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Sustainability of External Debts: BRICST Countries *

Dış Borçların Sürdürülebilirliği: BRICST Ülkeleri

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ÖZ

Bu çalışma, küresel ekonomide giderek daha fazla önem kazanan BRICST ülkelerinde dış borçların sürdürülebilirliğini incelemektedir. Bu amaçla, borç sürdürülebilirliğine ilişkin üç temel gösterge olan Toplam Dış Borç Stoku/Milli Gelir, Toplam Dış Borç Stoku/İhracat ve Borç Servis Oranı 1994–2023 dönemi için analiz edilmiştir. Çalışmada yapısal kırılmaları ve yatay kesit bağımlılığını dikkate alan ikinci nesil panel birim kök testleri (Carrion-i-Silvestre, Pesaran CADF ve Becker Fourier KPSS) kullanılmıştır. Bulgular, Hindistan, Çin, Güney Afrika ve Türkiye'de dış borcun sürdürülemez olduğunu, buna karşın Brezilya ve Rusya'da sürdürülebilir olduğunu göstermektedir.

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ABSTRACT

This study investigates the sustainability of external debt in BRICST countries, a group that holds a strategic position in the global economy. For this purpose, three widely used indicators, namely Total External Debt Stock/GNI, Total External Debt Stock/Exports and Debt Service Ratio, of debt sustainability are analysed using annual data covering the period 1994–2023. The analysis employs second-generation panel unit root tests that allow for structural breaks and cross-sectional dependence, namely Carrion-i-Silvestre, Pesaran CADF, and Becker Fourier KPSS tests. The findings suggest that external debt is not sustainable in India, China, South Africa and Turkey, while it remains sustainable in Brazil and Russia.

1. Introduction

Since the industrial revolution, rising production and consumption have significantly increased global welfare. In this way, production and consumption have been realized at a faster and higher rate than ever before in the history of the world. However, this situation has also led to the rapid and high exploitation of factors of production. One of the main arguments of classical economics, "meeting unlimited human needs with limited resources", manifests itself at this point. Because ensuring the continuity of increasing production and consumption is only possible through the efficient and planned use of "limited resources". Similarly, the financial resources of countries are also limited, and their effective utilization is of great importance. When countries' own financial assets are not sufficient to accelerate their economic growth and development, they may resort to external borrowing. When these debts are used in productive areas, they can be a driving force for economic growth. It is expected that there will be no problem in the repayment and

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sustainability of external debts used in productive areas (Muhanji and Ojah, 2011). However, when foreign debts are used for luxury consumption expenditures of the public and private sectors, there are likely to be problems in paying the principal and interest on these debts in the future (Arnone, Bandiera and Presbitero, 2005). These problems increase countries' CDS premiums and the cost of reborrowing, impair the convertibility of debts and may lead countries to face economic crises (Lau and Lee, 2016). For this reason, it is useful to frequently analyse the sustainability of external debt, especially in developing countries that are in high need of external financing, and to produce the necessary policy recommendations in a timely manner and bring them to the attention of those concerned. The aim of this study is to analyse the sustainability of external debt in BRICST countries (Brazil, Russia, India, China, South Africa and Turkey), which have been widely mentioned in the last 20 years and are expected to dominate the global economy in the future according to Goldman Sachs analysis (Wilson and Purushothaman, 2003). The focus on BRICST economies arises from their shared characteristics as large emerging markets with increasing financial integration and exposure to global shocks. Although their institutional settings differ, all six countries experienced rapid external borrowing, volatile capital flows, and growth-driven debt dynamics during the study period. Analysing them jointly allows for identifying both common vulnerabilities—such as sensitivity to global interest rate cycles—and country-specific resilience factors. Turkey's inclusion, while sometimes categorized under the "Fragile Five," is justified by its comparable economic scale, trade openness, and exposure to external financing pressures. Similarly, Russia's resource-based debt structure contrasts with India's and China's manufacturing-driven patterns, providing a meaningful comparative perspective across different development models within the same emerging-market spectrum.

Framing the analysis in this way situates the empirical tests within a coherent theoretical model: stationarity of debt ratios represents long-run solvency, structural breaks correspond to regime changes following crises or policy shifts, and cross-sectional dependence reflects shared exposure to global financial conditions. Together, this approach bridges classical and modern theories of debt sustainability with empirical evidence from BRICST economies.

Using annual data from 1994 to 2023, the paper evaluates sustainability through three commonly employed debt indicators. After testing for cross-sectional dependence with the Breusch-Pagan LM test, three second-generation unit root tests are implemented: the Carrion-i-Silvestre test (which allows for structural breaks), the Pesaran CADF test (which addresses cross-sectional dependence and provides both country-specific and panel-level results), and the Becker Fourier KPSS test (which captures smooth structural breaks through a flexible Fourier approach). These complementary methods provide a robust framework for assessing external debt sustainability across the BRICST economies.

2. External Debt

The science of economics includes many factors, such as unemployment, inflation and political crisis, that affect and are affected by social events. For this reason, economics is recognized as a social science. However, measuring these factors with universal and consistent scientific methods is very important for accurately analysing the causes and consequences of social events. In this regard, Leon Walras (1874) stated in his study that economics is not only a social science by saying "pure theory of economics is a science which resembles the physico-mathematical sciences in every respect." (Walras, 1874: 71, Eren, 2018: 94).

According to the joint definition prepared by the IMF, BIS, OECD, and World Bank (1988), external debt refers to the total liabilities owed by a country's residents to non-residents, including both principal and interest, regardless of whether these have been paid or remain outstanding. In simpler terms, it captures the total amount that must be repaid in money, goods, or services to foreign creditors. The World Bank calculates this figure as the sum of long-term public and private debt, IMF loans, short-term debt with maturities of less than one year, and accrued interest.

3. Sustainability of External Debt

Debt sustainability depends on the ability of the debtor to repay its debt now or in the future. In terms of a country's external debt, external debt is sustainable when today's net debt is less than or equal to the present value of the country's net exports. That is, the trade surplus should be large enough if the country is a lender and the trade deficit should be small enough if the country is a borrower. However, this definition falls short in two respects (Blanchard and Das, 2017: 1):

(i). The present value of net exports is a random variable. In very bad cases, the above condition will not hold. This requires sustainability to be a probabilistic statement such as "there is a high probability that this condition will be met".

(ii). Net exports, like net debt, depend on the exchange rate. As long as the increase in net external debt due to a depreciation of the national currency is not greater than the increase in exports, a depreciation of the national currency always makes the debt sustainable.

In this context, external debt sustainability can be redefined as follows: debt is considered sustainable if, at the prevailing exchange rate, the likelihood is high that the net debt level does not exceed the present value of net exports.

External debt sustainability refers to a country's ability to repay current and future debts without default or renegotiation. If debts accumulate, they may threaten growth. At the same time, external debt should be repayable without distorting the country's economic variables such as inflation, employment and investment. The sustainability of

external debt will be possible only if the country grows at a rate higher than the interest on borrowing (Czerkawski, 1991).

The most extreme case of unsustainable external debt is explained by the debt overhang hypothesis (Krugman, 1988). In a debt overhang situation, lending countries are unable to collect their debts from borrowing countries because they have borrowed more than they can repay. In this situation, lenders have a confidence problem about getting their debts back in full, but they continue to lend to the debtor country, even though they foresee that they will not be able to get them back. This is because repayment of existing accumulated debts will only be possible with new loans, and there is a possibility that the new loans will turn into productive investments that will get the country out of debt. An alternative to issuing new debt to a debtor country that is in debt overhang and unable to repay its debts is to forgive part of the debtor country's debts. Here, lending countries have to make a choice. Either they will bear the risk of non-payment of new debts against the possibility of paying off the entire debt in the long run by issuing new debts, or they will forgive part of the existing debt and wait for the debtor country to pay off its decreasing debt burden. As a result, the sustainability of external debt is of utmost importance for both lender and borrower countries.

There are three distinct approaches to sustainability of external debt: financial approach, economic approach and intertemporal approach. The financial approach is an analysis approach that examines the relationship between interest to be paid and ability to pay (income). According to this approach (Cuddington, 1997):

(i). If the primary deficit is zero, the increase in the debt stock will be equal to the amount of interest.

(ii). If the primary deficit is negative, the increase in the stock of debt will be greater than the amount of interest.

(iii). If the primary deficit is positive, that is, if there is a primary surplus, the increase in the stock of debt will be less than the amount of interest. In fact, if the primary surplus is greater than the amount of interest, debt will decline over time.

In this approach, also known as the accounting approach or the borrower-based approach (Arnone, Bandiera and Presbitero, 2005: 8), it is possible to achieve a sustainable primary deficit as long as the growth rate of the economy is greater than the interest rate. What is important here is that the government should be able to increase its revenues to offset the increase in its debt.

In the economic approach, there are various ratios indicating the sustainability of external debt. These ratios not only show the level of debt for borrowing countries, but also provide information for lending countries about the repayment capacity and indebtedness of the country to which the debt will be given. In this respect, these ratios are very important for both sides. Three of these ratios are included in this study.

- **Total External Debt Stock/GNI:** It is one of the most widely used ratios indicating the external indebtedness of countries. In addition to measuring the creditworthiness of a country, it is also an important criterion in debt burden and risk calculations (Evgin, 2000: 59). For this ratio to increase, total external debt stock should increase while GNI is constant, GNI should decrease while total external debt stock is constant, or total external debt stock should increase faster than GNI. In all three cases, the country's indebtedness ratio will increase, and the country will become more dependent on external sources. The World Bank and the IMF have set ideal limits for this ratio. Accordingly, when a country's total external debt stock-to-GNI ratio falls between 30% and 50%, it is classified as moderately indebted, while ratios exceeding 50% indicate a highly indebted status. (Dibo, 2009: 43). If the ratio of a country's total external debt stock to GDP is below 30 percent, the country is considered to be lightly indebted (Gümüş, 2025: 558).

- Total External Debt Stock/Exports: This ratio is a ratio that shows the country's external debt solvency. This is because external debts borrowed in foreign currency are repaid in foreign currency and foreign currency inflows to countries through exports. A ratio between 165% and 275% means that the country is moderately indebted, while a ratio higher than 275% means that the country is heavily indebted (Söyler, 2001: 20). If the ratio of total external debt to exports is below 165 percent, the country is considered to be lightly indebted (Gümüş, 2025: 560; Evgin, 2000: 67). Similar to the total external debt stock/GNI ratio, the increase in this ratio does not yield favorable results for the debtor country.

- Debt Service Ratio: It is calculated as total external debt service/exports. Total external debt service is considered as the sum of the principal and interest amounts that a country has to pay within a year. This ratio shows the country's short-term liquidity strength. A high level of this ratio indicates that there is a liquidity problem in the country and that the country may have difficulty in paying its short-term debts (İnce, 2001: 171). This ratio, which shows the solvency of the country especially in the short term, can also be considered in the medium term. Countries with a ratio between 18% and 30% are considered to be moderately indebted, while countries with a ratio above 30% are considered to be heavily indebted (Evgin, 2000: 59). If the debt service ratio is below 18 percent, the country is considered to be lightly indebted (Gümüş, 2022: 235). A decrease in this ratio indicates an improvement in the balance of payments, while an increase indicates a deterioration.

In the intertemporal approach, the government's budget constraint is considered intertemporally and total budgets in future periods are analysed collectively. According to this approach, if the net external surplus to be used for external

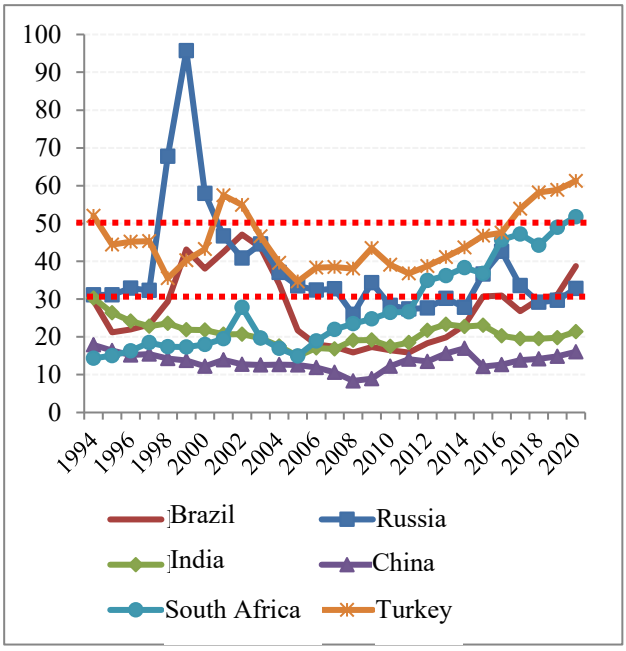
debt repayments is equal to the net external debt, it means that the external debt is sustainable (Sawada, 1994). In other words, if the current stock of external debt at the end of period t is equal to the present value of future external surpluses, external debt can be paid.

4. External Debt in BRICST Countries

External debts are an important problem area for many developed and developing countries, and these debts can bring countries to the brink of economic and political crises from time to time. Excessive increases in external debts led to debt crises in Mexico, Argentina and Brazil in the 1980s and to the moratorium in Russia in 1998 (Bilici, 2016). In 2001, external debts caused problems again in Argentina, and in 2010, they manifested themselves in European countries including Greece, Portugal, Ireland, Italy and Spain (Yavuz et al. 2013: 133).

In this section, economic indicators of BRICST countries are presented graphically. The graphs presented belong to total external debt stock/GNI, total external debt stock/exports and total external debt service/exports ratios, which are the indebtedness indicators described in the economic approach. The data displayed in the graphs are derived from the World Bank.

Graph 1: Total External Debt Stock/GNI Ratios of BRICST Countries

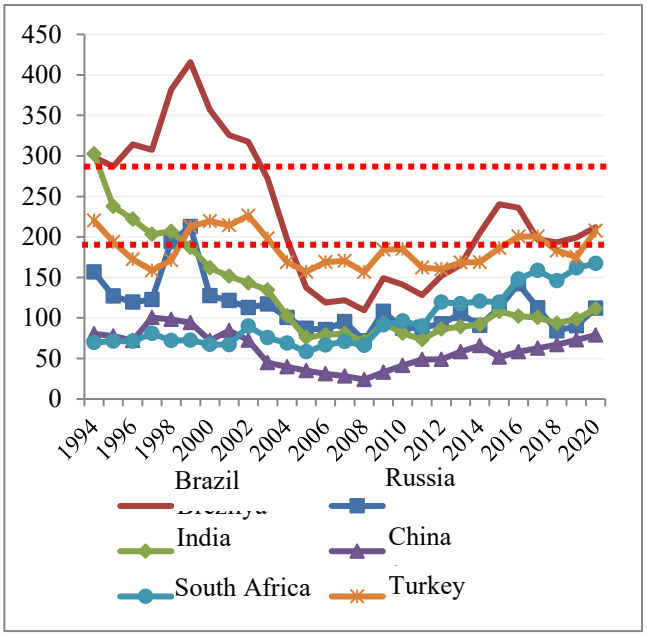


Note: Horizontal red lines indicate thresholds of 30% and 50%. Source: Data taken from the World Development Indicators databank published by the World Bank.

The ratios of the countries displayed in Figure 1 exhibit a declining trend until 2008, followed by a renewed upward trend in the subsequent period. Although Russia's rate increased significantly between 1997 and 1999, it returned to its previous levels over time. The most stable countries among these countries are China and India. The total external debt stock/GNI ratios of these two countries have remained almost unchanged over time. As of 2020, Turkey and South Africa have external debt above the over-indebtedness threshold.

The graphical evidence provides valuable insights into the dynamics of external debt sustainability, complementing the econometric results. In Graph 1, the total external debt stock-to-GNI ratios reveal that Turkey and South Africa crossed the over-indebtedness threshold after 2008, a development that is far from coincidental. The global financial crisis triggered sharp capital outflows from emerging markets, forcing both economies to rely more heavily on external borrowing to stabilize growth. In Turkey's case, the combination of rapid credit expansion, a widening current account deficit, and a strong domestic currency led to rising external liabilities. Similarly, South Africa's post-2008 surge reflects its dependence on commodity exports and portfolio inflows, both of which proved volatile during global downturns. Crossing the threshold thus indicates not merely a statistical shift but a structural deterioration in external resilience—signalling that both countries entered a period where debt accumulation outpaced income growth, raising solvency and liquidity concerns.

Graph 2: Total External Debt Stock/Export Ratios of BRICST Countries

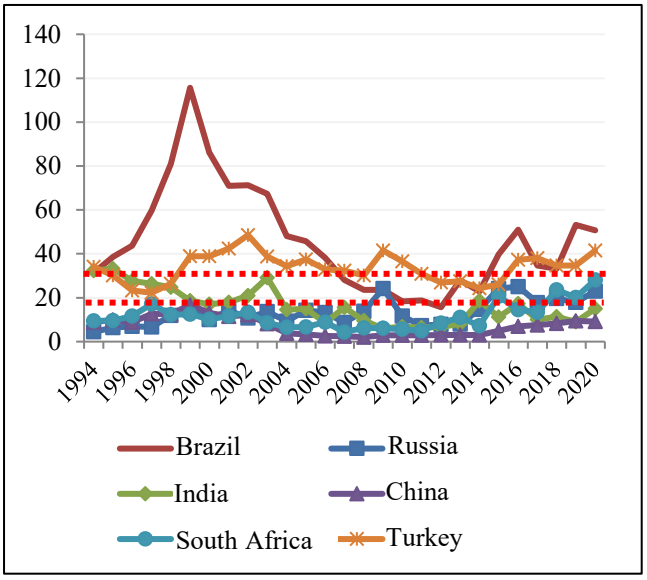


Note: Horizontal red lines indicate thresholds of 165% and 275%. Source: Data taken from the World Development Indicators databank published by the World Bank.

Graph 2 shows that countries' total external debt stock/export ratios generally declined until 2008 and then started to increase again. Brazil and Russia experienced a significant jump in this ratio towards the end of the 1990s, but stabilized in the following periods. China has been the most stable country in terms of the total external debt

stock/exports ratio and has been able to maintain this ratio at almost the same level throughout the years. As of 2020, Brazil, Turkey and South Africa have been moderately indebted countries.

Graph 3: Total External Debt Service/Export Ratios of BRICST Countries



Note: Horizontal red lines indicate thresholds of 18% and 30%. Source: Data taken from the World Development Indicators databank published by the World Bank.

In terms of the total external debt service/exports ratio in Graph 3, Brazil experienced a major crisis in the early 2000s but overcame this crisis until 2011 and managed to reduce this ratio to below the medium indebtedness threshold. China has also managed to maintain its indebtedness in this area and has not deviated significantly from its average. As of 2020, Brazil, Turkey and South Africa have external debt above the over-indebtedness threshold.

Graph 3, depicting the debt service-to-export ratios, further illustrates how debt pressures evolved in the early 2000s. Brazil's sharp increase between 2000 and 2003 aligns with the domestic financial instability preceding the 2002 presidential transition and the legacy of the 1999 devaluation. Rising debt service obligations during this period reflected higher global risk premia and limited access to external financing, which only eased after Brazil secured IMF assistance and regained market confidence in 2003. The subsequent decline in the ratio supports the notion that credible fiscal adjustments and exchange rate flexibility can restore debt sustainability after episodes of distress.

According to the graphs presented so far, Turkey's situation in terms of external debt indicators is not promising. Although Brazil and South Africa occasionally exceed critical thresholds, they do not have as a persistent and major problem as Turkey. China, Russia and India, on the other hand, do not seem to have any problems and it can be concluded that these countries can easily sustain their external debt.

5. Literature Review

The sustainability of external debt has been widely examined for both advanced and emerging economies, yet the results often differ depending on the methodology, time period, and country-specific dynamics considered. This is particularly evident for the BRICST economies, where the literature presents mixed evidence.

For Brazil, some studies conclude that the country's external debt position is unsustainable (George and Shanmugam, 2023; Cline, 2021; Yalçınkaya, 2019; Bozoklu & Yılancı, 2014; Jayme Junior, 2001). Others, however, identify either weak sustainability (Oskay, 2024; Akın and Güneş, 2022; Göçer, 2021) or full sustainability (Raybaudi et al., 2004; Issler & Lima, 2000).

Research on Russia is similarly divided. George and Shanmugam (2023) and Yalçınkaya (2019) suggests unsustainability, while Gümüş (2025), Oskay (2024) and Bozoklu and Yılancı (2014) present the opposite view, arguing that Russia's external debt is in fact sustainable.

In the case of India, the findings span the full spectrum. Some works report weak sustainability (Shankar and Trivedi, 2023; Akın and Güneş, 2022; Cline, 2021; Göçer, 2021; Chandia et al., 2019), others conclude sustainability (Gümüş 2025, Oskay, 2024; Llorca, 2017; Pradhan, 2014; Lau et al., 2013), while George and Shanmugam (2023) and Jha and Sharma (2004) argue that debt levels are unsustainable.

Studies on China lean more toward sustainability. Gümüş (2025), Oskay (2024), George and Shanmugam (2023), Göçer (2021), Sun (2018), Llorca (2017), and Lau et al. (2013) find supportive evidence, though Yalçınkaya (2019) presents a contrasting result.

For South Africa, results vary significantly. Some analyses indicate unsustainability (George and Shanmugam, 2023; Cline, 2021; Bozoklu & Yılancı, 2014), others point to weak sustainability (Oskay, 2024; Akın and Güneş, 2022; Göçer, 2021), and yet others conclude sustainability (George and Shanmugam, 2022; Yalçınkaya, 2019).

Finally, for Turkey, conclusions are highly inconsistent. Several studies highlight unsustainability (Togan and Togan, 2025; Kaya et al. 2025; Oskay, 2024; Dallı, 2022; Cline, 2021; Yalçınkaya, 2019; Göktaş and Hepsağ, 2015; Kıran, 2012; Yılancı & Özcan, 2008). By contrast, Akın and Güneş (2022), Göçer (2021) and Önel and Utkulu (2006) suggest weak sustainability, while Gümüş (2022) and Lau et al. (2013) report that Turkey's external debt is sustainable.

The mixed results highlight two points: findings depend strongly on the chosen method, and debt dynamics change over time with crises, policy shifts, or global shocks. This justifies repeated empirical investigation using updated data and robust testing strategies.

6. Econometric Analysis

6.1. Econometric Model

As econometric model, various macroeconomic indicators that explain the sustainability of external debt in economic approach are considered. Analyses were carried out on Total External Debt Stock/GNI, Total External Debt Stock/Exports and Debt Service Ratio. A complete data set for the BRICST (Brazil, Russia, India, China, South Africa and Turkey) countries subject to the analysis was only available for the period 1994-2023. Therefore, the analysis period covers the period of 1994-2023. Data were obtained from the World Bank. Analyses were carried out by using E-views 12 and Gauss 19.

6.2. Data Set

This section presents the graphs and descriptive statistics of the data sets for the variables and countries that will be analysed in this section. Graph 4 presents the graphs of the data sets for variables and countries.

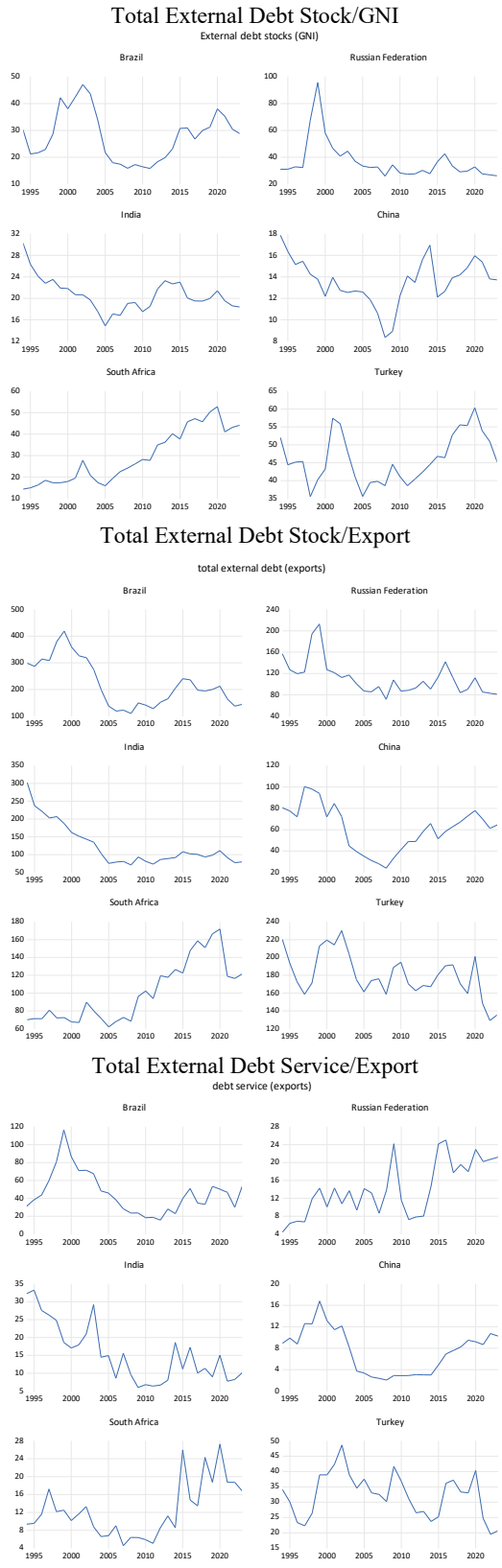
According to the graphs given in Graph 4, it is observed that all of the series have a constant term and a trend. Therefore, in the unit root analyses to be conducted, models with constant and trend will be used as deterministic models. Descriptive statistics of the variables to be analysed in the study are presented in Table 1.

Table 1: Descriptive Statistics of Variables

	Mean	Median	Max	Min	Standard Deviation
Total External Debt Stock/GNI	29.09	26.86	95.67	8.35	13.89
Total External Debt Stock/Export	133.14	116.88	419.00	24.00	71.60
Total External Debt Service/Export	21.25	16.26	116.56	2.07	17.33

According to Table 2, countries' total external debt stock/GNI ratios were realized as 28.78% on average. This ratio reached a maximum value of 95.67 and a minimum value of 8.35. According to this, BRICST countries are, on average, less indebted countries because a ratio between 30% and 50% indicates that the country is moderately indebted. In the total external debt stock/exports variable, the average of BRICST countries was 135.72%. The highest value of this indicator was 415.69 and the lowest value was 24. Again, according to this indicator, BRICST countries are low indebted countries on average, since a ratio of more than 165% puts the country in the position of a medium indebted country. In the total external debt service/exports variable, the average of BRICST countries was 21.31%. The maximum value of this indicator was 115.64, while the minimum value was 2.07. According to this indicator, also called the debt service ratio, BRICST countries are moderately indebted because countries with a debt service ratio between 18% and 30% are considered moderately indebted.

Graph 4: Graphs of Data Sets for Variables and Countries



6.3. Cross-Sectional Dependence

Before analysing external debt sustainability with unit root tests, the existence of cross-sectional dependence among the countries forming the panel should be tested. Because the countries that make up the panel may be jointly affected by shocks, and it is important to reveal this effect during the analysis and to choose appropriate analysis methods in terms of the reliability of the results.

There are different types of cross-sectional dependence tests used in the literature. Among these tests, the Breusch-Pagan (1980) LM test is a method that tests cross-sectional dependence when the time dimension of the panel is larger than the cross-sectional dimension (T>N) (Çınar and Özçalık, 2014: 5628). Since there are 6 countries and 27 years in the study, this test will be applied. Breusch-Pagan (1980) cross-sectional dependence test performs the analysis through the following equation:

$$LM = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\zeta}_{ij}^{2} \quad (1)$$

The expression $\hat{\zeta}_{ij}^{2}$ in the equation represents the square of the correlation between the residuals of unit i. and unit j. and is calculated by the following equation:

$$\hat{Z}_{ij}^{2} = \frac{\sum_{t=1}^{T}\hat{u}_{it}\,\hat{u}_{jt}}{(\llbracket\sum_{t=1}^{T}\hat{u}_{it})\rrbracket^{\frac{1}{2}}\left(\llbracket\sum_{t=1}^{T}\hat{u}_{jt}\right)\rrbracket^{\frac{1}{2}}} \quad (2)$$

The test statistic given here has a χ^2 distribution with $\frac{N(N-1)}{2}$ degrees of freedom. The hypotheses of this test are:

$$H_0 = Cov(u_{it}, u_{jt}) = 0$$
$$H_0 = Cov(u_{it}, u_{jt}) \neq 0$$

Rejecting the null hypothesis indicates the presence of cross-sectional dependence among the units.

In this study, such dependence is examined using the Breusch-Pagan LM test (1980), and the corresponding results are reported in Table 2.

Table 2: Cross-sectional Dependence Test Results

	Breusch-Pagan *LM*	
	Test Value	Probability
Total External Debt Stock/GNI	53.58*	0.00
Total External Debt Stock/Export	139.07*	0.00
Total External Debt Service/Export	60.15*	0.00

Note: * denote 1% significance level.

According to the cross-sectional dependence test results presented in Table 3, all series reject the null hypothesis of "no cross-sectional dependence" according to the Breusch-Pagan LM test. In other words, there is cross-sectional dependence in these series, and therefore, the analyses in the following sections will continue with methods that take this dependence into account.

6.4. Unit Root Tests

Stationarity analyses are sufficient in terms of sustainability. In other words, determining whether a series is stationary or not provides sufficient information about whether the macroeconomic variables represented by that series are sustainable or not. There are many studies on this issue in the literature such as Yılancı et al. (2021), Yılancı and Pata (2020), Aydın and Yılancı (2016). For this reason, this study will check the stationarity of the sustainability indicators considered in the economic approach and reveal whether these indicators are sustainable or not.

In the literature, panel unit root tests are generally classified into two groups: first-generation tests, which ignore cross-sectional dependence, and second-generation tests, which explicitly account for it (Şahin and Şen, 2021: 55). Since the Breusch-Pagan LM test indicated the presence of cross-sectional dependence in all series, the analysis proceeded with second-generation unit root tests, specifically those developed by Carrion-i-Silvestre et al. (2005), Pesaran (2007) CADF, and Becker et al. (2006) Fourier KPSS.

6.4.1. Carrion-i-Silvestre Test

The Carrion-i-Silvestre et al. (2005) unit root test belongs to the class of second-generation tests and is designed to incorporate structural breaks for each time series within a panel. In examining unit roots under multiple break scenarios, the procedure accounts for shifts in both the mean and the trend of the series. The test builds on the Hadri (2000) framework and adopts stationarity as the null hypothesis. An additional advantage of this method is that it produces both joint panel-level results and individual country-level outcomes. The specification of the model used in the Carrion-i-Silvestre (CiS) test that allows for structural breaks is as follows:

$$y_{it} = \beta_{it} + \delta_{it} + u_{it} \quad i = 1, 2 \ldots N \quad t = 1, 2 \ldots T \quad (3)$$

In this equation, β_{it} is:

$$\beta_{it} = \sum_{k=1}^{m_i}\varphi_{i,k}D(T_{b,k}^{i})_t + \sum_{k=1}^{m_i}\theta_{i,k}DU_{i,k,t} + \beta_{i,t-1} + \varepsilon_{i,t} \quad (4)$$

Here $\varepsilon_{i,t} \sim i.i.d(0, \sigma_{\varepsilon,i}^2)$ and $\beta_{i0} = \beta_i$ is a constant. The dummy variable in the equation, $T_{b,\ k}^{i}$, is the kth break date of the ith cross-section and is defined as follows:

$$D(T_{b,k}^{i})_t = 1\ if\ t = T_{b,k}^{i} + 1\ ; otherwise\ 0$$

$$DU_{i,k,t} = 1\ if\ t > T_{b,k}^{i}; otherwise\ 0$$

There is no constraint for k in the model (k=1,2 …m), that is, up to m breaks are allowed. Here the null hypothesis is:

$$H_0: \sigma_{\varepsilon,i}^2 = 0 \quad i = 1, 2 \ldots N$$

This hypothesis denotes stationarity. With this null hypothesis, Equation (4) can be rewritten as:

$$y_{it} = \beta + \sum_{k=1}^{m_i}\varphi_{i,k}DU_{i,k,t} + \sum_{k=1}^{m_i}\theta_{i,k}DT_{i,k,t}^{*} + \delta_i t + u_{i,t} \quad (5)$$

Here;

$$DT^{*}_{i,k,t} = t - T^{i}_{b,k} \; if \;\; t > T^{i}_{b,k} \; , otherwise \; 0$$

$$DT^{*}_{i,k,t} = \begin{cases} t - T^{i}_{b,k} & if \; t > T^{i}_{b,k} \\ 0 \; if \; t \leq T^{i}_{b,k} \end{cases}$$

Due to the nature of Equation (5), the CiS test incorporates the following three conditions.:

- Structural breaks influence each time series in the panel differently, and these effects are captured by the parameters $\theta_{i,k}$ and $\varphi_{i,k}$.
- Such breaks may occur at distinct points in time across series.
- The number of breaks can also vary from one time series to another.

The general equation giving the test results for the CiS unit root test is as follows:

$$LM(\lambda) = N^{-1} \sum_{i=1}^{N} (\widehat{\omega}_i^{-2} \, T^{-2} \sum_{t=1}^{T} S_{i,t}^{2}) \qquad (6)$$

Carrion-i-Silvestre et al. (2005) method is used in the study and both the overall panel and individual country results are presented in the tables below. Models with constant and trend were preferred in the analysis process.

Table 3: CiS Test Results for Total External Debt Stock/GNI

	Test Statistics	Critical Values %10	%5	%1	Number of Breaks	Break Dates
Brazil	0.044	0.270	0.381	0.615	1	2004
Russia	0.187	0.214	0.300	0.570	1	1999
India	0.096	0.451	0.605	0.980	2	2004 2015
China	0.038	0.458	0.614	1.064	2	2007 2014
South Africa	0.051	0.335	0.464	0.745	2	2003 2019
Turkey	0.354***	0.353	0.507	0.848	2	2000 2005
Overall	14.621	32.681	38.871	53.327	-	-

Note: *** denotes 10% significance level.

According to the test results of the total external debt stock/GNI series, all countries in the panel except Turkey are individually stationary under structural break. Therefore, all countries except Turkey are in a sustainable position according to the total external debt stock/GNI indicator. Likewise, the overall panel result also shows that countries' external debt is sustainable. Again, for this indicator, there is one structural break in Brazil in 2004, one structural break in Russia in 1999, two structural breaks in India in 2004 and 2015, two structural breaks in China in 2007 and 2014, two structural breaks in South Africa in 2003 and 2019, and two structural breaks in Turkey in 2000 and 2005.

Table 4: CiS Test Results for Total External Debt Stock/Export

	Test Statistics	Critical Values %10	%5	%1	Number of Breaks	Break Dates
Brazil	0.033	0.268	0.342	0.457	2	1998 2004
Russia	0.153	0.331	0.407	0.575	1	1999
India	0.087	0.314	0.381	0.545	1	2004
China	0.132	0.141	0.141	0.141	1	2002
South Africa	0.098	0.175	0.226	0.330	2	2008 2018
Turkey	0.221	0.223	0.301	0.535	0	-
Overall	7.972	13.901	16.494	21.421	-	-

According to the test results of the total external debt stock/export series, all countries in the panel are individually stationary under structural break. Therefore, all countries are in a position to sustain their external debt according to the total external debt stock/exports indicator. Likewise, the overall panel result also shows that countries' external debt is sustainable. Again, for this indicator, there are two structural breaks in Brazil in 1998 and 2004, one structural break in Russia in 1999, one structural break in India in 2004, two structural breaks in China in 1998 and 2005, one structural break in South Africa in 2004 and two structural breaks in Turkey in 1998 and 2003.

Table 5: CiS Test Results for Total External Debt Service/Export

	Test Statistics	Critical Values %10	%5	%1	Number of Breaks	Break Dates
Brazil	0.093	0.448	0.632	1.107	2	1998 2007
Russia	0.068	0.276	0.395	0.648	1	2014
India	0.031	0.291	0.391	0.654	1	2011
China	0.038	0.313	0.435	0.788	2	1998 2006
South Africa	0.047	0.273	0.393	0.611	1	2014
Turkey	0.063	0.271	0.389	0.761	2	1998 2015
Overall	3.575	26.072	31.236	44.476		

According to the test results of the total external debt service/export series, all countries in the panel except Turkey are individually stationary under structural break. Therefore, all countries except Turkey can sustain their external debt according to the total external debt service/exports indicator. This indicates that Turkey has high short-term debt payments, i.e. it has a liquidity problem. Similarly, the overall panel result shows that countries' external debt is sustainable. Again, for this indicator, there are two structural breaks in Brazil in 1998 and 2007, one structural break in Russia in 2014, one structural break in India in 2011, two structural breaks in China in 1998 and 2006, one structural break in South Africa in 2014 and two structural breaks in Turkey in 1998 and 2015.

The structural breaks identified in the CiS tests are not mere statistical anomalies but coincide with major domestic and

global economic developments that directly shaped the external debt dynamics of BRICST countries. For Brazil, the 2004 break in the total debt-to-GNI ratio reflects the macroeconomic stabilization efforts following the 1999 currency crisis and the subsequent boom in commodity exports. The 1998 and 2004 breaks in the debt-to-export ratio correspond to the pre-IMF financial distress and the later recovery driven by stronger external demand, while the 1998 and 2007 breaks in debt service-to-export coincide with the Russian crisis contagion and the onset of the 2008 global financial turmoil.

In Russia, the 1999 break clearly mirrors the aftermath of the 1998 sovereign default and the Ruble collapse, whereas the 2014 break in the debt service-to-export ratio is associated with Western sanctions and the sharp depreciation of the Ruble following the annexation of Crimea.

For India, breaks in 2004 and 2015 (total debt-to-GNI) indicate transitions from the high-growth phase of the early 2000s to the post– "taper tantrum" adjustment period. The 2004 break in the debt-to-export ratio corresponds to the liberalization-driven surge in capital inflows, while the 2011 break in debt service-to-export captures the slowdown in exports and rising oil import bills that tightened external balances.

In China, the 2007 and 2014 breaks in the total debt-to-GNI ratio reflect, respectively, the pre-crisis export boom and the slowdown associated with the shadow banking and property market corrections. The 2002 break in the debt-to-export ratio relates to WTO accession and the consequent surge in trade, whereas the 1998 and 2006 breaks in the debt service-to-export series capture the Asian financial crisis and pre-2008 credit expansion phase.

South Africa's breaks in 2003 and 2019 (total debt-to-GNI) correspond to periods of exchange rate depreciation and, later, the pre-pandemic fiscal deterioration. The 2008 and 2018 breaks in the debt-to-export ratio align with the global financial crisis and subsequent commodity price downturns, while the 2014 break in debt service-to-export reflects declining investor confidence amid domestic policy uncertainty.

For Turkey, the 2000 and 2005 breaks in the total debt-to-GNI series coincide with the domestic banking crisis, IMF-supported stabilization, and EU accession-related capital inflows. The 1998 and 2003 breaks in the debt-to-export ratio correspond to contagion from the Asian/Russian crises and early structural reforms under the new fiscal rule regime. Finally, the 1998 and 2015 breaks in debt service-to-export reflect both global financial stress and post-2013 capital outflows linked to political and geopolitical tensions.

Collectively, these historical correspondences demonstrate that structural breaks in the CiS tests successfully capture the interaction between external shocks and country-specific vulnerabilities. They underline that debt sustainability assessments cannot be separated from the broader context of financial crises, trade cycles, and policy regime changes

6.4.2. Pesaran Test

The unit root test proposed by Pesaran (2007) belongs to the class of second-generation tests that explicitly address cross-sectional dependence. In the literature, this method is commonly known as the Cross-Sectionally Augmented Dickey-Fuller (CADF) test. While the CADF provides country-specific results within the panel, Pesaran's framework also includes the Cross-Sectionally Augmented IPS (CIPS) test, which delivers findings for the panel as a whole. A key strength of this approach is its reliability even when both the cross-sectional (N) and time-series (T) dimensions are relatively small. Moreover, it can be applied regardless of whether the time dimension is larger than the cross-sectional dimension or vice versa (Pesaran, 2007: 266–267)

The CADF test starts the process with the following equation where y_{it} is the observation value of the ith cross-section at time t:

$$y_{it} = (1 - \phi_i)\mu_i + \phi_i y_{i,t-1} + u_{it}$$

$$i = 1, 2, \dots N; t = 1, 2, \dots T \quad (7)$$

Here, The initial value, y_{i0}, is assumed to follow a density function with a finite mean and variance, while the error term, u_{it}, is specified to follow a single-factor structure:

$$u_{it} = \gamma_i f_i + \varepsilon_{it} \quad (8)$$

In the equation, f_i denotes unobserved common effects and ε_{it} denotes idiosyncratic errors. Substituting Equation (8) into Equation (7) and subtracting $y_{i,t-1}$ from both sides of Equation (7) yields the following equation:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i f_i + \varepsilon_{it} \quad (9)$$

Here; $\alpha_i = (1 - \phi_i)\mu_i$, $\beta_i = -(1 - \phi_i)$ and $\Delta y_{it} = y_{it} - y_{it-1}$. Hence, the unit root hypotheses are:

$$H_0: \beta_i = 0 \; for \; all \; i$$

$$H_1: \beta_i < 0, i = 1, 2, \dots N_1, \; \beta_i = 0, i = N_1 + 1, N_1 + 2, \dots, N$$

Among these hypotheses, H_0 implies that the series is non-stationary for all i's, while H_1 implies that the series is stationary.

The CIPS statistic for the panel as a whole can be calculated by averaging the CADF statistics calculated for each cross-section:

$$CIPS(N,T) = N^{-1} \sum_{i=1}^{N} CADF_i \quad (10)$$

CADF and CIPS tests were conducted for each variable and the results are presented in the tables below. Models with constant and trend were preferred in the analysis process. Maximum lag lengths are taken as 3.

Table 6: CADF and CIPS Test Results for Total External Debt Stock/GNI

	Lag	Test Statistics	Probability
Brazil	1	-2.77109	>=.10
Russia	3	-6.93407*	<0.01
India	0	-3.11814	>=.10
China	0	-2.65343	>=.10
South Africa	0	-2.63092	>=.10
Turkey	3	-5.67626*	<0.01
CIPS	-	-3.96399*	<0.01

Note: * denotes 1% significance level.

According to the results in Table 6, while the null hypothesis of non-stationarity is accepted in all countries except Russia and Turkey, this hypothesis is rejected in Russia and Turkey. In other words, in all countries except Russia and Turkey, the total external debt stock/GNI variable is non-stationary, and the external debt is found to be unsustainable in these countries. Only Russia and Turkey have sustainable external debt. The overall results of the panel show that the external debt of BRICST countries is generally sustainable.

Table 7: CADF and CIPS Test Results for Total External Debt Stock/Export

	Lag	Test Statistics	Probability
Brazil	3	-4.05318**	<0.05
Russia	3	-5.70459*	<0.01
India	3	-4.06269**	<0.05
China	3	-1.47266	>=.10
South Africa	3	-3.41624	>=.10
Turkey	0	-0.63672	>=.10
CIPS	-	-3.22435*	<0.01

Note: * and ** denote 1% and 5% significance levels, respectively.

According to the results in Table 7, the null hypothesis that the series are non-stationary is accepted in all countries except Brazil, Russia and India, while this hypothesis is rejected in Brazil, Russia and India. In other words, in all countries except Brazil, Russia and India, the total external debt/exports variable is non-stationary and external debt is unsustainable in these countries. Only Brazil, Russia and India have sustainable external debt. The results for the overall panel show that external debt is generally sustainable in BRICST countries.

According to the results in Table 8, the null hypothesis of non-stationarity is accepted in all countries except Brazil and Russia, while this hypothesis is rejected in Brazil. In other words, the total external debt service/exports variable is non-stationary in all countries except Brazil and Russia and external debt is unsustainable in these countries. Only Brazil's and Russia's external debt is sustainable. The results for the overall panel also show that external debt is unsustainable in BRICST countries.

Table 8: CADF and CIPS Test Results for Total External Debt Service/Export

	Lag	Test Statistics	Probability
Brazil	2	-3.92106**	<0.05
Russia	0	-3.66814***	<0.10
India	1	-2.78259	>=.10
China	0	-0.84476	>=.10
South Africa	3	-2.70871	>=.10
Turkey	0	-0.55868	>=.10
CIPS	-	-2.41399	>=0.10

Note: ** and *** denote %5 and 10% significance levels, respectively.

6.4.3. Becker Fourier KPSS Test

Unlike other tests with structural breaks following a linear and predetermined process, Fourier group tests follow a process in which the number, structure and location of structural breaks are not predetermined. Therefore, they are more powerful than other tests (Fendoğlu and Canpolat Gökçe, 2019: 24). The Becker et al. (2006) method starts the test with a data generation process as below:

$$y_t = X_t'\beta + Z_t'\gamma + r_t + \varepsilon_t \quad (11)$$

$$r_t = r_{t-1} + u_t \quad (12)$$

Here; ε_t is the stationary error term and u_t is independent and identically distributed (i.i.d.) with variance σ_u^2. Also here, $X_t = [1]$ is used for a level-stationary process in variable y_t and $X_t = [1, t]'$ for a trend-stationary process. The variable Z_t in Equation (11) captures the break in the deterministic term and is as in Equation (13):

$$Z_t = [\sin\left(\frac{2\pi kt}{T}\right), \cos\left(\frac{2\pi kt}{T}\right)]' \quad (13)$$

Here; k represents the frequency and T represents the sample size. Under the hypothesis of $\sigma_u^2 = 0$, the process described above in Equation (11) is stationary. The rationale behind this specification of the Z_t equation is that a Fourier expansion can converge to integrable functions with a desired level of accuracy. For example, let α_t be a function with an unknown number of breaks of unknown form. Regardless of the nature of the breaks, under very weak conditions, α_t can be converged to the desired level of precision by sufficiently long Fourier series:

$$\alpha(t) = \alpha_0 + \sum_{k=1}^{n} a_k \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} b_k \cos\left(\frac{2\pi kt}{T}\right);$$

$$n < \frac{T}{2}, \quad (14)$$

In Equation (14), n is the number of frequencies included in the convergence and k is a given frequency. Starting with $n = 1$, it is possible to increase the quality of the convergence by adding new frequencies. When $n = T/2$, $\alpha(t)$ will have a perfect fit. However, to make the problem tractable, it can be started with a single frequency Fourier convergence:

$$\alpha(t) \cong Z_t'\gamma = \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) \quad (15)$$

Here k is the frequency selected for convergence and $\gamma = [\gamma_1 + \gamma_2]'$ measures the width of the frequency. In Becker et al. (2006), the following models are estimated first to obtain the test statistic:

$$y_t = \alpha + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) \quad (16)$$

$$y_t = \alpha + \beta t + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) \quad (17)$$

Equation (16) tests for stationarity at level, while Equation (17) tests for stationarity with trend. $\tau_\mu(k)$ denotes the test statistics of Equation (16) and $\tau_\tau(k)$ denotes the test statistics of Equation (17) and these test statistics are calculated as follows:

$$\tau_\mu(k) \text{ or } \tau_\tau(k) = \frac{1}{T^2}\frac{\sum_{t=1}^{T}\tilde{S}_t(k)^2}{\tilde{\sigma}^2} \quad (18)$$

In the Equation $\tilde{S}_t(k) = \sum_{j=1}^{t}\tilde{e}_j$ and $\tilde{e}_j$ are the error terms of the least squares method from Equations (16) and (17). $\tilde{\sigma}^2$ is the nonparametric estimate of the long-run variance and is obtained using the truncation lag parameter l and the weights w_j as follows:

$$\tilde{\sigma}^2 = \tilde{\gamma}^2 + 2\sum w_j\tilde{\gamma}_j \quad (19)$$

Here; $\tilde{\gamma}_j$ is the jth autocovariance of the residuals $\tilde{e}_j$ obtained from Equations (16) and (17). The standard KPSS test is more powerful if the data generating process does not have a nonlinear trend. Therefore, the presence of a nonlinear trend should be tested. At a given frequency k, the corresponding F statistic is calculated as follows:

$$F_i(k) = \frac{(RSS_0 - RSS_1(k))/2}{RSS_1(k)/(T-q)}, \qquad i = \mu, \tau \quad (20)$$

Here; RSS_1 is the residual sum of squares and q is the number of independent variables. RSS_0 is the sum of squares without trigonometric terms. The null hypothesis of this test is stationarity while the alternative hypothesis is non-stationarity. Therefore, when the test statistic is smaller than the critical values, the null hypothesis of stationarity is accepted.

In this study, the Fourier KPSS unit root test proposed by Becker et al. (2006) is employed for the specification including both a constant and a trend. The results of the Fourier KPSS test for Brazil are reported in Table 9.

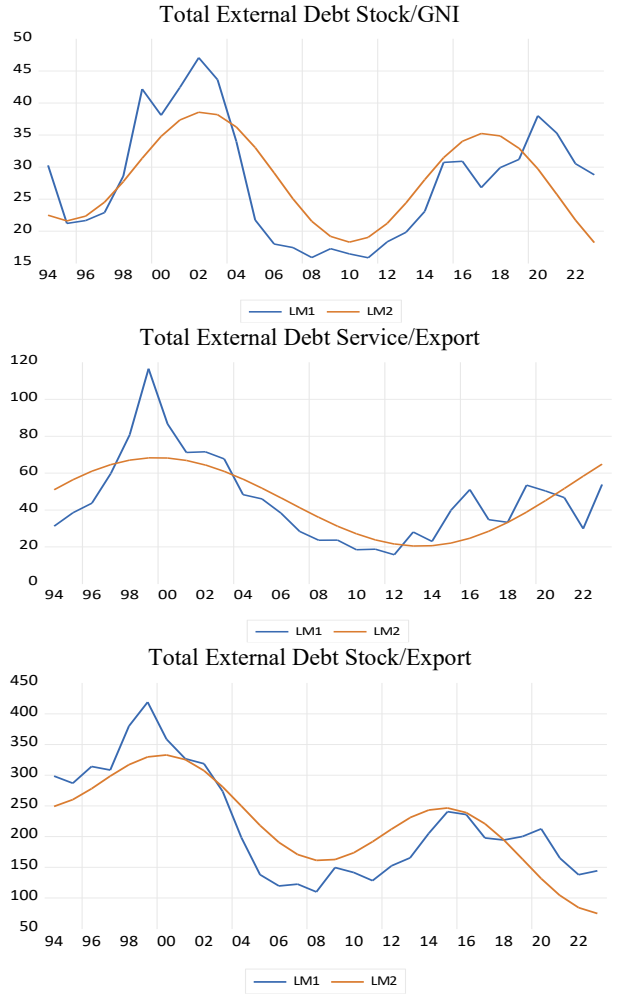
According to Table 9, all series of Brazil have unit roots at different significance levels. In other words, none of the series are stationary. This is because the test statistics are greater than the critical values. In this case, the null hypothesis that the series are stationary is rejected. This result implies that external debt in Brazil is unsustainable according to the Fourier KPSS test. Fourier KPSS graphs for Brazil are presented below.

Table 9: Fourier KPSS Test Results for Brazil

	k	Test Statistics	Critical Value %1	%5	%10
Total External Debt Stock/GNI	2	0.14*	0.2022	0.1321	0.1034
Total External Debt Stock/Export	2	0.17*	0.2022	0.1321	0.1034
Total External Debt Service/Export	1	0.068**	0.0716	0.0546	0.0471

Note: * and ** indicate 1% and 5% significance level, respectively. The maximum number of frequencies (k) is set to 3.

Graph 5: Fourier KPSS Graphs for Brazil



Results in Graph 5 clearly demonstrate that the series (blue lines) for Brazil follow smooth structural breaks and swings through the estimated time paths (red lines). Optimum number of frequencies in the series (k) can also be seen on the graphs. The results of the Fourier KPSS test for Russia are presented in Table 10.

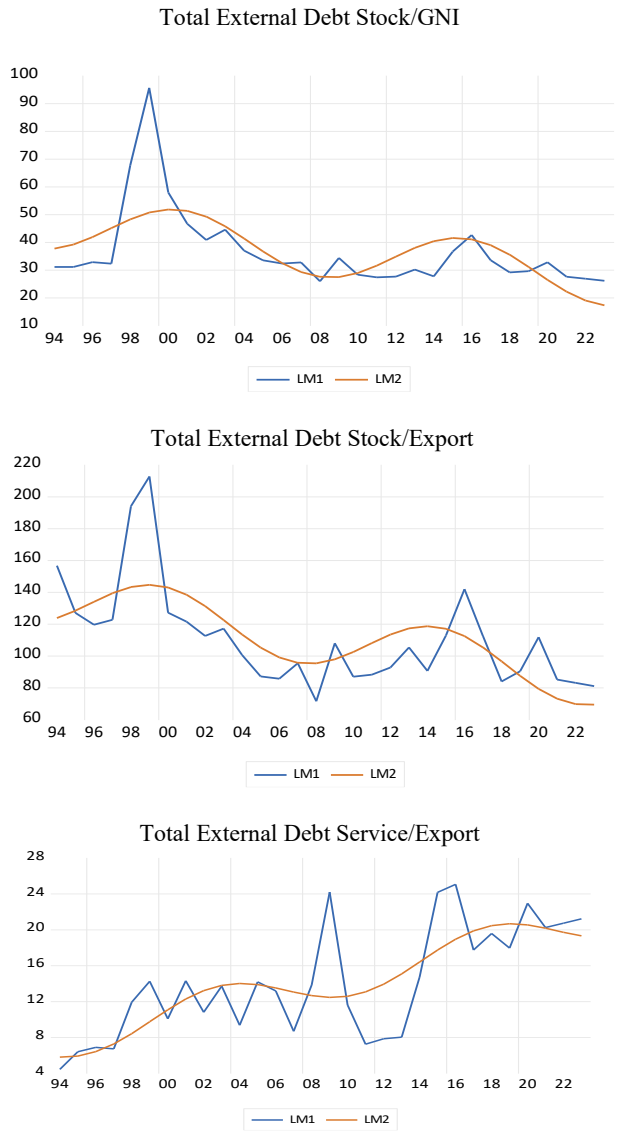
Table 10: Fourier KPSS Test Results for Russia

	k	Test Statistics	Critical Value %1	%5	%10
Total External Debt Stock/GNI	2	0.077	0.2022	0.1321	0.1034

Total External Debt Stock/Export	2	0.15*	0.2022	0.1321	0.1034
Total External Debt Service/Export	2	0.20**	0.2022	0.1321	0.1034

Note: *** indicate 10% significance level. The maximum number of frequencies (k) is set to 3.

Graph 6: Fourier KPSS Graphs for Russia



According to Table 10, since the test statistic obtained from the analyses for total external debt stock/GNI is smaller than the critical values, this series is stationary. In other words, Russia's external debt is sustainable in terms of these series. In the Total External Debt Stock/Exports and Total External Debt Service/Exports series, the test statistics are greater than the critical values at the 1% and 5% significance levels, respectively. Therefore, the null hypothesis of stationarity is rejected, and it is concluded that these series are non-stationary. In other words, according to this series, Russia's external debt is unsustainable. As a general conclusion, since most of the series are non-stationary (1 stationary and 2 non-stationary), it can be said that Russia's external debt is unsustainable. Fourier KPSS graphs for Russia are presented below.

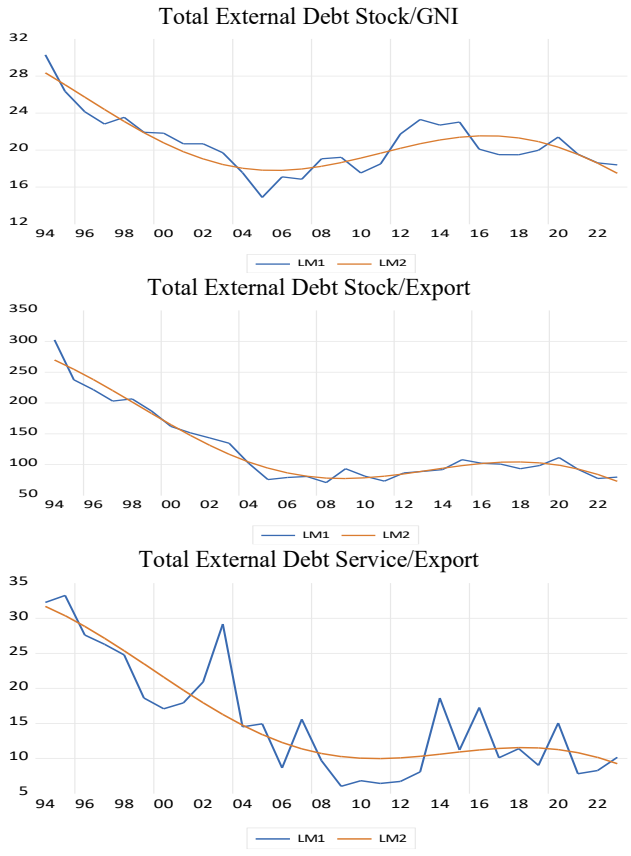
Results in Graph 6 clearly demonstrate that the series (blue lines) for Russia follow smooth structural breaks and swings through the estimated time paths (red lines). Optimum number of frequencies in the series (k) can also be seen on the graphs. The results of the Fourier KPSS test for India are presented in Table 11.

Table 11: Fourier KPSS Test Results for India

	k	Test Statistics	Critical Value		
			%1	%5	%10
Total External Debt Stock/GNI	1	0.08*	0.0716	0.0546	0.0471
Total External Debt Stock/Export	1	0.50*	0.0716	0.0546	0.0471
Total External Debt Service/Export	1	0.06**	0.0716	0.0546	0.0471

Note: * and ** indicate 1% and 5% significance levels, respectively. The maximum number of frequencies (k) is set as 3.

Graph 7: Fourier KPSS Graphs for India



According to the results in Table 11, the test statistics of all series are greater than the critical values. In other words, none of the series are stationary and external debt is unsustainable for India. Fourier KPSS graphs for India are presented below.

Results in Graph 7 clearly demonstrate that the series (blue lines) for India follow smooth structural breaks and swings through the estimated time paths (red lines). Optimum number of frequencies in the series (k) can also be seen on the graphs. The results of the Fourier KPSS test for China are presented in Table 12.

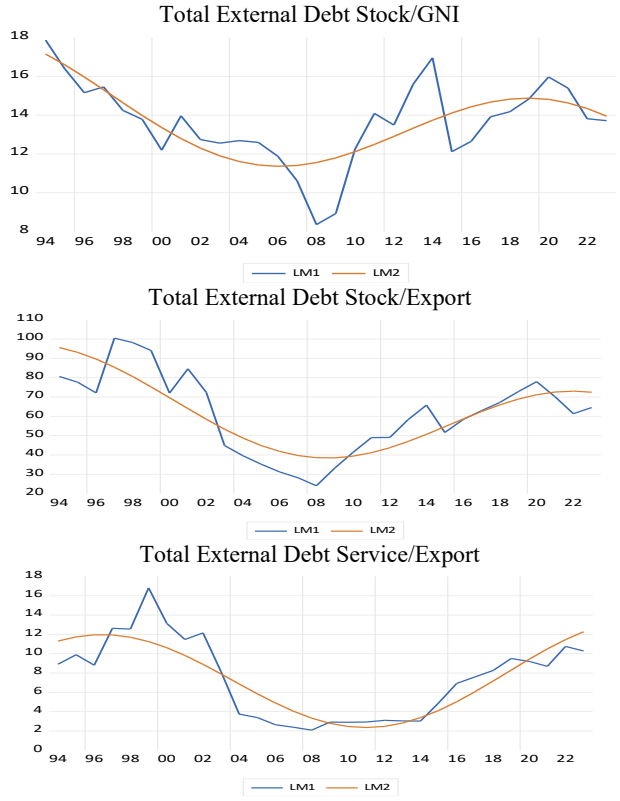
Table 12: Fourier KPSS Test Results for China

	k	Test Statistics	Critical Value		
			%1	%5	%10
Total External Debt Stock/GNI	1	0.048***	0.0716	0.0546	0.0471
Total External Debt Stock/Export	1	0.057**	0.0716	0.0546	0.0471
Total External Debt Service/Export	1	0.059**	0.0716	0.0546	0.0471

Note: ** indicates 5% significance level. The maximum number of frequencies (k) is set as 3.

According to the results in Table 12, all the series are not stationary. In general, the results suggest that China's external debt is unsustainable as all of the external debt indicators are unsustainable. Fourier KPSS graphs for China are presented below.

Graph 8: Fourier KPSS Graphs for China



Results in Graph 8 clearly demonstrate that the series (blue lines) for China follow smooth structural breaks and swings through the estimated time paths (red lines). Optimum number of frequencies in the series (k) can also be seen on the graphs. The results of the Fourier KPSS test for South Africa are presented in Table 13.

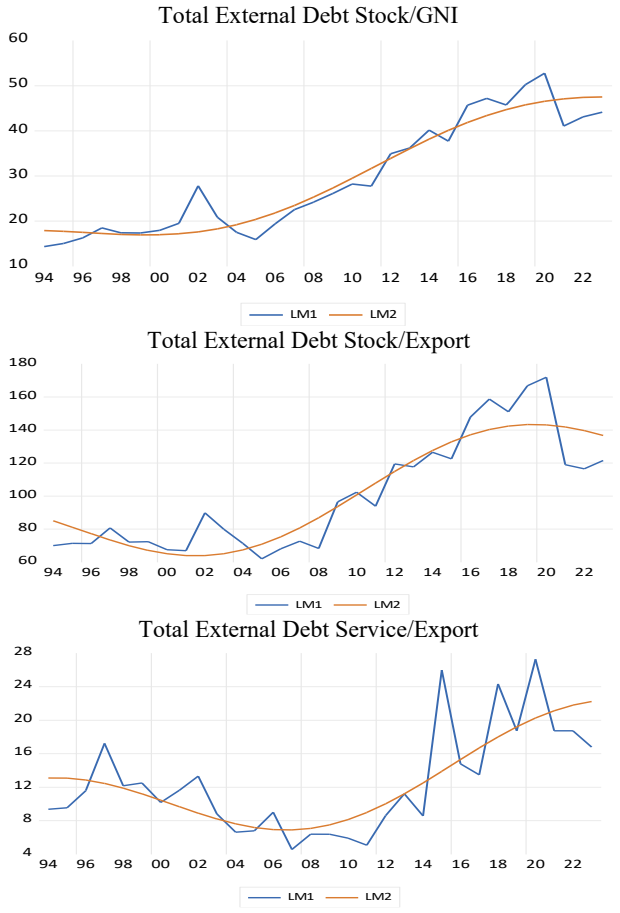
Table 13: Fourier KPSS Test Results for South Africa

	k	Test Statistics	Critical Value		
			%1	%5	%10
Total External Debt Stock/GNI	1	0.09*	0.0716	0.0546	0.0471
Total External Debt Stock/Export	1	0.06**	0.0716	0.0546	0.0471
Total External Debt Service/Export	1	0.06**	0.0716	0.0546	0.0471

Note: * indicates 1% significance level: * indicates 1% significance level. The maximum number of frequencies (k) is set to 3.

According to Table 13, all series for South Africa are non-stationary and unsustainable. Fourier KPSS plots for South Africa are presented below.

Graph 9: Fourier KPSS Graphs for South Africa



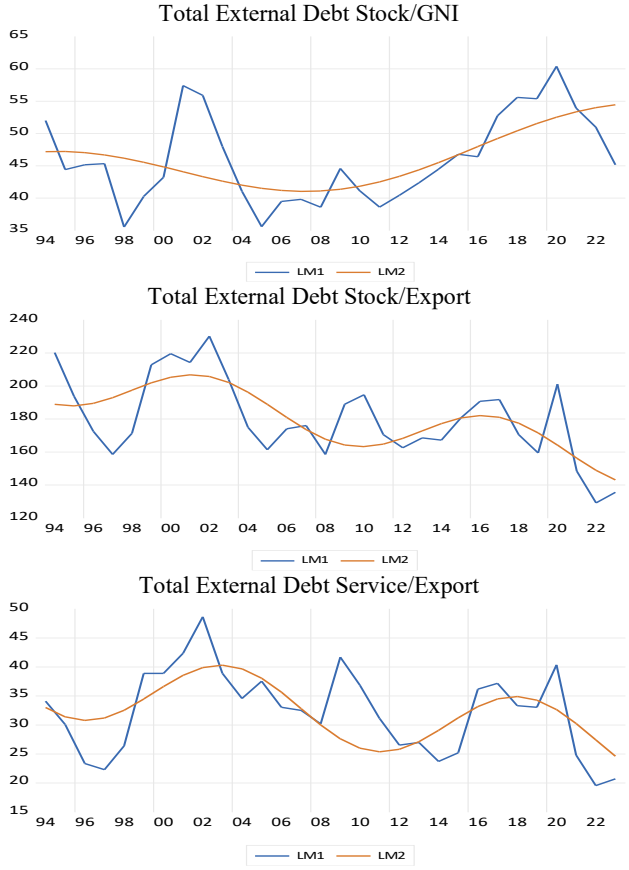
Results in Graph 9 clearly demonstrate that the series (blue lines) for South Africa follow smooth structural breaks and swings through the estimated time paths (red lines). Optimum number of frequencies in the series (k) can also be seen on the graphs. The results of the Fourier KPSS test for Turkey are presented in Table 14.

Table 14: Fourier KPSS Test Results for Turkey

	k	Test Statistics	Critical Value		
			%1	%5	%10
Total External Debt Stock/GNI	1	0.04	0.0716	0.0546	0.0471
Total External Debt Stock/Export	2	0.19**	0.2022	0.1321	0.1034
Total External Debt Service/Export	2	0.16**	0.2022	0.1321	0.1034

According to Table 14, total external debt stock/GNI is smaller than the critical values, this series is stationary. In other words, Turkey's external debt is sustainable in terms of these series. In the Total External Debt Stock/Exports and Total External Debt Service/Exports series, the test statistics are greater than the critical values at the 5% significance levels. Therefore, the null hypothesis of stationarity is rejected, and it is concluded that these series are non-stationary. In other words, according to this series, Turkey's external debt is unsustainable. As a general conclusion, since most of the series are non-stationary (1 stationary and 2 non-stationary), it can be said that Turkey's external debt is unsustainable.

Graph 10: Fourier KPSS Graphs for Turkey



Results in Graph 10 clearly demonstrate that the series (blue lines) for Turkey follow smooth structural breaks and swings through the estimated time paths (red lines). Optimum number of frequencies in the series (k) can also be seen on the graphs.

The divergence in findings across the CiS, Pesaran, and Becker Fourier KPSS tests underscores the importance of methodological context. The CiS test, by design, assumes stationarity as the null hypothesis and incorporates multiple structural breaks. This makes it particularly powerful in identifying sustainability when sharp regime shifts are present. However, its sensitivity to the number and placement of breaks may bias results toward stationarity.

In contrast, the Pesaran CADF/CIPS test accounts for cross-sectional dependence—a feature that is highly relevant for the BRICST economies given their integration into global financial markets. Yet, the small sample size (30 years) limits its power, often resulting in non-stationarity outcomes even when sustainability may be present. The Becker Fourier KPSS test, while more flexible in modeling smooth breaks, is sensitive to frequency selection and tends to produce stricter judgments of unsustainability.

6.4.4. Limitations of Tests

Although the applied tests offer important advantages in assessing debt sustainability, they are not without limitations. The CiS test, for instance, is sensitive to the choice and number of structural breaks, which may lead to different conclusions under alternative specifications. Similarly, the Pesaran CADF test, while addressing cross-sectional dependence, may suffer from size distortions in relatively small samples. The Fourier KPSS test allows for smooth structural breaks, yet the interpretation of frequency parameters can be ambiguous. Furthermore, the structural breaks detected in our analysis are not mere statistical artefacts but correspond to significant economic and political events. For example, the break in Brazil in 1999 coincides with the financial crisis, while Turkey's 2015 break can be linked to domestic political instability. These findings highlight that sustainability assessments should always be interpreted in the light of country-specific shocks and global crises, as such events can alter debt dynamics substantially.

7. Discussion

While this study follows a well-established empirical tradition in treating the stationarity of debt ratios as evidence of sustainability, it is important to acknowledge that this equivalence remains contested in literature. Stationarity implies that deviations from a long-run equilibrium are temporary and eventually mean-reverting implying that temporary shocks to debt eventually dissipate through fiscal adjustment, economic growth, or external balance improvements., which is consistent with the intertemporal budget constraint framework. However, several authors (e.g., Trehan and Walsh, 1991; Bohn, 1998; Mendoza and Ostry, 2008) caution that a stationary debt ratio does not automatically ensure long-run solvency, particularly when fiscal institutions are weak or when economies are exposed

to persistent external shocks. In such cases, stationarity may reflect short-term adjustments or cyclical corrections rather than genuine fiscal sustainability. Conversely, non-stationarity does not always imply insolvency, especially if temporary deficits are offset by future surpluses or structural reforms.

Alternative approaches, such as cointegration tests between government revenue and expenditure or probabilistic models of debt distress, can offer complementary insights. Nonetheless, unit root–based tests are particularly useful in this study's context for two reasons: (i) they directly capture the mean-reverting behaviour of external debt indicators under global shocks and structural breaks, and (ii) they allow comparability across heterogeneous countries with limited data availability. By employing the CiS, Pesaran CADF, and Becker Fourier KPSS tests, the analysis integrates different econometric perspectives—accounting for breaks, cross-sectional dependence, and smooth regime shifts—thus mitigating some limitations of traditional unit root frameworks.

Another limitation concerns indicator selection. The present analysis focuses on three key measures—external debt-to-GNI, external debt-to-exports, and debt service-to-exports—which capture solvency and liquidity dimensions of external borrowing. However, broader macro-financial vulnerabilities, such as fiscal balance sustainability, current account deficits, exchange rate volatility, and credit risk (proxied by CDS spreads or sovereign ratings), also play critical roles. Future research could expand this framework by incorporating these indicators or applying a multivariate approach to assess how exchange rate movements and fiscal positions jointly affect debt dynamics.

The study period (1994–2023) encompasses both pre- and post-pandemic dynamics, allowing a more comprehensive assessment of external debt sustainability in the BRICST economies. This extended timeframe captures the extraordinary fiscal and financial developments of the early 2020s, including the pandemic-induced surge in public borrowing, the subsequent tightening of global monetary conditions, and the sharp rise in interest rates beginning in 2021. These shocks significantly altered debt trajectories, particularly in emerging markets with substantial external financing needs.

By covering this expanded period, the analysis reflects not only the stabilization and reform episodes of the 1990s and 2000s but also the renewed vulnerabilities that emerged in the aftermath of COVID-19 and the global interest rate hike cycle. The inclusion of the 1994–2023 data therefore enhances the contemporary relevance of the findings, illustrating how the sustainability of external debt has evolved under intensified global financial pressures. Nevertheless, the unprecedented scale of recent fiscal expansions and shifts in capital flows suggests that debt dynamics remain highly sensitive to policy credibility, exchange rate management, and investor sentiment. The results should thus be interpreted as capturing both the long-run adjustment capacity of the BRICST economies and their renewed exposure to external shocks in the post-pandemic era.

8. Conclusion

This paper examined the sustainability of external debt in the BRICST countries over the period 1994–2020 using three second-generation panel unit root tests that account for structural breaks and cross-sectional dependence. The results consistently indicate that external debt is sustainable in Russia and Turkey, while Brazil, India, China, and South Africa exhibit unsustainable debt dynamics.

According to the results of the CiS test applied to the series, it was found that the total external debt service/exports ratio was non-stationary only in Brazil and Turkey, while all other series were stationary in all countries. According to CiS test, external debt is sustainable in all countries. According to the results of Pesaran test, total external debt stock/GNI series is sustainable only in Russia and Turkey, total external debt/exports series is sustainable only in Russia and India and total external debt service/exports series is sustainable only in Brazil. According to the results of the Pesaran test, in general, all series are unsustainable for all countries. Finally, according to the results of the Becker test, it is found that external debt in Brazil, India and South Africa is unsustainable in terms of all variables while external debt in Turkey is sustainable in terms of all variables. In addition, the total external debt stock/export series in Russia is unsustainable while the others are sustainable (2 sustainable and 1 unsustainable) and the total external debt stock/GNI series in China is sustainable while the others are unsustainable (1 sustainable and 2 unsustainable). Since the subject of the study is the sustainability of external debt in BRICST countries, it would be accurate to summarize the results on country basis.

The consolidated results presented in Table 15 provide a comprehensive assessment of external debt sustainability across the BRICST economies by combining the outcomes of the CiS, Pesaran CADF, and Becker Fourier KPSS tests. Overall, the findings reveal that Brazil and Russia demonstrate sustainable external debt dynamics across most indicators and methodologies. In both countries, debt ratios exhibit mean-reverting behaviour even when structural breaks and cross-sectional dependence are taken into account, suggesting that fiscal adjustments and external buffers have been sufficient to maintain long-term solvency.

Table 15: Consolidated Sustainability Results

	Brazil	Russia	India

	CiS	Pesaran	Becker	CiS	Pesaran	Becker	CiS	Pesaran	Becker
Total External Debt Stock/GNI	✓	×	×	✓	✓	✓	✓	×	×
Total External Debt Stock/Export	✓	✓	×	✓	✓	×	✓	✓	×
Total External Debt Service/Expor	✓	✓	×	✓	✓	×	✓	×	×
Result	✓	✓	×	✓	✓	×	✓	×	×

	China			South Africa			Turkey		
	CiS	Pesaran	Becker	CiS	Pesaran	Becker	CiS	Pesaran	Becker
Total External Debt Stock/GNI	✓	×	×	✓	×	×	×	✓	✓
Total External Debt Stock/Export	✓	×	×	✓	×	×	✓	×	×
Total External Debt Service/Export	✓	×	×	✓	×	×	✓	×	×
Result	✓	×	×	✓	×	×	✓	×	×

Note: ✓ represents sustainability and × represents unsustainability. If a test result is dominated by sustainable variables, the result is labelled ✓, and if unsustainable variables dominate, the result is labelled ×.

In contrast, India, China, South Africa, and Turkey display unsustainability signals in at least two of the three testing frameworks. These results indicate that their external debt positions remain more vulnerable to global financial tightening, exchange rate volatility, and domestic structural rigidities. The persistence of non-stationary patterns in these countries suggests that increases in external borrowing have not been fully offset by export growth or fiscal surpluses, implying heightened sensitivity to global interest rate cycles and capital flow reversals.

Taken together, the consolidated findings emphasize that external debt sustainability within the BRICST group is heterogeneous and conditional rather than uniform. While Brazil and Russia appear to have maintained solvency through a combination of export strength, fiscal discipline, and effective debt management, the remaining economies face greater challenges in aligning growth and external financing dynamics. These results highlight the importance of macroeconomic credibility, debt maturity optimization, and diversification of export bases in ensuring long-term sustainability amid rising global borrowing costs.

The results for Brazil are consistent with Raybaudi et al., (2004) and Issler & Lima, 2000, for Russia with Gümüş (2025), Oskay (2024) and Bozoklu & Yılancı (2014), for India with George and Shanmugam (2023) and Jha and Sharma (2004), for China with Yalçınkaya (2019), for South Africa with George and Shanmugam, 2023; Cline, 2021; Bozoklu & Yılancı, 2014 and finally for Turkey with Togan and Togan (2025), Kaya et al. (2025), Oskay (2024), Dallı (2022), Cline (2021), Yalçınkaya (2019), Göktaş & Hepsağ (2015), Kıran (2012) and Yılancı & Özcan (2008).

Several implications emerge from these results. First, external borrowing alone does not determine sustainability; what matters is whether debt is directed toward growth-enhancing investment or toward short-term consumption. Countries such as Russia and Turkey may have managed to strike a better balance in this regard, at least during the sample period. Second, the global financial cycle plays a crucial role. For example, the rise in debt ratios after the 2008 global crisis underscores how external shocks can quickly alter sustainability assessments. Finally, the mixed results across countries reflect the importance of domestic macroeconomic fundamentals—growth performance, export capacity, exchange rate stability, and fiscal discipline all shape debt trajectories differently.

The findings of this study should be interpreted in light of both theoretical perspectives and recent global developments. From a theoretical standpoint, the unsustainability results observed for Brazil, India, China, and South Africa resonate with the debt overhang hypothesis, where excessive debt accumulation hampers growth and discourages investment. The contrasting results for Russia and Turkey highlight the importance of the intertemporal budget constraint approach, as these countries appear to have managed to align debt dynamics with export revenues during the sample period.

In terms of recent developments, the global environment has shifted significantly after 2020. The COVID-19 pandemic

led to unprecedented fiscal expansions and rising public debt across both advanced and emerging economies. Subsequently, the sharp rise in global interest rates since 2021, driven by the U.S. Federal Reserve and other central banks, has increased external borrowing costs for emerging markets. This tightening cycle amplifies rollover risks, particularly for countries already classified as unsustainable in this study. For example, South Africa and Brazil, which rely heavily on foreign financing, face higher refinancing costs and capital outflow pressures. Similarly, India and China, while having stronger domestic savings, are not immune to the spillover effects of tighter global financial conditions.

These connections suggest that debt sustainability is not a static condition, but a dynamic outcome shaped by both domestic fundamentals and global cycles. The empirical evidence provided in this paper complements the existing literature by showing how sustainability assessments evolve with crises, structural breaks, and changes in the global financial environment.

Interpreting the results reached in the study, some policy advice is listed below:

(i). Efficient Use of Borrowed Funds: Sustainability depends not merely on the volume of borrowing but on how resources are allocated. Directing debt toward productive investments—such as infrastructure, technology, and export-oriented industries—can strengthen repayment capacity and reduce future vulnerabilities.

(ii). Strengthening Export Capacity: Since repayment relies on foreign exchange earnings, expanding and diversifying exports is crucial. Economies with narrow export bases, such as South Africa and Brazil, remain more exposed to global price swings.

(iii). Improving Fiscal and Monetary Discipline: Macroeconomic stability plays a key role in ensuring sustainability. Stronger fiscal frameworks, credible monetary policy, and effective debt management strategies can help prevent debt from escalating to unsustainable levels.

(iv). Crisis Preparedness and Global Shocks: The sharp increases in debt ratios following the 2008 financial crisis illustrate how external shocks quickly undermine sustainability. Countries need to maintain sufficient reserves, flexible exchange rate regimes, and precautionary fiscal buffers to withstand such episodes.

Along with this general advice and beyond the general principles of prudent borrowing and macroeconomic stability, several concrete country-specific policy implications emerge from the findings:

Countries with unsustainable debt dynamics, such as Brazil, India, China, and South Africa, should strengthen fiscal rules and enhance transparency in budgetary practices. Establishing medium-term fiscal frameworks and independent fiscal councils could help anchor expectations and reduce debt sustainability risks.

Since debt repayment capacity largely depends on foreign exchange earnings, policies should prioritize diversification of exports and upgrading value chains. For instance, reducing dependence on commodity exports (Brazil, South Africa) and focusing on high-value-added sectors can improve resilience to external shocks.

Extending the average maturity of external debt and reducing the share of short-term borrowing are crucial steps to mitigate rollover risk, as highlighted in the 1999 and 2015 breaks for Brazil and Turkey. Encouraging local currency bond markets and developing domestic capital markets can further limit foreign exchange vulnerabilities.

Since high CDS spreads increase refinancing costs, countries especially like Turkey should prioritize institutional reforms and policy credibility. Transparent communication reserves and fiscal policies, maintaining adequate foreign exchange reserves, and ensuring central bank independence are instrumental in lowering risk perceptions in international markets.

The sharp rise in global interest rates after the COVID-19 pandemic underscores the importance of pre-emptive buffers. Countries should adopt countercyclical fiscal policies, build precautionary reserves, and implement flexible exchange rate regimes to better absorb global financial shocks.

Taken together, these measures emphasize that sustainability cannot be achieved solely through lower borrowing but requires a comprehensive strategy combining fiscal prudence, external competitiveness, debt management, and credibility-enhancing reforms.

Based on these results, it can be stated that Brazil, India, China and South Africa, where external debt is not sustainable, should be more careful about external debt. At this point, countries with unsustainable external debt structures are advised to utilize their external debt in investment areas that may increase domestic savings, to make moves that will bring foreign exchange to the country by increasing growth and especially exports, not to re-borrow to repay existing debts, and to be prepared for the possibility that important indicators for external debt service such as growth/exports, which are already at high levels, may deteriorate in a short time due to unforeseen regional/global events such as war/crisis.

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