# Date stamping on the explosiveness of public debt: Evidence from the USA

Rafiqul Bhuyan, Ishrat Tarannum and Nazmul Hassan[1]

Abstract

*This paper examines the existence of explosive behaviours of public debt in the USA. Using the Supremum Augmented Dickey-Fuller (SADF) and Generalised SADF tests on data ranging from 1966 to 2018, we show that there is evidence of the beginning and end of several public debt explosiveness in the US. We observe that each explosiveness originates when the Backward Supremum Augmented Dickey-Fuller (BSADF) statistic exceeds its corresponding 95 per cent critical value and ends when its BSADF falls below that critical value. Further analysis shows that the explosive behaviours are dynamically positively correlated with trade openness and unemployment. The detected explosive debt suggests that fiscal sustainability is challenged and sound fiscal policies are absent. In order to keep on financing the costs of new debt issuance, government revenue sides are discussed.*

*JEL Classification: C8, C22, E6, G1, G12*
*Keywords: Public debt, Explosiveness, Trade openness, Unemployment, SADF, GSADF*

## 1. Introduction

The continuous rise of the US public debt ceiling has been an important economic question and concern for the policymakers, politicians, as well as economists. Literature suggests that government debt and overall economic growth are negatively correlated (Reinhart and Rogoff 2010; Kumar and Woo 2010; Reinhart *et al* 2012; and Swamy 2015). However, government expands public debt not only to create a pathway for future growth, but also to stabilise the economy from systemic failure caused by political decisions to finance wars, or by the unethical acts of corporate executives.

The recent historic financial collapse in 2008, driven by greed and predatory lending practices of US financial institutions, has led the government and federal reserve to coherently engage in liberal fiscal and monetary policy to save the economy from systemic failure and to reinstate economic growth. Yoon

(2012) identifies that war has been the major cause of government borrowing, before and immediately after the cold war era. In the last 50 years, the US has engaged in several wars (1980, 1991, and 2003), financed by excessive government borrowing. In addition, there have been major events, like the internet bubble (2000), financial collapse (2008), and natural disasters (SARS 2006, COVID19) where the US government and federal reserve have been heavily engaged in bolstering economic recovery.

Although excessive debt financing to save the economy from manmade financial collapse and natural disasters is justified and necessary, it is however, concerning to engage in excessive borrowing to finance wars. In this paper, we address US debt explosiveness relating to events over these last 50 years and suggest that even though relying on heavy debt may have an adverse long-run economic impact, these are necessary and appropriate measures taken by the government and federal reserve. We exploit the Supremum Augmented Dickey-Fuller (SADF) and the Generalised SADF tests as in Phillips *et al* (2011, 2015) as suggested by others (Corbet *et al* 2018; Sharma and Escobari 2018) to date stamp and to identify the beginning and end of periods of debt explosiveness in the USA.

We use the SADF and Generalised SADF as these tests are designed to capture any explosive behaviour demonstrated within the overall sample and to ensure if there are significant observations to initiate the recursion (Phillips *et al* 2011). Phillips *et al* (2011) argue that the GSADF test has the ability to cover more subsamples of the data and offer greater window flexibility to identify explosive behaviour in multiple episodes. Besides, recurring estimations of the GSADF test allow us to date stamp the origin and collapse of the explosive behaviour episodes in our debt data series, using a rolling window of start and end dates.

In this research, we document statistically significant evidence for the existence of multiple bubbles in US total public debt, as well as the federal debt held by different entities. Our analysis shows that the explosivity of US public debt is persistent over multiple periods. This persistence challenges long-run fiscal sustainability, which has been greatly emphasised after the financial crisis period 2008-2009 (Afonso and Jalles 2014). When a long-run condition is challenged by means of many excessive debt financing episodes, fiscal adjustment is appropriate to bring the debt dynamic back to sustainable growth (Bystrov and Mackiewicz 2020).

The existence of prolonged debt explosiveness indicates that policymakers fail to respond to the changes in the rates of economic growth and interest, government spending shocks, and adverse shocks from political events. In addition, government also likely fails to acquire adequate revenues to ensure its long-run capability to meet the financial responsibilities consistently. This explosivity of debt varies dynamically with time. So, without changes in fiscal policy, the persistent debt financing and budgetary imbalances could induce further need for debt financing and instability for economic growth. Our finding

suggests fiscal adjustment is neede, in order to restore long-run fiscal sustainability.

Yoon (2012) analyses the explosivity of the US total public debt over the 1791-2009 sample period, using the SADF statistical test proposed by Phillips *et al* (2011). We, however, exploit the Generalised SADF test as in Phillips *et al* (2015). We also examine the single and multiple explosiveness of US debt over time that is absent in Yoon (2012). Unlike Yoon (2012), we also attribute some of the explosivity to major economic events and macroeconomic variables.

We contribute to the explosiveness literature in several ways. First, using the most robust and updated version of ADF test statistics, we show multiple and persistent explosiveness of US debt that has been overlooked in the previous related literature. Second, using the DCC-GARCH model, we show the dynamic correlation between the US debt and macroeconomic variables such as unemployment and trade openness. Finally, our findings capture the extreme movement in US debt issuance and extend our limited understanding of short-run and long-run explosive behaviour in US debt. To be sustainable, fiscal policy, the budget deficit or debt needs to be stationary (Chortareas *et al* 2008; Westerlund and Prohl 2010; and Yoon 2012) and the public debt literature shows that public debt and overall economic growth are negatively related, moreso when debt exceeds 90 per cent of GDP. Our findings of the persistence in the US debt explosivity may provide a signal to reform current fiscal policy to reduce the debt level.

The rest of this paper proceeds as follows: Section 2 discusses the data and sample construction. Section 3 provides detailed discussions on the methodology. Section 4 discusses the empirical results on the single and multiple explosiveness of US debt. Section 5 provides contemporaneous co-explosivity. Section 6 shows the dynamic correlation between US debt explosiveness and macroeconomic variables. Section 7 concludes the paper.

## 2. The Data

We collect quarterly debt data of the US from the Fred Database,[2] from January 1966 to April 2018, to test our empirical specification. The macroeconomic data series included are gross domestic product (GDP) growth, inflation, population growth, foreign direct investment, trade openness, and unemployment, which-also come from the Fred Database. The advantage of this data source is that the time series for US total public debt and federal debt held by different entities are already inflation-adjusted and expressed quarterly, as a percentage of GDP.

We have several series with different start dates, given their availability in the Fred Database. For example, US total public debt starts in the first quarter of 1966. The data series for the federal debt held by foreign and international investors, federal reserve banks, the general public, and private investors start in the first quarter of 1970. The data series for the federal debt held by agencies and trusts start in the first quarter of 1981. All data series ended in the second

quarter of 2018. We have 210 observations for US total public debt. Table 1 provides descriptive statistics of different debt data series from 1966 to 2018. It is observed that the US has on average total public debt of about 57 per cent of its GDP and a standard deviation of about 23 per cent. We also observe that in some quarters, total public debt exceeds US GDP (which signals a strong caveat of fiscal policy reform), though it reduces down to about 30 per cent in other quarters.

The average portion of the federal debt held by foreign international investors is about 13 per cent with a 35 per cent (10 per cent) maximum (minimum). Federal Reserve Bank-held federal debt, is about 6 per cent, with a standard deviation of 5 per cent of US GDP. The summary statistics show that the largest portion of the federal debt is held by the general public. The average debt held by the general public is about 41 per cent, with a maximum of 77 per cent of US GDP. The general public holds the largest amount of federal debt in terms of treasury bills, notes, and bonds. The second-highest percentage of federal debt is held by private investors. Each of the different creditors has a wider variation in holding US total public debt across our sample period.

Table 1: Descriptive statistics of the US public debt and fed debt held by different entities.

| *Variable* | *N* | *Mean* | *Std Dev* | *Median* | *Minimum* | *Maximum* |
|---|---|---|---|---|---|---|
| Total Public Debt | 210 | 56.499 | 22.752 | 55.577 | 30.603 | 105.256 |
| Foreign Int'l Investors | 194 | 12.686 | 10.149 | 9.189 | 1.180 | 34.779 |
| Federal Reserve Bank | 194 | 6.081 | 3.283 | 4.944 | 3.213 | 15.659 |
| Public | 194 | 40.861 | 15.743 | 36.330 | 21.851 | 77.026 |
| Private Investors | 194 | 34.956 | 13.548 | 32.417 | 16.673 | 64.883 |
| Agencies and Trusts | 150 | 19.870 | 8.294 | 20.678 | 5.791 | 30.742 |

This Table provides descriptive statistics of US total public debt and federal debt held by different entities. US total debt and the debt held by different entities are measured as a percentage of Gross Domestic Product (GDP) obtained from the Federal Reserve Bank of St LOuis. Our sample period begins in 1966 and ends in 2018. We have 210 quarterly debt observations in this study.

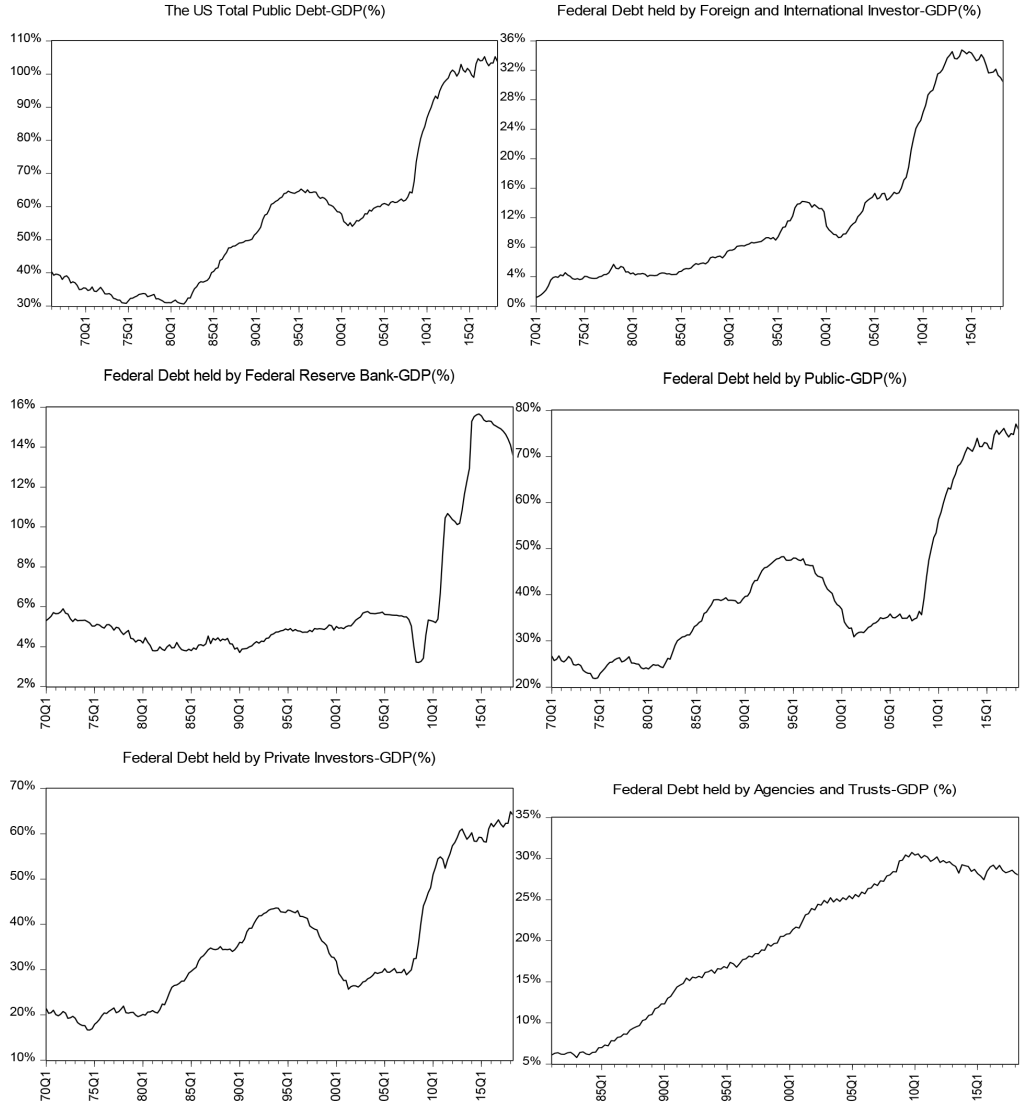
Figure 1 provides the time series graphs for US total public debt and federal debt held by different entities. The most striking features on these graphs occur around the global oil price shock in 1991 and during 2007–2009.

## 3. Methodology

To investigate and date stamp the beginning and ending periods of the explosiveness of the US public debt, we exploit the Supremum Augmented Dickey-Fuller (SADF) and Generalised SADF tests. In these tests, Augmented Dickey-Fuller (ADF)-style regressions shift the start and end dates of a rolling window, which allows stamping of their dates. As in Phillips *et al* (2011; 2015), we begin with the following ADF regression model:

$$\Delta y_t = \alpha_{r_1,r_2} + \beta_{r_1,r_2} y_{t-1} + \sum_{i=1}^{k} \varphi^{i}_{r_1,r_2} \Delta y_{t-i} + \varepsilon_t \quad (1)$$

Figure 1: This figure shows the time series plots of each of our six US debt measures. These series are quarterly inflation-adjusted as a percentage of Gross Domestic Product (GDP). All the time series data are obtained from the Fred Database (the Federal Reserve Bank of St Louis). The start dates of each series is different, given their different availability.



Where $y_t$ is the corresponding debt (total public, federal debt held by foreign and international investors, private investors, or so on). $\Delta y_t$ denotes first differences and the error term is assumed to follow a normal distribution, i.e. $\varepsilon \sim iidN\ (0,\sigma^2_{r1,r2})$. In the model, the k lagged difference terms are included to control for serial correlation. The subscripts $r_1$ and $r_2$ on the parameters to be estimated are the fractions of fractions of the total sample size that specify the start and end points of a subsample period. The estimates and the error term variance depend on these subscripts $r_1$ and $r_2$.

Although the left-sided unit root tests and the right-sided unit root tests are considered in Phillips *et al* (2011; 2015), our primary focus is to test the unit root null hypothesis against the alternative of mildly explosive behaviour in $y_t$, using the right-sided unit roots tests. Relatively right-sided unit roots tests are more informative about mildly explosive behaviour in the data, which can serve as a caveat to major fiscal policy reform. Thus, we proceed with the following test statistics:

$$ADF_{r_1}^{r_2} = \hat{\beta}_{r_1,r_2}/s.e.(\hat{\beta}_{r_1,r_2}) \tag{2}$$

We obtain the well-known standard ADF test statistic when we set r_1 to 0 and 1. We consider a recursive procedure on the estimation of $ADF_{r\_2,r\_1}$ to identify the occurrences of the explosive behaviour of US public debt. As proposed in Phillips *et al* (2011), we follow the supremum value of the $ADF_0^{r_2}$ on the forward recursive regression using the model below:

$$SADF(r_0) = \sup_{r_2 \in [r_0,1]} ADF_0^{r_2} \tag{3}$$

Escobari and Jafarinejad (2016) note that when the SADF statistic exceeds the right tail critical value, the unit root null hypothesis is rejected in favour of explosive behaviour. Using simulations, Homm and Breitung (2012) find that the SADF has greater power than the methods in Bhargava (1986), the modified Busetti and Taylor (2004), and the modified Kim (2000). Moreover, Phillips *et al* (2015) argue that this procedure can detect exuberance that may arise from a variety of sources including mildly explosive behaviour that may be induced by changing fundamentals such as the time-varying discount factor. While SADF performs well for a single boom and bust in a series, it may not consistently identify multiple bubbles. Phillips *et al* (2015) propose the GSADF to deal with multiple episodes of boom and bust. The GSADF methodology is designed to use a rolling and recursive sample, covering a larger number of subsamples than the SADF by allowing both the end point (r2) and the initial point (r1) to change. The GSADF statistic is given by:

$$GSADF(r_0) = \sup_{r_1 \in [0, r_2 - r_0],\, r_2 \in [r_0,1]} ADF_{r_1}^{r_2} \tag{4}$$

Rejection of the null in favour of the explosive alternative hypothesis requires that GSADF (r0) is greater than the right tail critical value. To date stamp the

beginning and the end of the bubble/explosiveness, Phillips *et al* (2015) suggest obtaining the Backward Sup ADF (BSADF) statistic using the following method:

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} SADF_{r_1}^{r_2} \quad (5)$$

We then use the first observation in which the BSADF exceeds its critical value as the beginning of the explosiveness,

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \{r_2 : BSADF_{r_2}(r_0) > scv_{r_2}^{\alpha}\} \quad (6)$$

and the first observation after $\hat{r}_e + 3/T$ in which BSADF falls below its critical value as the end of the corresponding explosiveness episode[3],

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e + 90/T, 1]} \{r_2 : BSADF_{r_2}(r_0) < scv_{r_2}^{\alpha}\} \quad (7)$$

Where $scv_{r2}^{\alpha}$ is the 100(1−α) critical value of the SADF based on |r2T| observations and at a significance level α.[4] The distributions of the statistics GSADF (r0) and BSADFr2 (r0) in Eqs. (4) and (5) are non-standard, hence we use Monte Carlo simulations to obtain the critical values.

## 4. Empirical Results

Using models 3 and 4, we obtain the SADF and GSADF test statistics as well as the 90 per cent, 95 per cent, and 99 per cent critical values for the two tests using Monte Carlo simulations with 1,000 replications. We report the results in Table 2, which shows that the statistical values of both SADF and GSADF exceed their corresponding critical values, which supports the existence of explosiveness of US debt over the sample period. The values exceed their corresponding critical values even the 1 percent level. For US total public debt, both SADF and GSADF exceed their 1 per cent and 5 per cent right-tail critical value, respectively (SADF: 4.989 > 1.974 and GSADF: 4.989 > 2.775). These results remain robust for the federal debt held by foreign and international investors (SADF: 5.899 > 1.966 and GSADF: 6.333 > 2.741) and the federal debt held by the federal reserve bank (SADF: 5.727 >1.966 and GSADF: 5.727 > 2.741). For the federal debt held by the public, SADF exceed its 1 per cent right-tail critical value (SADF: 3.665 >1.966 and GSADF: 4.149 > 2.741).

Overall, the SADF test statistics provide statistically significant evidence of explosive behaviour in all six measures of US debt. Moreover, the GSADF provides statistically significant evidence for the existence of multiple bubbles in US total public debt, as well as the federal debt held by different entities. Note that the rolling windows used by the SADF in Eq. (2) are a subsample of the windows used by the GSADF in Eq. (3). This explains why the SADF and GSADF statistics are both the same in the debt series.

Table 2: SADF and GSADF statistics for the US debts.

| | *Statistics* | | *SADF Critical Values* | | |
|---|---|---|---|---|---|
| *Debt Measures* | *SADF* | *GSADF* | *99%* | *95%* | *90%* |
| | *(1)* | *(2)* | *(3)* | *(4)* | *(5)* |
| Total Public Debt | 4.9893 | 4.9893 | 1.9739 | 1.4170 | 1.1201 |
| Foreign & Int'l Debt | 5.8990 | 6.3326 | 1.9663 | 1.4144 | 1.1265 |
| Fed. Reserve Bank | 5.5272 | 5.5272 | 1.9663 | 1.4144 | 1.1265 |
| Public | 3.6653 | 4.1490 | 1.9663 | 1.4144 | 1.1265 |
| Private Investors | 2.8732 | 4.7001 | 1.9663 | 1.4144 | 1.1265 |
| Agencies and Trusts | 3.1207 | 3.1269 | 1.8496 | 1.4271 | 1.0930 |

| | *GSADF Critical Values* | | |
|---|---|---|---|
| *Debt Measures* | *99%* | *95%* | *90%* |
| | *(6)* | *(7)* | *(8)* |
| Total Public Debt | 2.7750 | 2.0756 | 1.8518 |
| Foreign & Int'l Debt | 2.7411 | 2.0948 | 1.8387 |
| Fed. Reserve Bank | 2.7411 | 2.0948 | 1.8387 |
| Public | 2.7411 | 2.0948 | 1.8387 |
| Private Investors | 2.7411 | 2.0948 | 1.8387 |
| Agencies and Trusts | 2.6971 | 2.1017 | 1.7817 |

This Table presents SADF and GSADF critical values. The sample spans from the first quarter of 1966 to the second quarter of 2018. The time-series data of each of our six US debt measurements are quarterly inflation-adjusted and scaled by GDP. All the time series data are obtained from the Fred Database (the Federal Reserve Bank of St Louis). SADF and GSADF critical values are estimated as in Phillips *et al* (2011) and Phillips *et al* (2015).

Figure 2 plots the recursive BSADF statistics against their corresponding 95 per cent critical value sequences, to identify multiple explosiveness of US total public debt. The first explosiveness of US total public debt spans from the third quarter of 1983 to the third quarter of 2001, with one implosiveness at the end. The second explosiveness spans from the first quarter of 2008 to the current period of the sample. Both of these two explosiveness events persist over a long time period.

Figure 3 shows three explosivenesses of the federal debt held by foreign and international investors. The first such explosiveness spans from the first quarter of 1986 to the fourth quarter of 1999. The second explosiveness spans from the first quarter of 2004 to the first quarter of 2006. The third explosiveness spans from the fourth quarter of 2007 to the second quarter of 2018. The first and third explosivenesses persist over a long time period.The major economic events over time seem responsible for the explosiveness.

Figure 4 shows four explosivenesses of the federal debt held by the Federal Reserve Bank. The first of these spans from the first quarter of 1981 to the third quarter of 1981. The second explosiveness spans from the third quarter of 2002 to the third quarter of 2003. The third explosivness spans from the first quarter of 2008 to the first quarter of 2009 The fourth explosiveness spans from the first quarter of 2011 to the second quarter of 2018.

Figure 2: GSADF: Explosive behaviour periods in US total public debt. US public debt is measured as a percentage of Gross Domestic Product (GDP) obtained from the Federal Reserve Bank of St Louis. The sample starts in the first quarter of 1966 and ends in the second quarter of 2018.

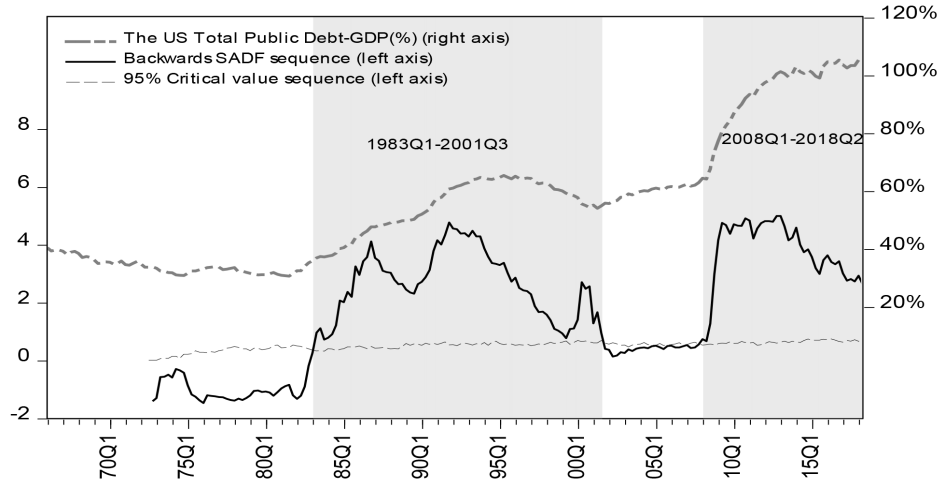



Figure 3: GSADF: Explosive behaviour periods in the US debt held by foreign and international investors. US foreign and international debt is measured as a percentage of Gross Domestic Product (GDP) obtained from the Federal Reserve Bank of St Louis.

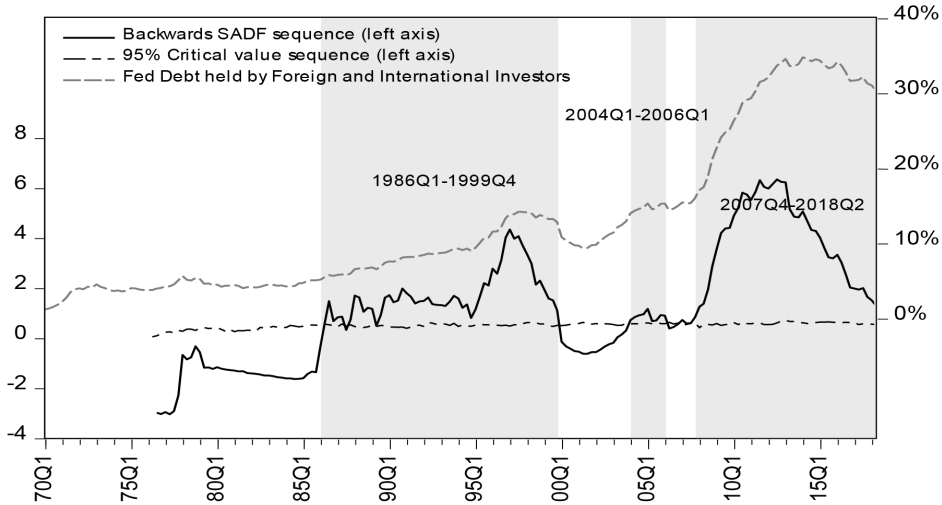


Figure 4: GSADF: Explosive behaviour periods in the US debt held by the federal reserve bank. The federal debt held by the federal reserve bank is measured as a percentage of Gross Domestic Product (GDP) obtained from the Federal Reserve Bank of St Louis.

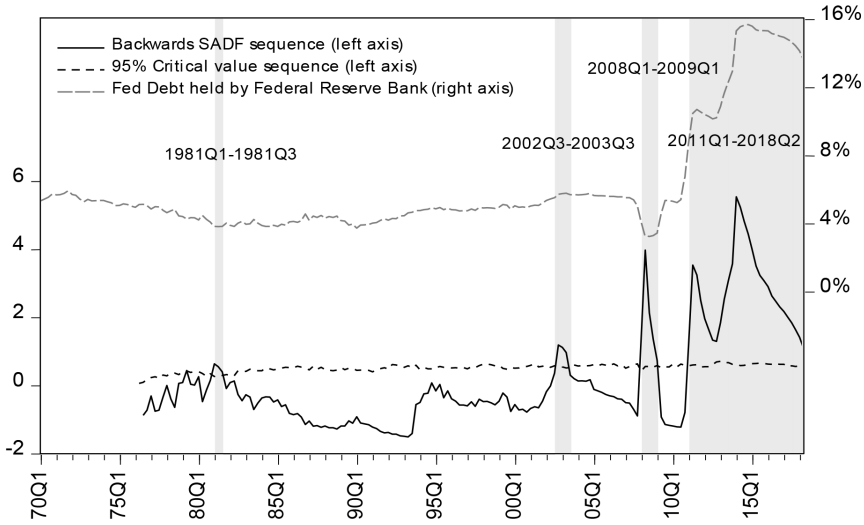



Figure 5: GSADF: Explosive behaviour periods in the US debt held by the public. The federal debt held by the public is measured as a percentage of Gross Domestic Product (GDP) obtained from the Federal Reserve Bank of St Louis.

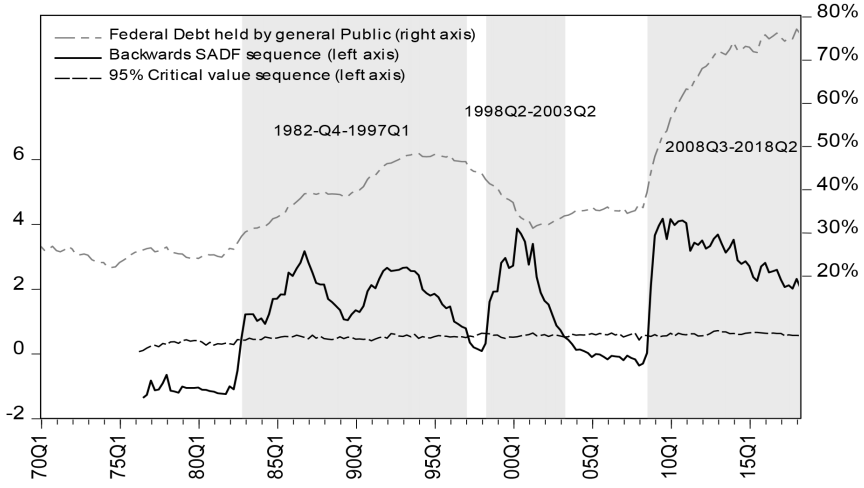


Figure 6: GSADF: Explosive behaviour periods in the US debt held by private investors. The federal debt held by private investors is measured as a percentage of Gross Domestic Product (GDP) obtained from the Federal Reserve Bank of St Louis.

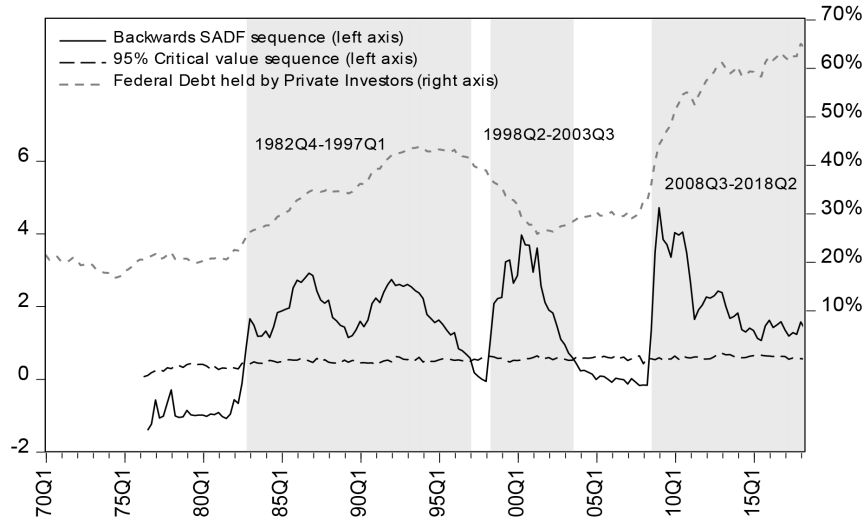



Figure 7: GSADF: Explosive behaviour periods in the US debt held by trusts and agencies. The federal debt held by trusts and agencies is measured as a percentage of Gross Domestic Product (GDP) obtained from the Federal Reserve Bank of St Louis.

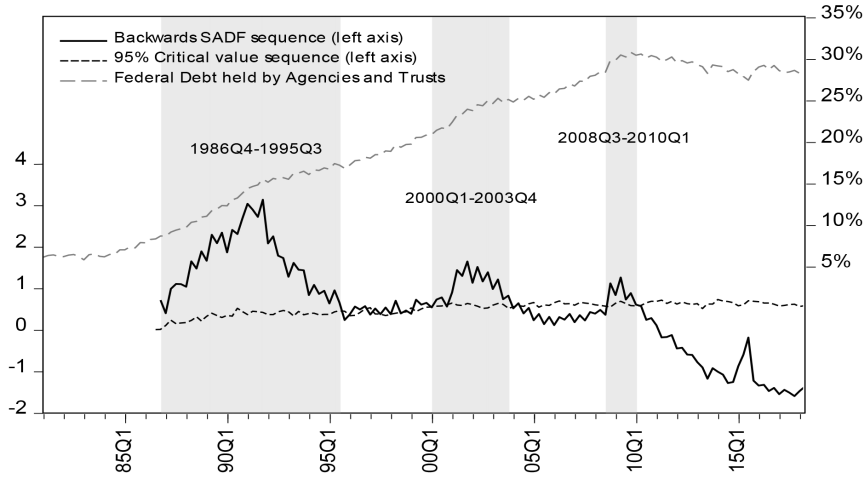


Figure 5 shows three explosivenesses of the federal debt held by the public. The first of these spans from the fourth quarter of 1982 to the first quarter of 1997. The second explosiveness spans from the second quarter of 1998 to the second quarter of 2003. The third explosiveness spans from the third quarter of 2008 to the second quarter of 2018.

Figure 6 shows three explosivenesses of the federal debt held by private investors. The first of these spans from the fourth quarter of 1982 to the first quarter of 1997. The second explosiveness spans from the second quarter of 1998 to the second quarter of 2003. The third explosiveness spans from the third quarter of 2008 to the second quarter of 2018. The first and third explosiveness persist over a long time.

Figure 7 shows three explosivenessse of the federal debt held by agencies and trusts. The first of these spans from the fourth quarter of 1986 to the third quarter of 1995. The second explosiveness spans from the first quarter of 2000 to the fourth quarter of 2003. The third explosiveness spans from the third quarter of 2008 to the first quarter of 2010. The first explosiveness persists over a long time period. This finding is consistent with those reported in Bystrov and Mackiewicz (2020).

## 5. Comovement of macroeconomic variables

In an un-tabulated correlation matrix, we see US total public debt is highly positively correlated with two major macroeconomic variables: trade openness and unemployment. We find that their correlation is around 0.70 with trade openness; and 0.53 with unemployment. Figure 8 shows their plots. Following Engle (2002), we then use the dynamic conditional correlation model to investigate the time-varying correlation of US total debt with macroeconomic variables. Based on the DCC-GARCH model, the results are plotted in Figure 9. The DCC-GARCH model confirms that a time-varying correlation exists between US total public debt and both trade openness and unemployment.[5] The initial correlation is negative but it turns positive after 1985. The initial negative correlation may be to the result of some unexpected economic event before 1985. However, overall the time-varying correlation provides evidence that these two macroeconomic variables co-move with the public debt.

## 6. Conclusion

This paper attempts to employ the new recursive flexible window right-tailed ADF testing procedure introduced in Phillips *et al* (2011), further enhanced in Phillips *et al* (2015), to detect and date-stamp empirically the origin and the collapse of the explosiveness of the US total public debt. Each explosiveness originates when the Backward Supremum Augmented Dickey-Fuller (BSADF) statistic exceeds its corresponding 95 per cent critical value and ends when its BSADF falls below that critical value. Further analysis shows that the persistence of explosive behaviours is dynamically positively correlated with two macroeconomic variables: trade openness (0.7) and unemployment (0.53).

Figure 8: GSADF of the US total debt held and trade openness and unemployment. US total debt is measured as a percentage of Gross Domestic Product (GDP) obtained from the Federal Reserve Bank of St Louis. Trade openness and unemployment data are also obtained from the Federal Reserve Bank of St Louis.

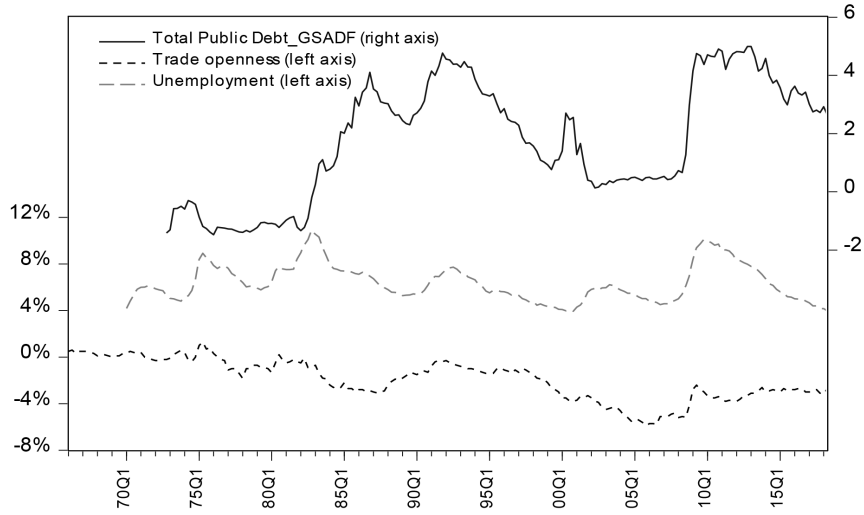
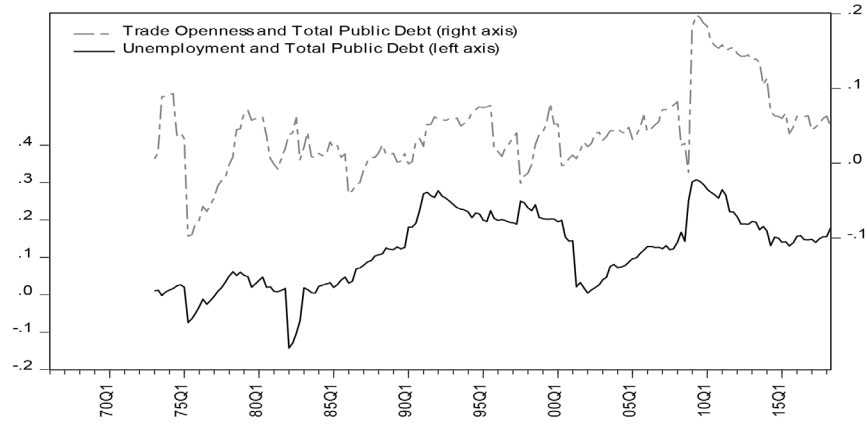



Figure 9: Dynamic Conditional Correlation between GSADFs of US total debt held and trade openness and unemployment. US total debt is measured as a percentage of Gross Domestic Product (GDP) obtained from the Federal Reserve Bank of St Louis.



Our findings shed light on capturing the extreme movement in US debt issuance of short-run and long-run explosive behaviour in US debt. This persistence of multiple explosivity of US debt challenges the fiscal sustainability that is needed to ensure the long-run stability, to consistently meet government spending needs with available resources. This challenge requires fiscal adjustment to restore the fiscal sustainability of the US government.

Given this challange, in order to satisfy the intertemporal budgetary constraint, we highlight several policy implications: to estimate budgetary constraints in the long run and set a target of debt financing; to avoid accumulating beyond the targeted contingent government liabilities; and to minimise the fiscal risk associated with contingent liabilities by strengthening the institutional framework, e.g. through rules-based policy. We believe that the future direction of research can focus on economic policy measures due to various events and its long-run sustainable economic impact and growth. It can also address whether a higher permanent debt-to-GDP ratio is not an economic threat, but rather a new regime of a sustainable economy and policy standard.

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## Endnotes

1. Rafiqul Bhuyan (corresponding author]: Department of Accounting and Finance, Alabama A&M University, 4900 Sheridan St North, Huntsville, AL 35811, USA, email: rafiqul.bhuyan@aamu.edu. Ishrat Tarannum, University of Texas Rio Grande Valley, USA. Nazmul Hassan, East West University Dhaka, Bangladesh. We like to thank reviewers for their valuable inputs to improve the paper. We also like to thank editors of the Journal for handling of the article to make it ready to publish. We, however, claim responsibility for the entire content quality or notable flaws in the manuscript.

2. See the public debt as a percentage of gross domestic product at https://fred.stlouisfed.org/series/GFDEGDQ188S

3. We use 3/T, as we identify explosiveness of US debt as lasting more than 3 quarters.

4. [.] is the floor function that gives the integer part of the argument.

5. Trade openness and unemployment data are also obtained from the Federal Reserve Bank of St Louis.

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