

# THE DEBT THRESHOLD IN THE CONTEXT OF DEBT SUSTAINABILITY: A COMPARISON BETWEEN EGYPT AND JAPAN USING THE LSTR APPROACH

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**Abstract.** Previous studies show mixed findings with respect to the association between public debt (proportioned to GDP) and economic growth, which should be reexamined. No research has looked at how differences in economic structures, inflation stability, central bank ability to monetize debt, and the stage of economic development can determine their ability to manage and service the public debt and to mitigate the potential deleterious impacts of debt on growth. This paper helps fill this gap in literature by using data from 1974 to 2022 to investigate, in a comparative manner, the existence of debt-GDP thresholds in Egypt (as a developing country) and Japan (as a developed country). These two countries have been chosen due to the differences between both in terms of the above-mentioned factors. To do so, the logistic smooth transition regression is conducted. We found evidence for a statistically significant positive relationship between public debt (proportioned to GDP) and economic growth before crossing the estimated threshold at 72.77% for Egypt and at 205.88% for Japan. Beyond the threshold, public debt has harmful effects on economic growth, suggesting an asymmetric association between the two main variables. Such estimated thresholds, regarding keeping public debt (proportioned to GDP) below the estimated thresholds, could help policymakers design their long-term macroeconomic strategies in the sense that debt below the threshold can be productive. These thresholds can be dealt with as a fiscal anchor.

**Keywords:** economic growth, public debt, structural breaks, LSTR model, Egypt, Japan.

**JEL Classification:** C5, H1, H6, O4.

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## 1. Introduction

Sovereign governments use public debt as a predominant instrument for managing the fiscal imbalance created by the mismatch between revenues collected and their spending needs. When faced with resource constraints, governments often resort to borrowing to finance their plans to expand economic activities, strengthen infrastructure, create capital, and use their productive spending. When expenditures exceed revenues, the government has two basic

choices, either to eliminate the deficit by reducing expenditures and/or increasing revenues, or to finance that deficit by increasing the national debt balance (Herndon et al., 2014). Global economic contraction and recent financial crises have pushed governments around the globe to stimulate aggregate demand through fiscal expansion procedures, which requires the government to find new ways to finance those expansions and the consequent increase in public deficits. The problem is that excessive debt accumulation makes fiscal management difficult, depletes government income from debt service and interest payments, which leads to a serious shortage of resources to support development demands (Baldacci et al., 2014). Similarly, productivity and revenue creation will be constrained when nations employ debt for non-developmental spending. The government will therefore be unable to pay back the debt and interest that has accumulated. Public debt will have detrimental macroeconomic effects and be unsustainable. Unsustainable and excessive debt levels and escalating public deficits have long-term effects on governments performance and efficiency because government bond holders may become less confident in their investment. Moreover, if the debt reaches unmanageable levels, the government may default. Hence, the issue of fiscal sustainability receives considerable attention in the economic debate (Chudik et al., 2017; Clements et al., 2003).

The debate over the sustainability of public debt has grown significantly over the last few decades, encompassing scholars, decision-makers, and financial market players. There have been a number of recent attempts to establish techniques for quantitatively evaluating debt sustainability as well as to define and theoretically explain the idea (see, e.g., D'Erasmus et al. (2016) and Blanchard et al. (2021)). The ability of a nation to pay off its debt without creating any financial imbalances is known as debt sustainability. Whether or not a nation is experiencing a debt crisis, sound debt management techniques are essential to macroeconomic policy and good governance. A stable economy depends on sustainable debt management. To ensure that these economies' investment needs are not impacted, it is crucial to evaluate how secure their debt is (Marquez, 2000). Many studies have urged countries to borrow reasonably to help promote economic growth (Diamond & He, 2014; Fischer & Schnabl, 2018). The tendency to borrow excessively without planning to invest may result in a considerable amount of debt and interest payment obligations, which will be detrimental to the economy (Munir & Mehmood, 2018). In this context, studies like Augustine and Rafi (2023), Makun (2021), Eberhardt and Presbitero (2015), and Aguiar et al. (2009), among others, have focused on determining the appropriate "threshold" level of government debt that fosters economic growth.

Government interventions in economic growth via public debt, tax policies, and public expenditure represent a global economic policy concern. Berg et al. (2012) indicate that economic growth is impacted by changes or balances in the public debt through four basic mechanisms. That is, (a) public investment and spending, (b) private saving, (c) overall productivity, and (d) real and nominal long-term interest rates for sovereign governments. There is no consensus among economists on the relationship between public debt and economic growth. The theoretical literature delves into this relationship, differentiating between four cases, namely lack of influence, unfavorable influence, favorable influence, and non-monotonic influence.

### 1.1. Neutrality of public debt

The real economy remains unaffected by increases in public debt and government spending if they have an identical effect on private savings. Barro (1989) and Buchanan (1976) suggest that government debt has only a direct impact on private consumption and saving decisions, without leading to the possibility of net economic growth. This means that differences in domestic and foreign public debt stocks do not change with changes in key real macroeconomic variables, and therefore on the growth path of the economy. This supports the idea that fiscal policy is ineffectual since it aligns with the neoclassical framework's concept that the state of the economy affects changes in public debt caused by expansionary fiscal policies. Therefore, government debt cannot be utilized as a vehicle for economic stimulus, according to Barro-Ricardo's equivalence theory.

### 1.2. Negative impact of public debt

The unfavorable impact of debt on growth is mainly explained by the debt accumulation hypothesis. This leads to financial deterioration and in a way that distorts the ability of the private sector to make the best future investment decisions (Reinhart et al., 2012). The debt burden hypothesis states that public debt hinders economic expansion through three different pathways. The first is the rational expectation hypothesis, which contends that if a significant governmental debt makes future policies uncertain—possibly via inflation and financial repression—the unfavorable impact of debt may be significantly bigger (Cochrane, 2011a; Panizza & Presbitero, 2013). The conventional crowding-out effect theory serves as the second channel. In other words, government borrowing limits the economy's ability to lend, which raises real interest rates significantly, discourages adequate private sector investment, and causes the economy to deteriorate (Huang et al., 2018). Thirdly, the theory of financial illusion contends that public debt affects economic growth negatively. According to Pereira and Rodrigues (2001), fiscal illusion happens when taxpayers fail to understand the full tax burden that comes with replacing government debt with tax financing. These economic actors will therefore mistakenly believe that this bartering increases their net worth, increasing their present consumption at the expense of investments and savings, resulting ultimately in diminished long-term economic growth rates. Countries heavily reliant on short-term borrowing to fund rising debt levels are susceptible to confidence crises, which can trigger sudden and unexpected financial crises, as noted by Reinhart and Rogoff (2009) and supported by several models.

### 1.3. Positive impact of public debt

There is also an array of literature that emphasizes the significance of public debt in the process of economic growth, which is mainly supported by Adolph Wagner's hypothesis of the "law of rising public expenditures" and the effect of the Keynesian fiscal multiplier. Wagner postulated that economic progress and the proportion of public sector are positively correlated, which results in higher public spending, the majority of which is funded by debt (Kobayashi, 2015). However, the Keynesian perspective on this positive association is

a combination of two: (a) massive levels of public debt stimulate high levels of productive public spending, which act as automatic economic stabilizers; and (b) government spending funded by deficits has a larger positive multiplier impact on the economy than spending funded by taxes (Holtfrerich, 2013). In this context, public debt has a positive effect on economic growth. When interest rates rise, full employment output falls, and unemployment is high, fiscal expansion increases long-term aggregate demand and is self-financed in a stagnant economy, according to DeLong et al. (2012). Pattillo et al. (2006) also suggest that domestic capital markets are strengthened by government borrowing from such markets, thereby stimulating total investment.

#### 1.4. Non-monotonic influence of public debt

Contrary to the points of view discussed above, others assert a non-monotonic (asymmetric or threshold) association between public debt and economic growth. Accordingly, public debt is thought to have a favorable influence on economic growth at lower levels and an unfavorable influence at greater levels (Eberhardt & Presbitero, 2015; Makun, 2021; Mupunga & Le Roux, 2015; Reinhart & Rogoff, 2010b). Krugman (1988) asserts that rising debt encourages growth because the crowding-in impact in government takes precedence over the crowding-out effect when it falls below a certain threshold. However, Krugman acknowledges that public debt will eventually have an unfavorable influence on growth since the crowding-out effect would outweigh the crowding-in effect. The crowding-out effect, according to Krugman, happens when government loans to cover fiscal deficits lower the quantity of lendable funds available to the private sector, which lowers total domestic investments.

Overall, our paper investigates the existence of the debt-GDP thresholds in both Egypt and Japan using time series data over 1974–2022 due to data constraints. The reason behind choosing both countries is that the former is a low-middle-income country with high inflation, externally constrained economy (Tanna et al., 2018), and weak institutions, while the latter is an advanced and industrialized economy with low inflation, reserve-currency environment, and robust and strong institutions. Such contrast highlights how dissimilarities in the economic structure of the two countries and the nation's ability to alleviate the deleterious effects of debt (if they exist) on growth and to sustain its debt can influence the estimate of the threshold effects. We found evidence for a statistically significant positive association between public debt proportioned to GDP and economic growth before crossing the estimated threshold at 72.77% for Egypt and 205.88% for Japan. Beyond the estimated threshold, public debt has harmful effects on economic growth, suggesting a non-monotonic and asymmetric association between the two main variables.

The remainder of this study is as follows: Section 2 presents the literature review. Section 3 exhibits data description, variables, and cointegration and nonlinearity tests. Section 4 illustrates the econometric model (logistic smooth transition regression, LSTR) conducted to estimate the public debt to GDP threshold. Section 5 discusses the findings. Finally, Section 6 concludes.

## 2. Literature review

Numerous scholars have conducted empirical studies on the effects of governmental debt. They employ a range of samples from high-income, low-income, and developing nations throughout various time periods, with mixed conclusions. While some research has revealed that public debt significantly affects economic growth, other studies have suggested that it actually boosts it. Others have discovered that public debt reduces rates of economic expansion. Finally, a growing body of empirical evidence indicates that public debt and economic progress have a nonlinear relationship. More specifically, in the context of the hypothesis of public debt neutrality, Kourtellos et al. (2013) highlighted the effect of public debt on the real GDP per capita growth rate for 82 advanced economies over 1980–2009. Their study reached the conclusion of a neutral relationship between debt and growth. Similarly, Panizza and Presbitero (2012) investigated the same nexus in some advanced OECD countries, and discovered the same finding. Also, Heimberger (2023) found that an increase in the public debt proportioned to GDP by 10 percentage point is associated with a 0.14 percentage point decrease in growth rates. Additionally, there is no consistent threshold for public debt beyond which growth declines, as estimates are influenced by data and econometric choices, indicating insufficient evidence for a consistently negative impact of public debt on growth. Finally, Schclarek (2004) analyzed the impact of public debt on GDP per capita growth in a sample of industrialized countries and developing countries over 1970–2002, reaching a conclusion of no relationship between both variables.

A substantial amount of empirical research supports the negative impact between the two variables (e.g., Ahlborn & Schweickert, 2018; Clements et al., 2003; Cochrane, 2011a, 2011b; Égert, 2015a; Gómez-Puig & Sosvilla-Rivero, 2015, 2018; Kumar & Woo, 2010; Panizza & Presbitero, 2013; Szabó, 2013). More specifically, Gómez-Puig and Sosvilla-Rivero (2018) looked at the relationship between GDP growth rates and public sector debt in the nations that make up the eurozone between 1961 and 2013. The findings exhibit that public debt has a detrimental effect on long-run economic growth. Ahlborn and Schweickert (2018) examined the same relationship for some OECD countries and developing nations between 1970 and 2010 and concluded that the relationship varies greatly between countries due to the degree of financial instability caused by each economic system. More idiosyncratically, public debt has a linearly unfavorable impact on the long-run growth in poorer, less developed nations, but it disappears or even turns positive in wealthier nations. On the other hand, they found a distinct negative growth effect of public debt for countries with continental economies (core EU members), which increases significantly as public debt levels rise beyond a threshold of 75% of GDP. For liberal Anglo-Saxon countries, no such effect was seen. Scandinavian nations are dealing with an additional, more pronouncedly non-linear association between public debt and economic development. According to their estimates, low levels of public debt have neutral economic impacts, but as debt approaches 60% of GDP, it starts to decline.

In order to determine if public debt has a negative nonlinear effect on growth if it surpasses 90% of GDP, Égert (2015a) tested a variant of the Reinhart and Rogoff (2010b) dataset. The estimation results are highly sensitive to assumptions about the minimum number of observations needed in each nonlinear regime, data frequency, and the time component and

country coverage considered. Debt and growth were discovered to be positively associated below the 90% debt threshold and negatively associated after surpassing it in a few instances when an adverse and asymmetric effect, like Reinhart and Rogoff, could be detected. The unfavorable impacts on growth begin at a low level of public debt proportioned to GDP (20–60%). This implies that low levels of public debt and infrastructure may present chances for high-return public investment. In order to determine the degree of debt sustainability, Oyadeyi et al. (2024) investigated the threshold effect of debt on economic development in Nigeria over 1981–2021. In this vein, they employed a threshold ARDL technique with two regimes. The results showed that 46.1% is the ideal level for total debt proportioned to GDP. They also indicated that economic growth is significantly enhanced by debt ratios below the threshold levels. However, Nigeria's economic growth is adversely and significantly impacted by debt ratios above the threshold levels. Furthermore, Albu and Albu (2021) used a wavelet approach to establish both short- and long-run linkages between the two variables in the Euro area. They argued that elevated levels of public debt raise questions about debt sustainability, having a detrimental effect on economic productivity. They ascertained that fiscal consolidation is a prerequisite to restore economic growth since high debt levels can have detrimental consequences on fiscal stability. To investigate the impact of institutional quality (IQ) on debt sustainability, Lee et al. (2023) used data for 82 countries of varying income levels, as classified by the World Bank. Their dynamic threshold panel regression revealed that IQ significantly influenced the fiscal reaction function, which encompasses debt sustainability and fiscal policy. In high-income and upper middle-income countries, fiscal adjustment declined once IQ surpasses a certain threshold. Conversely, in lower-middle- and low-income countries, enhancing IQ beyond the threshold can facilitate sustainable debt management.

In the same context, Greiner (2011) highlighted that in long-run growth rates are higher in countries where the government pursues a debt strategy that causes the public debt proportioned to GDP to asymptotically approach zero than in economies where the government runs deficits so that the ratio is positive. This result can be explained by the fact that, in comparison to the scenario where the public debt proportioned to GDP is zero, the return on physical capital is smaller when the public debt to GDP ratio is positive. Moreover, Le and Phan (2022) found that economic growth is influenced unfavorably by public debt in a panel of 201 countries over 1990–2020. Besides, they found evidence against threshold effects.

Contrarily, there are empirical studies that have found a positive impact of public debt on economic growth (e.g., Abbas & Christensen, 2010; Owusu-Nantwi & Erickson, 2016; Uzun et al., 2012). To evaluate the growth impact of domestic debt, Abbas and Christensen (2010) developed public domestic debt database spanning 93 emerging markets and low-income countries between 1975 and 2004. They found that moderate amounts of noninflationary domestic debt, as a percentage of GDP, are proven to have a positive impact on economic growth. Likewise, Owusu-Nantwi and Erickson (2016) examined the connection between Ghana's growth rate of real GDP and government debt from 1970 to 2012. The analysis discovered a significant long-term positive relationship between both variables.

In the context of detecting nonlinearities, a large body of empirical work supporting the nonlinear association between public debt and economic growth (e.g., Baum et al., 2013; Caner et al., 2010; Cecchetti et al., 2011; Checherita-Westphal & Rother, 2010; Herndon

et al., 2014; Kumar & Woo, 2010; Minea & Parent, 2012; Reinhart & Rogoff, 2010a, 2010b). More specifically, Baum et al. (2013) checked how public debt affected GDP growth rates in twelve European nations for the period over 1990 to 2010. According to their research, public debt has a short-term beneficial effect on real GDP growth. The relationship, however, diminished to about zero as the public debt proportioned to GDP gets closer to 67 per cent. They discovered that public debt had an adverse effect on real GDP growth rates when the debt proportioned to GDP exceeded 95 per cent. Minea and Parent (2012) analyzed the relationship between the two variables and revealed compelling evidence in favor of the threshold argument. They found that when the government debt proportioned to GDP fluctuates between 90% and 115%, a negative correlation between public debt and the real GDP growth rate exists. Caner et al. (2010) conducted an analysis for twenty-six developed and seventy-five developing countries over 1980–2008. They used Hansen's (1996, 2000) threshold methodology and found that the public debt/GDP threshold is 64% for emerging markets and 77% for developed countries.

Using data for 20 advanced economies over 1946–2009, Herndon et al. (2014) discovered that for nations with a ratio of more than 90% of governmental debt to GDP, the relationship between both variables tends to be more linear. Beyond this threshold, the public debt becomes detrimental to economic growth. Reinhart and Rogoff (2010b) found that low GDP growth rates in both developed and emerging nations are linked to high levels of debt proportioned to GDP, surpassing 90%, using a sample of forty-four countries (twenty advanced nations and twenty-four emerging economies) over two hundred years. The findings also imply that negative GDP growth rates in emerging economies are associated with lower public debt/GDP ratios, below 60%. Finally, in a panel of seventy-one developing nations, Law et al. (2021) examined the association between the two variables from 1980 to 2015. They discovered the presence of a threshold of debt proportioned to GDP at 51.65%, which is lower than that one exists in the literature.

The 2020 pandemic severely affected the global economy, leading to significant declines in GDP and increased public deficits. However, policy responses were swift, particularly in the Eurozone, unlike the delayed reaction during the 2008–2012 crisis. In this context, Della Posta et al. (2022) presented an analytical model examining the COVID-19 effects on public debt sustainability, focusing on the dynamics of the Italian public debt proportioned to GDP, which rose from 135% to 155%. The model suggested that economic policies can mitigate large shocks, emphasizing that fiscal policy coordination is crucial. The completion of the Eurozone construction and potential reforms to the Stability and Growth Pact are vital for bolstering economic conditions in the European Union (EU). The study also highlighted risks of rising inflation and stagnant GDP due to external factors, such as the Russia-Ukraine war, potentially leading Italy back to recessionary conditions similar to past economic crises.

Bernardo et al. (2024) analyzed the rise in indebtedness during the COVID-19 pandemic, particularly comparing developed countries and emerging markets and developing economies (EMDE). It emphasized the different impacts on debt dynamics, with EMDE facing increased external and public debt burdens, while developed economies largely saw an increase in public debt from fiscal support. The paper argued that the crisis has exacerbated the North-South economic divide, highlighting that EMDE, which were already heavily indebted,

lack the financial capacity to respond effectively to the pandemic's challenges. Suggested measures for alleviating debt vulnerability include both orthodox approaches, such as fiscal consolidation and wealth taxation, and heterodox policies like high inflation strategies and debt restructuring. In the same vein, Pratibha and Muniyoor (2025) analyzed India's increasing public debt post-COVID-19, highlighting concerns about debt sustainability and its effect on economic growth. Over the period from 1985 to 2023, they used the quadratic ARDL, and found that India has exceeded a critical debt threshold of 76.83%, influenced by heightened public spending during the pandemic. While rising public debt adversely impacted primary surplus, the role of IQ is pivotal in mitigating this effect and promoting economic growth.

Using a dataset of 14 OECD nations taken into consideration over the years 1981–2017, Ciaffi et al. (2024) tried to quantify the linear and non-linear effects of government spending on output and public debt sustainability using the Local Projections technique. They demonstrated that government spending multipliers in linear models are near to one and that expansionary fiscal policy stimulates lowering the public debt/GDP ratio by using the Blanchard and Perotti technique to find fiscal policy shocks. A fiscal policy shock caused bigger multipliers and a stronger decrease in the public debt-to-GDP ratio in economic phases characterized by a high rather than a low debt-to-GDP ratio, according to results when non-linearities are considered. The combined consequences of the COVID-19 epidemic and the situation in Ukraine were the main subject of El-Naser et al.'s (2025) study, which examined the factors influencing public debt sustainability in EU member states. To address the endogeneity and heterogeneity aspects, they used the Generalized Method of Moments (GMM) for the 2000–2022 period. The results proved the long-term persistence of delayed debt's substantial beneficial influence on current state debt. Rising state debt is mostly caused by economic downturns, military spending, and private debt, particularly in times of geopolitical unrest and economic instability. The study also emphasized how government spending, inflation, and GDP per capita affect fiscal stability, shedding new light on how crucial it is to manage public debt, especially in times of crisis by implementing long-term fiscal restraint and countercyclical strategies.

### 3. Data description and the variables

Our study utilizes time series data for Egypt and Japan over 1974–2022. We incorporate the real GDP growth rate as a proxy for economic growth (at the 2015 constant prices), as the dependent variable, *GDP\_GR*. The public debt proportioned to GDP, *DEBT\_GDP*, is a regressor. Their data are extracted from the World Development Indicators (WDI) database of the World Bank. To control for misspecification, other variables that influence the relationship between public debt to GDP and economic growth have been included. The selection of control variables is influenced by different debt-growth empirical literature of Law et al. (2021), Okwoche and Nikolaidou (2022), Osińska et al. (2020), and Oyadeyi et al. (2024), inter alia, along with what the debt-growth literature suggests and uses (as reviewed earlier). As long as these factors are correlated with the dependent variable, including them in the model strengthens the association between public debt and economic growth (Fischer, 1993). Some other relevant control variables, such as labor market dynamics, global financial conditions, supply chain

disruptions, and productivity shocks, have been excluded from our model due to relatively small sample size and small degrees of freedom. Such exclusion could affect our estimates for the debt-to-GDP threshold or make the smooth transition function flat, depending on the relativeness of the excluded variables to debt dynamics.

Correspondingly, we utilize a set of the following variables. For Egypt, these variables are: Final government consumption expenditure (% of GDP), *GCONS\_GDP*, which is also referred to as “general government consumption” and comprises all current government spending on the acquisition of goods and services (including remuneration of employees). Most of the spending on national security and defense is also incorporated, although government military spending is not included in capital creation. Domestic credit to private sector proportioned to GDP, *CREDIT*, which refers to the financial resources that financial institutions provide to the private sector in the form of trade credits, loans, acquisitions of non-equity securities, and other accounts receivable. Current account balance proportioned to GDP, *CUR\_GDP*. Such a balance consists of net exports of tangible and intangible items, as well as net primary and net secondary income. Gross fixed formation (% of GDP), *GCF\_GDP*, as a proxy for investment spending. Interest payments paid on sovereign debt (% of government revenues), *INT\_REV*. These variables are obtained from the WDI database. Real effective exchange rate, *REER*, which gauges how a nation’s actual currency value has changed in relation to its trading partners’ basket. REER is sourced from Brussels European and Global Economic Laboratory (Bruegel) database<sup>1</sup>.

For Japan, control variables consist of *GCONS\_GDP*, *CREDIT*, *INT\_REV*, and *REV\_GDP*. The latter variable denotes the government revenues (% of GDP). It includes cash collected through social contributions, taxes, and other sources, such as fees, fines, rent, and earnings from sales or property profits. Accordingly, the debt-GDP threshold model in Egypt and Japan could be specified, respectively, as follows

$$GDP\_GR_t = \beta_0 + \beta_1 \Delta DEBT\_GDP_t + \beta_2 GCONS\_GDP_t + \beta_3 \Delta CREDIT_t + \beta_4 \Delta CUR\_GDP_t + \beta_5 \Delta GCF\_GDP_t + \beta_6 \Delta INT\_REV_t + \beta_7 \Delta REER_t + \varepsilon_t \quad (1)$$

$$GDP\_GR_t = \beta_0 + \beta_1 \Delta DEBT\_GDP_t + \beta_2 \Delta GCONS\_GDP_t + \beta_3 \Delta CREDIT_t + \beta_4 \Delta INT\_REV_t + \beta_5 \Delta REV\_GDP_t + \varepsilon_t \quad (2)$$

where  $\Delta$  indicates the operator of the first difference. The parameter  $\beta_1$ , in Eq. (1) and Eq. (2), expresses the symmetric influence of public debt proportioned to GDP on economic growth. In the context of the smooth transition regression (STR) model, this impact will be divided into two main regimes. Parameters  $\beta_2 : \beta_7$  in Eq. (1) and  $\beta_2 : \beta_5$  in Eq. (2) signify the impact of control variables for Egypt and Japan, respectively.  $\beta_0$  denotes the constant term and  $\varepsilon_t$  refers to the stochastic error term, which is supposed to be normally distributed,  $N(0, \sigma_\varepsilon^2)$ . The STR method is employed to empirically estimate Egypt’s and Japan’s public debt thresholds (i.e., the possible asymmetric association between public debt proportioned to GDP and growth) over the study period. Prior research examining both countries to investigate this association has never employed this method.

<sup>1</sup> Bruegel database could be visited at <https://www.bruegel.org/>.

### 3.1. Descriptive statistics

Tables 1 and 2 show no serious multicollinearity among the explanatory variables in both countries as the variance inflation factor (VIF) is lower than five or ten and the correlation coefficient is below 0.8 (Kennedy, 2008, p. 199; Marcoulides & Raykov, 2019; Wooldridge, 2020, p. 92). Accordingly, those variables could be easily entered into the analysis with no caveats.

The descriptive statistics for both countries, highlighted in Tables 3 and 4, show that in both nations,  $\Delta$  DEBT\_GDP series has a comparatively high standard deviation (Std. Dev.). Conversely, economic growth exhibits very minimal volatility. Moreover, the two major variables' values have a rather wide dispersion, as seen by the maximum and minimum values.

**Table 1.** Egypt's correlations matrix

| Series                | VIF  | (1)     | (2)     | (3)     | (4)     | (5)     | (6)    | (7)     | (8)    |
|-----------------------|------|---------|---------|---------|---------|---------|--------|---------|--------|
| (1) GDP_GR            |      | 1.0000  |         |         |         |         |        |         |        |
| (2) $\Delta$ DEBT_GDP | 1.97 | -0.1045 | 1.0000  |         |         |         |        |         |        |
| (3) GCONS_GDP         | 1.40 | 0.6343  | 0.2747  | 1.0000  |         |         |        |         |        |
| (4) $\Delta$ CREDIT   | 1.22 | 0.0702  | -0.0055 | 0.1290  | 1.0000  |         |        |         |        |
| (5) $\Delta$ CUR_GDP  | 1.88 | -0.0505 | 0.0551  | -0.0483 | -0.3868 | 1.0000  |        |         |        |
| (6) $\Delta$ GCF_GDP  | 1.43 | 0.1646  | 0.0388  | 0.2576  | 0.2874  | -0.4372 | 1.0000 |         |        |
| (7) $\Delta$ INT_REV  | 1.10 | -0.3070 | 0.1420  | -0.1835 | -0.0910 | 0.0686  | 0.0078 | 1.0000  |        |
| (8) $\Delta$ REER     | 2.21 | 0.2678  | -0.5731 | 0.0619  | 0.10794 | -0.4187 | 0.0599 | -0.1404 | 1.0000 |

**Table 2.** Japan's correlation matrix

| Series                 | VIF  | (1)     | (2)    | (3)     | (4)     | (5)    | (6)    |
|------------------------|------|---------|--------|---------|---------|--------|--------|
| (1) GDP_GR             |      | 1.0000  |        |         |         |        |        |
| (2) $\Delta$ DEBT_GDP  | 1.77 | -0.6278 | 1.0000 |         |         |        |        |
| (3) $\Delta$ GCONS_GDP | 1.83 | -0.6964 | 0.6393 | 1.0000  |         |        |        |
| (4) $\Delta$ CREDIT    | 1.17 | -0.0533 | 0.0203 | 0.0175  | 1.0000  |        |        |
| (5) INT_REV            | 1.29 | -0.1925 | 0.0109 | -0.1155 | 0.1013  | 1.0000 |        |
| (6) $\Delta$ REV_GDP   | 1.56 | -0.6925 | 0.3321 | 0.3033  | -0.2660 | 0.3474 | 1.0000 |

**Table 3.** Egypt's descriptive statistics

| Series    | GDP_GR | $\Delta$ DEBT_GDP | GCONS_GDP | $\Delta$ CREDIT | $\Delta$ CUR_GDP | $\Delta$ GCF_GDP | $\Delta$ INT_REV | $\Delta$ REER |
|-----------|--------|-------------------|-----------|-----------------|------------------|------------------|------------------|---------------|
| Mean      | 5.2851 | 0.7523            | 12.9797   | 0.3673          | 0.0347           | -0.0389          | 0.9987           | -0.754        |
| Median    | 4.920  | -0.220            | 11.450    | 0.0450          | -0.3009          | -0.2706          | 1.0209           | 7.500         |
| Max.      | 13.28  | 35.480            | 25.33     | 11.960          | 8.7057           | 7.0974           | 6.7551           | 35.110        |
| Min.      | 1.130  | -20.400           | 7.270     | -7.060          | -7.6303          | -5.1811          | -4.247           | -110.3        |
| Std. Dev. | 2.4642 | 10.499            | 4.1232    | 3.5860          | 2.8442           | 2.8058           | 2.2515           | 28.542        |
| Skewness  | 0.9211 | 0.9443            | 1.4072    | 0.6363          | 0.4250           | 0.4610           | 0.1153           | -2.105        |
| Kurtosis  | 4.0428 | 4.6269            | 4.9735    | 4.2511          | 4.6620           | 3.2076           | 3.1798           | 7.6688        |
| J-B       | 9.1484 | 12.427            | 24.122    | 6.3696          | 6.9691           | 1.7865           | 0.1711           | 79.042        |
| Prob.     | 0.0103 | 0.0020            | 0.0000    | 0.041           | 0.0307           | 0.4093           | 0.9180           | 6.8574        |
| Obs.      | 49     | 48                | 49        | 48              | 48               | 48               | 48               | 48            |

*Note:* Min. and Max. signify the minimum and the maximum value, respectively. J-B refers to the Jarque-Bera test statistics for normality and Obs. denotes number of observations.

**Table 4.** Japan's descriptive statistics

| Series    | GDP_GR  | $\Delta$ DEBT_GDP | $\Delta$ GCONS_GDP | $\Delta$ CREDIT | INT_REV | $\Delta$ REV_GDP |
|-----------|---------|-------------------|--------------------|-----------------|---------|------------------|
| Mean      | 2.0075  | 5.0950            | 0.1723             | 1.5625          | 29.6963 | -0.5235          |
| Median    | 1.9050  | 5.0699            | 0.0700             | 1.3249          | 29.7755 | 0.0804           |
| Max.      | 6.660   | 22.280            | 1.350              | 18.130          | 30.2022 | 0.0804           |
| Min.      | -5.690  | -6.2399           | -0.3899            | -28.620         | 27.7855 | -1.5300          |
| Std. Dev. | 2.4125  | 5.4732            | 0.3859             | 6.9154          | 0.5038  | 0.7879           |
| Skewness  | -0.7478 | 0.5082            | 1.2357             | -1.3116         | -2.1198 | -0.5164          |
| Kurtosis  | 4.1620  | 4.2644            | 4.5735             | 9.5001          | 7.3912  | 1.2667           |
| J-B       | 7.1753  | 5.2641            | 17.1675            | 98.267          | 74.5153 | 8.1422           |
| Prob.     | 0.0277  | 0.0719            | 0.0002             | 0.0000          | 0.0000  | 0.0171           |
| Obs.      | 48      | 48                | 48                 | 48              | 48      | 48               |

Note: Same notes apply as in Table 5.

Except for  $\Delta$  INT\_REV and  $\Delta$  REER for Egypt and except INT\_REV and  $\Delta$  REV\_GDP for Japan, the mean is higher than the median for every variable. This suggests a positive skewness in the data distribution, i.e., asymmetrical distribution. However, normality of the residuals is what matters most, rather than the normality of each variable independently.

### 3.2. Testing of stationarity

Granger and Newbold (1974) and Phillips (1988) argue that the variables must be stationary to prevent spurious regressions and correlations. The specification of STR technique requires all variables to be integrated of order zero,  $I(0)$ , i.e., stationary at level (Dimitraki & Emmanouilidis, 2024). That is, variables should not be nonstationary in any way. Such non-stationarity could be triggered by the existence of, for instance, autoregressive unit roots, deterministic trends, or unconditional heteroskedasticity. Otherwise, the first-difference can be used to transform nonstationary variables to be stationary (Creamer & Botha, 2017; Mátyás et al., 1999; Ogaki, 1993). Conventional unit root tests, such as Dickey and Fuller (1981), Phillips and Perron (1988), and KPSS test of Kwiatkowski et al. (1992) are typically used (without considering structural breaks)<sup>2</sup>. All conventional stationarity tests have minimal power and can yield biased and inaccurate conclusions on the stationarity of time series if structural breaks occur during the DGP, generating erroneous estimations and spurious cointegration. Furthermore, these tests are significantly impacted by small sample size distortions (Choi, 2015, pp. 28–29; Culver & Papell, 1997; Montañés et al., 2005; Ng & Perron, 2001; Schwert, 1989). Taylor et al. (2001) claimed that the conventional unit root test's potency versus nonlinear unit root tests can be quite low.

#### 3.2.1. Kapetanios test

Taking structural breaks into account while checking for the existence of unit roots, we employ the methodology of Kapetanios (2005) that checks stationarity of the trend and/or intercept with up to 5 endogenously selected structural breaks. Kapetanios (2005) claimed

<sup>2</sup> To preserve space, the authors have excluded the results of traditional unit root tests; however, they are available upon demand.

that the test's potency drops as the number of breaks rises. Accordingly, we permit only two structural fractures because of our small sample size. This test is expressed as follows

$$y_t = \alpha_0 + \alpha_1 t + \rho y_{t-1} + \sum_{i=1}^p \lambda_i \Delta y_{t-i} + \sum_{i=1}^s \phi_i DU_{i,t} + \sum_{i=1}^s \gamma_i DT_{i,t} + \varepsilon_t, \quad (3)$$

where  $\alpha_0$  and  $\alpha_1$  are the constant term and trend, respectively;  $\rho$  refers to the autoregressive term's parameter of order one;  $DT_{i,t}$  is the time trend's break dummy, whereas  $DU_{i,t}$  denotes to the break constant term's break dummy.  $H_0$  signifies non-stationarity with  $s$  structural breaks.

For Egypt and Japan, respectively, Tables 5 and 6 reveal that *DEBT\_GDP* is nonstationary at its level,  $I(1)$ , with two structural breaks at the significance level of 5%. The non-rejection of the unit root in both the Egyptian and Japanese debt-GDP ratio is consistent with empirical studies, e.g., Bohn (1998) for the United States data and Corsetti and Roubini (1991) for international evidence. Economic growth, *GDP\_GR*, is stationary in both countries at level,  $I(0)$ . Other variables are a mix of both  $I(0)$  and  $I(1)$ . Nonstationary variables are included in our STR regression analysis after taking the first difference.

**Table 5.** Kapetanios test for Egypt

| Variables | Test Stat. |                            | C or T * | I (d) | Result | Break dates     |                 |
|-----------|------------|----------------------------|----------|-------|--------|-----------------|-----------------|
|           | Level      | 1 <sup>st</sup> difference |          |       |        | 1 <sup>st</sup> | 2 <sup>nd</sup> |
| GDP_GR    | -6.3565**  | -6.8012**                  | C , T    | I (0) | Yes    | 1985            | 2010            |
| DEBT_GDP  | -4.6587    | -5.4596**                  | C , C    | I (1) | No     | 1982            | 2012            |
| GCONS_GDP | -5.4031**  | -6.1679**                  | C , C    | I (0) | Yes    | 1992            | 2013            |
| CREDIT    | -1.2992    | -6.9960**                  | C , C    | I (1) | No     | 1999            | 2009            |
| CUR_GDP   | -4.3893    | -6.3566**                  | C , C    | I (1) | No     | 1982            | 1991            |
| GCF_GDP   | 5.8944     | -8.6331**                  | C , T    | I (1) | No     | 1990            | 2010            |
| INT_REV   | -4.8332    | -6.7990**                  | C , C    | I (1) | No     | 1996            | 2008            |
| REER      | -4.5195    | -5.4909**                  | C , C    | I (1) | No     | 1986            | 2006            |

Notes:

- \*\*refers to significance at the 5%. Critical values for the intercept (C) and time trend (T) at 5% are -5.096 and -6.113, respectively, and are obtained from Kapetanios (2005, Table 1).
- We employ the modified Akaike information criterion to determine the lags number. According to  $l = \{4(7/100)^{1/4}\}$ , the maximum lags number is ascertained using Schwert's (1989) criterion.
- \*The significance of C and T, for both levels and first differences, are indicated by the letter that is arranged first in the notation (C , T).
- Yes signifies stationary variables at the significance level of 5%. No denotes nonstationary variables that required to be first-differenced. I (d) signifies the order of integration.

### 3.3. Cointegration test "Bounds test"

Numerous cointegration methods scrutinize the association among economic variables in the long run, such as Engle and Granger (1987), Johansen (1991, 1995), and Phillips and Ouliaris (1990). All these methods need the corresponding variables to be  $I(1)$ . Nevertheless, these restrictions do not apply to the bounds cointegration test that developed by Pesaran et al. (2001) and Pesaran and Shin (1997). As can be seen from Tables 5 and 6, our dataset consists of variables that are stationary at level,  $I(0)$ , and others stationary at the first difference,  $I(1)$ . Accordingly, the bounds test is the suitable cointegration test to fit these variables.

**Table 6.** Kapetanios test for Japan

| Variables | Test Stat. |                            | C or T <sup>+</sup> | I (d) | Result | Break dates     |                 |
|-----------|------------|----------------------------|---------------------|-------|--------|-----------------|-----------------|
|           | Level      | 1 <sup>st</sup> difference |                     |       |        | 1 <sup>st</sup> | 2 <sup>nd</sup> |
| GDP_GR    | −6.5162**  | −8.3648**                  | C , T               | I (0) | Yes    | 1991            | 2011            |
| DEBT_GDP  | −3.7233    | −5.7967**                  | C , C               | I (1) | No     | 1989            | 2011            |
| GCONS_GDP | −4.8509    | −7.0003**                  | C , T               | I (1) | No     | 1989            | 2009            |
| CREDIT    | 0.3871     | −5.8356**                  | C , C               | I (1) | No     | 1987            | 2003            |
| INT_REV   | −6.7073**  | −7.7455**                  | C , C               | I (0) | Yes    | 1983            | 1997            |
| REV_GDP   | −3.7201    | −7.5358**                  | C , C               | I (1) | No     | 1992            | 2002            |

Note: Same notes apply as in Table 5.

**Table 7.** The bounds testing for Egypt

| Test Stat.                                         | Signif.                                 | I (0) | I (1) |
|----------------------------------------------------|-----------------------------------------|-------|-------|
| Overall <i>F</i> -bounds test                      | Narayan's (2005) critical values        |       |       |
| <i>F</i> -Stat. = 16.1562***                       | 10%                                     | 2.21  | 3.42  |
| <i>K</i> = 7, <i>n</i> = 50                        | 5%                                      | 2.59  | 3.94  |
|                                                    | 1%                                      | 3.49  | 5.15  |
| <i>F</i> -Bounds test of the independent variables | Sam et al.'s (2019) critical values     |       |       |
| Wald <i>F</i> -Stat. = 13.8004***                  | 10%                                     | 1.86  | 3.34  |
| <i>n</i> = 50                                      | 5%                                      | 2.24  | 3.93  |
|                                                    | 1%                                      | 3.08  | 5.20  |
| <i>t</i> -Bounds test of the dependent variable    | Pesaran et al.'s (2001) critical values |       |       |
| <i>t</i> -Stat. = −9.5983***                       | 10%                                     | −2.57 | −4.23 |
|                                                    | 5%                                      | −2.86 | −4.57 |
|                                                    | 1%                                      | −3.43 | −5.19 |

Note: \*\*\* refers to the 1% significance level. *K* denotes the number of regressors under Case 3 of unrestricted intercept and no trend. According to Schwarz Bayesian information criterion (SBIC) of Schwarz (1978), the number of lags equals only one for Egypt.

**Table 8.** The bounds testing for Japan

| Test Stat.                                         | Signif.                                 | I (0) | I (1) |
|----------------------------------------------------|-----------------------------------------|-------|-------|
| Overall <i>F</i> -bounds test                      | Narayan's (2005) critical values        |       |       |
| <i>F</i> -Stat. = 9.0517***                        | 10%                                     | 2.31  | 3.51  |
| <i>K</i> = 6, <i>n</i> = 50                        | 5%                                      | 2.73  | 4.06  |
|                                                    | 1%                                      | 3.66  | 5.33  |
| <i>F</i> -Bounds test of the independent variables | Sam et al.'s (2019) critical values     |       |       |
| Wald <i>F</i> -Stat. = 18.579***                   | 10%                                     | 1.90  | 3.42  |
| <i>n</i> = 50                                      | 5%                                      | 2.32  | 4.03  |
|                                                    | 1%                                      | 3.31  | 5.46  |
| <i>t</i> -Bounds test of the dependent variable    | Pesaran et al.'s (2001) critical values |       |       |
| <i>t</i> -Stat. = −6.8275***                       | 10%                                     | −2.57 | −4.04 |
|                                                    | 5%                                      | −2.86 | −4.38 |
|                                                    | 1%                                      | −3.43 | −4.99 |

Note: Same notes apply as in Table 7. According to SBIC, the number of lags equals only one for Japan.

The bounds test presents three tests to give a complete picture of the cointegration or the long run relationship among the variables. Pesaran et al. (2001) present two groups of asymptotic critical values; that is, variables that are stationary at level and at the first difference, which are dedicated to testing the significance of the  $t$ -bounds test of the regressand. Since the  $t$ -statistic exceeds the critical values' upper bound, Table 7 for Egypt and Table 8 for Japan reveal a cointegration association at all levels of significance. The Wald  $F$ -bounds test's asymptotic critical values for checking the significance of the regressors are generated by Sam et al. (2019). Referring to Tables 7 and 8, the Wald  $F$ -statistic is greater than the critical values' upper bound at all significance levels, rejecting the null hypothesis of no cointegration. Finally, for small-sample size (between 30 to 80 observations), Narayan (2005) provided asymptotic critical values to test the significance of the whole model. According to both Tables 7 and 8, a cointegration association exists among the model's variables since the overall  $F$ -statistic exceeds the critical values' upper bound.

### 3.4. BDS test

Prior to estimating the STR model, we need to investigate the linear/nonlinear process of the threshold variable (i.e., DEBT\_GDP). To do so, the BDS test, developed by Broock et al. (1996), is utilized, with  $H_0$  of symmetric independence, implying that the data generating process for DEBT\_GDP is identically and independently distributed, whereas  $H_1$  indicates that DEBT\_GDP is asymmetric. The results, presented in Table 9 for Egypt and Table 10 for Japan, reject  $H_0$  as both bootstrapped and asymptotic  $p$ -values are lower than the significance level of 5%. Consequently, DEBT\_GDP has an asymmetric process and can be estimated with the STR approach with no caution.

**Table 9.** BDS test for Egypt

| $m$ | z-Stat. | $p$ -Value |              |
|-----|---------|------------|--------------|
|     |         | Asymptotic | Bootstrapped |
| 2   | 13.1920 | 0.000***   | 0.000***     |
| 3   | 12.8372 | 0.000***   | 0.000***     |
| 4   | 12.0840 | 0.000***   | 0.000***     |

*Note:* \*\*\* refers to the 1% significance level.  $m$  denotes the number of embedded dimensions. Because our sample is small, we restrict  $m$  to four.

**Table 10.** BDS test for Japan

| $m$ | z-Stat. | $p$ -Value |              |
|-----|---------|------------|--------------|
|     |         | Asymptotic | Bootstrapped |
| 2   | 29.0075 | 0.000***   | 0.000***     |
| 3   | 30.0744 | 0.000***   | 0.000***     |
| 4   | 31.7560 | 0.000***   | 0.000***     |

*Note:* Same notes apply as in Table 9.

## 4. LSTR Approach

Parameter instability occurs when the estimated parameters' statistical characteristics change over time or between different data subsamples. Changes in the regimes that govern policy, changes in the underpinning economic structure, changes in the measurement errors or quality of the data, or changes in the actions of economic agents are among many causes of parameter instability. It could impact the validity and dependability of empirical results significantly, as well as the forecasts precision and recommendations for decision-makers<sup>3</sup>. This issue can be solved in several ways, such as regime-dependent or regime-switching models and time-dependent parameter models. Chan et al. (2017) claim that these models perform well and can generate more precise probability estimates for key macroeconomic indicators.

LSTR, Markov switching regression (MSR), and threshold regression (TR) are examples of asymmetric models. There are several important conceptual distinctions between these models, despite the fact that their design permits the empirical observation of discrete, nonlinear effects. Compared to TR and LSTR, MSR uses less prior information. A smoothed regime probability in an MSR model can be thought of as a flexible transition function derived from the data. To put it another way, MSR models depend on the unobserved or latent state process that causes the nonlinear dynamics (regime flipping). However, in TR or LSTR models, choosing a transition variable is necessary when defining the transition function. In contrast to other nonlinear models like MSR, LSTR models usually assume that the number and values of the thresholds are unknown and permit the asymmetric effect to be triggered by observed variables (Chan et al., 2017; Deschamps, 2008).

One of the main limitations in LSTR models is that they assume continuous and smooth, not abrupt, adjustments between low and high regimes. Abrupt adjustments prevail at times of crises such as substantial policy shifts, sovereign defaults, capital flight, inflationary shocks, pandemics, and last but not least, geopolitical tensions that usually escalate in the Middle East, threatening Egypt and in the South China sea, threatening Japan. In other nonlinear models, the regime change may occur abruptly or discontinuously. Instead, the LSTR model makes sense to presume that the regime changes without incident but gradually (Zivot & Wang, 2005, ch. 18). According to Potter (1999), abrupt regime changes are thought to be impractical or unrealistic since the majority of economic variables require time to transition between regimes. Consequently, the STR model has been conducted to investigate the association between public debt and economic growth in both economies over the study period. STR models are more realistic, allowing to estimate the optimal debt/GDP ratio endogenously, defined as a gradual transition between several regimes (Phiri, 2020; Zhang, 2017). Such an estimation technique is proposed and modified by Granger and Teräsvirta (1993), Teräsvirta (1994), Lundbergh et al. (2003), Gonzalez et al. (2005), and Fok et al. (2005). The fundamental formula for the STR models, which have a sole transition function with two extreme regimes, can be represented as follows:

<sup>3</sup> See, for example, Bai and Perron (1998), Phillips and Hansen (1990), and Zivot and Andrews (1992) for additional details on parameter instability.

$$y_t = \beta_0 DEBT\_GDP_t + \beta_1 DEBT\_GDP_t \Psi(q_t; \gamma, c) + \delta_0 z_t + \varepsilon_t, \quad t = 1, \dots, T, \quad (4)$$

where  $y_t$  is the regressand (i.e., economic growth);  $DEBT\_GDP$  denotes the threshold variable (i.e., the public debt proportioned to GDP);  $z$  signifies control variables that govern the debt-growth association.  $\beta_0$  and  $\beta_1$  are parameters vectors express the symmetric and asymmetric components, respectively.  $\varepsilon_t$  refers to the stochastic error term. The relationship becomes symmetric if  $\beta_0 = \beta_1$ ; otherwise, it is asymmetric.

The formula represented in Eq. (4) describes a continuous and bounded function between 0 and 1. Furthermore, it depends on two things: (1) the threshold parameter ( $c$ ) which exists in the middle of the transition from the low to the high regime; and (2) the continuous transition or threshold variable ( $q$ ).  $\gamma$  denotes the slope of the transition function and describes the rate at which one regime transitions into another. Following Granger and Teräsvirta (1993), Lundbergh et al. (2003), and Gonzalez et al. (2005), our debt-growth LSTR function is of the following form

$$\Psi(q_t; \gamma, c) = \left[ 1 + \exp \left( -\gamma \prod_{j=1}^m (q_t - c_j) \right) \right]^{-1}, \quad (5)$$

where  $\gamma$  denotes a positive slope, and  $c_1 \leq c_2 \leq \dots \leq c_m$ . As discussed later, the remaining non-linearity test reveal that our analysis should be restricted to only one threshold (i.e.,  $m = 1$ ). In other words, the STR is logistic, i.e., LSTR(1). Higher values of  $\gamma$  are associated with rougher transition and thus,  $\Psi(q_t; \gamma, c)$  moves closer to the indicator function. Conversely, when  $\gamma$  is close to zero, the LSTR model has a single regime. Lastly, the two extreme regimes are represented by high and low values of  $q$ .

## 5. Results discussion

LSTR findings of the debt-GDP ratio threshold are shown in Tables 11 and 12 for Egypt and Japan, respectively. More specifically, Table 11 reveals that, before approaching the estimated threshold of public debt proportioned to GDP ( $\hat{c} = 72.77\%$ ), there is a statistically positive and significant association between public debt proportioned to GDP and economic growth in the Egyptian economy at the 5 percent level of significance (0.0509;  $p$ -value < 0.02). More indicatively, an increase in debt to GDP ratio of 1 percent stimulates GDP growth by about 0.051 percent. Put differently, in the lower regime (if public debt-GDP ratio is less than 72.77%), debt significantly contributes to Egypt's GDP growth rate. For Japan, Table 12 shows that, before approaching the threshold estimated at 205.88%, GDP growth in Japan is affected positively and significantly by public debt to GDP ratio at the 1 percent level of significance (0.0208;  $p$ -value < 0.000). In other words, in the lower regime (if  $DEBT\_GDP$  is less than 205.88%), debt significantly contributes to Japan's GDP growth rate.

The positive association between public debt proportioned to GDP and economic growth in the lower regime in both economies is consistent with Wagner's law of rising public expenditure and the effect of Keynes's fiscal multiplier. Such a positive association is credited to the fact that most of the increased public spending is financed by debt. This spending is triggered by the increasing share of the public sector, which is required for enhancing the level of development. Furthermore, the economy is automatically stabilized by considerable amounts of productive public spending, which are stimulated by large public debt.

Additionally, compared to tax-financed government spending, spending financed by the deficit has a stronger positive multiplier impact on the economy, as argued by the Keynesians. Such a positive relationship is also supported by previous studies, like DeLong et al. (2012), Abbas and Christensen (2010), Owusu-Nantwi and Erickson (2016), Uzun et al. (2012), and Abbas and Christensen (2010). Beyond the estimated threshold, Table 11 shows that public debt has a deleterious impact on economic growth in Egypt ( $-0.0330$ ;  $p$ -value  $< 0.0175$ ), suggesting an asymmetric (nonlinear) association between the two variables. That is, an increase in the debt/GDP ratio of 1 percent, after surpassing the estimated threshold of approximately 72.77 percent, is significantly associated with a decline in GDP growth of about 0.03 percent.

**Table 11.** LSTR estimates for Egypt

| Regressand: Economic growth ( <i>GDP_GR</i> ) |                 |                |                     |                 |
|-----------------------------------------------|-----------------|----------------|---------------------|-----------------|
| Regressors                                    | Coefficient     | Standard error | <i>t</i> -Statistic | <i>p</i> -Value |
| <i>Lower Regime</i>                           |                 |                |                     |                 |
| DEBT_GDP ( <i>L</i> )                         | 0.0509          | 0.0210         | 2.4218              | 0.0205**        |
| <i>Higher Regime</i>                          |                 |                |                     |                 |
| DEBT_GDP ( <i>H</i> )                         | −0.0330         | 0.0132         | −2.4879             | 0.0175**        |
| <i>Transition Parameters</i>                  |                 |                |                     |                 |
| Threshold ( $\hat{c}$ )                       | 72.77           | 5.7393         | 12.678              | 0.0000***       |
| Slope ( $\hat{\gamma}$ )                      | 14.09           |                |                     |                 |
| <i>Non-Varying Regressors</i>                 |                 |                |                     |                 |
| GCONS_GDP                                     | −1.8178         | 0.2371         | −7.668              | 0.0000***       |
| $\Delta$ CREDIT                               | 0.2312          | 0.0770         | 3.0012              | 0.0048***       |
| $\Delta$ CUR_GDP                              | 0.1825          | 0.1587         | 1.1501              | 0.2575          |
| $\Delta$ GCF_GDP                              | 0.1047          | 0.0776         | 1.3494              | 0.1854          |
| $\Delta$ INT_REV                              | −0.3987         | 0.1091         | −3.652              | 0.0008***       |
| $\Delta$ REER                                 | 0.0344          | 0.0095         | 3.6298              | 0.0009***       |
| Constant                                      | 3.0194          | 1.2236         | 2.4676              | 0.0184**        |
| <i>Diagnostic Tests</i>                       |                 |                |                     |                 |
| Adjusted $R^2$                                | 0.5959          |                |                     |                 |
| SSR                                           | 112.07          |                |                     |                 |
| LM test                                       | 1.7844 [0.4098] |                |                     |                 |
| BPG test                                      | 6.3654 [0.4978] |                |                     |                 |
| JB test                                       | 1.9074 [0.3853] |                |                     |                 |
| Remaining nonlinearity test                   | 0.8522 [0.3631] |                |                     |                 |
| Parameter constancy test                      | 0.3763 [0.9228] |                |                     |                 |

**Notes:**

- \*, \*\* and \*\*\* refer to the 10, 5 and 1% levels of significance, respectively. In square brackets, *p*-values are reported.
- Non-parametric HAC estimator is used to remedy heteroscedasticity and autocorrelation.
- JB signifies Jarque–Bera test, LM test refers to Breusch–Godfrey autocorrelation test, while BPG denotes Breusch–Pagan–Godfrey heteroskedasticity test. SSR refers to sum of squared residuals.

For the Japanese economy, Table 12 highlights that economic growth deteriorates as public debt proportioned to GDP surpasses the estimated threshold ( $-0.0115$ ;  $p$ -value  $< 0.0013$ ), suggesting an asymmetric association between the two variables. That is, an increase in debt-GDP ratio of 1 percent, after crossing the estimated threshold of approximately 205.88 percent, is significantly associated with a decline in economic growth of about 0.01 percent. In this context, Égert (2015b) ascertains that among some OECD economies, Japan has a positive relationship between both variables in the high regime, despite the existence of nonlinearity. Accordingly, if both countries have a plan to receive help from the government borrowing, they should keep their public debt proportioned to GDP below the estimated threshold.

The apparent differences between both estimated thresholds in Egypt and Japan could be attributed to differences in the economic structure of the two countries, inflation stability, financial market sophistication, and the country's ability to mitigate and contain the deleterious effects of debt (if they exist) on economic growth and sustain its debt. That is, compared to the Egyptian economy, the Japanese economy is more efficient and more powerful in managing its public debt to foster its economic growth, and more able to benefit from government borrowing, especially from the Bank of Japan, with relatively low interest rates in a more sustained way.

**Table 12.** LSTR estimates for Japan

| Regressand: Economic growth ( $GDP\_GR$ ) |                 |                |             |           |
|-------------------------------------------|-----------------|----------------|-------------|-----------|
| Regressors                                | Coefficient     | Standard error | t-Statistic | p-Value   |
| <i>Lower Regime</i>                       |                 |                |             |           |
| DEBT_GDP (L)                              | 0.0208          | 0.0058         | 3.5831      | 0.0009*** |
| <i>Higher Regime</i>                      |                 |                |             |           |
| DEBT_GDP (H)                              | $-0.0115$       | 0.0033         | $-3.4701$   | 0.0013*** |
| <i>Transition Parameters</i>              |                 |                |             |           |
| Threshold ( $\hat{c}$ )                   | 205.88          | 1.9102         | 107.779     | 0.0000*** |
| Slope ( $\hat{\gamma}$ )                  | 52.70           |                |             |           |
| <i>Non-Varying Regressors</i>             |                 |                |             |           |
| $\Delta$ GCONS_GDP                        | $-2.9859$       | 0.6434         | $-4.6407$   | 0.0000*** |
| $\Delta$ CREDIT                           | $-0.0883$       | 0.0247         | $-3.5726$   | 0.0009*** |
| INT_REV                                   | $-1.2098$       | 0.4508         | $-2.6837$   | 0.0105**  |
| $\Delta$ REV_GDP                          | $-0.1827$       | 0.0551         | $-3.3187$   | 0.0019*** |
| Constant                                  | 4.7996          | 1.5243         | 3.1487      | 0.0027*** |
| <i>Diagnostic Tests</i>                   |                 |                |             |           |
| Adjusted $R^2$                            | 0.7932          |                |             |           |
| SSR                                       | 40.027          |                |             |           |
| LM test                                   | 1.6828 [0.4311] |                |             |           |
| BPG test                                  | 10.013 [0.1878] |                |             |           |
| JB test                                   | 1.3853 [0.5002] |                |             |           |
| Remaining nonlinearity test               | 0.7922 [0.4668] |                |             |           |
| Parameter constancy test                  | 0.4763 [0.8228] |                |             |           |

Note: Same notes apply as in Table 11.

Such an unfavorable association between the two main variables, after crossing the threshold, is due to the harmful effects of debt on productive investments and both health and education allocations as a percentage of public spending (the crowding-out effect). Such a crowding-out effect also leads to increased real interest rate and then diminishes private sector investment, as discussed in Huang et al. (2018). Also, this negative association could be justified by the debt accumulation hypothesis (or debt overhang hypothesis); that is, reduced total capital accumulation in an economy is a result of significant amounts of accumulated debt, as proposed in Reinhart et al. (2012). Moreover, escalated levels of public debt can have a considerably more negative impact if they raise uncertainty about future policy through financial repression and inflation (Cochrane, 2011a; Panizza & Presbitero, 2013). The negative association is consistent with the literature (e.g., Ahlborn & Schweickert, 2018; Clements et al., 2003; Cochrane, 2011a, 2011b; Égert, 2015a; Gómez-Puig & Sosvilla-Rivero, 2015, 2018; Kumar & Woo, 2010; Panizza & Presbitero, 2013; Szabó, 2013). Furthermore, the nonlinear relationship, ascertained by the LSTR technique, is consistent with previous research (e.g., Baum et al., 2013; Caner et al., 2010; Cecchetti et al., 2011; Checherita-Westphal & Rother, 2010; Eberhardt & Presbitero, 2015; Herndon et al., 2014; Krugman, 1988; Kumar & Woo, 2010; Law et al., 2021; Makun, 2021; Minea & Parent, 2012; Mupunga & Le Roux, 2015; Reinhart & Rogoff, 2010a, 2010b).

Figure 1 summarizes our results of the estimated threshold of the public debt proportioned to GDP for both economies using the LSTR technique, showing the smooth transition between low and high debt regimes and ascertaining the smooth and asymmetric adjustment between these regimes. Our results of the variant estimated thresholds for Egypt and Japan are in accordance with the conclusion of Égert (2015a) that such estimated threshold varies over time and is influenced by dissimilarity in the economic structure and differences in the capability of the economy to sustain its debt and mitigate the mischievous effects of debt on economic growth.

More specifically, Cohen-Setton and Oikawa (2022) argue that the Japanese economy have witnessed years of government borrowing to support public expenditure—including social welfare programs and initiatives to boost economic growth—that have mostly caused this great degree of debt. Although, historically, economists advise that a public debt proportioned to GDP exceeding 60–90% could raise questions regarding a nation's fiscal

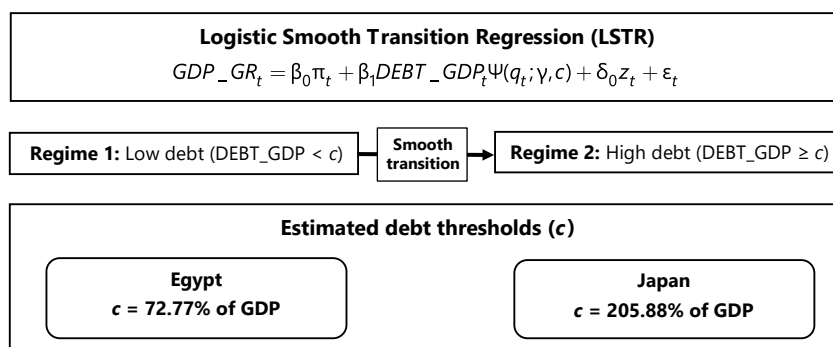


**Figure 1.** Debt threshold model using LSTR framework

sustainability, Japan's particular situation (including its domestic debt ownership and capacity to issue debt in its own currency) allows it to manage much higher levels without an immediate economic crisis. Nevertheless, future hazards come from sluggish economic growth, population changes, and long-term sustainability.

The consideration of structural and geopolitical implications justifies the differences in the estimated thresholds for the two economies. More specifically, Egypt has a long history of reliance on foreign financing to stimulate its development process; besides, its economy is vulnerable to supply chain disruptions and volatile global commodity prices, for instance, due to COVID pandemic. Moreover, it is exposure to exchange rate fluctuations which directly feed monetary instability. On the other hand, interest rates rise and inflation hikes, resulting in boosting debt-servicing pressures. This complicated situation ends up with escalating the risks of approaching or surpassing the estimated debt threshold of 72.77%. Among OECD nations, Japan has an unprecedented gross debt proportioned to GDP. For the Japanese economy, the ability to raise and manage domestic sources of finance is robust. According to Hoshi and Ito (2014), interest rates on Japanese government bonds are still modest and steady since the majority of bond holders are Japanese citizens, who are prepared to take on more Japanese government bonds without demanding high returns. However, a decrease in the working-age population is anticipated, accompanied by a constant GDP per working-age population rate, putting pressures on its ability to accumulate more debt.

In addition, Tables 11 and 12 reveal that the estimated slope for both countries in the transition function ( $\hat{\psi} = 14.09$  for Egypt and 52.70 for Japan) is relatively high. This suggests a rather swift but smooth regime change. Consequently, relationship of interest is described by two extreme regimes with a smooth transition.

Regarding the control variables, Tables 11 and 12 demonstrate a negative association between final government expenditure on consumption (% of GDP) and GDP growth in both countries at the 1% level of significance. This finding ascertains that government consumption spending crowds out its investment and productive spending. The private sector's domestic credit, proportioned to GDP, affects economic growth positively and significantly in Egypt, but negatively and significantly in Japan. At the 1% level of significance, interest payments (% of government revenues) have an unfavorable and significant impact on GDP growth in both countries. Put differently, the government dedicates a sizable portion of its revenues to repaying both domestic and foreign residents, rather than promoting productive investments. Besides, the real effective exchange rate impacts Egypt's economic growth positively and significantly. Both gross fixed formation and current account balance (proportioned to GDP) have an insignificant impact on Egypt's economic growth, as can be seen in Table 11. Lastly, government revenues (% of GDP) impacts Japan's economic growth inversely, as shown in Table 12.

In addition, Tables 11 and 12 highlight that our STR model can approximately explain 59% and 79% of the overall fluctuations in GDP growth in Egypt and Japan, respectively, over the study period. Wooldridge (2020, p. 35) and Stock and Watson (2020, p. 406) debate that low  $R^2$  (or  $\bar{R}^2$ ) values do not necessarily mean the regression model is worthless, and that relying solely on  $R^2$  (or  $\bar{R}^2$ ) as a criterion of effectiveness can lead to serious problems. Additionally, the residuals of our estimated models are normally and identically distributed since the JB

test's null hypothesis cannot be rejected. Both autocorrelation and heteroscedasticity are absent from our estimates for Egypt and Japan. In addition, we verified that the STR model fits Egypt's and Japan's data better when using a single threshold (LSTR(1)) as opposed to two thresholds (exponential STR, ESTR(2)). In this regard, we employed the remaining nonlinearity test that checks how many regimes there are, with  $H_0$  implies that the LSTR has a single threshold against an  $H_1$  that we have more than one threshold. This test reveals that our estimated model has only one threshold and no additional nonlinear interactions. Given that the test statistics were 0.85 and 0.79 for Egypt and Japan, respectively, and  $p$ -values were 0.36 and 0.47, respectively, the null hypothesis cannot be rejected. Lastly, the findings of testing for parameter constancy, which have a test statistic of 0.376 and 0.47 for Egypt and Japan, respectively, and a  $p$ -value less than 0.92 and 0.82, respectively, show that  $H_0$  of parameter constancy is irrefutable. This suggests that our STR is well specified.

## 6. Conclusions and policy recommendations

Our study empirically explored the association between the public debt to GDP ratio and economic growth in Egypt and Japan (i.e., the debt threshold) over 1974–2022. The choice of these two countries, which differ in terms of their economic structure and the development stage, is not only to figure out how variations in the economic structure of the two economies can affect the estimated debt threshold, but also to highlight how the country's ability to alleviate the harmful effects of debt (if they exist) on GDP growth can help it sustain its cumulative debt. In this vein, the LSTR estimation technique was performed to estimate the threshold level of public debt proportioned to GDP that after being crossed the latter variable is highly expected to have deleterious effects of economic growth.

The findings manifested a statistically significant positive association between public debt to GDP ratio and GDP growth in the lower regime (before crossing the estimated threshold at 72.77% for Egypt and 205.88% for Japan). This positive relationship is consistent with the law of rising public expenditure and the Keynesian fiscal multiplier. Our findings are also consistent with predominant literature. Public debt shows unfavorable effects on GDP growth above the estimated threshold, revealing a non-monotonic relationship between the study's two primary variables. In Egypt, economic growth is reduced by about 0.03% for every 1% increase in the public debt to GDP ratio above 72.77%. Similarly, one percent rise in the debt ratio above 205.88% lowers Japanese economic growth by about 0.01%. This negative association, after surpassing the estimated threshold, could be attributed to the crowding-out effect and explained by the hypothesis of debt overhang. It is also explained by inflation and financial repression. This asymmetric relationship we found is consistent with the predominant strand of literature. The enormous difference between both estimated thresholds ascertains that the Japanese economy is more efficient and more powerful in managing and sustaining its public debt to foster economic growth.

Policymakers in both countries are invited to suppress their public debt proportioned to GDP below the estimated threshold to benefit from the government borrowing. That is, public debt can offer an advantageous and supportive environment for strengthening long-term macroeconomic policy below the threshold level. Moreover, these thresholds can be dealt

with as a fiscal anchor and an early-warning indicator for macroeconomic risk. Lastly, we investigated and compared between only two countries, Egypt and Japan, confirming that adopting a universal benchmark for debt threshold ignores the differences across countries in terms of economic structures, inflation stability, central bank ability to monetize debt, and the stage of economic development. Consequently, future research may concentrate on the link between debt and GDP growth in a panel of countries, especially in the Middle East and North Africa region, showing how the economic and political turbulence in the region and also the abundance of oil revenues (in the Gulf countries, for example) affect its debt levels and debt sustainability.

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## Competing interests

Authors declare no conflict of interest.

## References

- Abbas, S., & Christensen, J. (2010). The role of domestic debt markets in economic growth: An empirical investigation for low-income countries and emerging markets. *IMF Staff Papers*, 57(1), 209–255. <https://doi.org/10.1057/imfsp.2009.24>
- Aguiar, M., Amador, M., & Gopinath, G. (2009). Investment cycles and sovereign debt overhang. *The Review of Economic Studies*, 76(1), 1–31. <https://doi.org/10.1111/j.1467-937X.2008.00523.x>
- Ahlborn, M., & Schweickert, R. (2018). Public debt and economic growth—economic systems matter. *International Economics and Economic Policy*, 15, 373–403. <https://doi.org/10.1007/s10368-017-0396-0>
- Albu, A., & Albu, L. (2021). Public debt and economic growth in Euro area countries. A wavelet approach. *Technological and Economic Development of Economy*, 27(3), 602–625. <https://doi.org/10.3846/tede.2021.14241>
- Augustine, B., & Rafi, M. (2023). Public debt-economic growth nexus in emerging and developing economies: Exploring nonlinearity. *Finance Research Letters*, 52, Article 103540. <https://doi.org/10.1016/j.frl.2022.103540>
- Bai, J., & Perron, P. (1998). Estimating and testing linear models with multiple structural changes. *Econometrica*, 66(1), 47–78. <https://doi.org/10.2307/2998540>
- Baldacci, E., Gupta, S., & Mulas-Granados, C. (2014). How effective is fiscal policy response in financial crises. In S. Claessens, M. Kose, L. Laeven, & F. Valencia (Eds.), *Financial crises: Causes, consequences, and policy responses* (pp. 431–457). International Monetary Fund. <https://doi.org/10.5089/9781475543407.071>
- Barro, R. (1989). The Ricardian approach to budget deficits. *Journal of Economic Perspectives*, 3(2), 37–54. <https://doi.org/10.1257/jep.3.2.37>
- Baum, A., Checherita-Westphal, C., & Rother, P. (2013). Debt and growth: New evidence for the euro area. *Journal of International Money and Finance*, 32, 809–821. <https://doi.org/10.1016/j.jimonfin.2012.07.004>

- Berg, A., Portillo, R., Buffie, E., Pattillo, C., & Zanna, L. (2012). *Public investment, growth, and debt sustainability: Putting together the pieces* (Working Paper WP/12/144). International Monetary Fund. <https://doi.org/10.5089/9781475504071.001>
- Bernardo, S., Vasconcelos, M., & Rocha, F. (2024). The widening of the North–South divide: Debt sustainability in a world weakened by COVID-19. *Economies*, 12(2), Article 42. <https://doi.org/10.3390/economies12020042>
- Blanchard, O., Gopinath, G., & Rogoff, K. (2021). Discussion on public debt and fiscal policy. *IMF Economic Review*, 69, 258–274. <https://doi.org/10.1057/s41308-020-00116-2>
- Bohn, H. (1998). The behavior of US public debt and deficits. *The Quarterly Journal of Economics*, 113(3), 949–963. <https://doi.org/10.1162/003355398555793>
- Broock, W., Scheinkman, J., Dechert, W., & LeBaron, B. (1996). A test for independence based on the correlation dimension. *Econometric Reviews*, 15(3), 197–235. <https://doi.org/10.1080/07474939608800353>
- Buchanan, J. (1976). Barro on the Ricardian equivalence theorem. *Journal of Political Economy*, 84(2), 337–342. <https://doi.org/10.1086/260436>
- Caner, M., Grennes, T., & Köhler-Geib, F. (2010). Finding the tipping point-when sovereign debt turns bad. In C. Braga & G. Vincelette (Eds.), *Sovereign debt and the financial crisis: Will this time be different?* (pp. 63–75). World Bank. <https://doi.org/10.1596/1813-9450-5391>
- Cecchetti, S., Mohanty, M., & Zampolli, F. (2011). *The real effects of debt* (BIS Working Paper No. 352). Bank for International Settlements.
- Chan, K., Hansen, B., & Timmermann, A. (2017). Guest editors' introduction: Regime switching and threshold models. *Journal of Business & Economic Statistics*, 35(2), 159–161. <https://doi.org/10.1080/07350015.2017.1236521>
- Checherita-Westphal, C., & Rother, P. (2010). *The impact of high and growing government debt on economic growth: an empirical investigation for the euro area* (Working Paper No. 1237). European Central Bank. <https://doi.org/10.2139/ssrn.1659559>
- Choi, I. (2015). *Almost all about unit roots: Foundations, developments, and applications*. Cambridge University Press. <https://doi.org/10.1017/CBO9781316157824>
- Chudik, A., Mohaddes, K., Pesaran, M., & Raissi, M. (2017). Is there a debt-threshold effect on output growth? *Review of Economics and Statistics*, 99(1), 135–150. [https://doi.org/10.1162/REST\\_a\\_00593](https://doi.org/10.1162/REST_a_00593)
- Ciaffi, G., Deleidi, M., & Capriati, M. (2024). Government spending, multipliers, and public debt sustainability: An empirical assessment for OECD countries. *Economia Politica*, 41(2), 521–542. <https://doi.org/10.1007/s40888-024-00335-0>
- Clements, B., Bhattacharya, R., & Nguyen, T. (2003). *External debt, public investment, and growth in low-income countries* (IMF Working Paper No. 03/249). International Monetary Fund. <https://doi.org/10.5089/9781451875904.001>
- Cochrane, J. (2011a). Inflation and debt. *National Affairs*, 9(2), 56–78.
- Cochrane, J. (2011b). Understanding policy in the great recession: Some unpleasant fiscal arithmetic. *European Economic Review*, 55(1), 2–30. <https://doi.org/10.1016/j.euroecorev.2010.11.002>
- Cohen-Setton, J., & Oikawa, K. (2022). Japans public debt sustainability before and after COVID-19. In B. Ferrarini, M. Giugale, & J. Pradelli (Eds.), *The sustainability of Asia's debt* (pp. 66–86). Edward Elgar Publishing. <https://doi.org/10.4337/9781800883727.00011>
- Corsetti, G., & Roubini, N. (1991). Fiscal deficits, public debt, and government solvency: Evidence from OECD countries. *Journal of the Japanese and International Economies*, 5(4), 354–380. [https://doi.org/10.1016/0889-1583\(91\)90004-A](https://doi.org/10.1016/0889-1583(91)90004-A)
- Creamer, K., & Botha, R. (2017). Assessing nominal GDP targeting in the South African context. *Central Bank Review*, 17(1), 1–10. <https://doi.org/10.1016/j.cbrev.2017.02.001>

- Culver, S., & Papell, D. (1997). Is there a unit root in the inflation rate? Evidence from sequential break and panel data models. *Journal of Applied Econometrics*, 12(4), 435–444. [https://doi.org/10.1002/\(SICI\)1099-1255\(199707\)12:4<435::AID-JAE430>3.0.CO;2-1](https://doi.org/10.1002/(SICI)1099-1255(199707)12:4<435::AID-JAE430>3.0.CO;2-1)
- D'Erasmus, P., Mendoza, E., & Zhang, J. (2016). What is a sustainable public debt? In J. Taylor & H. Uhlig (Eds.), *Handbook of macroeconomics* (vol. 2, pp. 2493–2597). Elsevier. <https://doi.org/10.1016/bs.hesmac.2016.03.013>
- DeLong, J., Summers, L., Feldstein, M., & Ramey, V. (2012). Fiscal policy in a depressed economy [with comments and discussion]. *Brookings Papers on Economic Activity*, 43(1), 233–297. <https://doi.org/10.1353/eca.2012.0000>
- Della Posta, P., Marelli, E., & Signorelli, M. (2022). COVID-19, economic policies and public debt sustainability in Italy. *Sustainability*, 14(8), Article 4691. <https://doi.org/10.3390/su14084691>
- Deschamps, P. (2008). Comparing smooth transition and Markov switching autoregressive models of US unemployment. *Journal of Applied Econometrics*, 23(4), 435–462. <https://doi.org/10.1002/jae.1014>
- Diamond, D., & He, Z. (2014). A theory of debt maturity: the long and short of debt overhang. *The Journal of Finance*, 69(2), 719–762. <https://doi.org/10.1111/jofi.12118>
- Dickey, D., & Fuller, W. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(4), 1057–1072. <https://doi.org/10.2307/1912517>
- Dimitraki, O., & Emmanouilidis, K. (2024). Interactional impact of defence expenditure and political instability on economic growth in Nigeria: Revisited. *Defence and Peace Economics*, 36, 533–544. <https://doi.org/10.1080/10242694.2024.2354992>
- Eberhardt, M., & Presbitero, A. (2015). Public debt and growth: Heterogeneity and non-linearity. *Journal of International Economics*, 97(1), 45–58. <https://doi.org/10.1016/j.jinteco.2015.04.005>
- Égert, B. (2015a). Public debt, economic growth and nonlinear effects: Myth or reality? *Journal of Macroeconomics*, 43, 226–238. <https://doi.org/10.1016/j.jmacro.2014.11.006>
- Égert, B. (2015b). The 90% public debt threshold: The rise and fall of a stylized fact. *Applied Economics*, 47(34–35), 3756–3770. <https://doi.org/10.1080/00036846.2015.1021463>
- El-Naser, A., Dincă, G., & Dincă, M. (2025). Investigating the determinants of public debt sustainability for European Union countries. *Scientific Annals of Economics and Business*, 72(1), 21–40. <https://doi.org/10.47743/saeb-2025-0001>
- Engle, R., & Granger, C. (1987). Cointegration and error correction: Representation, estimation, and testing. *Econometrica: Journal of the Econometric Society*, 55(2), 251–276. <https://doi.org/10.2307/1913236>
- Fischer, R., & Schnabl, G. (2018). Regional heterogeneity, the rise of public debt and monetary policy in post-bubble Japan: Lessons for the EMU. *International Economics and Economic Policy*, 15, 405–428. <https://doi.org/10.1007/s10368-017-0402-6>
- Fischer, S. (1993). The role of macroeconomic factors in growth. *Journal of Monetary Economics*, 32(3), 485–512. [https://doi.org/10.1016/0304-3932\(93\)90027-D](https://doi.org/10.1016/0304-3932(93)90027-D)
- Fok, D., Van Dijk, D., & Franses, P. (2005). A multi-level panel STAR model for US manufacturing sectors. *Journal of Applied Econometrics*, 20(6), 811–827. <https://doi.org/10.1002/jae.822>
- Gómez-Puig, M., & Sosvilla-Rivero, S. (2015). The causal relationship between debt and growth in EMU countries. *Journal of Policy Modeling*, 37(6), 974–989. <https://doi.org/10.1016/j.jpolmod.2015.09.004>
- Gómez-Puig, M., & Sosvilla-Rivero, S. (2018). Public debt and economic growth: Further evidence for the Euro area. *Acta Oeconomica*, 68(2), 209–229. <https://doi.org/10.1556/032.2018.68.2.2>
- Gonzalez, A., Teräsvirta, T., & Van Dijk, D. (2005). *Panel smooth transition regression models* (Research Paper No. 165). Quantitative Finance Research Centre, University of Technology, Sydney.
- Granger, C., & Newbold, P. (1974). Spurious regressions in econometrics. *Journal of Econometrics*, 2(2), 111–120. [https://doi.org/10.1016/0304-4076\(74\)90034-7](https://doi.org/10.1016/0304-4076(74)90034-7)

- Granger, C., & Terasvirta, T. (1993). Modelling non-linear economic relationships. Oxford University Press.
- Greiner, A. (2011). Economic growth, public debt and welfare: Comparing three budgetary rules. *German Economic Review*, 12(2), 205–222. <https://doi.org/10.1111/j.1468-0475.2010.00516.x>
- Hansen, B. (1996). Inference when a nuisance parameter is not identified under the null hypothesis. *Econometrica: Journal of the Econometric Society*, 64(2), 413–430. <https://doi.org/10.2307/2171789>
- Hansen, B. (2000). Sample splitting and threshold estimation. *Econometrica*, 68(3), 575–603. <https://doi.org/10.1111/1468-0262.00124>
- Heimberger, P. (2023). Do higher public debt levels reduce economic growth?. *Journal of Economic Surveys*, 37(4), 1061–1089. <https://doi.org/10.1111/joes.12536>
- Herndon, T., Ash, M., & Pollin, R. (2014). Does high public debt consistently stifle economic growth? A critique of Reinhart and Rogoff. *Cambridge Journal of Economics*, 38(2), 257–279. <https://doi.org/10.1093/cje/bet075>
- Holtfrerich, C. (2013). *Government debt in economic thought of the long 19<sup>th</sup> century* (Discussion Paper No. 2013/4). Freie Universität Berlin, School of Business and Economics.
- Hoshi, T., & Ito, T. (2014). Defying gravity: Can Japanese sovereign debt continue to increase without a crisis?. *Economic Policy*, 29(77), 5–44. <https://doi.org/10.1111/1468-0327.12023>
- Huang, Y., Panizza, U., & Varghese, R. (2018). *Does public debt crowd out corporate investment? International evidence* (CEPR Discussion Paper No. DP12931). Centre for Economic Policy Research.
- Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica: Journal of the Econometric Society*, 59(6), 1551–1580. <https://doi.org/10.2307/2938278>
- Johansen, S. (1995). *Likelihood-based inference in cointegrated vector autoregressive models*. Oxford University Press. <https://doi.org/10.1093/0198774508.001.0001>
- Kapetanios, G. (2005). Unit-root testing against the alternative hypothesis of up to m structural breaks. *Journal of Time Series Analysis*, 26(1), 123–133. <https://doi.org/10.1111/j.1467-9892.2005.00393.x>
- Kennedy, P. (2008). *A guide to econometrics* (6<sup>th</sup> ed.). Blackwell Publishing Ltd.
- Kobayashi, K. (2015). Public debt overhang and economic growth. *Public Policy Review*, 11(2), 247–276.
- Kourtellis, A., Stengos, T., & Tan, C. (2013). The effect of public debt on growth in multiple regimes. *Journal of Macroeconomics*, 38, 35–43. <https://doi.org/10.1016/j.jmacro.2013.08.023>
- Krugman, P. (1988). Financing vs. forgiving a debt overhang. *Journal of Development Economics*, 29(3), 253–268. [https://doi.org/10.1016/0304-3878\(88\)90044-2](https://doi.org/10.1016/0304-3878(88)90044-2)
- Kumar, M., & Woo, J. (2010). *Public debt and growth* (IMF Working Paper No. 10/174). International Monetary Fund. <https://doi.org/10.5089/9781455201853.001>
- Kwiatkowski, D., Phillips, P., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of Econometrics*, 54(1–3), 159–178. [https://doi.org/10.1016/0304-4076\(92\)90104-Y](https://doi.org/10.1016/0304-4076(92)90104-Y)
- Law, S., Ng, C., Kutun, A., & Law, Z. (2021). Public debt and economic growth in developing countries: Nonlinearity and threshold analysis. *Economic Modelling*, 98, 26–40. <https://doi.org/10.1016/j.econmod.2021.02.004>
- Le, T., & Phan, L. (2022). Examining The non-linear impact of external debt on economic convergence. *Journal of Economic Integration*, 37(3), 377–422. <https://doi.org/10.11130/jei.2022.37.3.377>
- Lee, C., Ahmad, R., Karim, Z., & Khalid, N. (2023). Institutional quality, income level, and debt sustainability: new evidence using dynamic panel threshold regression. *Technological and Economic Development of Economy*, 29(5), 1520–1538. <https://doi.org/10.3846/tede.2023.19247>
- Lundbergh, S., Teräsvirta, T., & Van Dijk, D. (2003). Time-varying smooth transition autoregressive models. *Journal of Business & Economic Statistics*, 21(1), 104–121. <https://doi.org/10.1198/073500102288618810>

- Makun, K. (2021). External debt and economic growth in Pacific Island countries: A linear and nonlinear analysis of Fiji Islands. *The Journal of Economic Asymmetries*, 23, Article e00197. <https://doi.org/10.1016/j.jeca.2021.e00197>
- Marcoulides, K., & Raykov, T. (2019). Evaluation of variance inflation factors in regression models using latent variable modeling methods. *Educational and Psychological Measurement*, 79(5), 874–882. <https://doi.org/10.1177/0013164418817803>
- Marquez, N. (2000). Debt sustainability in the ECCB area. *Social and Economic Studies*, 49(2/3), 77–108.
- Mátyás, L., Gourieroux, C., & Phillips, P. (1999). *Generalized method of moments estimation*. Cambridge University Press.
- Minea, A., & Parent, A. (2012). *Is high public debt always harmful to economic growth? Reinhart and Rogoff and some complex nonlinearities* (CERDI, Etudes et Documents No. 18). <https://shs.hal.science/halshs-00700471>
- Montañés, A., Olloqui, I., & Calvo, E. (2005). Selection of the break in the Perron-type tests. *Journal of Econometrics*, 129(1–2), 41–64. <https://doi.org/10.1016/j.jeconom.2004.09.003>
- Munir, K., & Mehmood, N. (2018). Exploring the channels and impact of debt on economic growth: Evidence from South Asia. *South Asia Economic Journal*, 19(2), 171–191. <https://doi.org/10.1177/1391561418794692>
- Mupunga, N., & Le Roux, P. (2015). Estimating the optimal growth-maximising public debt threshold for Zimbabwe. *Southern African Business Review*, 19(3), 102–128.
- Narayan, P. (2005). The saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics*, 37(17), 1979–1990. <https://doi.org/10.1080/00036840500278103>
- Ng, S., & Perron, P. (2001). Lag length selection and the construction of unit root tests with good size and power. *Econometrica*, 69(6), 1519–1554. <https://doi.org/10.1111/1468-0262.00256>
- Ogaki, M. (1993). Generalized method of moments: Econometric applications. In G. Maddala, C. Rao, & H. Vinod (Eds.), *Handbook of statistics* (vol. 11, pp. 455–488). Elsevier. [https://doi.org/10.1016/S0169-7161\(05\)80052-5](https://doi.org/10.1016/S0169-7161(05)80052-5)
- Okwoche, P., & Nikolaidou, E. (2022). *Public debt, growth, and threshold effects: A comparative analysis based on income categories* (Discussion Paper No. 2022–02). School of Economics, University of Cape Town, South Africa.
- Osińska, M., Kufel, T., Błażejowski, M., & Kufel, P. (2020). Modeling mechanism of economic growth using threshold autoregression models. *Empirical Economics*, 58(3), 1381–1430. <https://doi.org/10.1007/s00181-018-1560-2>
- Owusu-Nantwi, V., & Erickson, C. (2016). Public debt and economic growth in Ghana. *African Development Review*, 28(1), 116–126. <https://doi.org/10.1111/1467-8268.12174>
- Oyadeyi, O., Agboola, O., Okunade, S., & Osinubi, T. (2024). The debt-growth nexus and debt sustainability in Nigeria: Are there reasons to be concerned? *Journal of Policy Modeling*, 46(1), 129–152. <https://doi.org/10.1016/j.jpolmod.2023.11.004>
- Panizza, U., & Presbitero, A. (2012). Is high public debt harmful for economic growth? New evidence. In G. Corsetti (Ed.), *Austerity: Too much of a good thing?* (pp. 91–96). Citeseer, Pennsylvania State University.
- Panizza, U., & Presbitero, A. (2013). Public debt and economic growth in advanced economies: A survey. *Swiss Journal of Economics and Statistics*, 149(2), 175–204. <https://doi.org/10.1007/BF03399388>
- Pattillo, C., Gulde, A., Carey, K., Wagh, S., & Christensen, J. (2006). *Sub-Saharan Africa: Financial sector challenges*. International Monetary Fund. <https://doi.org/10.5089/9781589065659.071>
- Pereira, A., & Rodrigues, P. (2001). *Public debt and economic performance* (DGEP Working Paper No. 20). Ministry of Finance, Portugal.

- Pesaran, M., & Shin, Y. (1997). An Autoregressive distributed-lag modelling approach to cointegration analysis. *Econometrics and Economic Theory in the 20<sup>th</sup> Century*, 31, 371–413.  
<https://doi.org/10.1017/CCOL521633230.011>
- Pesaran, M., Shin, Y., & Smith, R. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289–326. <https://doi.org/10.1002/jae.616>
- Phillips, P. (1988). Regression theory for near-integrated time series. *Econometrica: Journal of the Econometric Society*, 56(5), 1021–1043. <https://doi.org/10.2307/1911357>
- Phillips, P., & Hansen, B. (1990). Statistical inference in instrumental variables regression with I(1) processes. *The Review of Economic Studies*, 57(1), 99–125. <https://doi.org/10.2307/2297545>
- Phillips, P., & Ouliaris, S. (1990). Asymptotic properties of residual based tests for cointegration. *Econometrica*, 58(1), 165–193. <https://doi.org/10.2307/2938339>
- Phillips, P., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, 75(2), 335–346. <https://doi.org/10.1093/biomet/75.2.335>
- Phiri, A. (2020). Endogenous monetary approach to optimal inflation–growth nexus in Swaziland. *African Journal of Economic and Management Studies*, 11(4), 559–571.  
<https://doi.org/10.1108/AJEMS-07-2018-0217>
- Potter, S. (1999). Nonlinear time series modelling: An introduction. *Journal of Economic Surveys*, 13(5), 505–528. <https://doi.org/10.1111/1467-6419.00096>
- Pratibha, S., & Muniyoor, K. (2025). India's debt dilemma: Investigating threshold, primary surplus, and institutional quality. *Journal of Emerging Market Finance*, 24(4), 439–460.  
<https://doi.org/10.1177/09726527251345112>
- Reinhart, C., Reinhart, V., & Rogoff, K. (2012). Public debt overhangs: Advanced-economy episodes since 1800. *Journal of Economic Perspectives*, 26(3), 69–86. <https://doi.org/10.1257/jep.26.3.69>
- Reinhart, C., & Rogoff, K. (2009). *This time is different: Eight centuries of financial folly*. Princeton University Press. <https://doi.org/10.1515/9781400831722>
- Reinhart, C., & Rogoff, K. (2010a). *Debt and growth revisited* (MPRA Paper 24376). University Library of Munich, Germany. <https://mpra.ub.uni-muenchen.de/id/eprint/24376>
- Reinhart, C., & Rogoff, K. (2010b). Growth in a time of debt. *American Economic Review*, 100(2), 573–578. <https://doi.org/10.1257/aer.100.2.573>
- Sam, C., McNown, R., & Goh, S. (2019). An augmented autoregressive distributed lag bounds test for cointegration. *Economic Modelling*, 80, 130–141. <https://doi.org/10.1016/j.econmod.2018.11.001>
- Schclarek, A. (2004). *Debt and economic growth in developing and industrial countries* (Working Paper No. 34). School of Economics and Management, Department of Economics, Lund University.
- Schwarz, G. (1978). Estimating the dimension of a model. *The Annals of Statistics*, 6(2), 461–464. <https://doi.org/10.1214/aos/1176344136>
- Schwert, W. (1989). Tests for unit roots: A Monte Carlo investigation. *Journal of Business & Economic Statistics*, 20(1), 5–17. <https://doi.org/10.1198/073500102753410354>
- Stock, J., & Watson, M. (2020). *Introduction to econometrics* (4<sup>th</sup> ed.). Pearson Education.
- Szabó, Z. (2013). The effect of sovereign debt on economic growth and economic development. *Public Finance Quarterly = Pénzügyi Szemle*, 58(3), 251–270.
- Tanna, S., Li, C., & De Vita, G. (2018). The role of external debt in the foreign direct investment–growth relationship. *International Journal of Finance & Economics*, 23(4), 393–412. <https://doi.org/10.1002/ijfe.1628>
- Taylor, M., Peel, D., & Sarno, L. (2001). Nonlinear mean-reversion in real exchange rates: Toward a solution to the purchasing power parity puzzles. *International Economic Review*, 42(4), 1015–1042. <https://doi.org/10.1111/1468-2354.00144>

- Teräsvirta, T. (1994). Specification, estimation, and evaluation of smooth transition autoregressive models. *Journal of the American Statistical Association*, 89(425), 208–218.  
<https://doi.org/10.1080/01621459.1994.10476462>
- Uzun, A., Karakoy, C., Kabadayi, B., & Emsen, O. (2012). The impacts of external debt on economic growth in transition economies. *Chinese Business Review*, 11(5), 491–499.  
<https://doi.org/10.17265/1537-1506/2012.05.009>
- Wooldridge, J. (2020). *Introductory econometrics: A modern approach* (7<sup>th</sup> ed.). Cengage Learning, Inc.
- Zhang, L. (2017). Modeling the phillips curve in China: A nonlinear perspective. *Macroeconomic Dynamics*, 21(2), 439–461. <https://doi.org/10.1017/S1365100515000577>
- Zivot, E., & Andrews, D. (1992). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business and Economic Statistics*, 10(3), 251–270.  
<https://doi.org/10.1080/07350015.1992.10509904>
- Zivot, E., & Wang, J. (2005). *Modeling financial time series with S-plus* (2<sup>nd</sup> ed.). Springer.