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Whether the Multiple Bubbles Exist in the Bond Markets of Developed Countries?

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Abstract

The study uses SADF and GSADF tests to examine whether the multiple bubbles exist in the bond markets of developed countries. The results demonstrate that there is an evidence of multiple bubbles in the government bond markets of United States, Germany, and Japan. The main causes of the bubbles are huge fiscal deficit caused by the massive government debt-raising in order to adopt expansionary fiscal policies, over-tightening of monetary policy and significant volatility in the global markets resulted from two oil shocks. In recent years, major developed countries have adopted expansionary fiscal policies like tax-cutting and infrastructure expenditures to improve economic fundamentals by huge debt-raising. This study reminds government officials need to guard against the impacts of excessive uses of expansionary fiscal policies on the bond markets and international investors must pay greater attention to the impacts of fiscal deficits for the management of investment portfolios.

Keywords: Multiple bubbles, GSADF test, developed countries, government bond markets.

1. Introduction

Under the impact of various factors, the global financial markets and the real economies have been negatively affected, and thus many explosive behaviors and fluctuations have furtherly occurred. As far as we know, worldwide markets have experienced many crises, such as Oil shocks, Iran-Iraq War, the Gulf wars, Mexican financial crisis, Asian financial crisis, Russian financial crisis, Dotcom crisis, Subprime crisis, European sovereign debt crisis. Previous Scholars have adopted different methods for testing the presence of bubbles in financial markets, with numerous applications. Research on stock market bubbles includes West [31], Diba and Grossman [7], Froot and Obstfeld [11], Porter and Smith [26], Gurkaynak [14], Homm and Breitung [15], and Papneja and Pathak [22]. Many papers have studied housing markets, such as Baker [3], Phillips and Yu [23], Greenaway-McGrevy and Phillips [12], and Shi et al. [27]. Commodity markets have been explored by Bertus and Stanhouse [5], Etienne et al. [8], and Zhao et al. [32], among others.

Finally, exchange rates have been examined by van Norden [28], Applegate [2], Jirasakuldech et al. [18], Maldonado et al. [20], Bettendorf and Chen [6], Jiang et al. [17], and Hu and Oxley [16]. However, researchers have seldom investigated the presence of the bubbles in bond markets.

The "bond market" generally refers to the market for government bonds, though there are also bond markets for corporate bonds and financial instruments such as mortgage bonds. Government bonds are the instrument used by national governments to finance government debts and the benchmark standards for long term interest rates on corporate bonds and mortgages. They are often seen as a safe investment with a guaranteed rate of interest. If government bond yields fluctuate rapidly and explosively, damage to both fiscal and monetary policies with occur, with impacts on economic growth and investment. Bubbles are characterized as excess volatility in, and explosive behavior of, asset prices (see Flood and Hodrick [10], Evans [9], Abreu and Brunnermeier [1]). Understanding of bubbles of government bonds is very important to investors.

Recent developments in 'right-tailed only' unit root tests, including the supremum Augmented Dickey-Fuller (SADF) and generalized SADF (GSADF) proposed by Phillips et al. [25] and Phillips et al. [24] respectively, have become widely used tests for bubbles. This study uses the SADF and GSADF tests to examine whether multiple bubbles exist in the developed countries' bond markets. Our results show that multiple bubbles exist in the United States, Germany, and Japan bond markets based on the GSADF test. The main reasons of the bubbles are huge fiscal deficit caused by the massive government debt-raising in order to adopt expansionary fiscal policies, over-tightening of monetary policy and significant volatility in the global markets resulted from two oil shocks.

The remainder of this paper is organized as follows. Section 2 describes the methodology proposed by Phillips et al. [25] and Phillips et al. [24]. Section 3 presents the data resources and summary statistics. Section 4 describes the empirical results. Section 5 concludes the main findings and policy implications.

2. Methodology

Based on the explosive property of bubbles, Diba and Grossman [7] recommend the strategy of using a stationarity test for the logarithmic asset price and observable market fundamentals. The conventional stationarity test is based on the standard ADF test or Phillips-Perron test, which has an explosive alternative hypothesis. Considering the model

$$\Delta\omega_t = \mu + \theta\omega_{t-1} + \sum_{d=1}^{D} \varphi_j \Delta\omega_{t-d} + \varepsilon_t \tag{2.1}$$

where ω_{t-1} is the logarithmic asset price, $\varepsilon_t \sim N(0, \sigma^2)$, and j is the number of the lags which is determined by significance tests in the emprical applications. The null hypothesis of $\theta = 1$ implies that ω_{t-1} is a unit root process (and $\Delta\omega_t$ is stationary). The alternative hypothesis of $\theta > 1$ means that ω_{t-1} is an explosive process. However, Phillips and Yu [23] argue that their tests have discriminatory power because they are sensitive to the changes that occur when a process experiences changes from a unit root to a slightly explosive root or vice versus. This sensitivity is much greater than in left-tailed unit root tests against staionary alternatives. Further, this is not all, since bubbles usually collapse periodically. Consequently, conventional unit root tests have limited power to detect periodically collapsing bubbles (see Evans [9]). To address this weakness, Phillips and Yu [23] suggest using the supreme of recursively determined ADF T-statistics.

The SADF test estimates the ADF model repeatedly on a forward expanding sample sequence and tests the hypothesis based on the sup value of the corresponding ADF statistic sequence. The window size I_w ranges from I_0 to 1, where I_0 is the smallest sample window, while 1 is the largest sample window, which is the total sample size. Since the starting point I_1 of the sample sequence is fixed at 0, the ending point of each sample I_2 is equal to I_i, changing from I_0 to I_1. The ADF statistic for a sample that runs from 0 to I_2 is denoted by$\mathrm{ADF}_0^{I_2}$. The SADF statistic is defined as:

$$\mathrm{SADF}(I_0) = \sup_{I_2 \in [I_0, 1]} \{\mathrm{ADF}_{I_2}\}. \tag{2.2}$$

SADF is particularly effective when there is a single bubble episode in the sample. However, there could be multiple asset price bubbles when the sample period is long. Phillips et al. [24] demonstrate that when the sample period includes multiple bubble episodes of origination and collapse, the SADF test may suffer from the existence of multiple bubbles. This shortcoming is particularly evident in long time series or rapidly changing markets for which more than one episode of abundance is examined.

To overcome this shortcoming and deal with multiple bubble episodes, the generalized sup ADF(GSADF) test is used with flexible window widths in the implementation proposed by Phillips et al. [24]. Instead of fixing the origin point of the recursion on the first observation, the GSADF test extends the sample coverage by changing the origin and the ending point of the recursion over a feasible range of flexible windows. Since the GSADF test covers more sub-samples of the data and has greater window flexibility, it is more effective than the SADF test in detecting explosive behavior when multiple bubbles take place in the data.

The GSADF test continues repeatedly running a series sample sequence based on the ADF test. However, this sample sequence is broader than that of the SADF test. In addition to varying the end point of the regression I_2 from I_0 to 1, the GSADF test allows the origin point I_1 to change within a feasible range, from 0 to $I_2 - I_0$. Because the GSADF test covers more sub-samples and has greater window flexibility, its precision in detecting explosive behavior in multiple episodes has improved. The superior accomplishment of the GSADF test is manifested in simulations comparing the two tests in terms of their size and power in boom detection. Phillips et al. [24] shows that the GSADF statistic is defined as the largest ADF statistic over the feasible ranges of I_1 and I_2. They define this statistic as GSADF(I_0). That is,

$$\mathrm{GSADF}(I_0) = \sup_{I_2 \in [I_0, 1], I_1 \in [0, I_2 - I_0]} \{\mathrm{ADF}_{I_1}^{I_2}\}. \tag{2.3}$$

Phillips et al. [24] demonstrate that the moving sample GSADF diagnostic outperforms the SADF test based on an expanding sample size in detecting explosive behavior in multiple bubble episodes and seldom gives false alarms, even in relatively modest sample sizes. This is because the GSADF test covers more subsamples of the data and has greater window flexibiliby. The generalized SADF test (GSADF) is able to detect potential multiple bubbles in the data and thus overcomes the problems of the SADF test.

Similar to the SADF procedure, if the null hypothesis of no bubbles is rejected in the GSADF test, a second step is implemented to consistenctly date-stamp the starting and ending points of this(these) bubble(s). The starting point of a bubble is defined as the date, denoted T_{1e} (in fraction terms), at which the backward sup ADF (BSADF) sequence crosses the corresponding critical value from below. Similarly, the ending point of a bubble is defined as the date, denoted T_{fe} (in fraction terms), at which the backward sup ADF sequence crosses the corresponding critical value from above.

Formally, the estimates of the bubble periods based on the GSADF test are defined by:

$$\widehat{I}_e = \inf_{I_2 \in [I_0,1]} \{I_2 : \mathrm{BSADF}_{I_2}(I_0) > \mathrm{cv}_{I_2}^{\beta_T}\}, \tag{2.4}$$

$$\widehat{I}_f = \inf_{I_2 \in [\widehat{I}_e,1]} \{I_2 : \mathrm{BSADF}_{I_2}(I_0) < \mathrm{cv}_{I_2}^{\beta_T}\}, \tag{2.5}$$

where $\mathrm{cv}_{I_2}^{\beta_T}$ is the $100(1-\beta_T)\%$ critical value of the sup ADF statistic based on (T_{I_2}) observations. The BSADF(I_0) for $I_2 \in (I_0, 1)$, is the backward sup ADF statistic that relates to the GSADF statistic by noting that:

$$\mathrm{GSADF}(I_0) = \sup_{I_2 \in [I_0,1]} \{\mathrm{BSADF}(I_0)\}. \tag{2.6}$$

3. Data Resources and Summary Statistics

In this paper, we use the monthly 10-year government bond yields of the developed countries (United States, Germany, and Japan) for our empirical study. These are represented by *US10Y, EU10Y*, and *JP10Y*, respectively, which US10Y represents the monthly 10-year government bond yield in United States, *EU10Y* in Germany, and so on. These data are obtained from the Thomson Reuters Database. Because of differing data availabilty, we have different starting periods for each country. *US10Y* starts from April, 1953, *EU10Y* starts from January, 1957, and *JP10Y* starts from October, 1966. All these countries' bond yields end in December, 2018. Table 1 lists the summary statistics for the monthly 10-year government bond yields of the developed countries. The Table 1 shows that Japan's 10-year government bond yield has highest volatility among the government bonds of these countries using standard deviation measures (i.e., 3.0226), while Germany's is the lowest. Except for Germany's 10-year government bond yield, the other variables exhibit right skewness. As for the kurtosis statistics, in addition

Table 1: Summary statistics results.

Variables	*US10Y*	*EU10Y*	*JP10Y*
Mean(%)	5.8020	5.7919	4.2745
Median(%)	5.3000	6.2000	4.5350
Maximum(%)	15.8200	11.3700	10.3000
Minimum(%)	1.4580	-0.1270	-0.2250
Std. Dev.(%)	2.8565	2.4915	3.0226
Skewness	0.8991	-0.5732	0.1146
Kurtosis	3.5414	2.8434	1.5225
Jarque-Bera	115.9367***	41.3937***	58.4021***
Observations	789	742	627

Notes: *US10Y*, *EU10Y*, and *JP10Y* represent monthly 10-year government bond yields for United States, Germany, and Japan, respectively. ***,**, and * represent the significance levels at 1% , 5%, and 10%, respectively.

to United States' 10-year government bond yield, which are leptokurtic, other variables are platykurtic. Additionally, the results reject the null hypothesis of the normality by Jarque-Bera test.

4. Empirical Results

We use the SADF and GSADF test to investigate whether bubbles exist in the bond markets of United States, Germany, and Japan. The results are obtained from Monte Carlo simulations with 2000 replications, for which the smallest windows are 58, 56, and 51 observations, respectively, as listed in Tables 2 to 4. The GSADF statistics for US10Y, EU10Y, and JP10Y are 3.6682, 3.6534 and 3.9368, which exceed their respective 1% right-tail critical values (i.e., 3.6682 > 2.8789, 3.6534 > 2.8368 and 3.9368 > 2.9268). The results show that the null hypothesis of no bubble is rejected for *US10Y*, *EU10Y*, and *JP10Y* by the GSADF test. The empirical study demonstrates that there is evidence of multiple bubbles in the United States, Germany, and Japan bond markets based on the GSADF test. On the other hand, in terms of the SADF test, the statistics for *US10Y* and *JP10Y* are exceeding their respective 1% right-tail critical values respectively (i.e., 2.8569 > 2.0352 and 2.7379 > 2.0838), while it is only greater than its respective 10% right-tail critical values (i.e., 1.3797 > 1.2428). This result indicates that the GSADF test outperforms the SADF test in detecting the multiple bubbles, as proposed by Phillips et al. [24], which demonstrates that the moving sample GSADF diagnostic outperforms the SADF based on an expanding sample size in detecting explosive behavior in multiple bubble episodes and seldom gives false alarms, even with relatively modest sample sizes.

Table 2: SADF and GSADF test results for *US10Y*.

	SADF	GSADF
Test statistic	2.8569***	3.6682***
Prob.	0.0000	0.0000
Finite sample critical values		
99%	2.0352	2.8789
95%	1.5091	2.3249
90%	1.2671	2.0966

Notes: Critical values for both tests were obtained via Monte Carlo simulation with 2000 replications (sample size 789, run with EViews) from April 1953 to December 2018. The smallest window has 58 observations. ***,**,* represent 1%, 5%, and 10% significance levels, respectively.

Table 3: SADF and GSADF test results for *EU10Y*.

	SADF	GSADF
Test statistic	1.3797*	3.6534***
Prob.	0.0740	0.0000
Finite sample critical values		
99%	2.0144	2.8368
95%	1.5074	2.3070
90%	1.2428	2.0867

Notes: Critical values for both tests were obtained via Monte Carlo simulation with 2000 replications (sample size 742, run with EViews) from January 1957 to December 2018. The smallest window has 56 observations. ***,**,* represent 1%, 5%, and 10% significance levels, respectively.

Based on the GSADF test, we conclude that multiple bubbles exist in the United States, Germany, and Japan bond markets. We further analyse the bubble-detection results for these markets in Figures 1 to 3.

For further inspection, we draw the GSADF test results with 95% critical values for the 10-year benchmark government bond yields of United State, Germany and Japan as Figures 1 to 3. There are three lines in each figure, which represent the 10-year government bond yield (right axis), the 95% critical sequence (left axis) and the GSADF statistic (left axis) from top to bottom. Figures 1 to 3 display the evidence for the origin and collapse of bubbles in the United State, Germany and Japan bond markets,

Table 4: SADF and GSADF test results for *JP10Y*.

	SADF	GSADF
Test statistic	2.7379***	3.9368***
Prob.	0.0010	0.0000
Finite sample critical values		
99%	2.0838	2.9268
95%	1.5013	2.3126
90%	1.2208	2.0755

Notes: Critical values for both tests were obtained via Monte Carlo simulation with 2000 replications (sample size 627, run with EViews) from October 1966 to December 2018. The smallest window has 51 observations. ***,**,* represent 1%, 5%, and 10% significance levels, respectively.

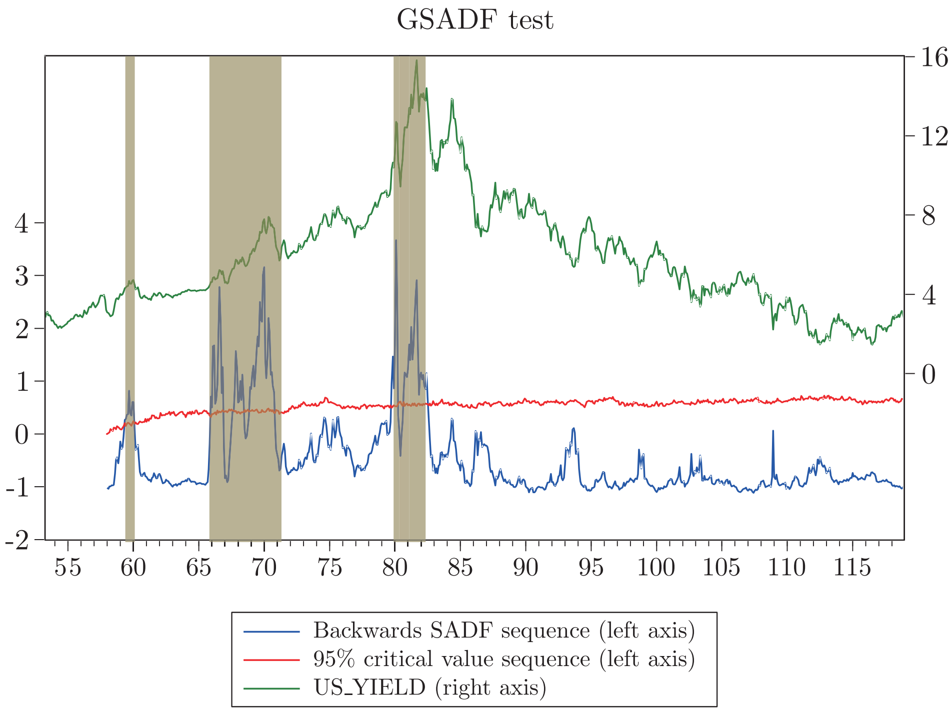

Figure 1: GSADF test of US 10-year benchmark government bond yield.
Note: the shadows are subperiods with bubbles.

respectively.

Figure 1 shows three bubbles in the United State bond market. The periods of the bubbles are from March 1959 to January 1960, from January 1966 to July 1970, and from

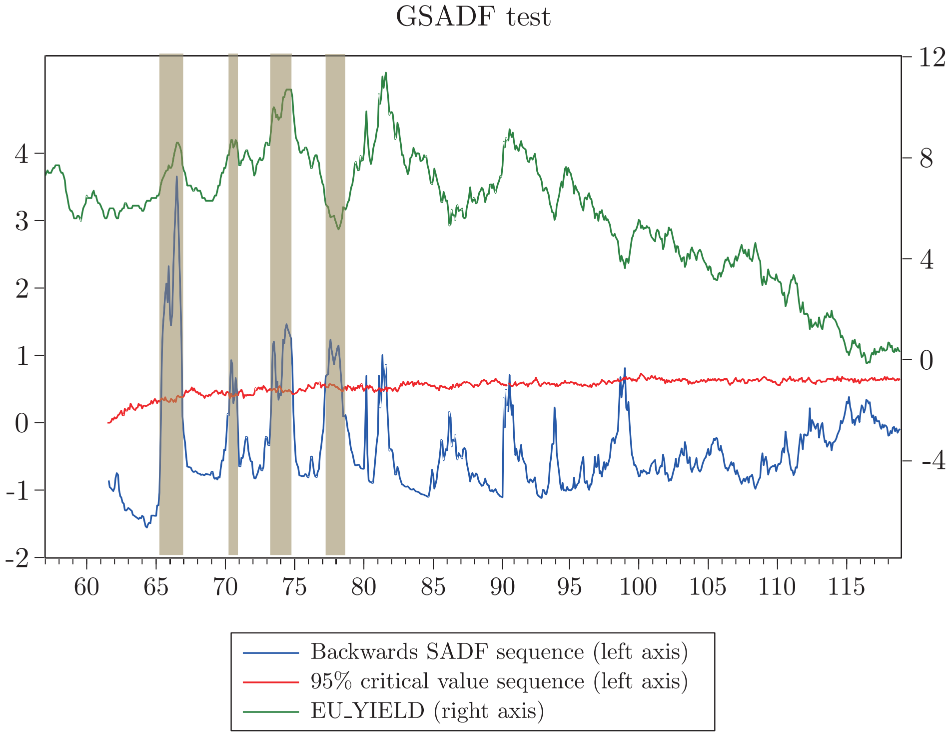

Figure 2: GSADF test of Germany 10-year benchmark government bond yield.
Note: the shadows are subperiods with bubbles.

July 1979 to August 1982, which lasted for ten months, fifty-four months, and thirty-seven months respectively. During the periods of bubble generation, the US economy faced high inflation and low economic growth (i.e., staflation). Among them, the third bubble period (1979-1982) has experienced the second oil crisis. The main reasons for the bubbles in the United State bond market were the government's huge fiscal deficit policy and the increase in monetary policy interest rates.

We find four major bubbles in the Germany government bond market from Figure 2, which occcured from May 1965 to March 1967, May 1970 to March 1971, May 1973 to August 1974, and April 1977 to August 1978. Most of the bubble periods lasted within twenty months. The first bubble was mainly generated from tightening monetary policy, which was adopted by the government to solve the rising inflation situation. In the rest periods of bond bubbles, the German economy experienced the crisis of stagflation in the 1970s and the first oil crisis. The main reason for the rest bubbles was the deterioration of Germany's fiscal.

Finally, looking at Figure 3, there were two bubbles in the Japan bond market, from June 1972 to April 1975 and from August 1977 to November 1978, which lasted for thirty-four months and fifteen months respectively. During the periods of bubble occurrence, the Japan economy experienced the crisis of staflation in the 1970s and the first oil crisis. The bond bubbles were mainly generated from Japan's fiscal deterioration.

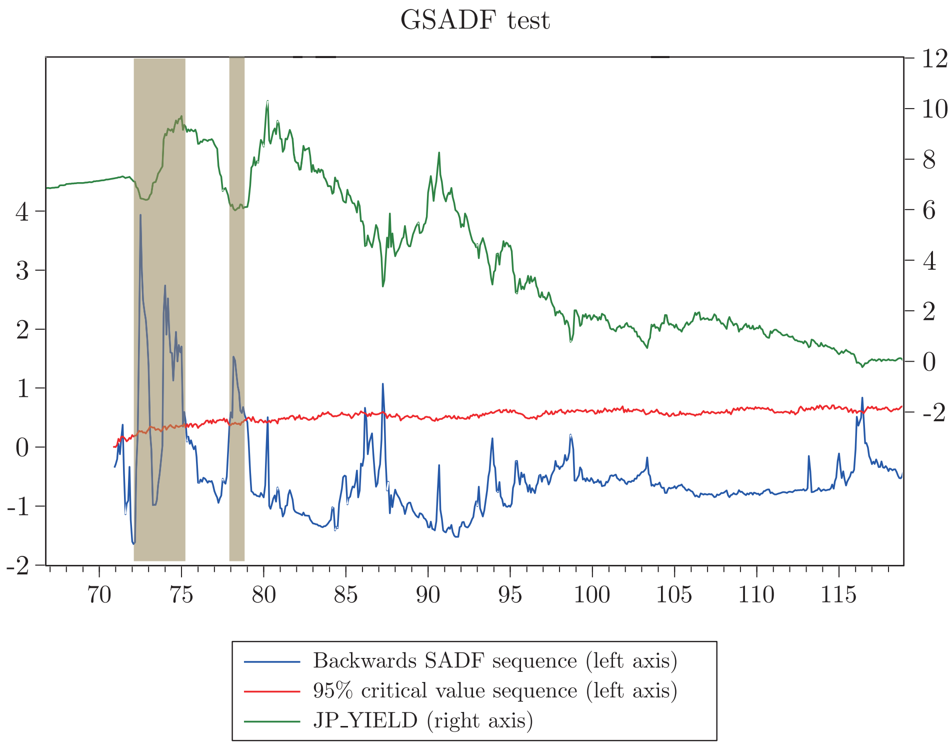

Figure 3: GSADF test of Japan 10-year benchmark government bond yield.
Note: the shadows are subperiods with bubbles.

Our results demonstrate the existence of mulitple bubbles in the United States, Germany, and Japan government bond markets based on the GSADF test. They also have some implications for these economies. First, these periods of multiple bubbles generation have experienced the stagflation and oil crisis of the 1970s. Then, excess expansionary fiscal policies such as tax cuts and infrastructure expenditures which adopted by these governments not only worsened fiscal situation but further cause the bubbles of the bond markets. Finally, over-tightening of monetary policy also result in the bubbles existence in the bond markets.

In sum, the impacts of huge fiscal deficit and over-tightening of monetary policy on the bond markets of developed countries with multiple bubbles are critical. Gruber and Kamin [13] find a robust and significant effect of fiscal positions on long-term bond yields. They further demonstrate that the marginal effect of the projected deterioration of fiscal positions adds about 60 basis points to U.S. bond yields. Laubach [19] examines the effects of government debt and deficits on Treasury yields is complicated by the need to isolate the effects of fiscal policy from other influences. They demonstrate that for the entire 30-year sample for which these projections are available, the estimated effects of government deficits and debt on interest rates are statistically significant and economically relevant: about 25 basis points per percentage point increase in the projected deficit/GDP ratio, and 3 to 4 basis points for the debt/GDP ratio. On the other hand, the fiscal deficit or the fiscal deterioration will generate currency depreciation and further cause international capital outflows. Warnock, F. E. and Warnock, V. C. [30] shows that foreign purchases of U.S. government bonds have an economically large and statistically significant impact on long-term interest rates. They futher estimate that absent the substantial foreign inflows into U.S. government bonds the 10-year Treasury yield would be 80 basis points higher.

As a result, in recent years, major countries such as United States, Germany, Japan, and some develpoed countries have adopted expansionary fiscal policy tools like tax-cutting and infrastructure expenditures by massive debt-raising to stimulate economic development. This study reminds government officials need to guard against the impacts of excessive uses of expansionary fiscal policies on the bond markets and international investors must pay greater attention to the impacts of fiscal deficits for the management of investment portfolios.

5.Conclusions

The study uses the SADF and GSADF tests, proposed by Phillips et al. [25] and Phillips et al. [24], respectively, to examine whether there are multiple bubbles in the bond markets of developed countries. The results show that multiple bubbles exist in the United States, Germany, and Japan bond markets based on the GSADF test, which outperforms the SADF test, consistent Phillips et al. [24].

There are several implications of these findings. First, these periods of multiple bubbles generation have experienced the stagflation and oil crisis of the 1970s. Then, excess expansionary fiscal policies such as tax cuts and infrastructure expenditures which adopted by these governments not only worsened fiscal situation but further cause the bubbles of the bond markets. Finally, over-tightening of monetary policy also result in the bubbles existence in the bond markets.

In sum, our study demonstrates that the impacts of huge fiscal deficit and over-tightening of monetary policy on the bond markets of developed countries with multiple bubbles are critical. In recent years, major countries such as United States, Germany, Japan, and some develpoed countries have adopted expansionary fiscal policy tools like tax-cutting and infrastructure expenditures by massive debt-raising to stimulate economic development. This study reminds government officials need to guard against the impacts of excessive uses of expansionary fiscal policies on the bond markets and international investors must pay greater attention to the impacts of fiscal deficits for the management of investment portfolios.

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