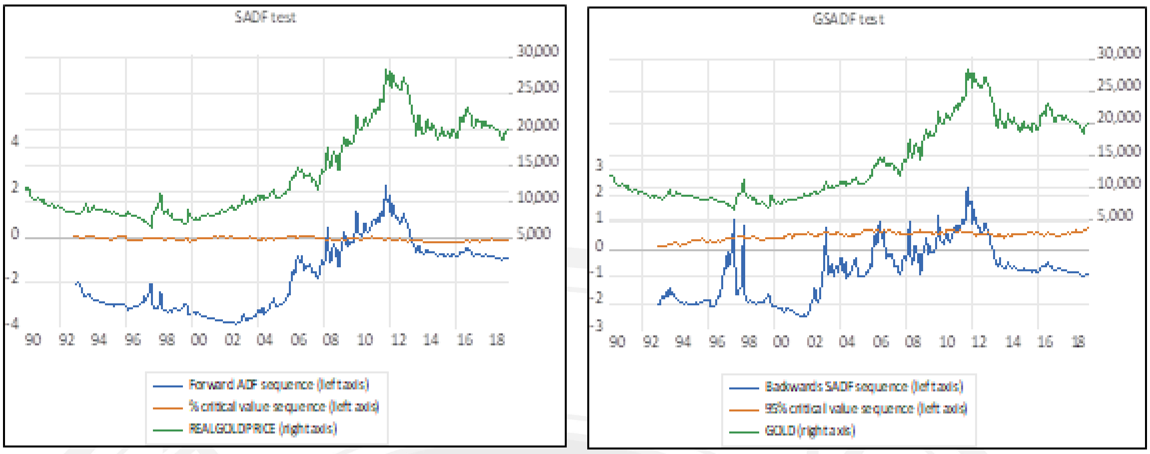

Figure 2.5 The Time Stamping of the Real Gold Price Using PWY and PSY Algorithm

Next, the agricultural commodity is tested for the bubbles. The selected agricultural commodity is rubber. The results of the test are shown in Table 2.8 and Table 2.9 for the existence of the bubbles and the date stamping respectively and the illustration of the date stamping is shown in Figure 2.6.

Table 2.8 The Right-tail ADF Test of the Real Rubber Price

	PWY				PSY			
Countries	SADF	Critical Value			GSADF	Critical Value		
	t-statistic	99%	95%	90%	t-statistic	99%	95%	90%
Thailand	1.5711	1.9157	1.5041	1.1739	1.7087	2.9740	2.9740	1.9303
Malaysia	4.5402	1.9578	1.4859	1.2452	4.5402	2.9520	2.2137	1.9685

Table 2.9 Time Stamping for the Real Rubber Price

		Thailand		Malaysia	
		PWY	**PSY**	**PWY**	**PSY**
Sub-period 1	Start	Jun-06	-	Oct-93	Oct-93
	End	Aug-06	-	Nov-93	Nov-93
Sub-period 2	Start	Jan-11	-	Aug-94	Aug-94
	End	Jul-11	-	Jun-95	Jun-95
Sub-period 3	Start	-	-	Jun-06	Oct-03
	End	-	-	Sep-06	Dec-03
Sub-period 4	Start	-	-	Jun-08	Feb-06
	End	-	-	Oct-08	Sep-06
Sub-period 5	Start	-	-	Nov-10	Dec-10
	End	-	-	Jul-11	May-11

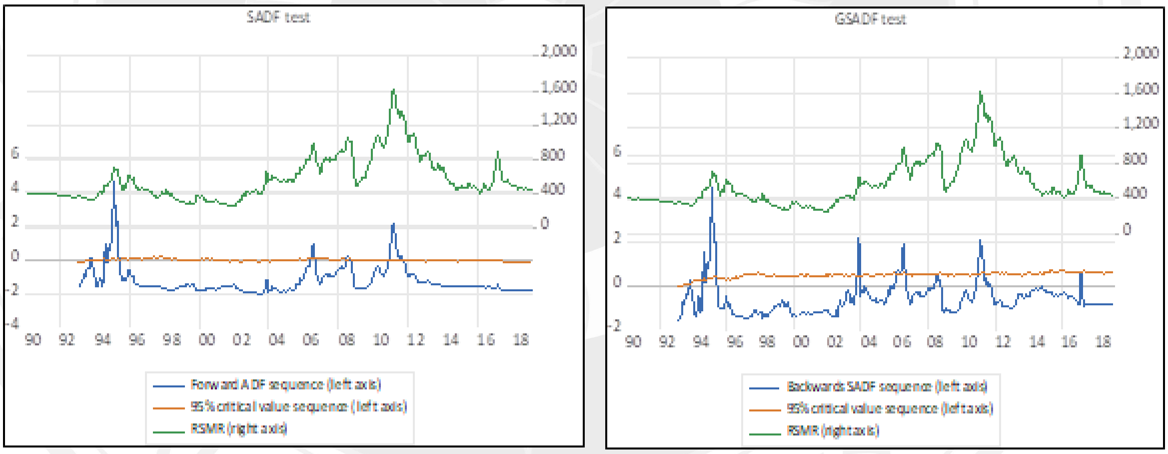

Figure 2.6 The Time Stamping of the Real Rubber Price Using PWY and PSY Algorithm for Malaysia's Data Set

From Table 2.8, we can observe that for Malaysia's case, the SADF and GSADF tests reject the null hypothesis at 99% confidence level while for Thailand's case, only the SADF test rejects the null hypothesis at 5% significance level. For the time stamping, both Thailand and Malaysia experience the bubble episode in the real rubber prices in 2006 and 2011. Malaysia also has the bubbles in the real rubber price during 1993 to 1995. This cannot be captured in Thailand as the data set starts from December 1994.

Lastly, the test is conducted over the real estate prices. The house price bubble is one of the most important variables in the global financial crisis during 2007 to 2009. here, four types of the real estate are tested: prices of house (with extra space), townhouse (without extra space), condominium, and land of Thailand. The existence of the bubbles and the time stamping are shown in Table 2.10 and Table 2.11 respectively. For the diagram of the time stamping, the selected graphs are shown in Figure 2.7.

Table 2.10 The Right-tail ADF Test of the Real Estate Real Price Index

	PWY				PSY			
Type	SADF	Critical Value			GSADF	Critical Value		
	t-statistic	99%	95%	90%	t-statistic	99%	95%	90%
House	-0.5685	1.9604	1.3746	1.0959	0.9582	2.7589	2.0466	1.7070
Townhouse	0.8584	1.9604	1.3746	1.0959	2.4841	2.7589	2.0466	1.7070
Condominium	0.7570	1.9604	1.3746	1.0959	1.8524	2.7589	2.0466	1.7070
Land	1.8897	1.9604	1.3746	1.0959	3.1420	2.7589	2.0466	1.7070

Table 2.11 Time Stamping for the Real Estate Real Price Index

		House		Townhouse		Condominium		Land	
		PWY	PSY	PWY	PSY	PWY	PSY	PWY	PSY
Sub-period 1	Start	-	-	-	Aug-13	-	Dec-14	Aug-15	Dec-13
	End	-	-	-	Oct-16	-	Mar-15	Apr-17	Mar-14
Sub-period 2	Start	-	-	-	Mar-17	-	Oct-15	-	Sep-14
	End	-	-	-	Open	-	Jan-16	-	Apr-17
Sub-period 3	Start	-	-	-		-	Oct-16	-	-
	End	-	-	-		-	Jan-17	-	-

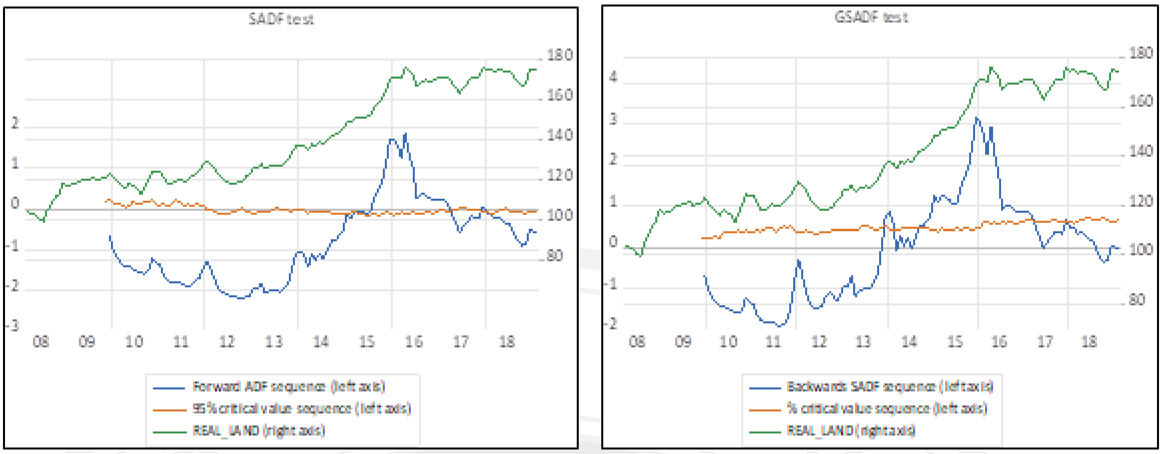

Figure 2.7 The Time Stamping of the Land Price Index in Real Term of the Using PWY and PSY Algorithm for Thailand's Data Set

From Table 2.10, except for the house, there is an evidence that the real estate prices in Thailand experience the explosive bubbles. The null hypothesis is rejected for townhouse, condominium, and land cases when we use the PSY model with the confidence level of 95%, 90%, and 99%. The bubbles start since 2013 and ends around April 2017. But for the townhouse, there is still on the run of the bubbles as can be seen in Figure 2.8.

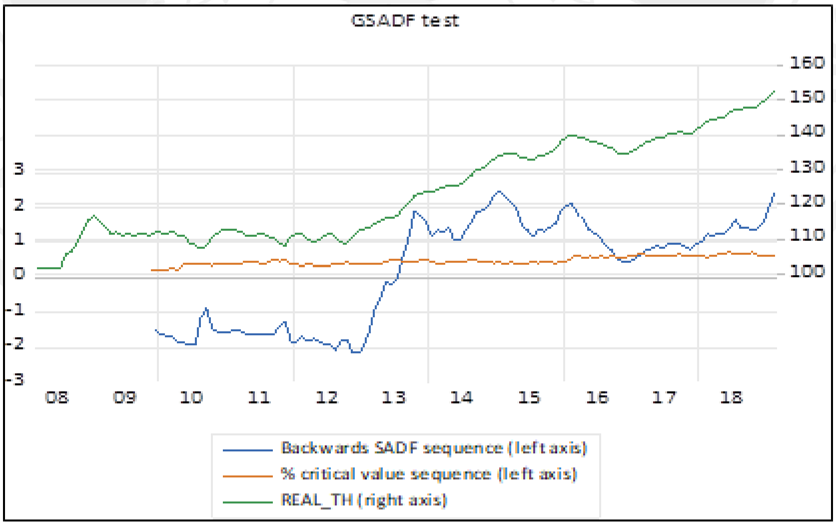

Figure 2.8 The Time Stamping of the Townhouse Price Index in Real Term of the Using PSY Algorithm for Thailand's Data Set

By the test of the PWY model and PSY model for the financial assets and non-financial assets by using the Southeast Asian countries' data, we find that these two models can capture most of the bubbles and their crashes in the tested period. But these two models cannot capture the bubbles and the crashes in the stock market during the Asian financial crisis in the late 1990s. Further investigation is needed to understand the reason why this crisis cannot be detected.

2.6 Economic Theories of Bubbles and Empirical Results

From the empirical results in section 2.5, it is still questionable whether the econometric tests (PWY model or PSY model) are capturing the episode of boom and burst of the bubbles as explained in the theory of bubbles. In this section, I compare the empirical results that get in the previous section with the existed economic theories of bubbles.

2.6.1 Some Basic Economic Theories of Bubbles

Under the boom – bust episode, the model predicts that there is a swing in the real activities, which are output, consumption, and investment in the economy. In the presence of the bubbles, the soaring asset price drives the real activities into the upward trend. In contrast, when the bubbles burst, the real activities sharply plummet. These explanations are the second check point to the empirical results.

According to Tirole (1985), bubbles however can crowd out the investment. Therefore, during the boom episode, the investment can decrease. This is the caution point for comparing the empirical results with the macroeconomic variables.

In Ventura (2012), the overlapping generations model is used to explain the bubbles and the capital flows. In the time of bubbles growth, the investment is expanded. Agents in the economy including the financial intermediaries can sell the bubbles to foreign countries to support their investment activities. At this period, the capital inflow increases. On the contrary, once the bubbles burst, the bubble asset cannot sell internationally and this causes the capital flight.

Ventura (2012) suggests that there should be the capital inflow when our empirical test shows a sign of bubbles and vice versa. This is the last point to be checked in this section.

In summary, the strategy for checking the empirical results of time stamping of the bubbles with the macroeconomic theories is to see the macroeconomic variables during each period of time that the bubble date stamping technique suggests for the beginning of the bubbles and the crashing of the bubbles. The relationship between the macroeconomic variables and the boom – bust episode can be shown in the following table.

Table 2.12 The Relationship Between the Macroeconomic Variables and the Boom – Bust episode

Macroeconomic variables	**Expected dynamic during bubbles 'Boom'**
Interest Rate	Low
Real Output (GDP)	Increase
Real Consumption	Increase
Real Investment	Increase or Decrease
Real Capital flow	Inflow

2.6.2 Data Set Using for the Comparison

For the comparison in this section, I use the date stamping results to see the impact on the macroeconomic variables. The data set used in this section is extracted from Datastream database. The summary of the data for this section is shown in Table 2.13.

Table 2.13 Data for Comparison between Bubbles Date Stamping Results and Macroeconomic Variables

Country	Variable	Proxy	Frequency	Selected Data Range
Thailand	Interest Rate	10-year Government Bond Yield	Monthly	May 1981 - Sep 2019
	GDP	GDP	Quarterly	Q1 1993 - Q3 2019
	Consumption	Private Consumption Expenditure	Quarterly	Q1 1993 - Q3 2019
	Investment	Changes in Inventory	Quarterly	Q1 1993 - Q3 2019
	Capital Flow	BOP - Capital and Financial Account	Quarterly	Q1 2005 - Q3 2019
Indonesia	Interest Rate	10-year Government Bond Yield	Monthly	May 2003 - Sep 2019
	GDP	GDP	Quarterly	Q1 2010 - Q3 2019
	Consumption	Private Consumption Expenditure	Quarterly	Q1 2010 - Q3 2019
	Investment	Gross Capital Formation	Quarterly	Q1 2010 - Q3 2019
	Capital Flow	BOP - Capital and Financial Account	Quarterly	Q1 2010 - Q3 2019
Malaysia	Interest Rate	10-year Government Bond Yield	Monthly	Jan 1996 - Sep 2019
	GDP	GDP	Quarterly	Q1 2015 - Q3 2019
	Consumption	Private Consumption Expenditure	Quarterly	Q1 2015 - Q3 2019
	Investment	Gross Capital Formation	Quarterly	Q1 2015 - Q3 2019
	Capital Flow	BOP - Capital and Financial Account	Quarterly	Q1 2015 - Q3 2019
Philippines	Interest Rate	10-year Government Bond Yield	Monthly	Feb 1999 - Sep 2019
	GDP	GDP	Quarterly	Q1 1998 -Q3 2019
	Consumption	Private Consumption Expenditure	Quarterly	Q1 1998 -Q3 2019
	Investment	Changes in Inventory	Quarterly	Q1 1998 -Q3 2019
	Capital Flow	BOP - Capital and Financial Account	Quarterly	Q1 1999 - Q3 2019
Singapore	Interest Rate	10-year Government Bond Yield	Monthly	Sep 1999 - Sep 2019
	GDP	GDP	Quarterly	Q3 1999 - Q3 2019
	Consumption	Private Consumption Expenditure	Quarterly	Q3 1999 - Q3 2019
	Investment	Gross Capital Formation	Quarterly	Q3 1999 - Q3 2019
	Capital Flow	BOP - Capital and Financial Account	Quarterly	Q3 1999 - Q3 2019

All of the data are modified to be in real term. For government bond yields, it is subtracted by the inflation rate which is calculated as a percentage change of consumer price index in the form of year-on-year basis. The real interest rate is calculated by using the nominal yields subtracting the inflation rate. The real interest rate has a unit as percent per annum. For other macroeconomic variables, they are adjusted to be real by dividing the variables with the consumer price index.

The comparison in this section starts from the graph and the statistical test which is presented in the next sub-section.

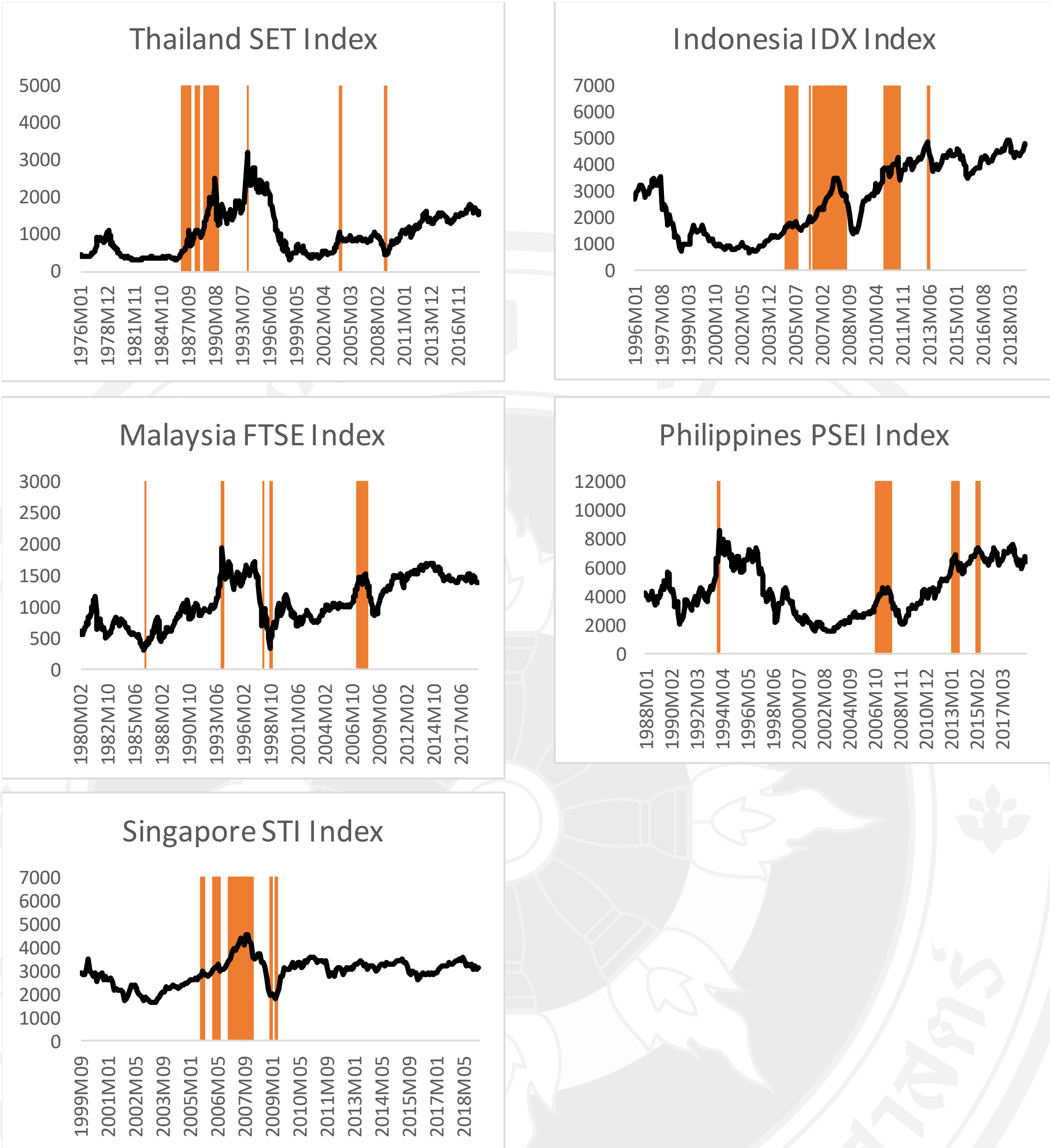

Figure 2.9 Bubbles Dating on the Stock Indices; Thailand, Indonesia, Malaysia, Philippines, and Singapore

The line graphs as shown in Figure 2.9 are the plot of the real price index of each country. Again, the real price index is the price index divided by the consumer price index. The shaded area in the graphs represent the bubble periods that can be detected from the PSY model. I decide to use only PSY date stamping algorithm because the results from Section 2.5 show the superior of PSY model over PWY model.

2.6.3 The Statistical Methods Using for the Comparison

In order to compare the test results with the actual macroeconomic variables, mere graphical comparison may not be reliable. Therefore, two statistical techniques are introduced in this study as follows.

2.6.3.1 Student's t-test with an Unequal Variance or Welch's Test

This is the test for mean of the two samples when the variance is assumed to be not equal. In this study, I want to test whether the mean of each macroeconomic variable has the different mean by comparing the mean for the whole sample size excluded bubble period with the mean of the variables on the bubble date detected by PSY model. There are five null hypothesis tests to be perform.

1) $H_0: \overline{r_b} = \overline{r_w}$ against $H_a: \overline{r_b} < \overline{r_w}$
2) $H_0: \overline{y_b} = \overline{y_w}$ against $H_a: \overline{y_b} > \overline{y_w}$
3) $H_0: \overline{c_b} = \overline{c_w}$ against $H_a: \overline{c_b} > \overline{c_w}$
4) $H_0: \overline{in_b} = \overline{in_w}$ against $H_a: \overline{in_b} \neq \overline{in_w}$
5) $H_0: \overline{BP_b} = \overline{BP_w}$ against $H_a: \overline{BP_b} > \overline{BP_w}$

where *r* is the real interest rate, *y* is the growth rate of the real GDP, *c* is the growth rate of the real private consumption, *in* is the growth rate of private investment, and *BP* is the ratio of the real balance of payment over real GDP. The bar above all of these variables designates for the average value of these variables.

The variables with subscript *b* represent the mean in bubble subsamples while the variables with subscript *w* are the mean of the sample without the bubble period. The first hypothesis tests whether the mean of real interest rate in bubble sub-period is relatively low. The second, third, fourth, and fifth hypothesis are to test whether real GDP, real consumption, real investment and real capital inflow, respectively, is relatively high when there exists bubble in the economy.

For the real investment, the theories suggest that there are two possible cases: bubbles crowd out investment as in Tirole (1985) and bubbles crowd in investment as in Farhi and Tirole (2012). Therefore, I use two tail tests on this issue.

For testing these hypotheses, the test statistic, called t-statistic, can be calculated from the following formula:

$$t = \frac{\overline{x_b} - \overline{x_w}}{s_\Delta} \text{ and } s_\Delta = \sqrt{\frac{s_b^2}{n_b} + \frac{s_w^2}{n_w}} \qquad (2.11)$$

where $\overline{x_i}$ is the mean of a variable in the sample *i* which can be in the bubble period or the non-bubble period, s_Δ is the standard error of this t-statistic, s_i^2 is the variance of sample *i* which can be bubble (b) or non-bubble (w) period, and n_i is the sample size of each group.

For the testing procedure, as same as other statistic test, it is needed to compare the t- statistic getting from equation (2.11) with the critical value. We can reject the null hypothesis when the t-statistic is less (greater) than critical value for the left (right) tailed test in case of one-tailed test. For the two-tailed test, the null hypothesis can be rejected when the absolute value of the t-statistic is greater than the critical value.

2.6.3.2 Regression Analysis with Dummy Variable

In the regression analysis, when the data set is suspected to have two (or more) different characteristics (qualitative variable) in explaining the dependent variable such as sex (male or female), education (high school, bachelor's degree, master's degree, etc.) or development level (developed, developing) and so on, dummy variable is commonly introduced into the regression model. I use this technique to test for the difference in value of the selected macroeconomic variables during the bubble and non-bubble period which are detected by the time stamp algorithm performed in Section 2.5.

The regression model that used in this sub-section is the simple linear regression where the explanatory variable is only dummy variable. The linear regression models that are used for the testing are shown as follows:

$$r_t = a_0 + a_1 Dummy_t + u_{1t}$$

$$y_t = b_0 + b_1 Dummy_t + u_{2t}$$

$$c_t = \alpha_0 + \alpha_1 Dummy_t + u_{3t}$$

$$in_t = \beta_0 + \beta_1 Dummy_t + u_{4t}$$

$$BP_t = \gamma_0 + \gamma_1 Dummy_t + u_{5t}$$

where *r* is the real interest rate, *y* is the growth rate of the real GDP, *c* is the growth rate of the real private consumption, *in* is the growth rate of private investment, and *BP* is the ratio of the real balance of payment over real GDP as same as the variables in Sub-section 2.6.3.1. The subscript *t* represents the time *t*.

The additional variable, *Dummy*$_t$, is a dummy variable for being in the bubble period determined by PSY model. $a_0, a_1, b_0, b_1, \alpha_0, \alpha_1, \beta_0, \beta_1, \gamma_0, \gamma_1$ are the parameters to be estimated from the regression model. u_{it} is the error term that follows a normal distribution with zero mean and constant variance where i = 1, 2, 3, 4, 5.

The hypothesis testing for this case is similar to those discussed earlier in Sub-section 3.6.2.1. The five hypotheses are written below:

a) $H_0: a_1 = 0$ against $H_a: a_1 < 0$
b) $H_0: b_1 = 0$ against $H_a: b_1 > 0$
c) $H_0: \alpha_1 = 0$ against $H_a: \alpha_1 > 0$
d) $H_0: \beta_1 = 0$ against $H_a: \beta_1 \neq 0$
e) $H_0: \gamma_1 = 0$ against $H_a: \gamma_1 > 0$

All null hypotheses are expected to be rejected.

In the testing, not only the above testing hypotheses are performed, but also the standard test related to time-series data analysis is also performed. If there exists any kind of problem (such as autocorrelation), the proper remedy will be applied.

Testing's strategy is starting from the graph of each macroeconomic variables with the shaded color during the bubble period. Then the t test of two samples assumed different variances among the groups and regression analysis with dummy variable are performed. The results from the test are shown in the next sub-section.

2.6.4 Test Results

The results of the test for each macroeconomic variable are presented in the sequence of graphical analysis, t test, and regression analysis. There are some macroeconomic variables that are not available in some countries, so those countries are skipped in the analysis.

2.6.4.1 Real Interest Rate

The real interest rate is the only variable that all countries have enough data for the test. Figure 2.10 depicts the real interest rate graph over the shaded bubble period for each country.

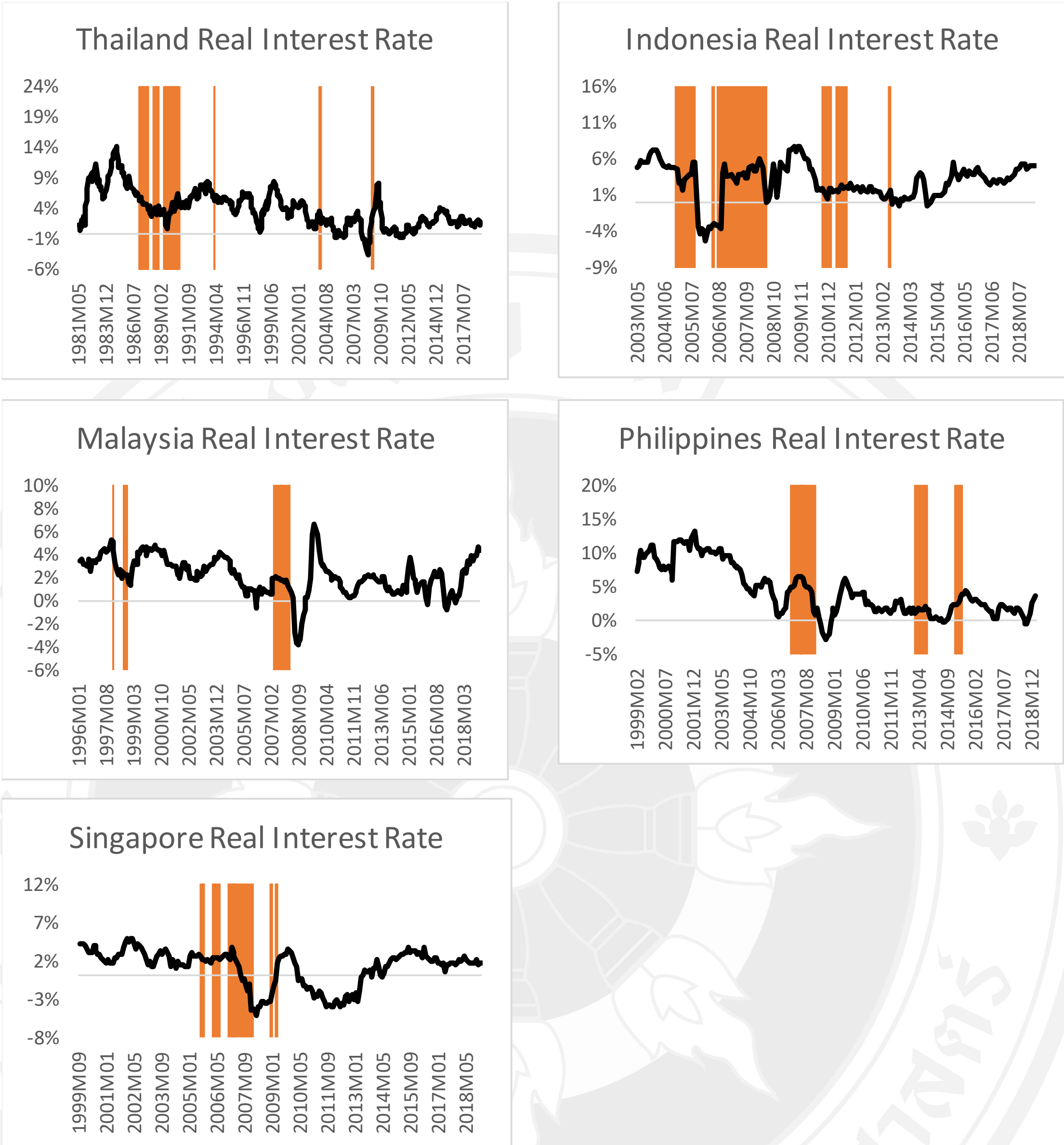

Figure 2.10 Bubbles Dating and the Real Interest Rate (10-year Government Bond Yields); Thailand, Indonesia, Malaysia, Philippines, and Singapore

From Figure 2.10, Philippines and Singapore seem to have low real interest rate during the bubble period. Table 2.14 presents the mean difference between the real interest rate during bubbles period and out of the bubble period: $\overline{r_b} - \overline{r_w}$. Here, Thailand seems to have the wrong sign from what theories predicted.

Table 2.14 The Difference between the Real Interest Rate during Bubble and Non-bubble Period

	Thailand	Indonesia	Malaysia	Philippines	Singapore
Bubble	4.16%	2.73%	2.16%	3.66%	0.71%
Non-Bubble	3.88%	3.05%	2.21%	4.55%	1.19%
Difference	0.29%	-0.31%	-0.05%	-0.89%	-0.48%

Table 2.15 The Statistical Tests for Confirming the Difference between the Real Interest Rate during Bubble and Non-bubble Period

		Thailand	Indonesia	Malaysia	Philippines	Singapore
t-test	t-stat	1.08511	-0.79525	-0.19220	-1.95214	-1.03386
	p-value	0.1403	0.2142	0.4247	0.0277	0.1541
Dummy	coefficient	0.00135	-0.00312	-0.00053	-0.00309	-0.00065
	p-value	0.6899	0.4621	0.8975	0.4749	0.7721

From Table 2.15, both t-test and regression with dummy variable show the same direction which can be observed from the sign of the t-stat and coefficient. Interestingly, for the Philippines, the test result from t-test shows that on average the real interest rate during the bubble period is lower than one in non-bubble period at 95% level of confidence. Additionally, in the case of Thailand we find the positive sign for both tests. This means that during asset bubble boom, Thailand's real interest rate is higher than the period without bubbles which contradicts the theories. This may be because the PSY model cannot capture the bubble date accurately in the case of Thailand. However, we still need to check for other macroeconomic variables.

Further investigation is suggested by Tirole (1985): at the time of bubbles boom, the interest rate is less than growth rate of the economy. To look into the matter, Table 2.16 gives the mean of the difference between the real interest rate and the economic growth of each country during bubble period and non-bubble period.

Table 2.16 The Difference between the Modified Real Interest Rate during Bubble and Non-bubble Period

	Thailand	**Indonesia**	**Malaysia**	**Philippines**	**Singapore**
Bubble	-0.63%	-4.24%	N/A	-2.75%	-6.26%
Non-Bubble	-1.08%	-2.55%	N/A	-0.57%	-3.74%
Difference	0.44%	-1.69%	N/A	-2.18%	-2.53%

From Table 2.16, the economic growth is, on average, greater than the real interest rate regardless of bubbles. Still, we interpret that even though the non-bubble-period real interest rate is less than the growth rate of the economy, the bubble-period real interest rate should be even lower. Therefore, only Thailand's case seems to be preliminarily off the theoretical prediction. Note that the data of Malaysia is not available so I report it as N/A.

Table 2.17 The Statistical Tests for Confirming the Difference between the Modified Real Interest Rate during Bubble and Non-bubble Period

		Thailand	**Indonesia**	**Malaysia**	**Philippines**	**Singapore**
t-test	t-stat	0.19620	-7.53191	N/A	-4.29822	-2.59112
	p-value	0.4261	0.0000	N/A	0.0000	0.0069
Dummy	coefficient	0.00686	-0.01691	N/A	-0.02185	-0.02528
	p-value	0.6810	0.0033	N/A	0.0161	0.0119

The results from Table 2.17 confirms our observation in Table 2.16. Only Thailand's case is against the theories because both t-stat test and the regression with dummy test suggest that the differences between real interest rate and the economic growth during bubble period and non-bubble period are not statistically different. So far, PSY model seems to fail to detect bubble period of Thailand.

2.6.4.2 Growth Rate of Real GDP

For the growth rate of real GDP, Malaysia has no available data that covers the period of bubbles boom captured by the PSY algorithm. So, the statistical tests are performed for just four countries. Figure 2.11 plots the graph of GDP growth of each country.

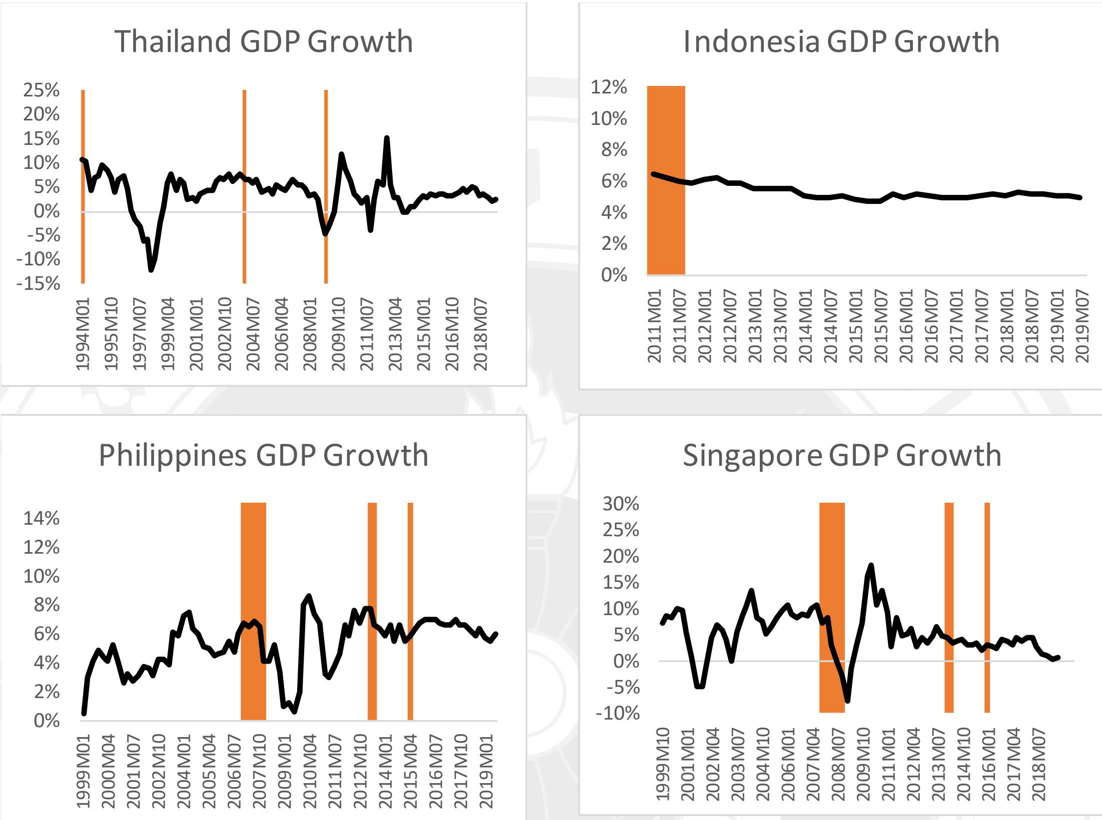

Figure 2.11 Bubbles Dating and the Growth Rate of Real GDP; Thailand, Indonesia, Philippines, and Singapore

For the real GDP growth, the frequency of the data is changed to be quarter and the number of the observation becomes smaller. From the graphs showing in Figure 2.11, they seem not to have any signal that in the bubble period, the average of the growth rate in real GDP is greater than the growth rate in non-bubble group. Especially for Singapore group, it seems that the growth rate of GDP on average is lower when the economy is detected to be in the asset price bubbles boom.

Before observing the statistical test results, I present the difference in mean of the real GDP growth between the rate during bubbles and out of the bubble period or $\overline{y_b} - \overline{y_w}$ in Table 2.18.

Table 2.18 The Difference between the Growth Rate of GDP during Bubble and Non-bubble Period

	Thailand	Indonesia	Malaysia	Philippines	Singapore
Bubble	4.18%	6.25%	N/A	6.33%	5.82%
Non-Bubble	3.69%	5.25%	N/A	5.13%	5.07%
Difference	0.48%	1.00%	N/A	1.20%	0.75%

The difference of the average of growth rate in real GDP are all positive as explained by the theories. However, it is needed to test whether the results are correct statistically. The statistical tests are performed and the results are present in Table 2.19.

Table 2.19 The Statistical Tests for Confirming the Difference between the Growth Rate of GDP during Bubble and Non-bubble Period

		Thailand	Indonesia	Malaysia	Philippines	Singapore
t-test	t-stat	0.10496	6.61655	N/A	2.83646	0.34886
	p-value	0.4630	0.0035	N/A	0.0075	0.3676
Dummy	coefficient	0.00479	0.01002	N/A	0.01200	0.00746
	p-value	0.8412	0.0002	N/A	0.0692	0.6382

The results show that the sign is theoretically consistent for all countries according to both testing methods. However, Thailand and Singapore test results are not statistically significant, meaning that their GDP growths during bubble period and non-bubble period are not statistically different.

2.6.4.3 Growth Rate of Real Consumption

For the growth rate of real consumption, Malaysia has no available data that covered in the period of bubbles boom captured by the PSY algorithm. So, the analysis is performed with four countries. The graphs that represent for this variable is shown in Figure 2.12

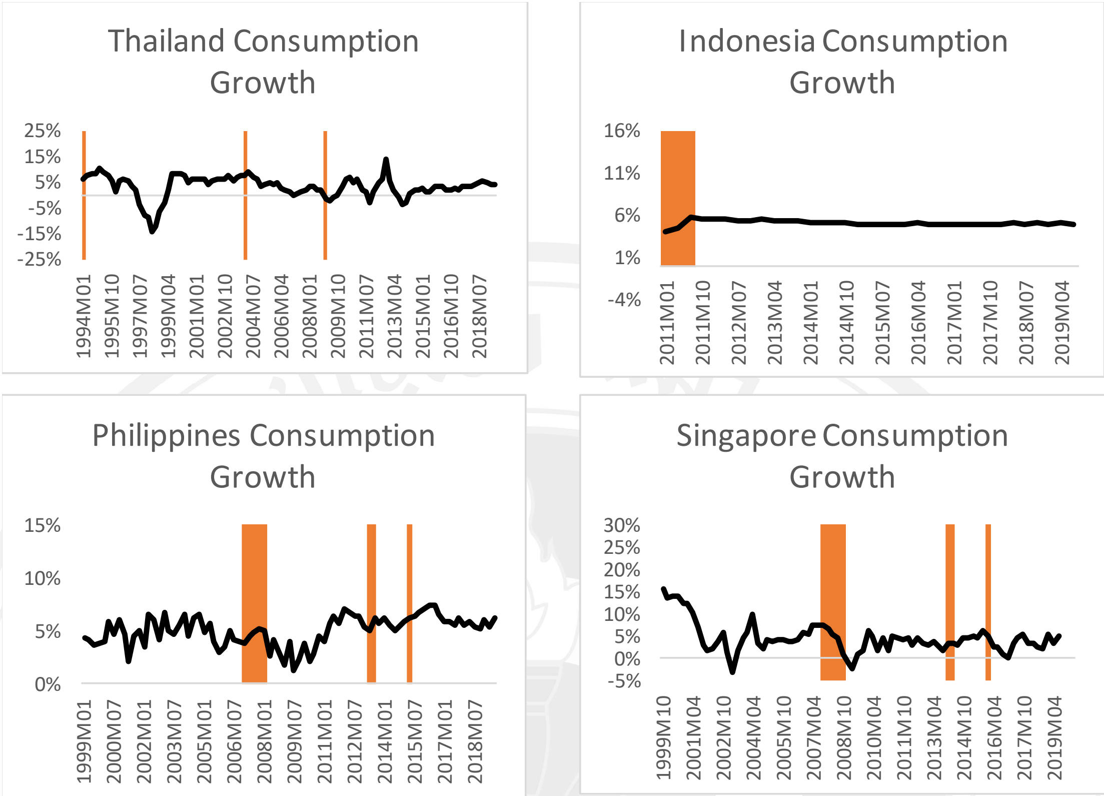

Figure 2.12 Bubbles Dating and the Growth Rate of Real Consumption; Thailand, Indonesia, Philippines, and Singapore

From the graph, it is difficult to judge whether the growth in real consumption is greater or lower when the economy is detected to have the bubbles. For the difference of the average growth rate of consumption between the different groups, it can be shown in the following table

Table 2.20 The Difference between the Growth Rate of Consumption during Bubble and Non-bubble Period

	Thailand	**Indonesia**	**Malaysia**	**Philippines**	**Singapore**
Bubble	4.27%	4.86%	N/A	5.12%	4.32%
Non-Bubble	3.48%	5.15%	N/A	5.06%	4.58%
Difference	0.79%	-0.29%	N/A	0.06%	-0.26%

From this table, it can be observed that Indonesia's and Singapore's real consumption growth have the negative value which is against the economic bubble theories. Again, the statistical tests are necessary to check whether the values in the above are statistically significant. The statistical tests are shown in the Table 2.21.

Table 2.21 The Statistical Tests for Confirming the Difference between the Growth Rate of Real Consumption during Bubble and Non-bubble Period

		Thailand	**Indonesia**	**Malaysia**	**Philippines**	**Singapore**
t-test	t-stat	0.28999	-0.54530	N/A	0.17911	-0.20037
	p-value	0.3996	0.3201	N/A	0.4304	0.4226
Dummy	coefficient	0.00787	-0.00044	N/A	0.00341	-0.00582
	p-value	0.7615	0.9499	N/A	0.5785	0.6685

For the rate of growth in real consumption, it is failed to reject the null hypothesis, even at 10% significant level, for all four countries that the growth rate of real consumption is higher when the economy is detected to be in the asset price bubbles boom. From the statistical tests, it cannot be concluded that the growth rate real consumption in Indonesia and Singapore goes against the theories as we suspect earlier.

2.6.4.4 Growth Rate of Real Investment

For this macroeconomic variable, the availability of the data for the real investment is quite limited. There are only two countries that the data are available; Indonesia and Singapore. The graphs of the growth rate of real investment can be observed from the Figure 2.13

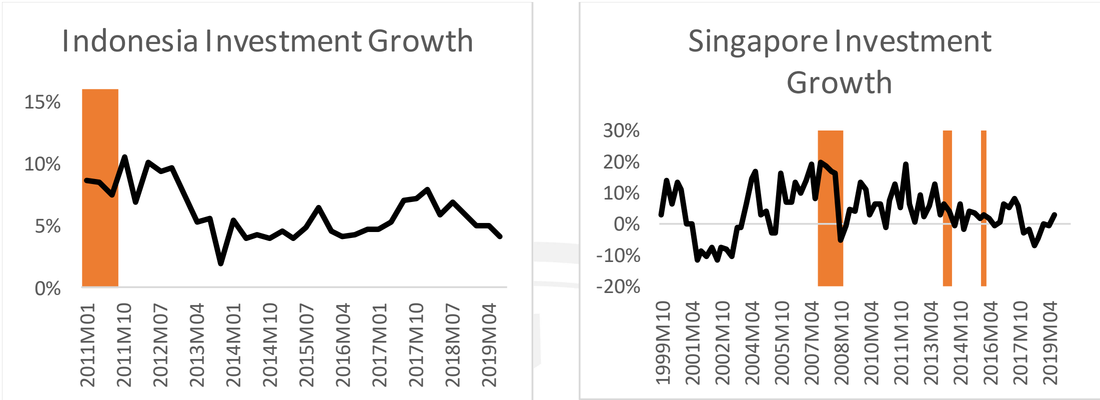

Figure 2.13 Bubbles Dating and the Growth Rate of Real Investment; Indonesia, and Singapore

It is difficult to see whether the investment is higher or not during the detection of the bubbles in the economy. It is easier to have a glance first on the number. The difference of the average growth rate of real investment between the different groups, it can be shown in the following table

Table 2.22 The Difference between the Growth Rate of Investment during Bubble and Non-bubble Period

	Thailand	**Indonesia**	**Malaysia**	**Philippines**	**Singapore**
Bubble	N/A	8.28%	N/A	N/A	9.96%
Non-Bubble	N/A	5.89%	N/A	N/A	3.68%
Difference	N/A	2.38%	N/A	N/A	6.27%

For both countries, the difference of the average of the growth rate of real investment is in the positive number. This means that during the bubble stage, the investment is crowded in as per suggested in Farhi and Tirole (2012). To confirm the result properly, it is needed to perform the statistical tests. The results are reported in the Table 2.23.

Table 2.23 The Statistical Tests for Confirming the Difference between the Growth Rate of Real Investment during Bubble and Non-bubble Period

		Thailand	**Indonesia**	**Malaysia**	**Philippines**	**Singapore**
t-test	t-stat	N/A	4.78953	N/A	N/A	2.07491
	p-value	N/A	0.0014	N/A	N/A	0.0647
Dummy	coefficient	N/A	0.02383	N/A	N/A	0.06271
	p-value	N/A	0.052	N/A	N/A	0.0228

The results from the statistical tests show that investment's growth is higher when the economy is detected that there is bubble. It can be rejected null hypothesis at 1% significant level for t-test and 10% significant level for regression analysis for Indonesia's case while 10% and 5% are the level of significant that we can reject null hypothesis for Singapore's case from the t-test and regression test respectively. These results confirm the crowded in phenomenon of the investment during the asset price bubble episode.

2.6.4.5 The Real Capital Flow to Real GDP Ratio

This macroeconomic variable is available only Singapore. The graph that shows the capital flow to GDP for Singapore can be illustrated as the following figure.

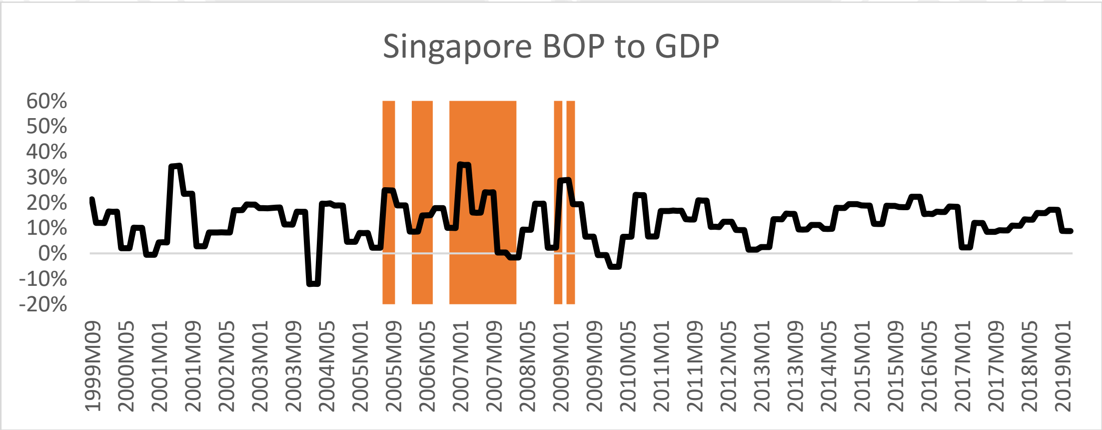

Figure 2.14 Bubbles Dating and the Growth Rate of Capital Flow to GDP, Singapore

For further understanding on this variable, the mean and its difference in mean between bubble and non-bubble stage is shown in the Table 2.24.

Table 2.24 The Difference between the Capital Flow to GDP during Bubble and Non-bubble Period

	Singapore
Bubble	16.38%
Non-Bubble	12.70%
Difference	3.68%

The data show that there is a positive value when we subtract the data in non-bubble period from the bubble situation. For the statistical tests, the results of the tests are showing in the Table 2.25.

Table 2.25 The Statistical Tests for Confirming the Difference between the Capital Flow to GDP during Bubble and Non-bubble Period

		Singapore
t-test	t-stat	1.63651
	p-value	0.0559
Dummy	coefficient	0.03437
	p-value	0.0712

The results from Table 2.25 show that we can reject null hypothesis at 10% level of significant for regression with dummy variable method and at 10% significant level for the t-test. These test results confirm that the capital inflow during the bubbles boom in the economy is greater than non-bubble period. This finding confirms the explanation from the theories of bubbles.

2.6.4.6 Combining the Results

To see whether the bubble date stamping algorithm introduced by Phillips et al. (2015) is able to accurately predict bubbles, I perform some statistical tests. The test hypotheses come from the macroeconomic theories of bubbles which explain that during the asset price bubbles occurred into the economy, the real interest rate is lower than non-bubble time. For the real activities, they are increasing during the bubbles period except for the case of investment which can be both increase or decrease during the bubbles period. For the capital flow, the theories explain that there is high capital inflow during the asset price bubbles boom.

By using the detection of the bubbles in stock price getting from Section 2.5, the behaviors of some macroeconomic variables during bubble period and non-bubble period are compared. The results are summarized in Table 2.26

Table 2.26 The Results Summary of the Statistical Tests for Confirming the Difference of Macroeconomic Variables during Bubble and Non-bubble Detection

		Thailand	**Indonesia**	**Malaysia**	**Philippines**	**Singapore**
Interest	t-test	X	NS	NS	PASS	NS
	Dummy	X	NS	NS	NS	NS
Modified Interest	t-test	X	PASS	N/A	PASS	PASS
	Dummy	X	PASS	N/A	PASS	PASS
GDP	t-test	NS	PASS	N/A	PASS	NS
	Dummy	NS	PASS	N/A	PASS	NS
Consumption	t-test	NS	NS	N/A	NS	NS
	Dummy	NS	NS	N/A	NS	NS
Investment	t-test	N/A	PASS	N/A	N/A	PASS
	Dummy	N/A	PASS	N/A	N/A	PASS
Capital Inflow	t-test	N/A	N/A	N/A	N/A	PASS
	Dummy	N/A	N/A	N/A	N/A	PASS

where X means that the empirical results gives the wrong direction from the theories, NS means that the sign from the test results give the signs conforming with the theories but fail the corresponding statistical inference, PASS means both sign and statistical tests are theoretically satisfied, and N/A means data are not available.

For Thailand, the detection from the PSY model may not represent the bubbles in the real-world condition as there is no PASS for any test. The PSY model is very likely to wrongly stamp the bubble date or it cannot stamp all of the bubble periods. It is out of the scope of this study to find out what is actually the reason why the prediction from PSY model cannot fit with the actual data.

For Malaysia, it is hard to conclude as we have a very limited available data. For the remaining countries, it can be seen that most of the results from statistical tests are satisfied. The detection of the bubbles by using the PSY model may be one of the tools for capturing the bubble periods.

However, many aspects of bubbles are still left out for this study. For example, the financial variables such as earnings, dividends, etc. or the behavioral economic variables such as herding behavior or overreaction are not considered here. Undoubtedly, these additional elements are likely to enhance the predictability of the bubble date stamping model and we leave this for the future study.

2.7 Conclusion

In this study, the right-tail ADF test has been applied for testing the explosive bubbles. The techniques that used in this study are SADF test GSADF test which are proposed by Phillips et al. (2011) and Phillips et al. (2015). By using these techniques, we can find whether the time series of the asset prices have the explosive bubbles. Furthermore, these two models can capture the time stamp for the start and the end of the bubbles in the sub-period of our testing data.

These two models can explain well for the explosive bubbles in the price of both financial assets and physical assets in the past. However, these two models cannot capture the crashes in the stock market during the Asian financial crisis in 1997 or the subprime crisis during 2007 – 2008 in some countries such as Thailand.

The question is whether both date stamping algorithms of PWY and PSY model are accurate. To test this, I compare the results of bubble date stamping with the macroeconomic variables. In the macroeconomic theories of the bubbles, the bubbles emerge when the real interest rate is low. In addition, the bubbles raise the real economic activities such as the GDP and consumption, although it is ambiguous for the investment. Finally, during the bubbles, there is a surge of capital flow. According to these theories, five hypotheses are tested to see the difference of each macroeconomic variable during bubble period and non-bubble period determined by the date stamp from PSY model.

There are two statistical methods applied for the testing; t-stat test for the difference of means and the regression analysis with the dummy variable. The results show that for Thailand case, the date stamping is not accurate because there are no any macroeconomic variables passes the tests. But for Indonesia, Philippines, and Singapore, their macroeconomic variable behaviors conform with the bubble theories, suggesting the effectiveness of PSY model in specifying the bubble episodes.

CHAPTER 3

CAN GOVERNMENT BOND REPLACE RATIONAL BUBBLES? THE EMPIRICAL INVESTIGATION ON SINGAPORE AND THAILAND

3.1 Abstract

This paper aims to test the theoretical policy implication on rational bubbles. Many works, including Caballero and Krishnamurthy (2006), Kocherlakota (2009), and Martin and Ventura (2011), suggested that government bonds can rule out rational bubbles. We constructed our own bubble index using the Fourier transformation technique and, as a result, found the empirical support of the theory in the case of Singapore, but not in the case of Thailand. For the case of Singapore, the credibility in an ability to collect tax and the appropriate yield of government bonds are keys to the effectiveness of such the anti-bubble policy. Moreover, we also found that expansionary fiscal policies empirically accelerate the growth of bubbles.

3.2 Introduction

Asset price bubbles are evidently the key factor that often plays a crucial role in almost every economic crisis. The in-depth study on theoretical rational bubbles has grown extensively. This massive literature sheds light on how rational bubbles can emerge and how to prevent them. One policy implication to solve rational bubbles problem is to replace them with an asset that has an analogous structure except that it must be crash-free. In the literature, the sole example of such asset is given as government bond. There are other policy implications in suppressing rational bubbles such as the leaning against the wind policy, see Galí (2014) and Blot, Hubert, and Labondance (2017).

This paper aims to empirically investigate the validity of this theoretical possibility in the case of Singapore and Thailand. To see whether government bond can replace rational bubbles, we first need to quantify the rational bubbles out of the asset price. Then, we statistically test whether the aggregate outstanding government bond can reduce rational bubbles and under which conditions such policy is effective.

To contemplate the idea of government bond being a perfect substitute of rational bubbles, we must first understand what rational bubbles are. The asset price bubble is the difference between the actual price of the asset and its fundamental value, which is the present value of all future dividends. Rational bubbles are asset price bubbles that can survive in the general equilibrium framework, and the store of value that emerges when the rate of interest is too low. The low-return economy may result from either the dynamically inefficiency problem as in Tirole (1985) and Weil (1987) or the credit-constrained economy as in Caballero, Farhi, and Hammour (2006) and Farhi and Tirole (2012). However, Santos and Woodford (1997) showed that under normal economic environments, bubbles cannot emerge in the general equilibrium.

Since the primitive economy gives a low return, rational bubbles thus help raise the interest rate which improves the welfare of the economy. Rational bubbles thrive under two conditions. First, they must grow at least at the rate of interest so that the people would demand them. Second, they, however, cannot grow too fast to be eventually unaffordable as in Ventura (2012), Hirano and Yanagawa (2016), Bejan and Bidian (2014), Werner (2014), Miao and Wang (2014), and Miao, Wang, and Zhou (2015).

With sufficient high return, people purchase rational bubbles with the hope to sell to people from the next generation. This process continues through an inter-generational trust which can be broken at any time. This brings about the probability of bubble bursting. The crash of bubbles causes the sudden stop of all economic activities. In particular, the sharp drop in asset price suddenly drives down households' wealth and, hence, consumption falls. The debt widely defaults as the value of collateralized asset plummets. Widespread bankruptcy occurs, and financial institutions stop functioning. Hence, the prolonged recession prevails.

Bubbles are bad only because of their potential to crash. If we can find an alternative asset that gives the same return as rational bubbles but does not crash, this asset will perfectly replace rational bubbles and lead to Pareto improvement. Caballero and Krishnamurthy (2006), Kocherlakota (2009), and Martin and Ventura (2011) suggested that government bonds can do the job. The rationale behind the efficacy of government debt is the fact that the government's taxation authority makes its debt less risky. The government can issue bonds with the same return as bubbles and then roll over these debts forever. This action can be fully supported by the country's future tax revenue. If the government's tax ability were perfectly credible, then the total future tax revenue would be perceived to be infinitely large enough to guarantee no default at any point in time. With this perception, the rollover is smooth and there is no need for the government to tax for this sake.

Notably, two important features for government bonds to replace rational bubbles are worth highlighting: the government's tax ability must be credible, and government bonds must give the same return as rational bubbles. In reality, many countries struggle with tax evasion problem, especially developing countries. Buehn and Schneider (2016) developed the time series of tax evasion across 38 countries from 1999 to 2000 and found that the tax evasion rate is range from 6.8% in the case of Mexico to 0.5% in the case of the United States. Since the size of tax evasion directly represents the inability of the government to tax, government bonds of the country with high tax evasion lose the potential to substitute rational bubbles. The other evidence on differences in tax ability prevails through differences in appropriate public debt levels across countries. Pienkowski (2017) estimated the maximum public debt limits and found that, on average, the advanced economy, the emerging economy, and the low-income economy possess the baseline debt limit equal to 137%, 58%, and 40% of GDP, respectively. These huge differences in public debt limits reflect the differences in tax ability of each type of economies. Thepmongkol and Sethapramote (2018) endogenously calculated the maximum public debt limits for ASEAN countries. Moreover, since the government is the most secure identity in the economy, government bonds are usually considered to be nearly risk-free and, hence, give the lowest return. With the relatively low return of government bonds, it would be hard to discourage bubble holding.

Using the data of Singapore and Thailand, we find the favorable result consistent with the theory, especially in Singapore's case. However, if we do not take into account the government's tax ability and the rate of return of government bonds, the positive relationship between rational bubbles and outstanding government bonds is instead observed in both Singapore and Thailand cases. In addition, we find that the rate of return of government bonds is more important for the bubble substitution. This implies that the government should raise its bond's return to solve the bubble problem. This action must be implemented with great care because the rise in the risk-free rate would transfer some productive investment into the unproductive debt rollover as in Domeij and Ellingsen (2018). Such trade-off may result in welfare reduction and require a discretional judgment based on specific economic context as in Kindleberger (1995) and Shiratsuka (2005).

In this paper, we constructed a series of bubbles in the stock's price following Khokasai and Thepmongkol (2018). First, we decomposed the stock price into many filtered series using Fourier transformation technique. Next, we run the regression of each filtered series on bubble-related macroeconomic variables to select the best-filtered series consistent with the rational bubble theory. We chose the Fourier transformation technique over the principle component analysis (PCA) used to construct the UBS Swiss Real Estate bubble index due to the theoretical reason. The Union Bank of Switzerland (UBS) provides the index since 2011. In details, the PCA technique does not directly extract bubble element from the asset price but creates the bubble index from the linear combination of bubble-related macroeconomic variables which is not theoretically sound.

3.3 Brief Review of Rational Bubbles Theories

Firstly, we summarize the dynamic macroeconomic model that widely uses in the study of the bubbles called Overlapping Generations Model (OLG). Below, we follow Tirole (1985) which is mostly referred by the researchers in the field. Secondly, we review various strands of the literature regarding the study of bubbles.

3.3.1 Overlapping Generations and the Asset Price Bubbles

Overlapping generations model or OLG is one of the models that is often used in macroeconomics analysis. In this model, each agent has a finite lifespan. There are infinite generations in the economy but for a given time period there are a finite number of generations living together in the overlapping fashion. In the simple 2-period-lived agent model, there are two generations living in any particular period; the young and the old generation. In the analysis, the researchers can make different assumptions about the number of the generations or any other concerned points in which the researchers need to explain some specific phenomena in their studies.

In this section, we follow the model outlined in Tirole (1985) is developed from Diamond (1965). The explanation in this sub-section may slightly differ from the original paper but the main idea is the same.

The model is assumed to be the production economy with 2-period-live agents. People in this economy work when they are young and retire themselves when they are old. All of the young are assumed to have perfectly inelastic labor supply. The population are growing at the constant rate *n*. Denote L_t as the population of the generation t which is also the total labor force of time t:

$$L_t = (1+n)L_{t-1} = (1+n)^t L_0 \tag{3.1}$$

Equation (3.1) shows that the population grows at the constant rate *n* at all times. Without loss of generality, the model is assumed that L_0 is equal to one and the labor force at time *t* is $L_t = (1+n)^t$.

Although only the young works, both generations consume goods that are produced in the economy and get the utility from that consumption. The individual consumption is denoted by c_t^y for the young and $c_t^{o\,o}$ for the old. The aggregate consumption in this economy, denoted by C_t, is the summation of total consumption of young generation and old generation or

$$C_t = c_t^y L_t + c_t^o L_{t-1}$$

The young works and earns wage, w_t, while the old saves a part of their young wage to finance his own consumption when he is old. The old's savings are denoted as s_{t+1}. This saving depends on wage at time *t* and the real interest rate at time *t + 1*, $s(w_t, (1 + r_{t+1}))$.

There is only one good in this economy. Two input factors are required in the production process which are capital (K) and labor (L). The production function here is assumed to be continuously twice differentiable function with constant returns to scale.

$$Y_t = F(K_t, L_t) = L_t f(k_t)$$

where Y_t is the total goods produced at time *t*, *F(•)* captures the technology used in the production, K_t is the capital stock at time *t*. The capital stock is assumed to have full depreciation which means that capital stock in this period cannot be used in the next period. Agents need to invest one period in advance to get the capital in the one-to-one basis. The small letter *k* is the capital per capita.

All markets are competitive. This assumption implies that the input factor price is equal to its marginal product. Then, the return on capital (real interest rate) is determined by

$$r_t = f'(k_t) \tag{3.2}$$

where r_t is real interest rate and $f'(k_t)$ is the marginal product of capital. The wage is determined by

$$w_t = f(k_t) - k_t f'(k_t) \tag{3.3}$$

It is implied that when the capital market is in the equilibrium, the aggregate of capital in next period is equal to the aggregate saving in this period. It can be shown as

$$K_{t+1} = L_t s(w_t, (1 + r_{t+1})) \tag{3.4}$$

From Equation (3.1), we can re-write Equation (3.4) as

$$k_{t+1} = s(w_t, (1 + r_{t+1})) / (1 + n) \tag{3.5}$$

In this case, there is no difference between saving and the capital per capita. According to Diamond (1965), Equation (3.2), (3.3) and (3.5) construct the equilibrium system which, under the standard saving function assumptions, has a unique competitive equilibrium and the real interest rate eventually converges to the unique steady state of the interest, $\bar{r}$. The dynamic under this situation is that when $\bar{r}$ is greater than *n*, the economy is dynamically efficient.

Fundamental Values and Bubbles

Tirole (1985) extended Diamond's work for analyzing the bubbles in the economy. He introduces assets into the economy as an alternative way to store the value across time. Those assets give the holders a real rent (dividend). The total rent for the economy is assumed to equal to R units of real goods per period. The fundamental value of the assets is defined as the sequence of real interest rate, r_t.

$$F_t = R\left[\sum_{s=t+1}^{\infty} \frac{1}{(1+r_t)\cdots(1+r_s)}\right]$$

where F_t is the fundamental value of the asset at time t. In Tirole's model, the asset has no dividend, thus it has zero fundamental value. In this case, any positive price of the asset becomes the pure bubble. Denote b_t as the bubble holding for each agent. By no-arbitrage condition, the bubbles must be non-negative and must give the return equal to the rate of return of capital which is the interest rate since both of them are the competitive choices of stores of value in the model. Adjusted with the rate of population growth, the bubble must satisfy the following condition:

$$b_{t+1} = \frac{1+r_{t+1}}{1+n} b_t \tag{3.6}$$

Now that agents have more choices of stores of value, Equation (3.5) is modified into the following:

$$s(w_t, (1+ r_{t+1})) = k_{t+1}(1+n) + b_t \tag{3.7}$$

Now, the bubbly equilibrium system consists of Equation (3.2), (3.3), (3.6) and (3.7). Equation (3.8) and (3.9) address the system:

$$b_{t+1} = \frac{1+f'(k_{t+1})}{1+n} b_t \tag{3.8}$$

$$s(f(k_t) - k_t f'(k_t)\,,\ f'(k_{t+1}) + 1) = k_{t+1}(1+n) + b_t \tag{3.9}$$

At steady state, the capital and bubble per capital hence must satisfy below equations:

$$1 + n = 1 + f'(\bar{k})$$

$$s(f(\bar{k}) - \bar{k}f'(\bar{k}), f'(\bar{k}) + 1) = \bar{k}(1+n) + \bar{b}$$

where $\bar{k}$ and $\bar{b}$ is the steady state of the capital stock and bubbles respectively.

To analyze the equilibrium dynamic of the bubbly economy, let $k_{t+1} = G(k_t, b_t)$ be the solution of the system of difference equations- Equation (3.8) and (3.9). By replacing this solution back to the equilibrium system, we get

$$b_{t+1} = \frac{1+f'(G(k_t,b_t))}{1+n} b_t \tag{3.10}$$

$$G(k_t, b_t) = \frac{s(f(k_t) - k_t f'(k_t), f'(G(k_t,b_t))+1) - b_t}{(1+n)} \tag{3.11}$$

$$G_k(k_t, b_t) = \frac{-s_w k_t f''(k_t)}{(1+n) - s_r f''(k_t)} \tag{3.12}$$

where $G_k(k_t, b_t)$ is the first derivative of function *G* with respect to capital stock, s_w is the first derivative of saving function with respect to wage, s_r is the first derivative of saving function with respect to real interest rate, and $f''(k_t)$ is the second derivative of production function per capita with respect to the square of capital stock.

The sign of Equation (3.12) is positive. This comes from the standard condition on savings function: the savings increase when the either wage or the real interest rate increases ($s_w > 0$ and $s_r > 0$). Moreover, the standard production function produces the output at the decreasing rate ($f''(k_t) < 0$).

By doing the similar process with Equation (3.12), total differentiation with respect to b_t yields

$$G_b(k_t, b_t) = \frac{-1}{(1+n) - s_r f''(k_t)} < 0 \tag{3.13}$$

The steady state condition for capital is $\Delta k_t \equiv k_{t+1} - k_t = G(k_t, b_t) - k_t = 0$. We can plot this condition in the capital-bubble plane in Figure 3.1 where k_D is the Diamond steady state in which the bubble is zero.

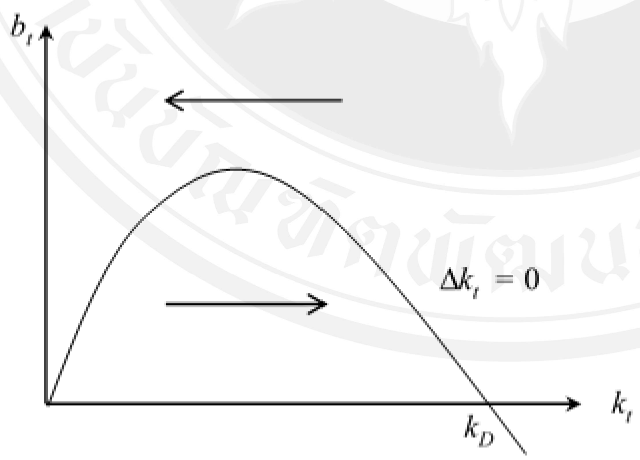

Figure 3.1 Phase Diagram for Capital Stock, k_t

The slope of the locus $\Delta k_t = 0$ can be calculated as follows:

$$\frac{db_t}{dk_t} = \frac{1 - G_k(k_t, b_t)}{G_b(k_t, b_t)} \tag{3.14}$$

The sign of the slope in Equation (3.14) can be calculated by using Equation (3.12) and (3.13). The slopes in Equation (3.14) evaluated at coordinate (0, 0) and the point (k_D, 0) are $\frac{db_t}{dk_t}(0,0) > 0$ and $\frac{db_t}{dk_t}(k_D, 0) < 0$. These results get from the Diamond condition that $G_k(0,0) > 1$ and $G_k(k_D, 0) < 1$ to ensure the stability of its steady state of capital in the world without bubbles.

The dynamic behavior of the capital when the capital is deviated from its steady state can be considered from $\Delta k_t \equiv k_{t+1} - k_t = G(k_t, b_t) - k_t$. To see the dynamic, we start looking at the case where $\Delta k_t > 0$. In this case, it implies that $k_{t+1} > k_t$ which makes $G(k_t, b_t) > k_t$. The situation that $G(k_t, b_t) > k_t$ can happen when the path is in the area under the locus $\Delta k_t = 0$. So, under this area the capital stock increases over time. In Figure 3.1, the right arrow (as the direction is to the right) under the locus $\Delta k_t = 0$ indicates the direction of its movement in the long run.

Conversely, in the case that $\Delta k_t < 0$, it implies that $G(k_t, b_t) < k_t$. This situation happens when the path starts in the area above the locus $\Delta k_t = 0$. When the economy is in the area over this locus, the real capital stock decreases. The left arrow in Figure 3.1 represents this dynamic.

Next, consider the dynamic behavior of bubbles. Like the dynamic of the real stock of capital, we start with the steady state condition for bubbles, $\Delta b_t \equiv b_{t+1} - b_t = \frac{1 + f'(G(k_t, b_t))}{1+n} b_t - b_t = 0$. The slope of the bubble steady state is

$$\frac{db_t}{dk_t} = -\frac{G_k(k_t, b_t)}{G_b(k_t, b_t)} \tag{3.15}$$

It is obvious that the value of the slope from Equation (3.15) is positive from Equation (3.12) and (3.13). The phase diagram to show the steady state condition for the bubble and its dynamic behavior can be shown in Figure 3.2

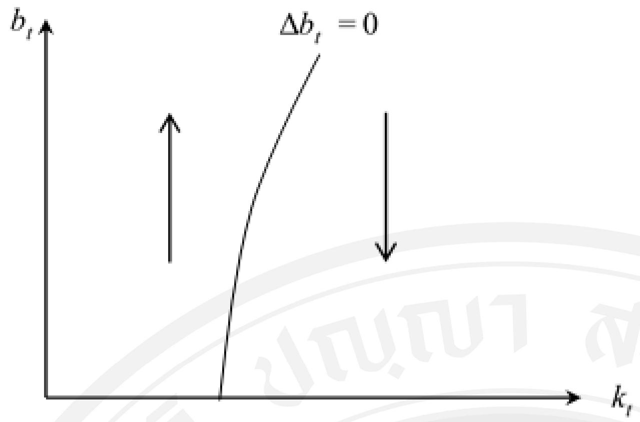

Figure 3.2 Phase Diagram for Bubble, b_t

Regarding the dynamic behavior of the bubbles, we start with the dynamic relationship of bubbles. The deviation from its steady state implies that $\Delta b_t \equiv b_{t+1} - b_t = \frac{1+f'(G(k_t,b_t))}{1+n} b_t - b_t$ is not equal to zero. The first case is the case when $\Delta b_t > 0$. This case implies that $\frac{1+f'(G(k_t,b_t))}{1+n} b_t - b_t > 0$ or $f'\big(G(k_t, b_t)\big) > n$. This situation implies that the economy is in the area where the slope is greater than the slope of the locus $\Delta b_t = 0$ or the area at the left-hand side of the locus $\Delta b_t = 0$. The dynamic behaviour from the first case is represented by the up arrow in Figure 3.2. This means that the bubbles increase over time when we are in the area on the left side of this locus $\Delta b_t = 0$.

The right-hand side of this locus implies that $f'\big(G(k_t, b_t)\big) < n$. Figure 3.2 gives a down arrow in phase diagram. It means that the bubbles decrease over time when the economy is in the right of its locus $\Delta b_t = 0$.

Next, we combine the graphs in Figure 3.1 and 3.2 in Figure 3.3.

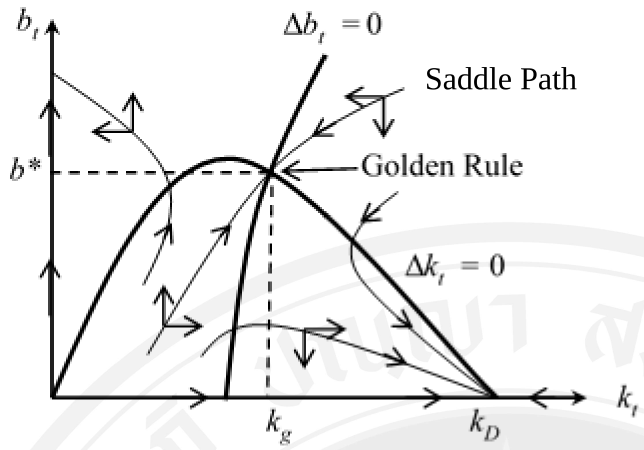

Figure 3.3 Phase Diagram of the Capital Stock and Bubbles

There is the steady state of the bubbles when the capital stock = k_g which is less than the k_D or the Diamond's steady state of the capital. This steady state bubble exists only when r_D <n which means that bubbles can emerge only when the bubble free economy has sufficiently low rate of return in storing value over time. Along the saddle path, the economy is converging to the bubbles steady state where the locus $\Delta b_t = 0$ intersects with the locus $\Delta k_t = 0$.

3.3.2 Literatures Regarding the Study of Bubbles

The lack of stores of value causes the economy to be vulnerable for bubbles to emerge. Given such a problem, bubbles can facilitate the demand for savings since bubbles' holders expect to gain from the future capital gain. Such a bubbly equilibrium can exist if the interest rate of the primitive economy is too low compared to the real economic growth. This is because the rate of return of bubbles, which is also the growth of bubbles, must equate the interest rate. The low interest rate ensures that bubbles do not grow too fast to become unaffordable. Notably, in the rational bubble literature, bubbles are a real variable.

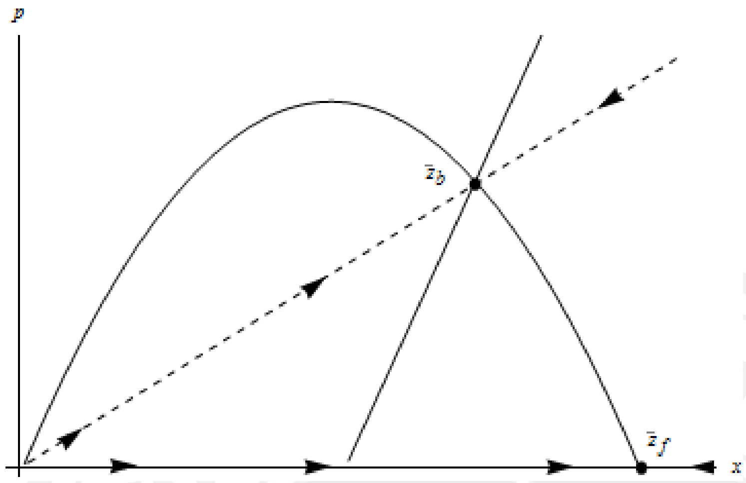

Figure 3.4 Bubbles Crowd out Investment

According to the bubble-generating mechanism, Tirole (1985) showed the existence of bubbly equilibrium in Figure 3.4. The phase diagram where the fundamental price of this asset is at zero and the horizontal axis forms a fundamental stable manifold with fundamental steady state $\bar{z}_f$. There exists the other steady state called bubbly steady state $\bar{z}_b$ where all points on the saddle path (dashed line) converge to. In details, given the initial capital stock at $\bar{z}_f$, the equilibrium may switch to the bubbly one and converge to $\bar{z}_b$. These bubbles crowd out investment as they compete for savings to solve the fundamental overinvestment problem.

The crowding-out effect is not a universal feature for bubbles. Many recent works showed that bubbles can crowd in investment. For example, Farhi and Tirole (2012) showed that bubbles that emerge because of the underlying credit constraint problem could crowd in investment. The logic is that the existing credit constraint suppresses the demand for loan and, hence, results in low interest rate fundamentally. Bubbles act as additional collateral to expand the credit limit leading to more credit provision and investment. Figure 3.5 illustrates this dynamic.

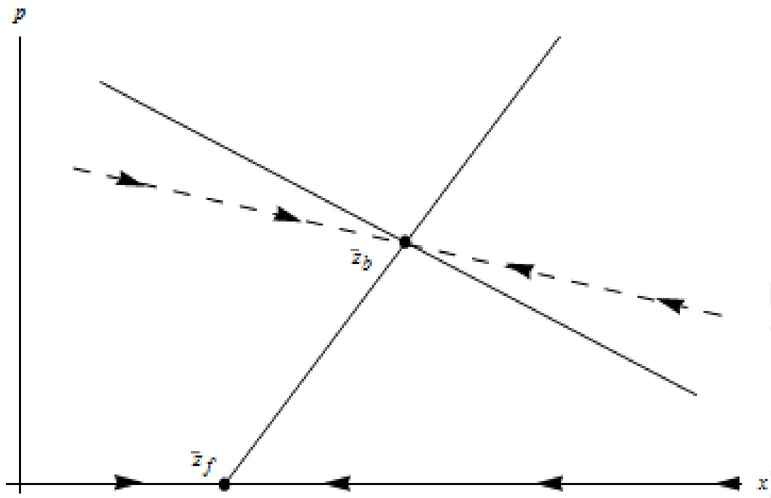

Figure 3.5 Bubbles Crowd in Investment

The boom-bust episode of bubbles captures the sudden switch between bubbly equilibrium and fundamental equilibrium. During the bubble boom, prices of goods and services increase, GDP rises. Thus, consumption also rises. The capital inflow and credit provision expand. Investment can theoretically be either increasing or decreasing depending on the underlying economic problem, although most empirical studies support the co-occurrence between bubble boom and investment boom. Interest rate might be slightly tricky as theories say bubbles help raise interest rate in comparison to fundamental equilibrium. However, within the bubbly dynamics, Figures 3.4 and 3.5 suggest that interest rate decreases while bubbles are booming. Table 3.1 summarizes the relationship.

Table 3.1 Expected Dynamics during the Bubble Boom

Macroeconomic indicators	Expected dynamics during bubble boom
Price of bubbly asset (RSP)	Increasing
Real GDP (RGDP)	Increasing
Real capital outflow (RCAP)	Decreasing
Real investment (RINV)	Increasing or decreasing
Real interest rate (RINT)	Decreasing

Regarding fiscal policies to tackle bubbles, it is simple to see that the contractionary fiscal policy can slow down rational bubbles since it lowers the real interest rate at which bubbles grow. However, neither a decrease in government expenditure nor a rise in tax can rule out bubbles. To eliminate bubbles, Caballero and Krishnamurthy (2006), Kocherlakota (2009), and Martin and Ventura (2011) proposed that the government can issue a bond with the exact structure as rational bubbles. Specifically, if the yield were the same, the people would prefer government bonds to bubbles. Moreover, if the government's tax ability is credible, these government bonds are backed up by the expectedly infinite amount of future tax income. Thus, the government can roll over the debt forever without any default concern. In other words, government bonds act like bubbles with no crash and, hence, completely crowd out bubbles.

3.4 Empirical Method

In this section, we outline our methodology in details. First, we describe how we create bubble index. Then, we use our bubble index to empirically test how government bonds can replace rational bubbles.

3.4.1 Bubble Index Construction

In this section, we follow Khokasai and Thepmongkol (2018) on how to extract rational bubbles by Fourier transformation and its selection criteria for being the bubble index. The methodology is as follows.

3.4.1.1 Asset Price Decomposition by Fourier Transformation

By definition, the asset price contains the fundamental value and bubbles. In this paper, we focus on rational bubbles in stock prices of Singapore and Thailand. According to the theory, the rational bubble is a real variable. Hence, we work on the relative stock price which is the ratio between the stock price index and the consumer price index.

To extract the bubble element out of the asset price, we apply Fourier Transformation to decompose the asset price time series into many series under different frequencies. We normalize the frequency domain into the normalized frequency domain range from 0 to 1. The low-frequency series has the long-wave-length characteristic, while the high-frequency series has the short-wave-length characteristic as in Press, Teukolsky, Flannery, and Vetterling (1992).

Since the normalized frequency domain is continuous, we need to aggregate the series over the particular definite range using a filtering technique. Here, we apply 18 filters. In particular, nine of them are low pass filters which allow the frequency in range 0 to 0.1*j*, while the remaining nine are high pass filters which allow the frequency in range 0.1*j* to 1, where *j* = 1, 2, …, 9. The summary of the low pass filter F_{lj} and high pass filters F_{hj} is shown in Table 3.2.

Table 3.2 Low Pass and High Pass Filters

Low pass filters			High pass filters		
Filtered series	Frequency band From	To	Filtered series	Frequency band From	To
F_{l1}	0	0.1	F_{h1}	0.1	1
F_{l2}	0	0.2	F_{h2}	0.2	1
F_{l3}	0	0.3	F_{h3}	0.3	1
F_{l4}	0	0.4	F_{h4}	0.4	1
F_{l5}	0	0.5	F_{h5}	0.5	1
F_{l6}	0	0.6	F_{h6}	0.6	1
F_{l7}	0	0.7	F_{h7}	0.7	1
F_{l8}	0	0.8	F_{h8}	0.8	1
F_{l9}	0	0.9	F_{h9}	0.9	1

3.4.1.2 Bubble Selection Scoring

To select the filter that best represents rational bubbles, we perform the following regression scoring. According to Equation (3.16), we regress each filtered series on 6 bubble-related macroeconomic variables defined in table 3.1.

$$F_{ijt} = \beta_{ij1} + \beta_{ij2}RLTSET_t + \beta_{ij3}RCAP_t + \beta_{ij4}RGDP_t + \beta_{ij5}RINV_t + \beta_{ij6}RINT_t + \varepsilon_{ijt} \quad (3.16)$$

where $i = l, h$.

Then, the scoring rule is that we will give 1 score for each statistically significant slope coefficient estimate with the theoretically expected sign as in Table 3.1. Otherwise, each gets 0 score. The filtered series that has the highest score is our bubble index (BUBBLE).

3.4.2 Regression of Rational Bubbles on Government Bonds

According to the theory, government bonds should replace rational bubbles under the condition that the government's tax ability is credible and government bond yield is high. Therefore, we need to adjust the government bond data to encapsulate the elements of tax ability and yield. To do so, we use the principal component analysis (PCA) over three inputs: real government bond outstanding, tax ability proxy, and real government bond yield. Then, we select the principal component whose loadings are all positive. Table 3.3 defines each adjusted government bond variable.

Table 3.3 Adjusted Government Bonds

Variable	Input(s) to PCA
$BOND_1$	Government bond outstanding
$BOND_2$	Government bond outstanding and tax ability
$BOND_3$	Government bond outstanding and average bond yield
$BOND_4$	Government bond outstanding, tax ability, and average bond yield

Additionally, we add a budget deficit (BUDGET) as a control variable. This is also to complete the picture of how fiscal policies can influence rational bubbles. In theory, expansionary fiscal policy stimulates the economy and, in turn, raises the real interest rate. Since rational bubbles grow at the rate of interest, we expect that an increase in budget deficit leads to an increase in bubbles. Our regression is specified by the Equation (3.17).

$$BUBBLE_t = \gamma_1 + \gamma_2 BOND_{it} + \gamma_3 BUDGET_t + \epsilon_t \tag{3.17}$$

where $i = 1,2,3,4$.

3.4.3 Related Econometrics Topics Using in Empirical Method

The purpose of this section is to give some econometrics background for the unfamiliar readers to understand the whole process of our empirical method. There are two topics that we would like to explain in details. The first topic is the spurious regression and the cointegration test. The second topic is the construction of the principal component analysis or PCA in short.

3.4.3.1 The Spurious Regression and The Cointegration Test

From Section 2.3.2.1 in Chapter 2, we have discussed on the effect of using non-stationary data series in the regression analysis. The result from running the regression cannot give the true relationship between the variables. This is known as the spurious regression. Even the results from this kind of regression seem to be favorable because the high goodness of fit and the statistical significance of the estimates, as all results from the spurious regression is meaningless. The reason is that it is a pure coincidence driven by the progressive of time that relates these variables.

To avoid this spurious regression problem, we need to perform the unit root test of each variable in our regression model. If any of the variable has a unit root, we have to modify that variable to be a stationary series (as described in Section 2.3.2.1, Chapter 2). The most popular way to make the series to be a stationary process is to make a difference on the series. This modified data is called difference-stationary series. This method can eliminate the stochastic trend in our data.
How can the difference remove the stochastic trend? Recall the random walk with drift discussed in Section 2.3.2.1:

$$y_t = \mu + y_{t-1} + \varepsilon_t \qquad (3.18)$$

Subtract Equation (3.18) with y_{t-1} for both sides:

$$y_t - y_{t-1} = \mu + y_{t-1} - y_{t-1} + \varepsilon_t$$

$$\Delta y_t = \mu + \varepsilon_t \qquad (3.19)$$

Equation (3.19) shows that, by first differencing help, the process becomes stationary as it depends on the white noise error term, ε_t, plus a constant μ. We say y_t is of an integrated of order one: $y_t \sim I(1)$. In general, if the process has to make d times of difference, we call the series an integrated of order d and can be written as $y_t \sim I(d)$. Most of macroeconomic variables and financial variables are non-stationary with the integration of order one or $I(1)$ process.

There is another case that its original series is not stationary. This case is called time-trend stationary process. This process can be described as follows.

$$y_t = \alpha + \beta t + \varepsilon_t \qquad (3.20)$$

where α and β are the model parameters and the variable t is the time variable. This series can be made to be the stationary process. We can make this series to be the stationary by using the detrend process. Referring to Equation (3.20), if we lag Equation (3.20) by one period, we have

$$y_{t-1} = \alpha + \beta(t-1) + \varepsilon_{t-1} \qquad (3.21)$$

By subtracting Equation (3.20) by Equation (3.21), it yields

$$\Delta y_t \equiv y_t - y_{t-1} = \beta + \varepsilon_t - \varepsilon_{t-1} \qquad (3.22)$$

The process that is represented in the Equation (3.22) is known as moving average (MA) process which is stationary.

The spurious regression can be avoided if all of the variables in the regression are stationary process. But in some cases, even the variables are not stationary, the regression may not result in the spurious regression This happens when the variables have cointegration.

Supposedly, y_t and x_t, are assumed to have the relationship:

$$y_t = \alpha x_t + u_t$$

$$\text{or } u_t = y_t - \alpha x_t \qquad (3.23)$$

In Equation (3.23), u_t is the linear combination of y_t and x_t. If y_t and x_t are both I(d) process, u_t is normally I(d) process as well. However, if y_t and x_t have long-term relationship, two series are cointegrated and hence u_t becomes I(0) process or stationary process.

The concept of cointegration can be extended to the multivariate case as long as there are at least two variables of the highest integrated order.

There are several methods to test for the cointegration. In this paper, we apply the method of Engle and Granger cointegration test. Consider the following regression:

$$y_t = \beta_1 + \beta_2 x_t + u_t \qquad (3.24)$$

The intuition of Engle and Granger test is that if the error term, u_t, in Equation (3.24) is stationary, y_t and x_t are cointegrated. In other words, a unit root test is applied on the residual term of the regression model. If the test shows that u_t does not have a unit root, there is a cointegration between variable y_t and x_t. If we find the cointegration among the variables in the regression model, the original regression can simply be run. However, if there is no cointegration, we need to difference all variables to be stationary before running regression for the short run relationship.

3.4.3.2 The Principal Components Analysis (PCA)

In statistics, the use of PCA is popular. One might apply the PCA technique for filling the missing data or solving the multicollinearity problem when the explanatory variables are highly correlated.

Technically, PCA is a tool to reduce the dimension of the data. Its method relies on the matrix decomposition. The decomposition of matrix in PCA can be shown as

$$\mathbf{V} = \mathbf{W\Lambda W^T} \tag{3.25}$$

Equation (3.25) is written in the matrix form where **V** is covariance matrix or correlation matrix, **Λ** is diagonal matrix of the eigenvalues of matrix **V**, and **W** is a matrix of the corresponding eigenvector in the same sequence of the eigenvalues in matrix **Λ**. The superscript **T** is the notation of matrix transpose. PCA is the one of an application of eigenvalue and eigenvector in matrix algebra.

Let **X** be a matrix with dimension n × k where n is the number of the observations and k is the number of our variables. Assume that each of variable in matrix **X** has zero mean, the variance-covariance matrix of **X** can be calculated by $\mathbf{V} = n^{-1}\mathbf{X^T X}$. For n ≥ k, we can get k eigenvalues, denoted as λ_i where i = 1, 2, …, k.

The summation of all eigenvalues of variance-covariance matrix is called total variation in **X**. The ratio of each eigenvalue, λ_i, to the total variation $(\lambda_i / \sum_{i=1}^{n} \lambda_i)$ shows how important of component i can explain the variation in that covariance matrix. In practice, the eigenvalues are sorted in descending fashion. Normally, only the first r components where $0 < r < k$ is sufficient to use for explaining the variation of the variance-covariance matrix.

Let **P** be n × k matrix that represents the principal component of matrix **V**. Define matrix **P** to have a relation with input matrix **X** as **P** = **XW** or the input matrix multiplied with the correspondent matrix of eigenvectors.

Because matrix **W** has an orthogonal property, its inverse is the same as its transpose. From the relationship of principal component matrix **P**, we know that **X**

= $\mathbf{PW^T}$. Interestingly, using only a few numbers of principal components are enough to approximate our input matrix **X**. We can approximate matrix **X** as

$$\mathbf{X} \approx \mathbf{P^*W^{*T}} \tag{3.26}$$

where **P*** is the matrix with dimension n × r and **W*** is the matrix with dimension r × k while matrix **X** still has original dimension n × k. From this point, we can use the new estimated principal components which have low correlation among each other but have high correlation with the original variables. These new variables from PCA can be used in regression analysis to replace the original variables. This technique helps when our original variables are undesirable such as in the case of high multicollinearity among the original variables or we want to reduce the number of explanatory variables by using a few principal components instead.

3.5 Data

Our study covers cases in Singapore and Thailand. Since bubbles may exist during a short period but no macroeconomic data is daily, we decide to conduct the analysis on a monthly basis. For the data that have a longer frequency in nature (quarterly or yearly), we convert them to be monthly data using equal shares. All data, except tax ability, are in nominal terms. We adjust most of them to real terms by dividing the data set by consumer price index (CPI). For interest rate and government bond yield, we subtract them with inflation rate (also calculated from CPI). The Singapore data set is shown in Table 3.4.

Table 3.4 Singapore's Data Set

Variable	Proxy	Frequency	Selected Data Range
Stock Price	STI Index	Monthly	Sep 1999 - Apr 2018
CPI	Singapore CPI (not seasonal adjusted)	Monthly	Sep 1999 - Apr 2018
GDP	Singapore GDP (not seasonal adjusted)	Quarterly	Q1 1999 - Q1 2018
Capital Outflow	Capital and Financial Account Net (BO	Quarterly	Q1 1999 - Q1 2018
Investment	Changes in Inventory	Quarterly	Q1 1999 - Q1 2018
Interest Rate	Deposit Rates	Monthly	Sep 1999 - Apr 2018
Government Bond	Government Bond Outstanding	Monthly	Sep 1999 - Apr 2018
Budget Deficit	Budget Deficit	Yearly	1999 - 2018
Tax Ability	Income Tax to GDP	Monthly	Jan 2003 - Apr 2018
Yield	Average Government Bond Yield	Monthly	Sep 1999 - Apr 2018

From Table 3.4, the Strait Time Index (STI) represents the stock price of Singapore. We choose the changes in inventory as a proxy for investment and the deposit rate for the interest rate. Government bond outstanding is the total value of all issued government bonds which have mixed maturities. Therefore, we average the yield of different maturity to proxy government bond yield. The difficulty is on the government tax ability variable. Ideally, the tax ability is best described by the ratio between the collected tax income and the full potential of tax income. The full potential covers all tax income that deserves to be collected from both the formal sector and informal sector and also from all kinds of taxes. The time series of such tax ability is not available. For the case of Singapore, the best we can find is the ratio between tax income and GDP. Note that all data came from Datastream.

For Thailand, the stock exchange index (SET) represents Thailand's stock price. All other variables use the proxies similarly as in the Singapore data set, except tax ability. Instead of the tax-to-GDP ratio, we use the ratio between a number of workers who report their income to Thailand's Revenue Department and the total labor force. This proxy is better than tax-to-GDP ratio because it directly shows the proportion of workers who intentionally escape from government taxation authority. The data on the number of reporting taxpayers is from the Revenue Department of Thailand (Source derived from the intranet (not publicly available) of Revenue Department of

Thailand) and the budget deficit data is from Thailand's Ministry of Finance, while other data are again from Datastream. Table 3.5 gives the summary.

Table 3.5 Thailand's Data Set

Variable	Proxy	Frequency	Selected Data Range
Stock Price	SET Index	Monthly	Apr 1975 - Dec 2016
CPI	Thailand CPI (not seasonal adjusted)	Monthly	Jan 1976 - Apr 2018
GDP	Thailand GDP (not seasonal adjusted)	Quarterly	Q1 1993 - Q3 2017
Capital Outflow	Capital Outflow	Monthly	Jan 1993 - Jun 2011
Investment	Private Investment Index	Monthly	Jan 1980 - Dec 2016
Interest Rate	Saving Interest Rate	Monthly	Jan 1978 - Dec 2016
Government Bond	Government Bond Outstanding	Monthly	Jun 1993 - Apr 2018
Budget Deficit	Budget Deficit	Monthly	Oct 2002 - Apr 2018
Tax Ability	Proportion of Tax Payers to Labor Forc	Yearly	2001 - 2015
Yield	Average Government Bond Yield	Monthly	Jan 1999 - Apr 2018

3.6 Empirical Results

Since the analysis is country-based, we report our results for the Singapore case first and Thailand next.

3.6.1 Singapore

We conduct the discrete Fourier transformation over Singapore's relative stock price defined by STI-to-CPI ratio. We found that the data has a high magnitude over the low frequency as shown in Figure 3.6. In other words, the data mostly consists of the long wave span series. This is consistent with Bhashyam, Doran, and Dorney (1999) and Gençay, Selçuk, and Whitcher (2001) studies which described that asset price data tend to fall towards the low frequency domain in the Fourier transformation.

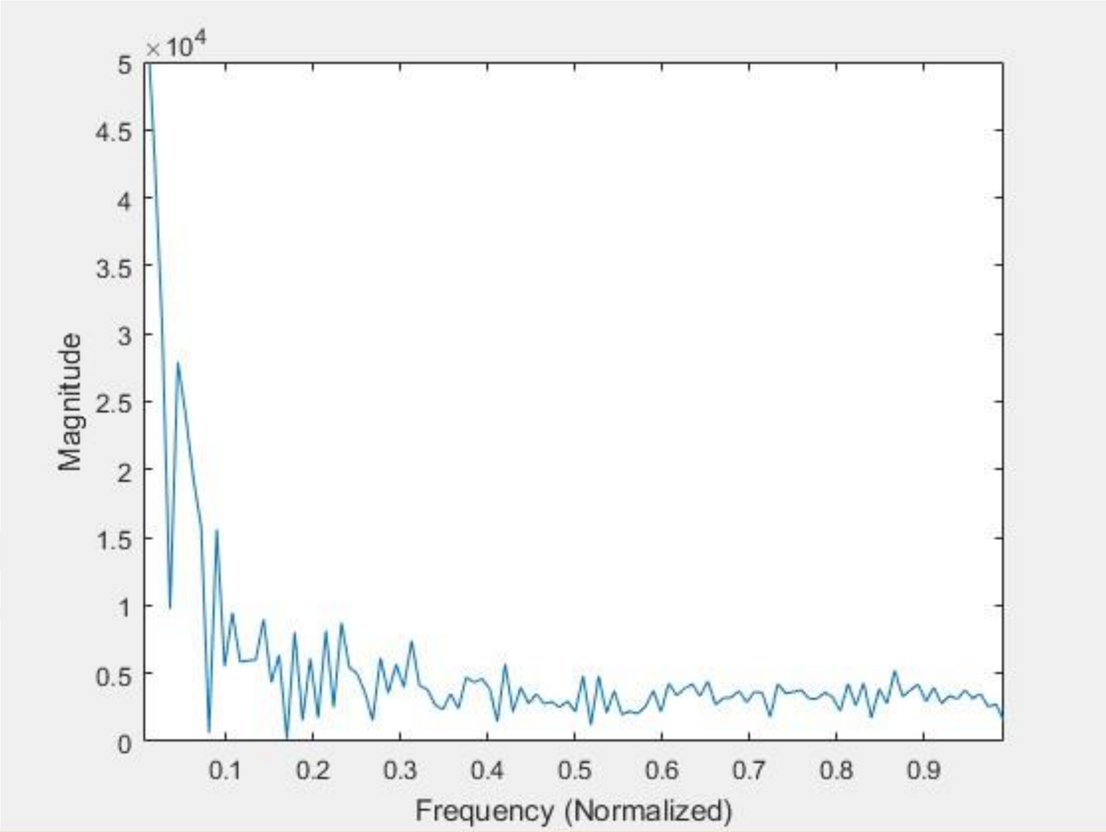

Figure 3.6 Magnitude of Singapore Relative Stock Price

Given our 18 filters, we obtained 18 filtered series as bubble index candidates. To perform the regression scoring, we followed the standard time series procedure: checking the unit root, cointegration test, and autocorrelation problem for non-cointegrated cases. The details are shown in the Appendix. The regression results of (3.16) and the scoring are reported in Table 3.6.

Table 3.6 Regression Scoring for Bubbles Index in Singapore Case

Filter	**Relative Stock Price**	**Real Capital Outflow**	**Real GDP**	**Real Investment**	**Real Interest**	**Total**
F_{l1}	0.862161*	-0.01068*	0.0078*	-0.045098*	3475.945	4
F_{l2}	0.862414*	-0.007682	0.009155*	-0.046523*	2705.543	3
F_{l3}	0.897338*	-0.004711	0.01086*	-0.041199*	2798.896	3
F_{l4}	0.894502*	-0.006688	0.011222*	-0.041023*	3176.867	3
F_{l5}	0.899278*	-0.006685	0.0073*	-0.043095*	3742.464	3
F_{l6}	0.892729*	-0.008076	0.007885*	-0.042936*	4026.234	3
F_{l7}	0.883212*	-0.009452	0.011766*	-0.040711*	4067.552	3
F_{l8}	0.897406*	-0.006815	0.007718*	-0.040883*	4783.275	3
F_{l9}	0.893595*	-0.008238	0.009546*	-0.04128*	4624.922	3
F_{h1}	-0.591711*	0.016872*	0.092041*	-0.010315*	-5012.582*	3
F_{h2}	-0.574593*	-0.000647	-0.023015*	0.046717*	-2760.171*	2
F_{h3}	-0.544792	0.00729	-0.100711*	0.1329*	-14755.03*	2
F_{h4}	0.069754	-0.042916*	-0.287613*	-0.079691*	8982.689*	2
F_{h5}	-0.28377*	0.000549	0.004918	0.003192	-1001.171	0
F_{h6}	-0.33719*	-0.006264*	-0.102945*	0.050256*	7796.849*	2
F_{h7}	0.273033	0.032009*	-0.043852	0.015209	2883.914	0
F_{h8}	-0.0927	-0.013937*	0.014814	0.004693	9396.255*	1
F_{h9}	-0.041287	-0.000408	-0.071526*	-0.034894*	5485.184*	1

Note: * The estimate is statistically significant at 10% significance level.

From Table 3.6, we can see that the filtered series F_{l1} has the highest score where only the interest rate is not significant. It is clear that low pass filtered series perform better than high pass ones. In details, it can be shown that most of the relative stock price data fall towards the low frequency domain in the Fourier transformation. This is consistent with Bhashyam et al. (1999) and Gençay et al. (2001). Therefore, we choose F_{l1} to be our Singapore bubble index. Note that the Fourier transformed series in the low frequency follows the long wave structure. Since our regression scoring selects the lowest pass filter, we expect F_{l1} to follow the longest wave span which shows somewhat the trend of the relative stock price. Figure 3.7 graphs the times series of relative stock price and F_{l1} as bubble index.

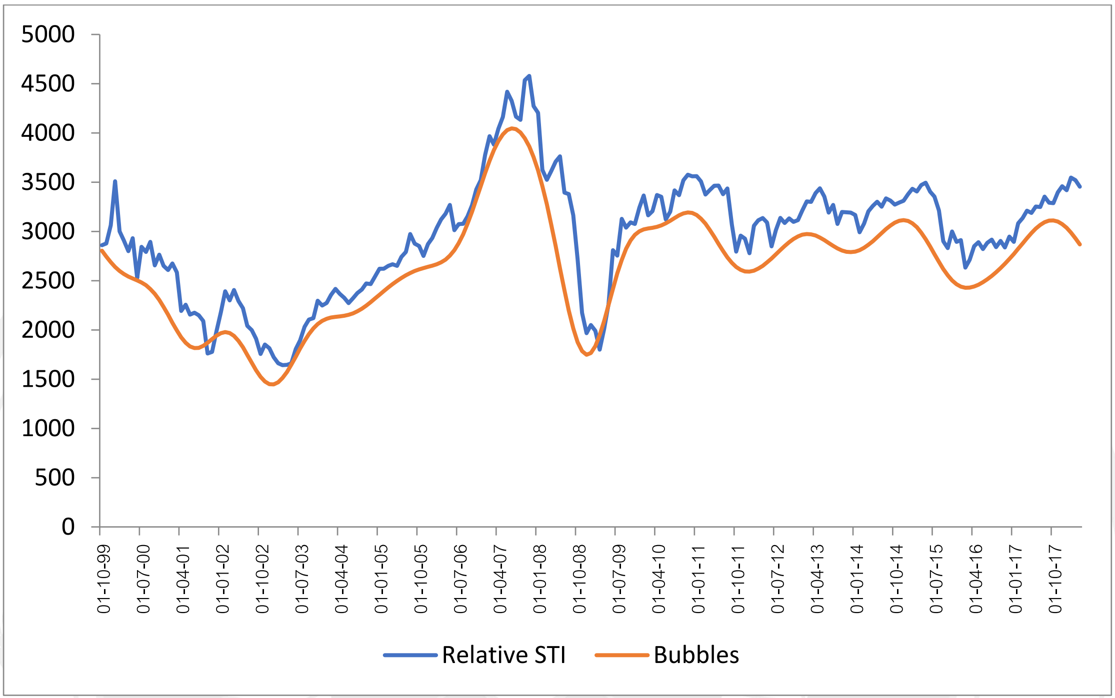

Figure 3.7 Singapore Relative Stock Price and Bubble Index

Next, we proceed to test the effect of government bonds on rational bubbles. As explained earlier, we need to take into account the tax ability and average yield of government bond as well. For Singapore, the data includes government bonds with a maturity of 1 month, 3 months, 1 year, 2 years, 5 years, 10 years, and 15 years. The PCA loadings of each adjusted bond variables are reported in Table 3.7.

Table 3.7 PCA Loadings of Each Adjusted Government Bond of Singapore

Variable	PCA loadings			Principle component's proportion
	Bond outstanding	Tax ability	Average bond yield	
BOND1	1	-	-	-
BOND2	0.707107	0.707107	-	0.5266
BOND3	0.707107	-	0.707107	0.5214
BOND4	0.570453	0.627744	0.529642	0.3622

To see the effect of each adjusted government bond on bubbles, we ran four different regressions as specified in (3.17). Again, the time series procedure is applied in every regression. Table 3.8 shows the result. We found that for the case of Singapore, the result is consistent with the rational bubble theory outlined in this paper. In particular, if we look for how government bond outstanding affects rational bubbles, we will find that government bonds ($BOND_1$) instead crowd in rational bubbles. This result still holds even when we take into account either tax ability or bond yield. However, with both in considerations, model 4 delivers us the government bond's coefficient estimate of -4.333096 which is of the expected negative sign. This implies that if the Singaporean government can strengthen its credibility in the authority to tax together with increasing its bond's yield, its government bonds can replace rational bubbles. In addition, we found that the expansionary fiscal stimulus like budget deficit also boosts up the development of bubbles in all cases as theoretically expected. Therefore, the Singapore government should be aware of the potential downfall in raising its spending or implementing tax cut policy as it may cause the eventual bubble crash.

Table 3.8 Effects of Government Bonds on Rational Bubbles - Singapore

Dependent variable: F_{l1}		Explanatory Variables				
		$BOND_1$	$BOND_2$	$BOND_3$	$BOND_4$	$BUDGET$
Model 1	Coefficient	1.042806*				0.613519*
Model 2	Coefficient		1.474726*			0.613522*
Model 3	Coefficient			1.47471*		0.613525*
Model 4	Coefficient				-4.333096*	6.851377*

Note: * The estimate is statistically significant at 1% significant level.

3.6.2 Thailand

The discrete Fourier transformation is also conducted over the relative stock price, SET-to-CPI ratio. The transformation result is shown in Figure 3.8. Thailand's relative stock price shows that the data has a high magnitude over the low frequency, the same as the Singapore data.

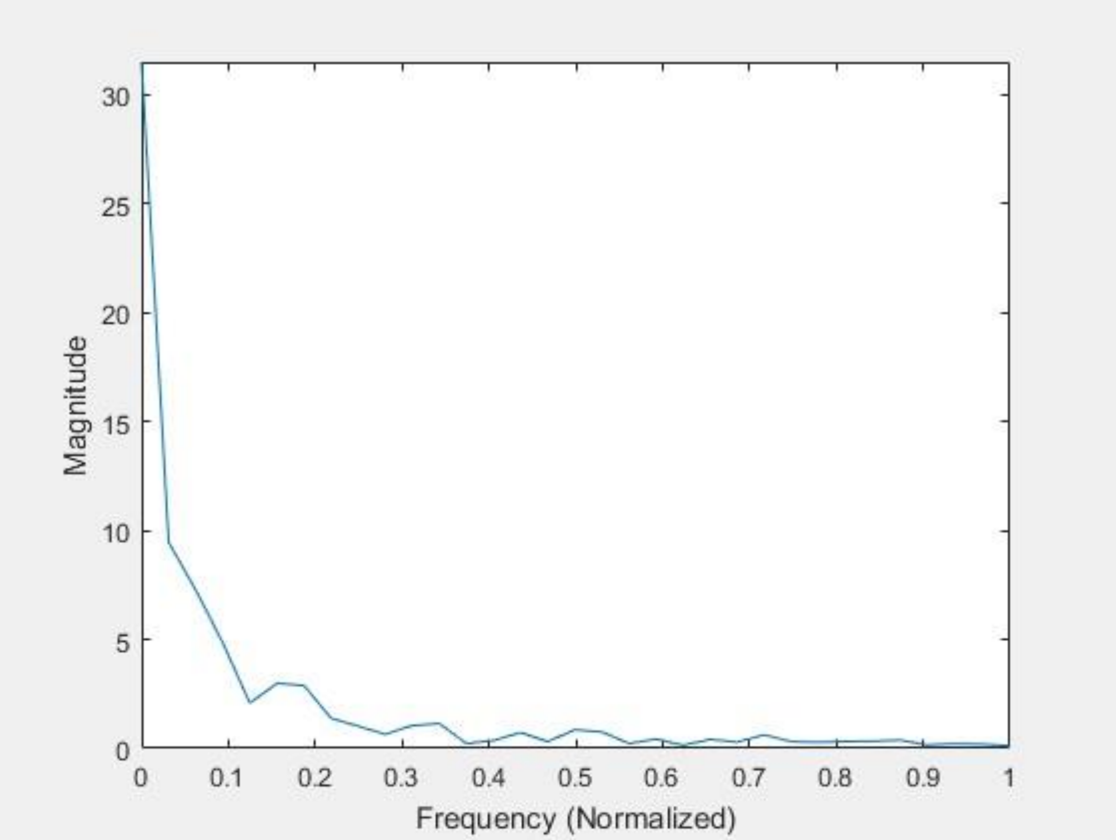

Figure 3.8 Magnitude of Thailand Relative Stock Price

The same process of time-series regression as in (1) is also performed for the 18 filters. The regression scoring for these 18 filters is shown in Table 3.9.

Table 3.9 Regression Scoring for Bubbles Index in Thailand Case

Filter	**Relative Stock Price**	**Real Capital Outflow**	**Real GDP**	**Real Investment**	**Real Interest**	**Total**
F_{l1}	0.043183*	0.00160	0.0000028	0.051063*	-0.011201*	3
F_{l2}	0.046176*	0.00174	0.0000033	0.057134*	-0.01111	2
F_{l3}	0.051804*	0.00188	0.0000037	0.063037*	-0.01255	2
F_{l4}	0.051382*	0.00188	0.0000037	0.063263*	-0.01234	2
F_{l5}	0.045214*	0.00161	0.0000032	0.055082*	-0.01109	2
F_{l6}	0.04561*	0.00161	0.0000034	0.055325*	-0.01087	2
F_{l7}	0.051093*	0.00181	0.0000039	0.06277*	-0.01192	2
F_{l8}	0.045605*	0.00161	0.0000034	0.056597*	-0.01077	2
F_{l9}	0.048257*	0.00164	0.0000036	0.059021*	-0.01124	2
F_{h1}	-0.00007	-0.00001	0.0000000	0.00312	-0.00062	0
F_{h2}	-0.00014	0.00005	0.0000003	0.00235	0.00039	0
F_{h3}	-0.00005	0.00001	0.0000001	0.00199	0.00011	0
F_{h4}	-0.00012	0.00001	0.0000003	0.002476*	0.000494*	1
F_{h5}	-0.00008	0.00001	0.0000004	0.001701*	0.000482*	1
F_{h6}	-0.00005	0.00000	0.0000002	0.001963*	0.000424*	1
F_{h7}	-0.00003	0.00001	0.0000002	0.001349*	0.00023	1
F_{h8}	-0.00001	0.00003	0.0000001	0.00061	0.00009	0
F_{h9}	-0.00001	0.00001	0.0000001	0.00034	0.00011	0

Note: * The estimate is statistically significant at 10% significance level.

We can observe clearly from Table 3.9 that F_{l1} gets the highest score. We selected F_{l1} as a bubble index for Thailand. We showed the graph of time series plot of Thailand relative stock price and the bubble index, F_{l1} as in Figure 3.9.

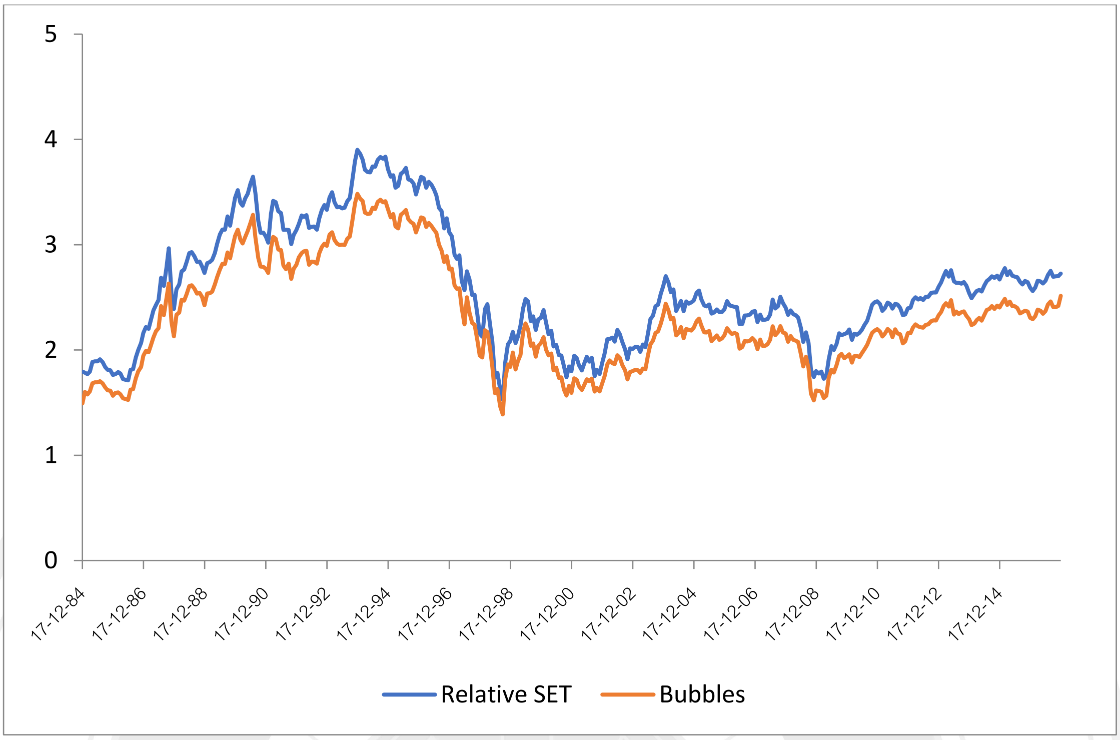

Figure 3.9 Thailand Relative Stock Price and Bubble Index

Similar to the Singapore case, because the longest wave span (F_{l1}) is selected, our bubble index shows the trend of the relative stock price.

We next performed the test for the effect of government bonds on rational bubbles. The tax ability and average yield of government bonds are taken into account as in the Singapore case. Thai government bonds series that we chose for yield calculation are in the maturity of 1 year, 2 years, 5 years, 7 years, 10 years, 12 years, and 14 years. We reported the PCA loadings of each adjusted bond variables in Table 3.10.

Table 3.10 PCA Loadings of each Adjusted Government Bond of Thailand

Variable	PCA loadings			Principle component's proportion
	Bond outstanding	Tax ability	Average bond yield	
BOND1	1	-	-	-
BOND2	0.707107	0.707107	-	0.8924
BOND3	0.707107	-	0.707107	0.5311
BOND4	0.701007	0.699978	0.136457	0.6000

We performed the regression as described in Equation (3.17) to check the effect of the government bond on the rational bubbles. The results of the regression are shown in Table 3.11. In contrast to Singapore, we cannot find the relationship between government bonds and the rational bubbles. We cannot reject the null hypothesis that the estimated parameters are statically different from zero even at the 10% significant level. The government bonds neither increase nor decrease the rational bubbles in the market. The results are still the same for the cases that we adjusted the taxability, yield, and both into the model. We suspected that either the credibility of tax collection of Thai government or the returns of holding government bonds or both cannot replace the returns from bubbles. The policy implication from this result is that the Thai government should increase their tax collection ability, or make the yield of its bond to be more attractive—the same as the bubbles in the market.

The budget deficit that we added as a control variable also has no impact to the rational bubbles as it is not statistically different from zero.

Table 3.11 Effects of Government Bonds on Rational Bubbles – Thailand

Dependent variable: F_{l1}		**Explanatory Variables**				
		$BOND_1$	$BOND_2$	$BOND_3$	$BOND_4$	$BUDGET$
Model 1	Coefficient	-0.0000011				0.00000003
Model 2	Coefficient		0.00000196			0.00000002
Model 3	Coefficient			-0.0000016		0.00000003
Model 4	Coefficient				0.0000020	0.00000002

3.6.3 Two-Country Comparison

We compared the results of Singapore and Thailand as per the analysis earlier. We started our study with the construction of the rational bubbles index. The time series regression scoring is applied for choosing the appropriated bubbles index from the potential 18 filters from the discrete Fourier transformation. From the regression results, F_{l1} which is the lowest pass filter gets the highest score from the regression analysis. Therefore, F_{l1} is selected for both Singapore and Thailand. This result is consistent with Bhashyam et al. (1999) and Gençay et al. (2001).

We then analyzed for the effect of the government bonds on the rational bubbles. For Thailand case, the results show that government bonds cannot reduce the rational bubbles as per expected by the theory. Even though the bonds that we use for testing are adjusted by tax ability and yields to make them close to the theory, we cannot see the impact of government bonds to the rational bubbles. In contrast, for the Singapore case, we can see the relationship between government bonds and the rational bubbles. The government bonds ($BOND_1$) themselves caused the crowd in effect to the rational bubbles. The results are also the same when we modified the bond with the credibility of tax collection ($BOND_2$) or yields ($BOND_3$). But when we adjusted these two factors altogether with the government bonds ($BOND_4$), the result shows that there is a negative relationship with rational bubbles.

In the Singapore case, the rational bubbles can be replaced by the government bonds once its government strengthens its tax ability together with its government bond yields. For Thailand, we suspect that the credibility of tax collection of its government and the government bond yields are not enough for investors to replace the bubbles with government bonds. This is the point that we need to have further study.

3.7 Conclusion

The asset price bubble is known as one of the factors of the economic crisis. To prevent this unpleasant result from the bubble, there is one suggestion from the previous study that we should replace the bubble with the asset that has an analogous structure except that it must be crash-free. The government bonds are suggested for the case. From this starting point, we tried to test whether the bubble can be replaced by government bonds or not. In this study, we chose Singapore and Thailand to test empirically.

We started our analysis with the bubble index construction. The stock index is selected for the representative of an asset that can create the bubble. To construct the bubble index, we applied the discrete Fourier transformation over the relative stock price which is defined as a stock index-to-CPI ratio. At this process, there are 18 filters generated as the output. Because these 18 filters are possible to be the rational bubbles representation, we did time series regression with various macroeconomics factors to check which filter is the best match with the theory of the rational bubbles. The results show that F_{l1}, which is the lowest pass filter, is the best match for both Singapore and Thailand.

We continued the study with the government bonds outstanding which is another factor in our analysis. We created four different ways of government bonds outstanding; original bonds outstanding ($BOND_1$), bonds with taxability adjusted ($BOND_2$), bonds with yields adjusted ($BOND_3$), and bonds with both taxability and yields adjusted ($BOND_4$). We applied PCA for adjusting the government bonds outstanding.

Finally, we tested whether the government bonds outstanding can replace the rational bubbles or not. The time series regression is performed for this testing. If the government bonds can replace the rational bubbles, the negative relationship is expected for the result. We also used the government budget as the control variable in the regression analysis. For Singapore, all four models showed that government bonds are statistically different from zero; however, the results among these four models are not identical.

On the one hand, the first three models ($BOND_1$ – $BOND_3$) displayed the positive relationship which means that the government bonds boost the rational bubbles. On the other hand, the last model ($BOND_4$) showed the negative sign. This implies that government bonds with the tax ability and their rate of returns help the reduction of the rational bubbles. For the control variable, government budget, all four models showed a positive relationship and are statistically significant. This result is consistent with the bubbles theory. This result suggests for Singapore to pay attention to the budget usage.

In contrast, for Thailand, there is no relationship between the rational bubbles and the government bonds, in all four models as the regression results showed no statistical significance. We suspect that the credibility of the tax collection of the Thai government is lower than investors' perspective or the government bonds yields are not in the same structure as bubbles. These suspicions are left for future study. Also, these findings in the study are just the results from Singapore and Thailand. We still need more comparative studies with the different developing and developed countries in order to generalize the result whether government bond can replace rational bubbles or not.

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APPENDIX

Table A.1 Unit Root Test Results for Singapore Time Series – Bubble Index Construction

Variables	Unit Root Test	Variables	Unit Root Test	Variables	Unit Root Test
F_{l1}	I(1)	F_{h1}	I(0)	RLTSI	I(1)
F_{l2}	I(1)	F_{h2}	I(0)	RCAP	I(0)
F_{l3}	I(1)	F_{h3}	I(1)	RGDP	I(1)
F_{l4}	I(1)	F_{h4}	I(1)	RINV	I(1)
F_{l5}	I(1)	F_{h5}	I(1)	RINT	I(0)
F_{l6}	I(1)	F_{h6}	I(1)		
F_{l7}	I(1)	F_{h7}	I(1)		
F_{l8}	I(1)	F_{h8}	I(1)		
F_{l9}	I(1)	F_{h9}	I(1)		

Table A.2 Cointegration Test Results for Singapore Time Series – Bubble Index Construction

Variables	Cointegrated	Variables	Cointegrated
F_{l1}	Yes	F_{h1}	No
F_{l2}	Yes	F_{h2}	No
F_{l3}	Yes	F_{h3}	No
F_{l4}	Yes	F_{h4}	No
F_{l5}	Yes	F_{h5}	No
F_{l6}	Yes	F_{h6}	No
F_{l7}	Yes	F_{h7}	No
F_{l8}	Yes	F_{h8}	No
F_{l9}	Yes	F_{h9}	No

Table A.3 Unit Root Test Results for Singapore Time Series – Test of the Effect of Government Bonds on the Rational Bubbles

Variables	Unit Root Test
BOND1	I(1)
BOND2	I(1)
BOND3	I(1)
BOND4	I(1)
BUDGET	I(1)

Table A.4 Cointegration Test Results for Singapore Time Series – Test of the Effect of Government Bonds on the Rational Bubbles

Model	Variables	Cointegrated
1	BOND1 + BUDGET	Yes
2	BOND2 + BUDGET	Yes
3	BOND3 + BUDGET	Yes
4	BOND4 + BUDGET	No

Table A.5 Unit Root Test Results for Thailand Time Series – Bubble Index Construction

Variables	Unit Root Test	Variables	Unit Root Test	Variables	Unit Root Test
F_{l1}	I(1)	F_{h1}	I(0)	RLTSI	I(1)
F_{l2}	I(3)	F_{h2}	I(0)	RCAP	I(0)
F_{l3}	I(4)	F_{h3}	I(0)	RGDP	I(1)
F_{l4}	I(2)	F_{h4}	I(1)	RINV	I(1)
F_{l5}	I(3)	F_{h5}	I(1)	RINT	I(1)
F_{l6}	I(0)	F_{h6}	I(1)		
F_{l7}	I(0)	F_{h7}	I(1)		
F_{l8}	I(1)	F_{h8}	I(1)		
F_{l9}	I(1)	F_{h9}	I(1)		

Table A.6: Cointegration Test Results for Thailand Time Series – Bubble Index Construction

Variables	Cointegrated	Variables	Cointegrated
F_{l1}	Yes	F_{h1}	Yes
F_{l2}	Yes	F_{h2}	Yes
F_{l3}	Yes	F_{h3}	Yes
F_{l4}	Yes	F_{h4}	Yes
F_{l5}	Yes	F_{h5}	Yes
F_{l6}	Yes	F_{h6}	Yes
F_{l7}	Yes	F_{h7}	Yes
F_{l8}	Yes	F_{h8}	Yes
F_{l9}	Yes	F_{h9}	Yes

Table A.7 Unit Root Test Results for Thailand Time Series – Test of the Effect of Government Bonds on the Rational Bubbles

Variables	Unit Root Test
BOND1	I(1)
BOND2	I(1)
BOND3	I(1)
BOND4	I(1)
BUDGET	I(1)

Table A.8 Cointegration Test Results for Thailand Time Series – Test of the Effect of Government Bonds on the Rational Bubbles

Model	Variables	Cointegrated
1	BOND1 + BUDGET	No
2	BOND2 + BUDGET	No
3	BOND3 + BUDGET	No
4	BOND4 + BUDGET	No

BIOGRAPHY

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