RESEARCH ARTICLE

Can Government Bond Replace Rational Bubbles? The Empirical Investigation on Singapore and Thailand

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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.

Keywords**:** Rational Bubbles, Fourier Transformation, Government Bonds, and Fiscal Policies.

JEL Classifications: G12, O23, E62

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.[1]

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,[2] 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 (see Tirole, 1985; Weil, 1987) or the credit-constrained economy (see Caballero, Farhi, & Hammour, 2006; Farhi & Tirole, 2012).

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 (see Ventura, 2012; Hirano &Yanagawa, 2017; Bejan & Bidian, 2015; Werner, 2015; Miao & Wang, 2015; Miao, Wang, & 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 intergenerational 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 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 (see Domeji & Ellingsen, 2018). Such trade-off may result in welfare reduction and require a discretional judgment based on specific economic context (see Kindleberger, 1995; and Shiratsuka, 2003).

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.[3] 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.

Brief Review of Rational Bubble Theories

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.

According to the bubble-generating mechanism, Tirole (1985) showed the existence of bubbly equilibrium in Figure 1. 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 . There exists the other steady state called bubbly steady state where all points on the saddle path (dashed line) converge to. In details, given the initial capital stock at , the equilibrium may switch to the bubbly one and converge to . 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 2 illustrates this dynamic.

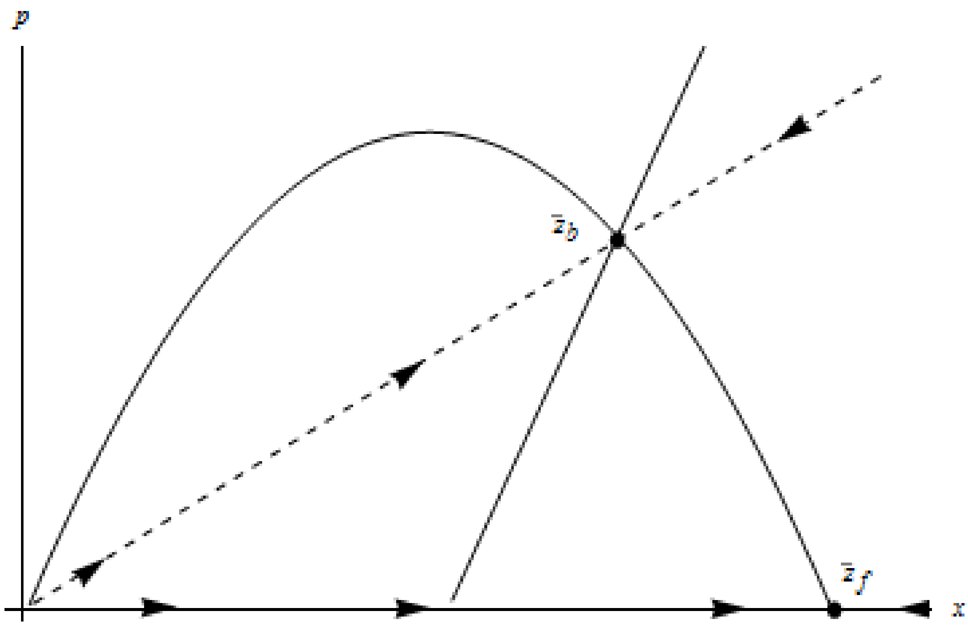

Figure 1. Bubbles crowd out investment

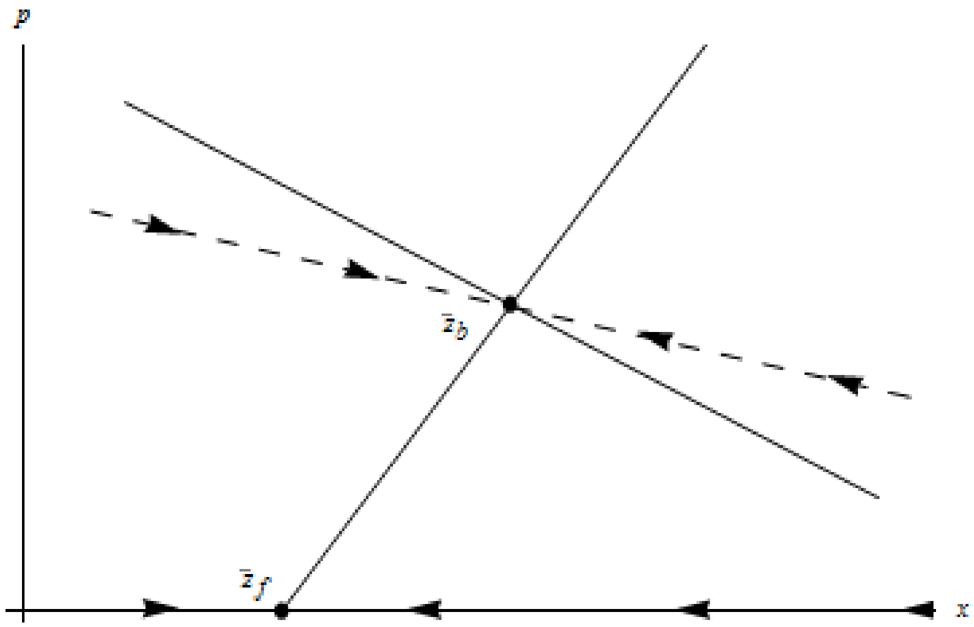

Figure 2. Bubbles crowd in investment.

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 1 and 2 suggest that interest rate decreases while bubbles are booming. Table 1 summarizes the relationship.

Table 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.

Empirical Methodology

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.

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.

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.[4] 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 (see Press, Teukolsky, Vetterling, & Frannery, 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 $0.1j$, while the remaining nine are high pass filters which allow the frequency in range $0.1j$ to 1, where $j = 1, 2, \ldots, 9$. The summary of the low pass filter F_{lj} and high pass filters F_{hj} is shown in Table 2.

Bubble selection scoring. To select the filter that best represents rational bubbles, we perform the following regression scoring. According to (1), we regress each filtered series on 6 bubble-related macroeconomic variables defined in Table 1.

$$F_{ijt} = \beta_{ij1} + \beta_{ij2}RLTSET_t + \beta_{ij3}RCAP_t + \beta_{ij4}RGDP_t + \beta_{ij5}RINV_t + \beta_{ij6}RINT_t + \varepsilon_{ijt} \quad (1)$$

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 1. Otherwise, each gets 0 score. The filtered series that has the highest score is our bubble index (BUBBLE).

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 principle component analysis (PCA) over three inputs: real government bond outstanding, tax ability proxy, and real government bond yield. Then, we select the

Table 2
Low Pass and High Pass Filters

Low pass filters			High pass filters		
Filtered series	Frequency band		Filtered series	Frequency band	
	From	To		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

principle component whose loadings are all positive. Table 3 defines each adjusted government bond variable.

Table 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 (2).

$$BUBBLE_t = \gamma_1 + \gamma_2 BOND_{it} + \gamma_3 BUDGET_t + \epsilon_t \quad (2)$$

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

Data

Our study covers cases in Singapore and Thailand.[5] 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 4.

From Table 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[6] and the budget deficit data is from Thailand's Ministry of Finance, while other data are again from Datastream. Table 5 gives the summary.

Results

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

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. In other words, the data mostly consists of the long wave span series. This is consistent with Bhashyam, Doran, and Dorney (1999) and Gencay, Seluck, and Whitcher (2002) studies which described that asset price data tend to fall towards the low frequency domain in the Fourier transformation.

Given our 18 filters, we obtained 18 filtered series as bubble index candidates. To perform the regression scoring, we followed the standard time

Table 4
Singapore 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	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
Government tax ability	Income Tax to GDP	Monthly	Jan 2003 - Apr 2018
Government bond yield	Average Government Bond Yield	Monthly	Sep 1999 - Apr 2018

Table 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
Government tax ability	Proportion of Reporting Taxpayers to Labor Force	Yearly	2001 – 2015
Government bond yield	Average Government Bond Yield	Monthly	Jan 1999 – Apr 2018

series procedure: checking the unit root, cointegration test, and autocorrelation problem for non-cointegrated cases.[7] The regression result of (1) and the scoring are reported in Table 6.

From Table 6, we can see that the filtered series F_{II} has the highest score where only the interest rate is not significant.[8] Therefore, we choose F_{II} 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_{II} to follow the longest wave span which shows somewhat the trend of the relative stock price. Figure 4 graphs the times series of relative stock price and F_{II} as 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 7.

To see the effect of each adjusted government bond on bubbles, we ran four different regressions as specified in (2).[9] Table 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 () 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 Singaporian 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.

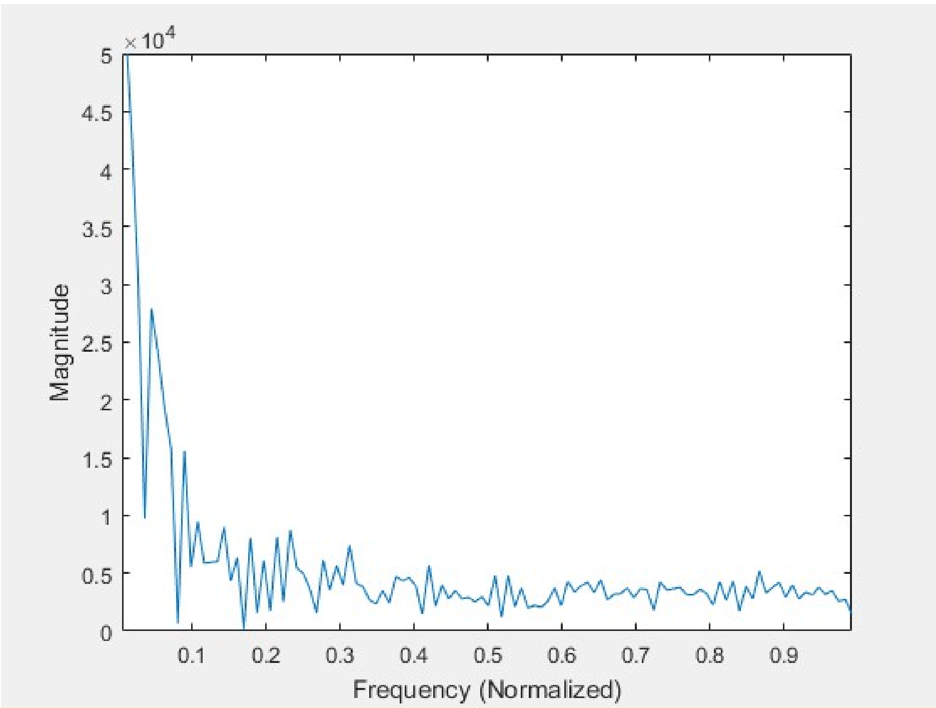

Figure 3. Magnitude of Singapore relative stock price.

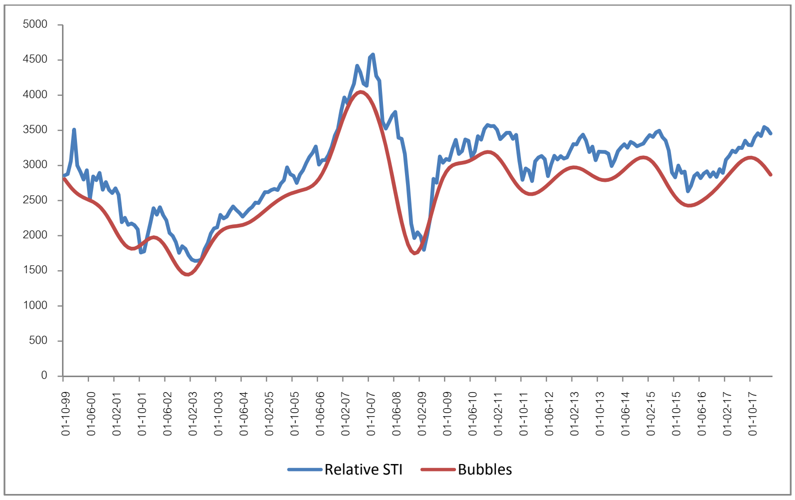

Figure 4. Singapore relative stock price and bubble index.

Table 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

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

Table 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

Table 8
Effects of Government Bonds on Rational Bubbles

Dependent variable: F_{1I}		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*

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

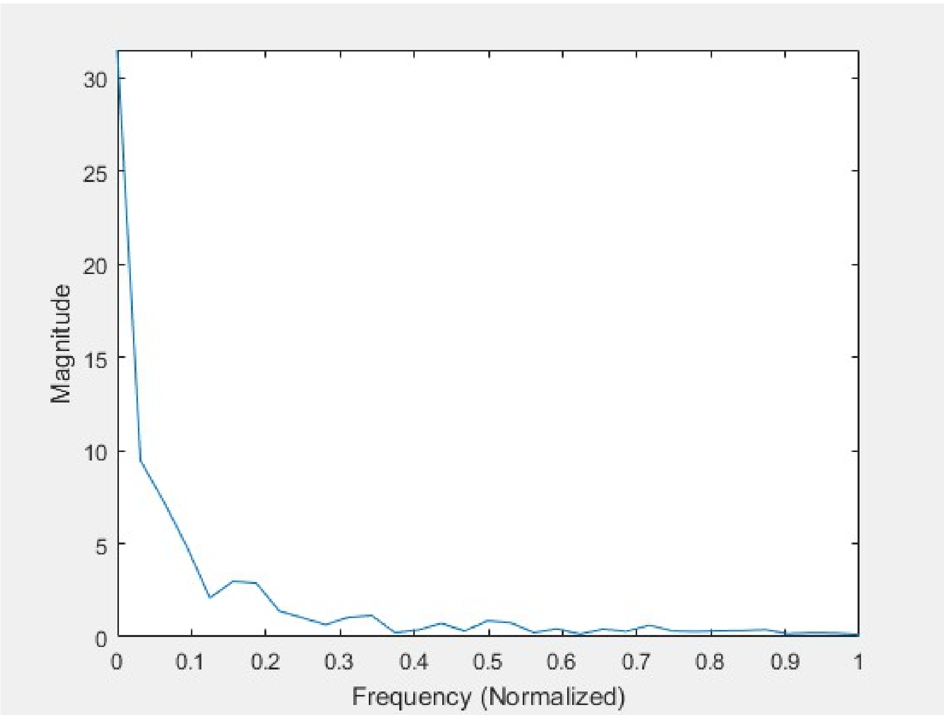

Figure 5. Magnitude of Thailand relative stock price.

Thailand

The discrete Fourier transformation is also conducted over the relative stock price, SET-to-CPI ratio. The transformation result is shown in Figure 5. Thailand's relative stock price shows that the data has a high magnitude over the low frequency, the same as the Singapore data.

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 9.

We can observe clearly from Table 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 6.

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

Table 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

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

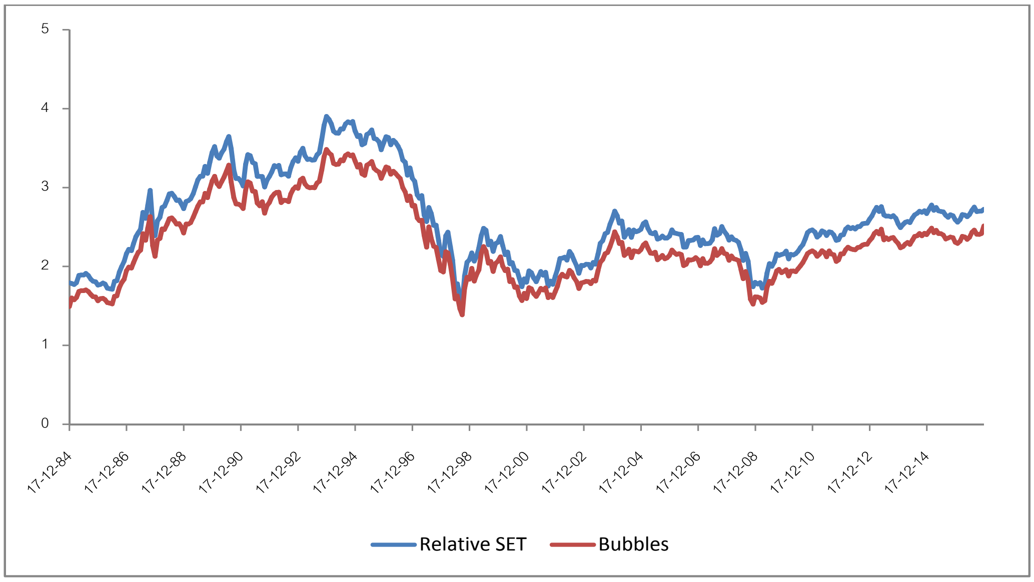

Figure 6. Thailand relative stock price and bubble index.

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 10.

We performed the regression as described in (2) to check the effect of the government bond on the rational bubbles. The results of the regression are shown in Table 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.

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 fransformation. From the regression results, F_{II} which is the lowest pass filter gets the highest score from the regression analysis. Therefore, F_{II} is selected for both Singapore and Thailand. This result is consistent with Bhashyam et al. (1999) and Gencay et al. (2002).

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

Table 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

Table 11
Effects of Government Bonds on Rational Bubbles

Dependent variable: F_{11}		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

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

($BOND_4$), 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.

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_{11}, 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 A1
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 A2
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 A3
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 A4
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 A5
Unit Root Test Results for 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 A6
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 A7
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 A8
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