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PRE

# The Philippine Review of Economics

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# Measuring fiscal policy sustainability in developing Asia: what does the Markov Switching Augmented Dickey-Fuller Test tell us?*

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This paper measures fiscal sustainability in 22 developing Asian countries for the period 1999–2017. Previous literature generates conflicting results: one paper applies the usual stationarity and cointegration tests and finds that fiscal policy is sustainable but in weak form. Another paper employs a fiscal reaction function and finds that fiscal policy is unsustainable. This paper uses an expanded version of the Markov Switching Augmented Dickey-Fuller test (MS-ADF), which remedies the shortcomings of conventional stationarity tests to provide more statistical power in the presence of nonlinearities and structural breaks. The MS-ADF has never been applied to this set of countries. Results show that the majority of the countries have "uncertain" debt trajectories, not definitively sustainable or unsustainable but somewhere in-between. This is a more nuanced picture of the debt trajectories in the region relative to what is obtained using the established methods. A more nuanced assessment could lead to more suitable policy corrections.

**JEL classification**: H63, C22
**Keywords**: fiscal policy sustainability, public debt, stationarity test, Markov Switching-ADF

## 1. Motivation and objectives

The COVID-19 pandemic, characterized by the rapid transmission of the virus across borders and lockdown restrictions, marked the largest global economic crisis in over a century [IMF 2022]. The pandemic created both supply and demand shocks, directly affecting government revenue due to unemployment, disrupted supply chains, and the bankruptcy of some institutions. Several countries provided stimulus packages to deal with the crisis, resulting in the largest one-year debt

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* This article is a revised and shortened version of the undergraduate research paper of Premacio and Vidar. The original paper won the Gerardo P. Sicat Award for Best Undergraduate Research Paper for AY 2022-23 and is available at the UPSE Library. T. Monsod was the research adviser.
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surge since World War II. In addition, the war between Russia and Ukraine created inflationary pressure and uncertainty, disrupting global economic recovery [World Economic Outlook 2022]. This succession of events led to considerable swings in debt ratios [Gaspar et al. 2022], a highly uncertain fiscal policy environment [IMF 2022], and renewed interest in assessing the debt vulnerability and fiscal policy sustainability of countries as a basis for policy correction.

The empirical literature on fiscal policy sustainability largely involves examining whether the sovereign's present value borrowing constraint—whether the current value of public debt equals the discounted sum of future surpluses exclusive of interest payments—holds [Velinov 2015].[1] To do this, three methods have been applied: testing the stationarity of public debt and deficits, testing whether government revenues and expenditures, inclusive of interest payments, are suitably cointegrated, and testing whether a government's primary balance reacts positively to lagged increases in debt. Among these, the most common is the first, where many use unit root tests such as the Augmented Dickey-Fuller (ADF) test or Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test to determine the stationarity of the debt-to-GDP ratio. However, such standard tests are unreliable in the presence of nonlinearities and may lead to incorrect conclusions, prompting the use of regime-switching models, such as the Markov Switching ADF (MS-ADF).

Velinov [2015] points out that the conventional MS-ADF is, however, still restrictive—not all parameters are allowed to be state-dependent, no more than two states are considered, and higher-order autoregressions are left out. Velinov then introduces a "very general" MS-ADF, which "expands" existing models. This expanded MS-ADF allows an unrestricted number of lags, regime switches, and state-dependent parameters, thereby capturing irregularities in the depth and duration of phases. In an application to 16 OECD countries, this innovation is shown to be "an improvement on simpler existing models".

To our knowledge, the expanded MS-ADF has not yet been applied to countries in developing Asia. In fact, there are only a few studies that focus on Asia and most use samples that end before 2010, or prior to the global financial crisis. One exception is a working paper by Thuy [2018], which applied both stationarity and cointegration tests on the debt-to-GDP ratios of eight ASEAN countries from 1987 to 2017. Using time series difference-stationarity ADF tests, extensions of ADF for panel stationarity, and tests for panel cointegration, it was found that countries in the sample demonstrated fiscal sustainability, although in "weak" form.[2] A second exception is Bui [2019], which applied the fiscal reaction function method to a panel of 22 developing Asian countries, including the countries studied in Thuy [2018]. Bui [2019] found that, except for three countries, fiscal policy in the region was unsustainable.

[1] The rest of this paragraph draws heavily on Velinov [2015].

[2] As Thuy [2018] explains, weak sustainability means that the bubble term goes to zero at a slower rate, as long as the growth rate of debt does not exceed the growth rate of the economy.

The conflicting results from these two papers and our reading of Velinov [2015] motivate our research. How would results from the stationarity test approach compare with the fiscal reaction function approach if the expanded MS-ADF test of Velinov [2015], which improves on the methods used in Thuy [2018], is employed instead? In our view, this knowledge would be valuable in itself and can be a welcome addition to the limited literature on fiscal policy sustainability in developing Asia.

The rest of our paper is organized as follows. Section 2 provides more detail on the main methods used to examine fiscal sustainability, their shortcomings, and the expanded MS-ADF. Section 3 details our econometric model, estimation method and decision algorithm, while Section 4 discusses data, diagnostic tests and model selection per country. Section 5 presents the MS-ADF results and compares these with results from conventional stationarity tests and the fiscal reaction function model of Bui [2019]. Section 6 concludes.

## 2. Assessing fiscal policy sustainability and the expanded MS-ADF

Hamilton and Flavin [1986] argued that governments, like households, are subject to borrowing constraints. They discuss a government's present value borrowing constraint (PVBC), which means that the expected present value of expenditures, exclusive of interest payments, should not exceed the expected present value of receipts. A fiscal policy is deemed sustainable if it satisfies the PVBC.

Currently, three main methods are employed to determine whether the PVBC holds. These are summarized in Table 1, which draws heavily from discussions in Velinov [2015] and Bui [2019]. The first method is testing the stationarity of the first difference of the public debt stock, which is attributed to Hamilton and Flavin [1986]. Stationarity of public debt is a "sufficient condition" for fiscal policy sustainability, and, moreover, "as long as debt follows a stationary trajectory, it is sustainable regardless of its actual level" [Velinov 2015]. The second method can be viewed as equivalent to testing if debt is on a stationary trajectory and involves testing whether government receipts and government expenditures, inclusive of interest payments, are cointegrated with a vector (1, −1) (Trehan and Walsh [1988;1991]; Hakkio and Rush [1991]).

The third method is from Bohn [1998;2007], who critiques the first two methods by showing why standard unit root and cointegration tests are "incapable of rejecting the consistency of data sets with the intertemporal budget constraint". Thus, "the common practice of judging a policy to be unsustainable on the basis of unit root and cointegration tests is invalid." Bohn suggests that examining the behavioral response of the primary balance may be a "more fruitful way of establishing debt sustainability". Specifically, a sufficient condition for the government to satisfy its intertemporal budget constraint is that the primary (non-interest) budget surplus is an increasing function of the (lagged) debt-GDP ratio.

**TABLE 1. Main methods for assessing fiscal sustainability**

| Method | Developed by | Variables | How fiscal sustainability is determined | Criticisms |
|---|---|---|---|---|
| **Stationarity Test** | Hamilton and Flavin [1986] | debt-to-GDP ratio | Debt series is difference-stationary. Otherwise, it is unsustainable.<br><br>Unit root tests, typically ADF or KPSS, are utilized. | The stationarity and cointegration conditions for sustainability are not necessary requirements for satisfying the intertemporal budget constraint. [Bohn 2007].<br><br>Conventional unit root tests have low power in the presence of nonlinearities and structural breaks which may lead to invalid conclusions (Afonso [2005]; Chen [2011]). |
| **Cointegration Test** | Trehan and Walsh [1988;1991]<br>Hakkio and Rush [1991] | debt-to-GDP ratio government receipts government expenditures (including interest payments) | Government receipts and government expenditures, inclusive of interest payments, are cointegrated (with a coefficient of about 1). This is equivalent to testing if debt is on a stationary trajectory. | The same critique by Bohn [1998; 2007].<br><br>This assumes that expected real interest rate is constant, which is not always the case, and the null hypothesis of unit root is difficult to reject with short time series [Bui 2019]. |
| **Fiscal reaction function** | Bohn [1998;2007] | primary balance and lagged public debt, controlling for temporary government expenditure, and the cyclical variations of output | The primary balance is an increasing function of the debt-to-GDP ratio. | This does not rule out a situation in which primary surpluses would need to exceed GDP to refinance debt [Ghosh et al. 2013].<br><br>In practice, lenders and policymakers are often concerned with perceived upper bounds of public debt which is not considered in this method [Velinov 2015]. |

The third method does not rule out the situation in which primary surpluses would need to exceed GDP to refinance public debt, however [Ghosh et al. 2013]. This is a problem in practice given that lenders and policymakers are often concerned with "perceived upper bounds on public debt", e.g., a limit on the debt-to-GDP ratio, say 60 percent, imposed by law or treaties [Velinov 2015]. Thus, notwithstanding the Bohn critique, many studies continue to use stationarity and cointegration test approaches.

The motivation to use regime-switching models to determine model stationarity is the fact that conventional stationarity tests such as ADF and KPSS do not always produce the same results. Velinov [2015] demonstrates this in an analysis of 16 OECD countries (Table 2). For instance, while both ADF and KPSS indicated that fiscal policy in Argentina and Finland was sustainable, they differed as regards Norway, Sweden, and UK (which KPSS deemed unsustainable) and Italy and Portugal (which ADF found to be unsustainable).

**TABLE 2. Conflicting results of conventional stationarity tests**

| Unit Root Test | Sustainable | Unsustainable |
|---|---|---|
| Augmented Dickey-Fuller (ADF) | Argentina, Finland, Norway, Sweden, UK | France, Germany, Greece, Iceland, Ireland, Italy, Japan, Portugal, Spain, Switzerland, US |
| Kwiatkowski–Phillips–Schmidt–Shin (KPSS) | Argentina, Finland, Italy, Portugal | France, Germany, Greece, Iceland, Ireland, Japan, Norway, Spain, Sweden, Switzerland, UK, US |

Source: Velinov [2015].

Velinov [2015] cites the low statistical power of conventional tests when the time series has a nonlinear nature [Chen 2011] as well as the bias of the ADF test towards nonrejection of the unit-root null hypothesis in the presence of structural breaks [Afonso 2005]. In contrast, the regime-switching MS-ADF (due to Hamilton [1989]) can accommodate nonlinearities, allow for states of nature (stationary and nonstationary) of public debt, and include the varying time paths of debt depending on states of nature associated with sources of systemic risks.

However, existing MS-ADF models still have shortcomings [Velinov 2015]. Most do not allow all parameters to be state-dependent, have not considered more than two states, and higher order autoregressions are often neglected, which may lead to erroneous conclusions. Thus, Velinov [2015] expanded existing models by allowing the number of lags and regimes to be unrestricted and parameters to be state-dependent.

Specifically, Velinov [2015] applied the following expanded MS-ADF model to test for unit roots:

$$\Delta B_t = v(S_t) + \Phi_1(S_t)B_{t-1} + \Phi_2(S_t)\Delta B_{t-1} + \Phi_3(S_t)\Delta B_{t-2} + \cdots + \Phi_{p+1}(S_t)\Delta B_{t-p+1} + u_t \,, \tag{1}$$

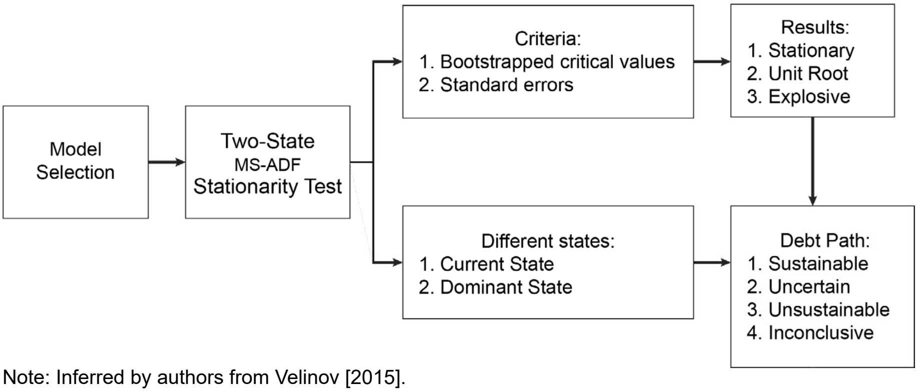
where $B_t$ is government debt, $\Phi_1$ is the coefficient on the first lag of $B_t$, and $\Phi_i$ , $i$ = 2, … $p$ +1, are coefficients on the first differences of government debt. $S_t$ is a first order discrete-valued Markov process which can take on values 1..., M, allowing the numbers of lags and states to be unrestricted and all the parameters to be potentially state-dependent. The residual term $u_t$ is assumed to have a normal distribution (as $u_t \sim$ Nid (0, $\boldsymbol{\sigma}^2$ ($S_t$)).

To select the appropriate number of lags of the model, Velinov [2015] used portmanteau tests based on MS-ADF residuals. The coefficient $\Phi_1$ in (1) is assumed to be state-dependent, and all autoregressive coefficients of higher lag orders are allowed to switch. Further, the number of states, as well as whether a state is current, or whether it is dominant, is determined by examining the estimated smoothed probabilities of the countries. A state is considered current if it is the state of the last period of the sample. A state is dominant if it is the state which the country is in with the longest duration based on its fiscal policies. The current states are determined by observing the estimated smoothed probabilities of each country while the dominant states are determined by comparing state-transition probabilities.

The MS-ADF null hypothesis is that a unit root exists in each state ($\Phi_1(S_t)$ = 0, for $S_t$ = 1...M). Negative values of test statistics imply stationarity while zero means that a unit root exists. Unlike conventional stationarity tests, positive values of the test statistic in each state can exist in the MS-ADF framework, indicating the presence of an explosive process.

After selecting the best model per country, some of which had two states and some three states, Velinov [2015] relied on both standard errors and parametrically bootstrapped critical values as criteria to determine the significance of parameters. In turn, the significance of parameters from both criteria determined whether the debt trajectory path of each country was "sustainable", "unsustainable", or "uncertain", i.e., it cannot be definitively categorized as sustainable or unsustainable. Whether a state was current and/or dominant, along with historical factors, also played a part in the assessment (Figure 1).

**FIGURE 1. The expanded MS-ADF**




Note: Inferred by authors from Velinov [2015].

Velinov [2015] did not provide a precise decision tree nor a list of rules to guide how exactly the two criteria could be used for judging the debt trajectory path of a country, however. For instance, it was not clear how conclusions are reached when only one criterion was satisfied (for instance, the parameter was significantly different from zero using standard errors only). Thus, to interpret our results, we construct a straightforward decision algorithm for using the two criteria, inferring rules from the analysis in Velinov [2015]. This is discussed in the next section.

## 3. Econometric model, estimation method, and decision rules

We adopt the model and approach in Velinov [2015].[3] Our econometric model is:

$$\Delta dgdp = v(S_t) + \Phi_1\,(S_t)dgdp_{t\text{-}1} + \Phi_2\,(S_t)\Delta dgdp_{t\text{-}1} + \Phi_3\,(S_t)\Delta dgdp_{t\text{-}2} + \cdots + \Phi_{p+1}(S_t)\Delta dgdp_{t\text{-}p+1} + u_t\,, \qquad (2)$$

where *dgdp* is government debt as a percentage of GDP. Scaling debt by GDP is necessary to avoid misleading results when performing unit root tests [Bohn 2019]. As in (1), $\Phi_1$ is the coefficient on the first lag of $B_t$, and $\Phi_i$, $i = 2, \ldots p + 1$, are coefficients on the first differences of government debt; $S_t$ is first order discrete-valued Markov process which can take on values 1..., M, and the residual term $u_t$ is assumed to be normally distributed.

We first undertake conventional ADF and KPSS unit root tests to determine model stationarity. The Akaike's Information Criteria (AIC) and Schwarz Information Criterion (SBIC) are used to select the best lag lengths; a lower AIC and SBIC indicate a better fit. In cases where the optimal lag order is different for AIC and SBIC, both lags were utilized. Finding the appropriate number of lags is important because selecting higher lag orders can increase the mean-square forecast errors of the VAR while underfitting the lag length often generates autocorrelated errors [Lütkepohl 1993].

Inconsistent ADF and KPSS results motivate the regime-switching MS-ADF. We check for serial autocorrelation (using residual portmanteau and LM tests), homogeneity (using ARCH-LM) and structural breaks (using Chow, Recursive and CUSUM-SQ tests) to support the use of a regime-switching model. The portmanteau test based on MS-ADF residuals is also used to choose the optimal lag among those with multiple lag orders.

We rely on two criteria to determine parameter significance—standard errors and bootstrapped critical values—to assess the sustainability of debt trajectories. To bootstrap, a non-parametric bootstrapping program is used, which offers a robust alternative and makes fewer assumptions compared to classic parametric

[3] Unless otherwise indicated, the methods described in this section follow Velinov [2015], which was explained in the preceding section.

methods.[4] We then apply a straightforward decision algorithm for using the two criteria, which we construct based on our interpretation of the Velinov's analysis. This algorithm is designed for a two-state model (since all countries in our sample were determined to have a two-state model) and has six rules. The rules are:

> Rule 1: The results from both criteria must be the same for either state 1 or state 2. Otherwise, the results are inconclusive, i.e., no conclusion can be drawn as to the sustainability of the debt path.
>
> Rule 2: If the two criteria agree in both states, then the debt path is sustainable if the criteria indicate stationary processes in both states; unsustainable if the criteria indicate explosive processes in both states; and uncertain if the criteria indicate unit root processes in both states, or the criteria indicate stationary processes in one state and explosive processes in the other state.
>
> Rule 3: When the two criteria agree for either state 1 or state 2 only, they must agree in a state that is both current and dominant. Otherwise, the result is uncertain.
>
> Rule 4: If Rule 3 holds, the debt path is sustainable if both criteria indicate a stationary process for that state which is current and dominant, and neither criterion indicates an explosive process for the other non-current and non-dominant state. If the latter does not hold, and a criterion indicates an explosive process for the other state, then the debt path is uncertain.
>
> Rule 5: If Rule 3 holds, the debt path is unsustainable if both criteria indicate an explosive process for the state that is current and dominant.
>
> Rule 6: If Rule 3 holds, the debt path is uncertain if both criteria indicate unit root processes for the state that is current and dominant.

The matrix in Figure 2 summarizes the algorithm. To provide an example, say state 1 is stationary in both criteria and state 2 is uncertain for both criteria (S-U-S-U).[5] State 1 is both current and dominant. Using the matrix, and moving from the left (S), to the top (U), to the right (S), and bottom (U), we see that S-U-S-U intersects at a block which indicates either "sustainable" or "uncertain" (row 1, column 5). Since Rule (2) applies—i.e., state 1 is stationary in both criteria and is also the current state and the dominant state—the debt path is sustainable.

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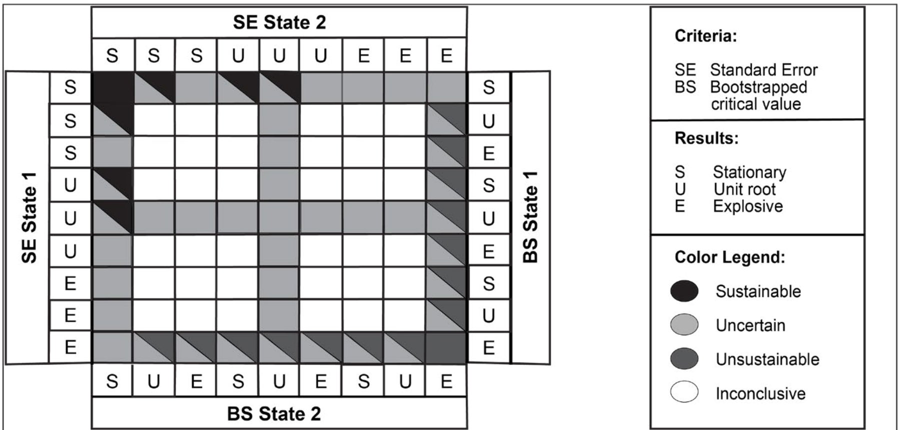
[4] This replaces the parametric method of Psaradakis [1998] which was employed by Velinov [2015].

[5] (S-U-S-U) follows the format (State 1 for criterion 1 - State 2 for criterion 1 - State 1 for criterion 2 - State 2 for criterion 2).

**FIGURE 2. MS-ADF fiscal sustainability decision matrix**




Notes:
1. ☐ Inconclusive - two criteria do not agree for either state. (Rule 1)

***Criteria agree on both states:***
2. ■ Sustainable - stationary processes for both states. (Rule 2)
3. ■ Uncertain - unit root processes for both states. (Rule 2)
4. ■ Unsustainable - explosive processes for both states. (Rule 2)

***Criteria agree on one state only:***
5. ◪ Unsustainable - stationary processes on current and dominant state; no explosive processes. (Rule 4)
Uncertain - stationary processes but not on current and dominant state. (Rule 4)
6. ◪ Unsustainable - explosive processes for current and dominant states. (Rule 5)
Uncertain - explosive processes but not on current and dominant state. (Rule 5)
7. ■ Uncertain - agree on one state but not in a state that is current and dominant state. (Rule 5)
8. ■ Uncertain - stationary processes on current and dominant state; explosive process/es on non-current and dominant. (Rule 4)
9. ■ Uncertain - unit root processes for current and dominant state. (Rule 6)

The statistical software used in this study is Stata 17 MP-Parallel Edition and R version 4.1.3 (March 10, 2022). Most of the diagnostic tests and the MS-ADF test are conducted in Stata. The portmanteau test was done using R.

## 4. Data, diagnostic tests, and model selection per country

### *4.1. Data*

We use annual frequency data on the (nominal) gross debt-to-GDP ratio taken from the World Economic Outlook Database, covering 1999–2017, for 22 developing Asian economies. We use a data set identical to Bui [2019] to produce comparable results.

As observed from Figure 3, most of the countries kept their debt below 60 percent of their GDP during the period covered. Among the 22 countries, Myanmar experienced the highest debt-to-GDP ratio (at 252 percent) in 1999 to 2007, Bhutan in 2011 to 2017, India in 2008, and Sri Lanka, from 2009 to 2010. On the other hand, Kiribati remained to have the lowest debt-to-GDP ratio in the region until 2014.

One can also broadly identify the stationarity of a series using visualization. Debt-to-GDP is stationary if it does not significantly change over time; graphically, a stationary trajectory would look like a straight line. For instance, Bangladesh, Cambodia, India, Kiribati, Marshall Islands and Micronesia show no visible long-term trend and thus, it is possible that these countries have stationary debt processes and sustainable debt paths (Figure 4). On the other hand, Indonesia, Lao PDR, Myanmar, Nepal, Papua New Guinea, Philippines, Sri Lanka, Solomon Islands, Thailand, and Vietnam appear to have trajectories on a downward trend (Figure 5) while Bhutan, China, Malaysia, Maldives, and Vanuatu exhibit trajectories on an upward trend (Figure 6). It is possible that these countries have nonstationary processes.

**FIGURE 3. Time plot of debt-to-GDP ratios per country**

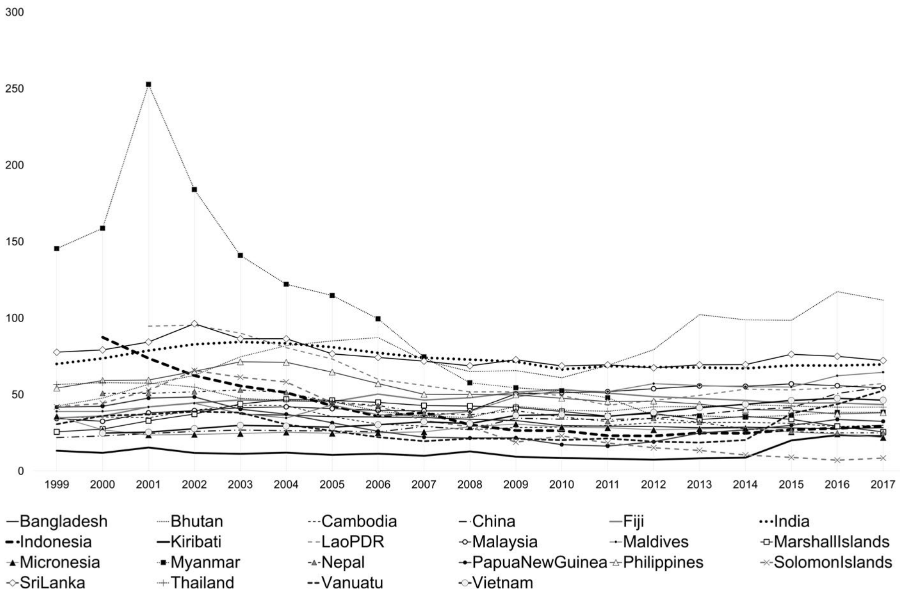



**FIGURE 4. Debt-to-GDP Graph of Bangladesh, Cambodia, India, Kiribati, Marshall Islands, and Micronesia**

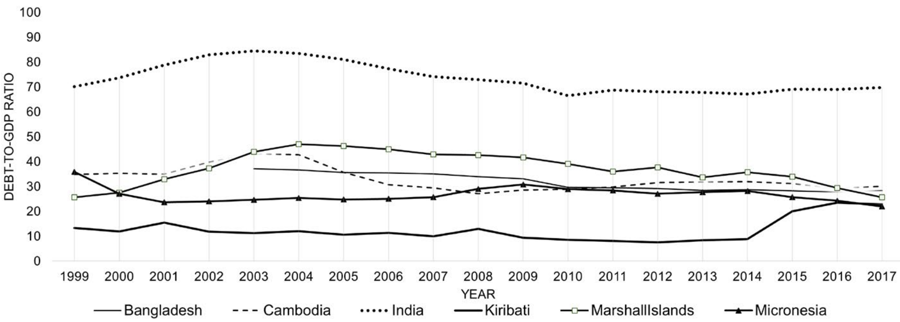


**FIGURE 5. Debt-to-GDP Graph of Indonesia, Lao PDR, Myanmar, Nepal, Papua New Guinea, Philippines, Sri Lanka, Solomon Islands, and Thailand**

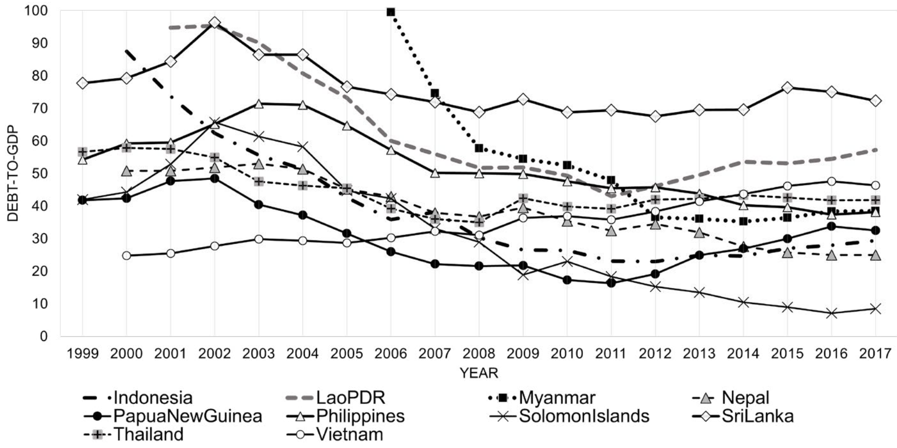
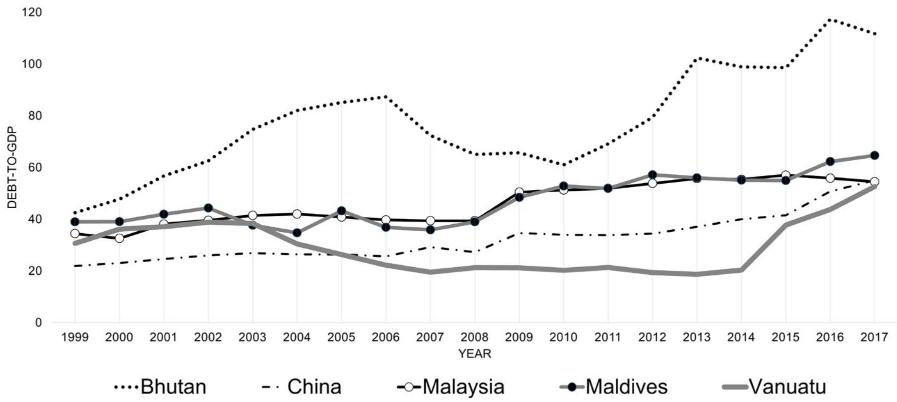



**FIGURE 6. Debt-to-GDP Graph of Bhutan, China, Malaysia, Maldives, and Vanuatu**




## *4.2. Diagnostic tests*

Table 3 presents the results of the diagnostic tests conducted. For conventional unit root tests, lag length is determined from the AIC and SBIC tests. If these tests provide different results, multiple lag lengths are used for the ADF and KPSS.

The debt trajectories of 11 countries are found to be stationary using only one of the tests but not the other. Specifically, Fiji, Indonesia, Lao PDR, Myanmar, and Papua New Guinea are considered stationary using the ADF test only, while Cambodia, Malaysia, Micronesia, Nepal, Philippines, and Solomon Islands are considered stationary by KPSS only. Only India and Sri Lanka's debt trajectories were found to be stationary by both the ADF and KPSS tests. The inconsistency of results from the two tests motivates the use of the MS-ADF.

**TABLE 3. Diagnostic tests for all countries**

| Country | Lag Length | Stationarity Tests | | Autocorrelation Tests+ | | | | Heteroske-dasticity Test+ |
|---|---|---|---|---|---|---|---|---|
| | | ADF* | KPSS** | $Q_{12}$[1] | $Q^{A}_{12}$[2] | $LM_5$[3] | $LMF_5$[4] | $ARCH_{LM}$ (12)[5] |
| Bangladesh | 1 | -1.38 | 0.15 | 0.99 | 0.89 | 0.65 | 0.67 | 0.90 |
| Bhutan | 1 | -1.31 | 0.12 | 0.87 | 0.51 | 0.45 | 0.49 | 0.34 |
| Cambodia | 2 | -1.60 | 0.08 | 0.15 | 0.02 | 0.65 | 0.66 | 0.26 |
| China | 2 | 2.12 | 0.17 | 0.46 | 0.04 | 0.20 | 0.29 | 0.89 |
| Fiji | 1 | -3.13 | 0.23 | 0.99 | 0.89 | 1.00 | 1.00 | 0.55 |
| India | 5 | -3.03 | 0.10 | 0.16 | 0.00 | 0.13 | 0.35 | 0.56 |
| | 1 | -1.56 | 0.12 | 0.29 | 0.04 | 0.12 | 0.21 | 0.98 |
| Indonesia | 4 | -0.98 | 0.15 | 0.35 | 0.01 | 0.26 | 0.41 | 0.32 |
| | 1 | -3.62 | 0.25 | 0.82 | 0.49 | 0.42 | 0.47 | 0.35 |
| Kiribati | 1 | -0.92 | 0.18 | 0.99 | 0.92 | 0.26 | 0.33 | 0.77 |
| Lao PDR | 1 | -3.26 | 0.23 | 0.87 | 0.35 | 0.69 | 0.69 | 0.22 |
| Malaysia | 1 | -1.48 | 0.08 | 1.00 | 0.95 | 0.87 | 0.86 | 0.98 |
| Maldives | 1 | -0.23 | 0.17 | 0.84 | 0.41 | 0.71 | 0.71 | 0.37 |
| Marshall Islands | 1 | -1.50 | 0.23 | 0.60 | 0.18 | 0.10 | 0.18 | 0.55 |
| Micronesia | 2 | -1.15 | 0.10 | 0.02 | 0.00 | 0.29 | 0.37 | 0.85 |
| Myanmar | 4 | -3.82 | 0.12 | 0.99 | 0.89 | 0.07 | 0.23 | 0.29 |
| | 3 | -2.50 | 0.13 | 0.99 | 0.91 | 0.47 | 0.52 | 0.92 |
| Nepal | 5 | -1.13 | 0.14 | 0.71 | 0.09 | 0.06 | 0.35 | 0.30 |
| | 1 | -0.53 | 0.06 | 0.97 | 0.75 | 0.31 | 0.38 | 0.16 |
| Papua New Guinea | 4 | -2.37 | 0.13 | 0.02 | 0.00 | 0.77 | 0.76 | 0.75 |
| | 2 | -2.76 | 0.17 | 0.06 | 0.00 | 0.05 | 0.14 | 0.57 |
| Philippines | 2 | -0.89 | 0.10 | 0.28 | 0.07 | 0.22 | 0.31 | 0.70 |
| Solomon Islands | 3 | -2.54 | 0.09 | 0.60 | 0.26 | 0.03 | 0.14 | 0.95 |
| Sri Lanka | 3 | -4.12 | 0.10 | 0.67 | 0.19 | 0.01 | 0.10 | 0.17 |
| Thailand | 1 | -2.29 | 0.23 | 0.81 | 0.39 | 0.94 | 0.93 | 0.32 |
| Vanuatu | 3 | -1.57 | 0.14 | 0.22 | 0.01 | 0.27 | 0.37 | 0.42 |
| Vietnam | 2 | -0.18 | 0.15 | 0.74 | 0.25 | 0.39 | 0.45 | 0.79 |

*Critical values are -3.75 at one percent, -3 at five percent, -2.63 at ten percent.
**Critical values are 0.216 at one percent, 0.176 at 2.5 percent, 0.146 at five percent and 0.119 at ten percent.
+ Only *p*-values are reported.
[1] Portmanteau test statistic using 12 lags with a $\chi^2$ distribution.
[2] Adjusted portmanteau test statistic using 12 lags with a $\chi^2$ distribution.
[3] LM test statistic using five lags with a $\chi^2$ distribution.
[4] LM test statistic using five lags with an *F* distribution.
[5] ARCH-LM test statistic using 12 lags with a $\chi^2$ distribution.

The next four columns contain the p-values of portmanteau and LM autocorrelation tests; columns 6 and 8 are the results when the tests were adjusted to accommodate smaller sample sizes. Most countries cannot reject the null hypothesis of no residual autocorrelation. The last column shows the p-values of the ARCH LM test for heteroskedasticity. For all countries, the null of no conditional heteroskedasticity cannot be rejected.

Chow, recursive and CUSUM-SQ tests (not reported in the table but available upon request) indicate evidence of structural breaks in the time series of majority of the countries, further supporting the use of a regime-switching model.

### *4.3. Model selection per country*

For each country, we select the appropriate number of lags of the regime-switching model using the portmanteau test, while the number of states is determined by observing the estimated smoothed probabilities (shown in the Appendix and explained further in Section 5). Notably all countries are found to have two states.

Table 4 presents the MS-ADF model used for each country, where MS(M) stands for Markov switching with M states, ADF(p) for ADF model with p lags, A for switching autoregressive parameters, and H for a switching variance parameter. As earlier mentioned, the coefficient of the first lag of government debt, $\Phi_1$, is assumed to be state-dependent while the autoregressive coefficients of higher lag orders are allowed to switch. Parameter stability tests were conducted to check if variance is state-dependent.

**TABLE 4. Model selected per country**

| Country | Model | Country | Model | Country | Model |
|---|---|---|---|---|---|
| Bangladesh | MS (2)-ADF (1) AH | Lao PDR | MS (2)-ADF (1)A | Papua New Guinea | MS (2)-ADF (2)A |
| Bhutan | MS (2)-ADF (1) AH | Malaysia | MS (2)-ADF (1)A | Philippines | MS (2)-ADF (1)A |
| Cambodia | MS (2)-ADF (2)A | Maldives | MS (2)-ADF (1) AH | Solomon Islands | MS (2)-ADF (3)A |
| China | MS (2)-ADF (2)A | Marshall Islands | MS (2)-ADF (1)A | Sri Lanka | MS (2)-ADF (3)A |
| Fiji | MS (2)-ADF (1) AH | Micronesia | MS (2)-ADF (2)A | Thailand | MS (2)-ADF (1)A |
| India | MS (2)-ADF (5)A | Myanmar | MS (2)-ADF (3)A | Vanuatu | MS (2)-ADF (3) AH |
| Indonesia | MS (2)-ADF (4)A | Nepal | MS (2)-ADF (5) AH | Vietnam | MS (2)-ADF (1) AH |
| Kiribati | MS (2)-ADF (1)A | | | | |

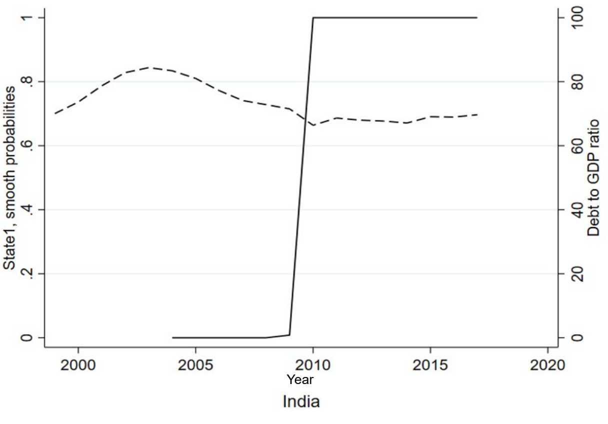
## 5. MS-ADF empirical results

Table 5 shows estimated parameters of state 1 and state 2 with their standard errors and bootstrapped critical values. Significant negative coefficients of state 1 and state 2 of the MS-ADF model—that is, ($\Phi(m) < 0$) which are significant at the ten percent level based on standard errors and bootstrapped critical values—indicate stationary states, while significant positive coefficients—i.e., ($\Phi(m) > 0$) which are significant at the ten percent level—indicate explosive states. The countries are arranged based on the coefficient $\Phi_1$—smallest to largest. In other words, from the most stationary to least stationary based on their first state.

Further, Table 5 presents parameters $p(nm)$ which are the probabilities of switching from state $n$ to state $m$. These parameters are used to determine which is the dominant state. Specifically, if $p_{11} > p_{22}$, then state 1 is the dominant state. The dominant state along with the current state are essential in interpreting the results of the MS-ADF (as evident in our decision algorithm discussed in Section 3).

To illustrate, Figure 7 shows the smoothed probabilities of state 1 of India.[6] The solid line is the smoothed probabilities (left axis) while the dashed line is the debt-to-GDP ratio (right axis). The initial state is state 1 but if the probability rises to 1, it implies that it transitioned to state 2; if the probability drops back to 0, it returns to state 1. For India, the initial state is state 1. It then transitioned to state 2 in 2009 and remained there. Hence, India's current state is state 2 and its dominant state is state 1 (0.88 > 0.29).

**FIGURE 7. State 1, smoothed probabilities, India**




[6] In a two-state model, the smoothed probabilities of state 2 are a mirror image of state 1's. Thus, graphs for state 2 need not be shown.

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**TABLE 5. State parameter estimates and state transition probabilities**

| Countries | *Φ*1 | SE | BS | *Φ*2 | SE | BS | $p_{11}$ | SE | $p_{22}$ | SE |
|---|---|---|---|---|---|---|---|---|---|---|
| Maldives | -0.39¶×» | 0.11 | 0.45 | 1.13* | 0.10 | 0.16 | 0.72 | 0.20 | 0.06 | 0.07 |
| Micronesia | -0.12×» | 0.04 | 0.35 | 0.30¶ | 0.41 | 0.51 | 0.92 | 0.09 | 0.18 | 0.11 |
| Sri Lanka | -0.14×» | 0.69 | 0.42 | -0.38¶ × | 0.07 | 1.85 | 0.90 | 0.26 | 0.37 | 0.41 |
| Cambodia | 0.17×» | 0.23 | 0.27 | -0.68¶× | 0.21 | 0.97 | 0.94 | 0.04 | 0.21 | 0.15 |
| India | 0.03» | 0.14 | 0.29 | -0.79¶ × | 0.05 | 0.51 | 0.88 | 0.08 | 0.29 | 0.25 |
| Papua New Guinea | 0.50¶» | 0.35 | 0.35 | 0.65** | 0.14 | 0.26 | 0.83 | 0.07 | 0.17 | 0.09 |
| Indonesia | 0.38*» | 0.19 | 0.38 | 0.35¶** | 0.03 | 0.21 | 0.68 | 0.24 | 0.39 | 0.56 |
| Kiribati | 0.57*» | 0.17 | 0.46 | 0.13¶ | 0.70 | 14.57 | 0.95 | 0.06 | 0.12 | 0.09 |
| Vanuatu | 1.04**» | 0.26 | 0.45 | -0.46× | 0.23 | 1.62 | 0.86 | 0.09 | 0.16 | 0.23 |
| Nepal | 0.40¶*» | 0.05 | 0.42 | 0.44* | 0.07 | 0.31 | 0.88 | 0.07 | 0.11 | 0.08 |
| Solomon Islands | 0.74**» | 0.08 | 0.53 | 1.20¶ | 0.09 | 0.74 | 0.70 | 0.42 | 0.07 | 0.05 |
| Malaysia | 0.44¶**» | 0.04 | 0.32 | 0.90* | 0.31 | 0.33 | 0.86 | 0.10 | 0.08 | 0.06 |
| Lao PDR | 0.95¶**» | 0.08 | 0.43 | 0.67** | 0.08 | 0.26 | 0.84 | 0.34 | 0.16 | 0.14 |
| Bhutan | 0.81¶** | 0.05 | 0.40 | 1.02**» | 0.10 | 0.15 | 0.51 | 0.21 | 0.72 | 0.30 |
| China | 1.15¶**» | 0.05 | 0.36 | 1.58** | 0.06 | 0.77 | 0.73 | 0.10 | 0.18 | 0.15 |
| Thailand | 1.01**» | 0.04 | 0.37 | 0.55¶** | 0.04 | 0.24 | 0.74 | 0.21 | 0.13 | 0.07 |
| Myanmar | 0.41¶**» | 0.01 | 0.35 | 1.24* | 0.01 | 0.31 | 0.88 | 0.07 | 0.54 | 0.56 |
| Philippines | 1.14**» | 0.02 | 0.32 | 0.78¶** | 0.04 | 0.57 | 0.92 | 0.18 | 0.05 | 0.04 |
| Fiji | 0.81¶** | 0.01 | 0.32 | 0.59*» | 0.13 | 0.41 | 0.00 | 0.00 | 0.22 | 0.11 |
| Marshall Islands | 1.00¶**» | 0.00 | 0.30 | 1.00** | 0.00 | 0.38 | 0.94 | 0.05 | 0.15 | 0.40 |

Note: *Φ*(*m*) the state parameter, *p*(*nm*) the transition probability of state *n* to *m*, SE refers to the standard error of the parameter *Φ*(*m*), BS is the bootstrapped critical value of *Φ*(*m*). No parameter estimates are obtained for Bangladesh and Vietnam hence their exclusion from this table.

¶ The current state
» The dominant state
× Stationary according to one criterion
×× Stationary according to both criteria
* Explosive according to one criterion
** Explosive according to both criteria

Table 6 summarizes the results and debt trajectory of each country. It shows that Bhutan, China, Lao PDR, Marshall Islands, Philippines, and Thailand have explosive processes for both states using both standard errors and bootstrapped critical values. By Rule 2 of the decision algorithm, this implies that their debt path is unsustainable.

For Vanuatu, state 1 is characterized as explosive by both criteria while state 2 is classified as stationary and unit root. Vanuatu's state 1 is current and dominant, hence by Rule 5, its debt trajectory is unsustainable.

Cambodia, Fiji, India, Indonesia, Kiribati, Malaysia, Maldives, Micronesia, Myanmar, Papua New Guinea, and Sri Lanka have uncertain debt paths. This is according to either Rule 2, where criteria indicate unit root processes for both states; Rule 3, where the current state and dominant state is not the same, or Rule 6, where criteria agree in only one state that is current and dominant and which has a unit root process. These scenarios make it difficult to evaluate whether their fiscal policies satisfy the PVBC condition, and to definitively categorize their debt path as sustainable or unsustainable. For example, Papua New Guinea has state 1 with unit root process and state 2 with an explosive process which implies that their debt path can either be unsustainable or uncertain. Since the state with a unit root process is current and dominant, Papua New Guinea's debt path is uncertain.

Two countries—Nepal and Solomon Islands—have inconclusive results by Rule 1. This means that the standard errors and bootstrapped critical values did not agree with their assessment of state 1 and state 2. Another two countries—Bangladesh, and Vietnam—are considered inconclusive because parameters could not be estimated. This could be because they have missing debt-to-GDP data leading to smaller sample sizes compared to other countries.

Table 7 presents the MS-ADF results alongside results from the fiscal reaction function of Bui [2019]. Out of 22 countries in the sample, the MS-ADF and Bui [2019] agree that six (Bhutan, China, Lao, Marshall Islands, Thailand, and Vanuatu) have debt trajectories that are unsustainable but disagree on all the rest. In particular, the debt paths of nine others (Cambodia, Fiji, Kiribati, Malaysia, Maldives, Micronesia, Myanmar, Papua New Guinea, and Sri Lanka) deemed by Bui [2019] to be unsustainable are considered to be uncertain using MS-ADF. Many of these countries with uncertain debt paths as per MS-ADF have at least one explosive state, which may imply that at some point, their fiscal policy may be unsustainable. The fiscal reaction function method of Bui [2019], however, does not allow for a regime switch and may have automatically categorized these countries as having unsustainable debt paths although it is not yet definite. Bangladesh, Nepal, Solomon Islands, and Vietnam, which were deemed unsustainable in Bui [2019], had inconclusive results using MS-ADF.

**TABLE 6. Debt trajectory per country**

| Countries* | State 1 SE | State 2 SE | State 1 BS | State 2 BS | Current State | Dominant State | Debt Trajectory Path |
|---|---|---|---|---|---|---|---|
| Bhutan | Explosive | Explosive | Explosive | Explosive | State 1 | State 2 | Unsustainable |
| Cambodia | Unit Root | Stationary | Unit Root | Unit Root | State 2 | State 1 | Uncertain |
| China | Explosive | Explosive | Explosive | Explosive | State 1 | State 1 | Unsustainable |
| Fiji | Explosive | Explosive | Explosive | Unit Root | State 1 | State 2 | Uncertain |
| India | Unit Root | Stationary | Unit Root | Unit Root | State 2 | State 1 | Uncertain |
| Indonesia | Explosive | Explosive | Unit Root | Explosive | State 2 | State 1 | Uncertain |
| Kiribati | Explosive | Unit Root | Unit Root | Unit Root | State 2 | State 1 | Uncertain |
| Lao PDR | Explosive | Explosive | Explosive | Explosive | State 1 | State 1 | Unsustainable |
| Malaysia | Explosive | Explosive | Unit Root | Explosive | State 1 | State 1 | Uncertain |
| Maldives | Stationary | Explosive | Unit Root | Explosive | State 1 | State 1 | Uncertain |
| Marshall Islands | Explosive | Explosive | Explosive | Explosive | State 1 | State 1 | Unsustainable |
| Micronesia | Stationary | Unit Root | Unit Root | Unit Root | State 2 | State 1 | Uncertain |
| Myanmar | Explosive | Explosive | Unit Root | Explosive | State 1 | State 1 | Uncertain |
| Nepal | Explosive | Explosive | Unit Root | Unit Root | State 1 | State 1 | Inconclusive |
| Papua New Guinea | Unit Root | Explosive | Unit Root | Explosive | State 1 | State 1 | Uncertain |
| Philippines | Explosive | Explosive | Explosive | Explosive | State 2 | State 1 | Unsustainable |
| Solomon Islands | Explosive | Explosive | Unit Root | Explosive | State 1 | State 1 | Inconclusive |
| Sri Lanka | Unit Root | Stationary | Unit Root | Unit Root | State 2 | State 1 | Uncertain |
| Thailand | Explosive | Explosive | Explosive | Explosive | State 2 | State 1 | Unsustainable |
| Vanuatu | Explosive | Stationary | Explosive | Unit Root | State 1 | State 1 | Unsustainable |

* Note: Bangladesh and Vietnam are not listed here, as they were not in Table 5.

**TABLE 7. Comparative results: expanded MS-ADF and Bui [2019]**

| Countries | *ADF* | *KPSS* | Expanded MS-ADF | Fiscal reaction function of Bui [2019] |
|---|---|---|---|---|
| Bangladesh | *Unsustainable* | *Unsustainable* | Inconclusive | Unsustainable |
| Bhutan | *Unsustainable* | *Unsustainable* | Unsustainable | Unsustainable |
| Cambodia | *Unsustainable* | *Sustainable* | Uncertain | Unsustainable |
| China | *Unsustainable* | *Unsustainable* | Unsustainable | Unsustainable |
| Fiji | *Sustainable* | *Unsustainable* | Uncertain | Unsustainable |
| India | *Sustainable* | *Sustainable* | Uncertain | Sustainable |
| Indonesia | *Sustainable* | *Unsustainable* | Uncertain | Sustainable |
| Kiribati | *Unsustainable* | *Unsustainable* | Uncertain | Unsustainable |
| Lao PDR | *Sustainable* | *Unsustainable* | Unsustainable | Unsustainable |
| Malaysia | *Unsustainable* | *Sustainable* | Uncertain | Unsustainable |
| Maldives | *Unsustainable* | *Unsustainable* | Uncertain | Unsustainable |
| Marshall Islands | *Unsustainable* | *Unsustainable* | Unsustainable | Unsustainable |
| Micronesia | *Unsustainable* | *Sustainable* | Uncertain | Unsustainable |
| Myanmar | *Sustainable* | *Unsustainable* | Uncertain | Unsustainable |
| Nepal | *Unsustainable* | *Sustainable* | Inconclusive | Unsustainable |
| Papua New Guinea | *Sustainable* | *Unsustainable* | Uncertain | Unsustainable |
| Philippines | *Unsustainable* | *Sustainable* | Unsustainable | Sustainable |
| Solomon Islands | *Unsustainable* | *Sustainable* | Inconclusive | Unsustainable |
| Sri Lanka | *Sustainable* | *Sustainable* | Uncertain | Unsustainable |
| Thailand | *Unsustainable* | *Unsustainable* | Unsustainable | Unsustainable |
| Vanuatu | *Unsustainable* | *Unsustainable* | Unsustainable | Unsustainable |
| Vietnam | *Unsustainable* | *Unsustainable* | Inconclusive | Unsustainable |

Source: Authors' computations except for last column which are from models 1 and 2 of Bui [2019].

Of the three countries Bui [2019] found to have sustainable debt paths, two were found by MS-ADF to have unsustainable debt paths (Indonesia, Philippines) and one was found to be uncertain (India). This might be because while the three countries have significantly reduced their debt-to-GDP ratios over the years, whether adjustments are sufficient to allow them to easily refinance their debt is not clear. The model in Bui [2019] would have captured the former but not the latter since the fiscal reaction function only considers how fiscal surpluses react to changes in debt and does not consider the actual fiscal position. The smoothed probabilities of the MS-ADF model also show that among the three countries, only India had a regime switch after the 2008 global recession, possibly explaining the "uncertain" (rather than "unsustainable") finding. In contrast, Bui [2019] found that all three countries adjusted their fiscal policies after 2008.

Table 7 also presents the results from the conventional ADF and KPSS tests (in columns 2 and 3). We note that the MS-ADF provides clarity, nuance, and likely more accuracy (as expected) relative to results from ADF and KPSS. Of the 11 countries mentioned in section 4.2 as having conflicting ADF and KPSS results, the MS-ADF classifies seven as having uncertain debt paths (Cambodia, Fiji, Indonesia, Malaysia, Micronesia, Myanmar and Papua New Guinea), two as having unsustainable debt paths (Lao, Philippines), and two as having inconclusive results (Nepal, Solomon Islands). For the 11 others that did not have different ADF and KPSS results, the MS-ADF concurs in only five instances (Bhutan, China, Marshall Islands, Thailand and Vanuatu, all classified unsustainable).[7] The other six were found by MS-ADF to have either inconclusive or uncertain results, although these countries were found to have either unsustainable (Bangladesh, Kiribati, Maldives, Vietnam) or sustainable (India, Sri-Lanka) debt trajectories by both ADF and KPSS.

## 6. Concluding remarks

This paper sets out to measure fiscal policy sustainability in 22 countries in developing Asia using a never-before applied regime-switching stationarity test, the expanded MS-ADF, due to Velinov [2015]. The model has better statistical power in the presence of nonlinearities and structural breaks, addressing the weaknesses of conventional stationarity tests like the ADF and KPSS. We use a data set that will allow a comparison of results with Bui [2019], which uses a fiscal reaction function approach to assess fiscal policy sustainability.

In contrast to results in Bui [2019], who finds that all countries have either unsustainable (19 countries) or sustainable (three countries) fiscal policies, the MS-ADF indicates a more nuanced picture of the region. Eleven countries are classified as having uncertain fiscal sustainability (Cambodia, Fiji, India, Indonesia, Kiribati, Malaysia, Maldives, Micronesia, Myanmar, Papua New Guinea, and Sri Lanka), while just seven are classified as having unsustainable fiscal policies (Bhutan, China, Lao PDR, Marshall Islands, Philippines, Thailand, and Vanuatu). Results for the remaining four countries (Bangladesh, Nepal, Solomon Islands and Vietnam) are inconclusive; no country is found to have sustainable fiscal policies.

In other words, the MS-ADF concurs with Bui [2019] for only 6 of the countries the latter found to be unsustainable, reclassifying 13 others as either uncertain or inconclusive. It also reclassifies one country that Bui [2019] found to be sustainable as uncertain. We also note that, as expected, the MS-ADF provides more clarity and nuance to the results arising from conventional stationarity tests.

[7] Interestingly, our ADF results are different from Thuy [2018]. For instance, our ADF did not find the debt path of Thailand to be sustainable, nor Indonesia and Myanmar's to be unsustainable. We suspect this is because Thuy [2018] failed to determine the appropriate lag length in conducting the ADF method.

Using the MS-ADF, it is possible that debt trajectories are not definitively sustainable or unsustainable but somewhere in-between. This nuance may be helpful in identifying areas of fiscal policy to improve and prioritize, leading to more suitable policy corrections.

The MS-ADF model encounters problems in finding the optimal solution for data with missing values and small sample size. For future studies, we recommend the use of a longer time series per country. The implications of the Bohn [1998, 2007] critique, about the validity of the stationarity conditions, also needs to be thought through vis the MS-ADF framework, notwithstanding the claims by Velinov [2015] that the MS-ADF is a practical choice.

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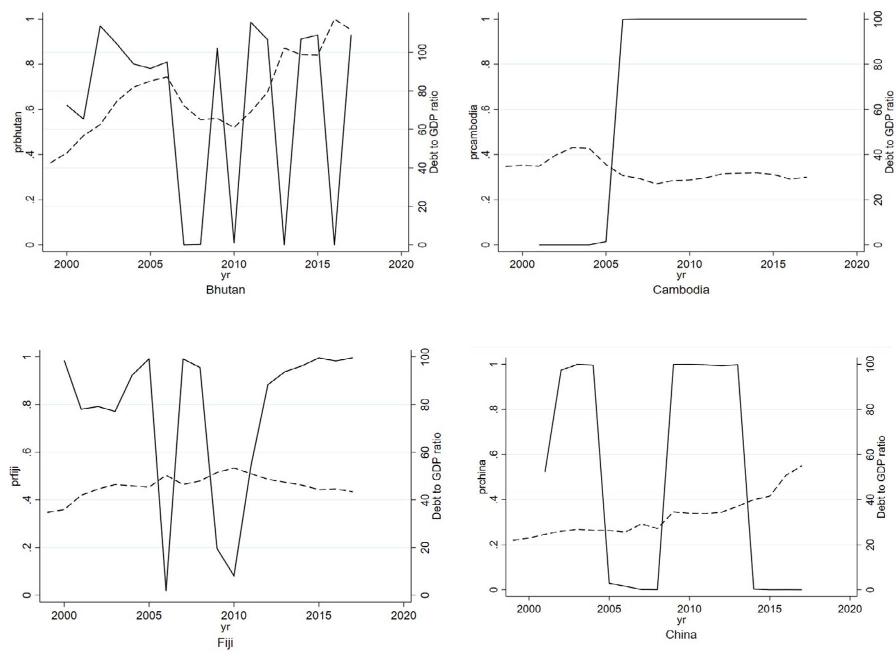
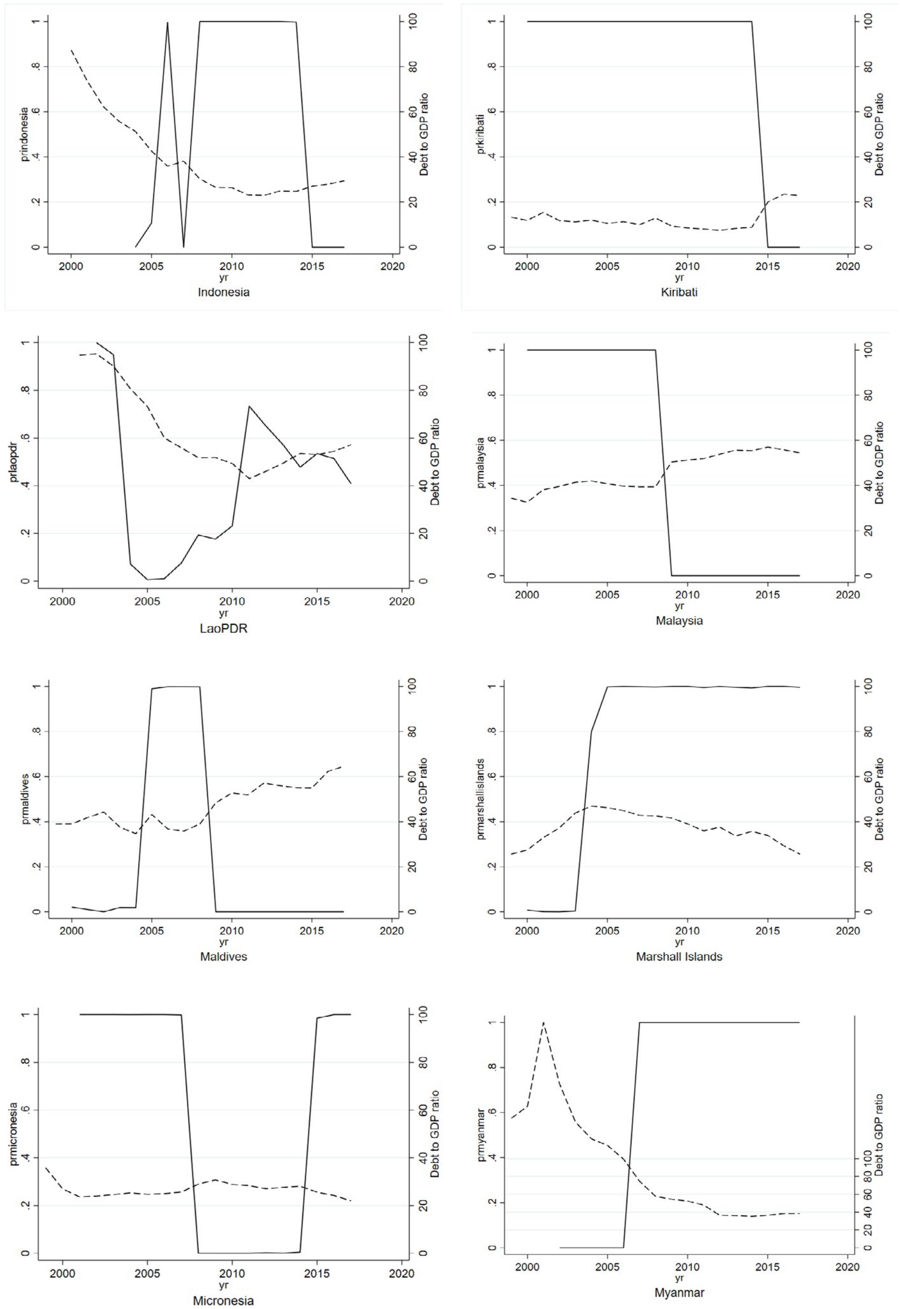
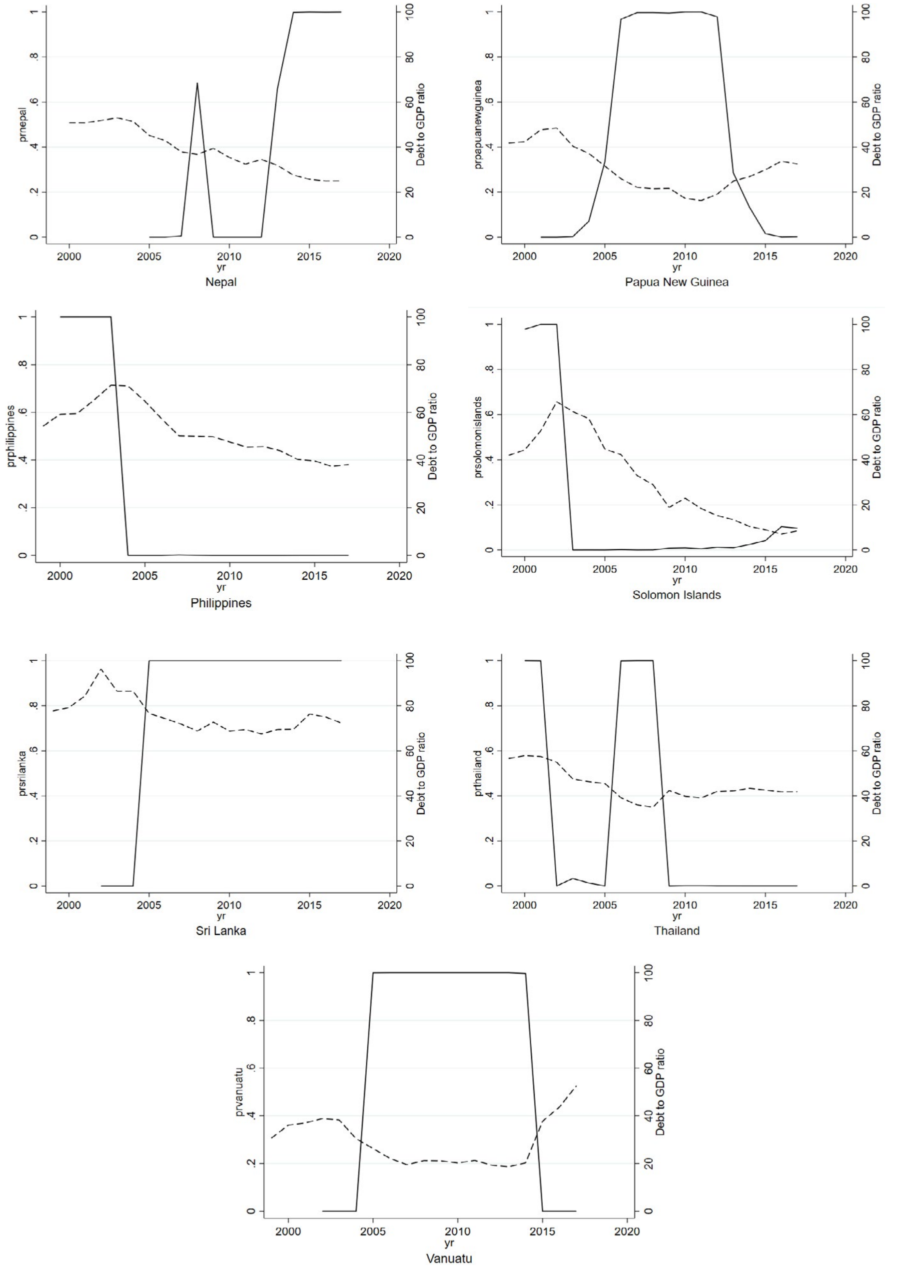
## Appendix. Model estimated smoothed probabilities of State 1



## Appendix. Model estimated smoothed probabilities of State 1 (continued)



## Appendix. Model estimated smoothed probabilities of State 1 (continued)




Notes:
[1] Solid lines are the smoothed probabilities (left axis), dashed lines are the debt-to-GDP ratio (right axis). Since State 2 smoothed probabilities are a mirror image of State 1 in two-state models, these are not shown.
[2] The graphs of Bangladesh and Vietnam are excluded since their smoothed probabilities of State 1 were not obtained.

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