Assessing Fiscal Sustainability with Panel Unit Root, Cointegration, and Granger Causality Tests: Evidence from the Broader Groups of Countries

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Abstract

The question of fiscal sustainability of countries has become one of the central topics in economic policy, especially in times of increasing public debts. One way to assess fiscal sustainability is to examine compliance with the intertemporal budget constraint, which involves testing the stationarity of government revenues and expenditures, the primary budget balance, and the first differences of public debt. Part of this approach includes testing cointegration and causality among different pairs of variables. Under this approach, the paper is focused on both first- and second-generation panel unit root tests, cointegration, and Granger causality test. This paper focuses on assessing the fiscal sustainability of four panels of countries divided by continents: Europe, Asia and Oceania, Africa, and Latin America, the Caribbean, and North America. It has been found that fiscal sustainability is present in all the broader groups of countries considered but in a weak form. Fiscal sustainability was confirmed when considering a constant in calculations, while deviations were observed among groups of countries when both a constant and trend were considered. The study serves as a starting point for a more extensive analysis of fiscal sustainability. For more accurate findings, it would be necessary to categorize countries into smaller and economically more homogeneous groups and analyze them using other fiscal sustainability methods as well.

Introduction

The issue of fiscal sustainability is gaining interest among researchers in recurring periods of economic crises as countries often rely on extensive government expenditures that are not balanced with either higher current or future government revenues. Such behavior results in increasing borrowing needs of governments, which leads to persistently higher public debt levels. Therefore, the study of fiscal sustainability is focused on two aspects. Firstly, the identification of factors that cause the inability to balance the budget balance and,

secondly, the negative effects of unsustainable public finance and public borrowing on the economy (Brady & Magazzino, 2018). Consequently, the key two variables that are studied under fiscal sustainability are primary budget balance and public debt (Krejdl, 2006).

The issue of ensuring fiscal sustainability is a phenomenon that affects all groups of countries. Low-income countries and emerging economies face vulnerable access to capital markets, rising public debts, an expanding public sector, and vulnerability to cyclical changes or financial contagion. On the other hand, developed economies confront challenges in ensuring fiscal sustainability over a longer time period, as their social measures are of a long-term nature and often require high financial inputs while facing demographic challenges. With the development of methods for assessing the present value of debt, there has been increased interest in studying fiscal sustainability, as countries have begun to accumulate long-term liabilities that are not evident in budget balances or assessed with current budget surpluses. Four dimensions of fiscal sustainability are highlighted. The first dimension is solvency, which is often emphasized by researchers and means the government's ability to repay its obligations. The next dimension is economic growth, as fiscal policy must pursue measures that lead to sustainable and long-term economic growth while considering fiscal sustainability. The third dimension is stability, referring to the government's capacity to repay future obligations with existing tax burdens. The last dimension is equity, which represents the government's capacity to repay its obligations without transferring costs to future generations. All four discussed dimensions of fiscal sustainability are intertwined and are not separate units of study in the phenomenon of fiscal sustainability (Schick, 2005).

The ability of the government to sustain credible public finances and the capacity to deliver public services over the long run are outlined in the definition of fiscal sustainability. It takes strategic monitoring and forecasting of future revenues and obligations, environmental conditions, and other socio-economic trends to ensure long-term fiscal sustainability and effective budget planning (OECD, 2013). Demographic trends, sudden economic contractions, and limited fiscal spaces pose challenges for countries in maintaining fiscal sustainability. Budget revenues must be carefully planned to ensure solvency without increasing the tax burden that falls on economic entities. The function of fiscal sustainability is also to ensure intergenerational equity, as excessive shifting of obligations to the future

causes a limited range of public services in the future. Fair fiscal policy must pursue conditions of fiscal sustainability in such a way that budget revenues meet fiscal capacities in the present and limit the transfer of the tax burden to future generations (OECD, 2009).

The country's public finances are described as sustainable when the present value of future budget surpluses is equalized with the current level of public debt. This condition is also described as the intertemporal budget constraint, under which the government can manage its public debt. Therefore, any public debt rollover does not cause excessive accumulation and does not pose an insolvency risk (Krejdl, 2006). The fulfillment of public sustainability conditions can improve a country's position on financial markets with more favorable conditions for issuing government bonds, as it reflects a lower probability of sovereign risk (Chen, 2014).

In this study, we examined the fiscal sustainability of countries in four panels divided by continents: Europe, Asia and Oceania, Africa, and Latin America, the Caribbean, and North America. The paper is structured as follows. We first reviewed the theory and empirical evidence in Section 2, which allowed us to determine the appropriate methodological approach and select the data set that is described in Section 3. In Section 4 we have presented the results, where we first presented descriptive statistics, then proceeded to present the first-generation unit root tests and Pesaran's second-generation unit root test. Testing fiscal sustainability with the unit root tests is the first methodological step, therefore, we have proceeded with testing the cointegration on various pairs of variables using Pedroni's test and Granger causality with the Dumitrescu-Hurlin test.

The main aim of the study is to detect the fiscal sustainability in the examined group of countries. The study contributes to the literature on the assessment of fiscal sustainability with a standard approach using panel unit root and cointegration tests with the inclusion of recent periods. Examination of a broader group of countries covers a significant number of countries that are usually left out in studies of smaller groups of countries, even if that contributes to more homogenous panels.

Theoretical Background and Literature Review

The main focus when studying fiscal sustainability is placed on the primary budget balance and public

balance. These two key fiscal variables mainly describe the fiscal conditions of a country (Croce & Juan-Ramón, 2003). The study of fiscal sustainability follows the arithmetic of the budget balance, where the relationship between government expenditures and government revenues is described. The budget deficit presents a situation where the government revenues insufficiently cover all government expenditures and interest from previously issued public debt, and other contingent liabilities, therefore, posing a risk of unsustainable public finances. The issue of budget deficit arises with its financing, as deficits are financed through the issuance of government bonds that accumulate public debt over time (Case et al., 2012, p. 179).

It is also important to observe the primary budget balance, as it excludes interest expenses on public debt. If the primary budget balance is in deficit, i.e., budgetary expenditures exceed budgetary revenues, or if the surplus of the primary budget balance is smaller than the real interest repayments on public debt, the country will find itself in a budget deficit. The reasons for a deficit in the primary budget balance can vary. The most common reasons are the need for countercyclical fiscal policy, wars, and natural disasters, structural reforms of the economy, delays in public financial consolidation, external shocks, and various economic-psychological factors (Guellec & Wunsch-Vincent, 2009; Döring & Oehmke, 2019). Fall et al. (2015) summarize the following political-economic factors as reasons for budgetary indiscipline:

- The lack of information about the conduct of fiscal policy leads to situations where politicians exploit the public's ignorance about the state of the public budget, therefore, the political cycle has a significant impact on the budget balance;
- The competition of political parties for election causes an increase in the scope of budget expenditures as a percentage of GDP, in order to ensure a relatively larger scale of public goods and services. Public borrowing represents a convenient tool for financing such political programs;
- Rent-seeking by various groups, who wish to gain budgetary benefits through lobbying without providing equivalent value, causes additional negative pressures on the unbalance of the budget;
- The pursuit of intergenerational solidarity causes the necessary increases in budget revenues to be deferred to the future, thereby transferring the burden of costs for servicing a relatively higher public debt and the current budget deficit onto future generations;

- Governments inadequately pursue the counter-cyclical orientation of fiscal policy and act in accordance with the business cycle, as there is often fiscal indiscipline in times of favorable macroeconomic conditions.

In the empirical literature review, we focused on referential studies of fiscal sustainability that incorporated the methodology for testing fiscal sustainability through panel unit root tests and cointegration, along with the assessment of the fiscal reaction function. The objective was to encompass studies that investigated different groups of countries, which are part of the broader panels of countries under study.

Chen (2014) analyzed the fiscal sustainability of the G7 group of countries and selected European countries using quarterly data from the first quarter of 1980 to the fourth quarter of 2012. By testing for the presence of a unit root in the public debt-to-GDP ratio variable, the author found that a unit root is present in the sample under study, indicating a violation of the fiscal sustainability condition. The public debt-to-GDP ratio shows time series stationarity for Canada, Germany, the USA, and Italy when calculations take into account a nonlinear trend in the long-term and asymmetric data adjustment. Brady & Magazzino (2019) investigated the stationarity and cointegration of budget revenues and expenditures in the case of Italy, examining the long-term characteristics of both fiscal variables between 1862 and 2013. It was found that a unit root is present throughout the entire period, which rejects the condition of fiscal sustainability, although weak cointegration can be detected, suggesting the weak presence of fiscal sustainability. The authors divided the entire observed period into different sub-periods and found that fiscal sustainability can be confirmed for the sub-period between 1862 and 1913, while fiscal sustainability cannot be confirmed for the period 1947-2013.

Magazzino (2022) studied the fiscal sustainability of a group of six countries included in the Gulf Cooperation Council during the period 1990-2017. Using Pesaran's unit root test and Pedroni's cointegration test, the author rejected the fiscal sustainability of the group of countries under consideration. Bahrain and Qatar stand out among the studied countries, with a unit root process present in all fiscal variables, as well as an absence of cointegration between budget revenues and expenditures, and between the primary budget balance and public debt. The same applies to Saudi Arabia and Oman, which do not show a long-term relationship between budget

revenues and expenditures. In the group of countries under consideration, a strong impact of changes in oil prices on budget revenues can be detected, which can explain the deviation from the conditions of fiscal sustainability.

Campo-Robledo & Melo-Velandia (2015) examined the fiscal sustainability of a group of eight Latin American countries over the period 1960-2009, using the Carrion-i-Silvestre et al. (2005) second-generation unit root test and the Westerlund (2006) cointegration test. The authors confirmed the fiscal sustainability of the Latin American countries group, although both budget expenditures and budget revenues did not reject the presence of a unit root. The fiscal sustainability of the countries under study could be confirmed through the cointegration between budget revenues and expenditures, even though the cointegration link is weak. Chile, Panama, and Uruguay have the relatively highest level of fiscal sustainability among the countries studied, while Colombia, Paraguay, Argentina, Ecuador, and Peru exhibited a relatively lower level of fiscal sustainability, having experienced numerous debt crises during the study period.

Similarly, Westerlund & Prohl (2010) confirmed the presence of fiscal sustainability for eight developed OECD countries between the first quarter of 1997 and the fourth quarter of 2005 using a similar approach. Beqiraj et al. (2018), who studied the fiscal sustainability of 21 OECD countries between 1991 and 2015, tested for stationarity with Pesaran's second-generation unit root test and cointegration of various fiscal variables. The fiscal variables studied are not among the conventional variables in analyses of countries' fiscal sustainability, as, besides the public debt-to-GDP ratio, variables like the cyclically adjusted primary budget balance and the ratio of public debt to potential GDP were tested. The authors found that fiscal sustainability could not be confirmed in the group of countries studied. Sandica (2013) found the presence of a unit root in both budget expenditures and revenues in a panel of the Czech Republic, Hungary, Poland, and Romania between the first quarter of 2000 and the fourth quarter of 2011, and confirmed cointegration between these variables, indicating fiscal sustainability in the countries under study. Krajewski et al. (2016) for 10 Central and Eastern European countries between 1990 and 2012, using first-generation unit root tests, found that public debt is integrated of order one, while the variables of budget expenditures and revenues are cointegrated. These findings confirm fiscal sustainability on the panel of countries under study, which was also confirmed by

estimating the fiscal reaction function using the Bohn (2007) method.

Baharumshah & Lau (2007) studied the fiscal sustainability of five East Asian countries between the first quarter of 1975 and the second quarter of 2003. Through first-generation unit root tests and cointegration, they confirmed the fiscal sustainability of the countries under study. Strong cointegration between real budget revenues and expenditures was confirmed for South Korea, Thailand, and Singapore, unlike Malaysia and the Philippines, which have relatively low cointegration vectors between real budget revenues and expenditures. The panel of South Asian countries, including India, Pakistan, Bangladesh, Sri Lanka, and Nepal, was studied by Shastri et al. (2018) for the period between 1985 and 2014. Using Pedroni's unit root test and Westerlund's cointegration test, they confirmed the long-term relationship between budget revenues and expenditures, indicating the presence of fiscal sustainability in the countries under study. Shastri et al. (2018) supported their findings with calculations of the fiscal reaction function but noted a low degree of fiscal sustainability in the long term. Rajakaruna & Suardi (2022) reached similar conclusions with the estimation of the fiscal reaction function for Sri Lanka, India, and Pakistan. A positive sign in the impact of public debt on the primary budget balance confirms the condition of fiscal sustainability, which, however, is not a sufficient condition, as additional tests rejected the presence of long-term fiscal sustainability.

Adams et al. (2010) studied the fiscal sustainability of 49 Asian and Pacific countries, members of the Asian Development Bank, between 1990 and 2008. The authors, with estimates of fiscal reaction functions and various supporting stress tests of alternative scenarios, confirmed the fiscal sustainability of the countries under study. Findings were reinforced with calculations for individual Asian regions and selected countries.

When studying fiscal sustainability, researchers often face data availability issues, leading to a limited set of countries that allows for analyzing over a longer period. Afonso & Jalles (2014) tested fiscal sustainability in 19 selected countries between 1880 and 2009. They confirmed the stationarity of the first difference of public debt for most of the countries under study, with only Spain and Japan standing out for rejecting long-term fiscal sustainability. The results of unit root tests and cointegration of budget expenditures and revenues showed consistent findings both in the study of individual countries and the entire panel.

Nzimande & Ngalava (2019) studied a group of 13 countries of the Southern African Development Community for the period 1980-2014, testing for the presence of a unit root with Pesaran's test and cointegration with Westerlund's test on the variables of budget expenditures and revenues. The authors did not reject the null hypothesis of the presence of a unit root, as the variables of budget expenditures and revenues are integrated of order one. Nevertheless, cointegration between the two fiscal variables could be confirmed, hence Nzimande & Ngalava (2019) confirmed the presence of fiscal sustainability in the countries under study. Khadan (2019) examined the fiscal sustainability of 10 Caribbean countries during the period 1991-1997. With unit root tests, cointegration, and fiscal sustainability function tests, the author confirmed weak fiscal sustainability. This status was affirmed by cointegration tests, which were also supported by the fiscal reaction function.

Afonso & Rault (2010) investigated 15 European Union countries between 1970 and 2006 using first- and second-generation unit root tests, and by checking the cointegration of budget expenditures and revenues, as well as real public debt and the primary budget balance. They found that the solvency condition was met, as the stock of real public debt is integrated of order zero. The results of unit root tests on budget expenditures and revenues were consistent, as both first- and second-generation tests confirmed the integration of both variables at order one. With Pedroni's and Westerlund's cointegration tests, cointegration between budget expenditures and revenues was confirmed, which means fiscal sustainability was affirmed in the selected European Union countries. In the study of individual countries, it was determined that Austria, Finland, France, Germany, the Netherlands, the United Kingdom, and Sweden meet the conditions of fiscal sustainability.

In their study of 19 European Union countries between 1996 and 2020, Afonso and Coelho (2022) also confirmed the solvency condition, as the first difference of the stock of real public debt showed stationarity using Pesaran's unit root test. Long-term cointegration links between budget revenues and expenditures, the primary budget balance as a percentage of GDP, public debt as a percentage of GDP, and public debt as a percentage of GDP with the primary budget balance as a percentage of GDP lagged by one time unit were also confirmed. Using Dumitrescu and Hurlin's panel Granger causality test, Afonso & Coelho (2022) found the following relationships: budget expenditures as a percentage of GDP influence budget revenues as a percentage of GDP,

lagged public debt as a percentage of GDP by one year affects the primary budget deficit as a percentage of GDP, lagged primary budget deficit as a percentage of GDP by one year affect public debt as a percentage of GDP, while budget revenues as a percentage of GDP do not influence budget expenditures as a percentage of GDP. The authors confirmed the fiscal sustainability of the countries under study with the fiscal reaction function test. They also found that fiscal rules and the overall budget as a percentage of GDP positively influence fiscal sustainability, while trade openness as a percentage of GDP, the current account balance as a percentage of GDP, and government efficiency negatively affect the primary budget balance.

Covered studies in the literature review reveal diverse findings on the state of fiscal sustainability in analyzed countries using unit panel unit root and cointegration tests. For panels as a whole in the existing literature it is common to confirm the presence of weak fiscal sustainability. Furthermore, between the countries in the examined panel, we can find heterogeneous results on fiscal sustainability among them. In the present article, we complement the literature on the assessment of fiscal sustainability with a methodological approach of using unit root and cointegration tests.

Methodology and Data Set Decription

The field of research on the fiscal sustainability of countries is related to the solvency of the public budget, which refers to meeting the intertemporal budget constraint. The fundamental variables studied in fiscal sustainability are public debt and primary budget balance (Bohn, 2007). The empirical literature distinguishes two standard approaches for verifying the solvency of the public budget. The first approach focuses on examining the characteristics of time series of fiscal and macroeconomic variables. This approach involves testing the stationarity and cointegration of various fiscal variables. However, this verification does not allow for firm conclusions about fiscal sustainability due to assumptions about the characteristics of fiscal variable time series. Therefore, a second approach emerged in the empirical literature, established by Bohn (1998; 2005; 2007) for testing the solvency of the public budget by estimating the fiscal reaction function. Bohn's method of testing fiscal sustainability involves estimating the marginal responsiveness of the budget surplus to various fiscal, macroeconomic, and other variables. With this approach, fiscal sustainability can be confirmed based on the positive marginal responsiveness of the budget balance to changes in public debt and other studied variables (Cho & Lee, 2022).

The approach to assessing fiscal sustainability by testing the stationarity of public debt and the cointegration of budget expenditures and revenues was established in the empirical literature by Hamilton & Flavin (1986) and Trehan & Walsh (1991). Time series are stationary when the mean and variance in the time unit are not changing in the time. While covariance between two time units is dependent only on the time lag between values of variables in these two time units and not from the actual period, from which the covariance is calculated. For the case of fiscal sustainability, the same order of integration for various fiscal variables is important, as discrepancy would present us with the different dynamics of fiscal variables and would lead us to the conclusion of assuming fiscal unsustainability.

The theory of fiscal sustainability can be explained by an equation that represents the budget constraint, which determines budget flows (Westerlund & Prohl, 2010):

$$G_t + (1 + r_t)D_{t-1} = R_t + D_t \qquad (1)$$

In Equation 1, G denotes budget expenditures, R represents budget revenues, D is public debt, and r represents the real interest rate paid on public debt. The verification of fiscal sustainability stems from testing the present value of the budget constraint (PVBC), which can be written with the following equation (Afonso, 2005):

$$D_{t-1} = \sum_{s=0}^{\infty} \frac{1}{(1+r)^{s+1}} (R_{t+s} - G_{t+s}) + \lim_{s \to \infty} \frac{D_{t+s}}{(1+r)^{s+1}} \quad (2)$$

The intertemporal budget constraint is met if the second term of the equation tends towards zero in the limit to infinity. At that point, the highest growth rate of public debt is constrained by the real interest rate, which in the literature is termed as the absence of a Ponzi game or the transversality condition. Governments must balance any increase in the present value of public debt with an increase in the surplus of the primary budget balance. Testing the absence of a Ponzi game can be done by verifying the stationarity of the first difference of public debt, while fiscal sustainability can also be assessed by testing the cointegration between budget revenues and expenditures. The process of assessing fiscal sustainability is conducted in the following steps (Afonso, 2005):

- First, unit root tests are conducted on the variables of budget expenditures and budget revenues. If the budget revenues are integrated of order zero and the budget expenditures have first-order integration, or if the budget expenditures are integrated of order zero and the budget revenues have first-order

integration, then we cannot confirm fiscal sustainability. If both budget revenues and budget expenditures are integrated of order zero, then such a result represents confirmed fiscal sustainability. In the case of first-order integration for both budget expenditures and budget revenues, a further cointegration test between budget revenues and budget expenditures is required.

- If budget revenues and budget expenditures are not cointegrated, then fiscal sustainability is not present. Despite the absence of cointegration between budget revenues and budget expenditures, such a connection does not pose a problem for fiscal sustainability if the budget revenues are higher than budget expenditures. In the case of cointegration between budget revenues and budget expenditures, it is necessary to check the value of the cointegration vector to assess fiscal sustainability.

- If the cointegration vector between budget expenditures and budget revenues equals 1, then there is fiscal sustainability with a constrained ratio between public debt and GDP. Fiscal sustainability is also present in the case of a cointegration vector that is less than 1, but in such a case, we have fiscal sustainability without a constrained ratio between public debt and GDP. If the cointegration vector between budget expenditures and budget revenues is greater than 1, then we cannot confirm fiscal sustainability.

However, it is necessary to be aware that verifying fiscal sustainability solely through the first approach, which consists of examining the characteristics of time series, can lead to misleading conclusions. Numerous unit root tests can show different results regarding the stationarity of fiscal variables, and such an examination of fiscal sustainability involves an excessive focus on past dynamics, which cannot guarantee the future dynamics of fiscal variables. Verifying fiscal sustainability with unit root and cointegration tests does not allow us to study and identify the various factors affecting fiscal sustainability, providing limited informational value about the formulated fiscal policy. A sensible complement is the second approach to verifying fiscal sustainability according to Bohn's method, which allows checking the impact of public debt, macroeconomic, and other variables on the primary budget balance with a regression model (Can, 2023).

In this research, we will limit ourselves to the approach of testing the stationarity and cointegration of various fiscal variables, taking into account the mentioned limitations of this approach.

The data for the analysis of fiscal sustainability were collected from the IMF database (2023), designed by Mauro et al. (2015). In line with the research of Afonso & Coelho (2022) and other studies presented in the literature review, data were collected for budget revenues, budget expenditures, the primary budget balance, and public debt. All the variables under study are expressed as a percentage of GDP. Annual data for all countries were obtained from the database, and then the selection of countries was based on the availability of data for the period between 1995 and 2021, which represents our study period. For the feasibility of empirical tests, we aimed to create balanced panels, so that countries included in the analysis had available data for the observed period between 1995-2021. 127 countries were divided into the following four groups based on geographical location:

- Europe – 30 countries and 27 years, resulting in 810 observations;
- Asia and Oceania – 37 countries and 27 years, resulting in 999 observations;
- Africa – 32 countries and 27 years, resulting in 864 observations;
- Latin America, the Caribbean, and North America – 28 countries and 27 years, resulting in 756 observations.

The division of countries into groups is shown in Appendix 1, where the four presented groups of countries make up separate panel data that we analyzed in the study. In these groups of countries, we tested the hypothesis stating: Fiscal sustainability is present in the studied groups of countries between 1995 and 2021.

Results

In this chapter, we first presented the descriptive statistics of the fiscal variables studied in the research. This is followed by the first-generation unit root tests of Levin, Lin & Chu, and Im, Pesaran & Shin, which we used to test the stationarity of budget revenues and expenditures, the primary budget balance, and the first difference of public debt. We then checked for the presence of a unit root on the same variables using Pesaran's test, as this second-generation unit root test accounts for cross-sectional dependence. Conclusions about the presence of fiscal sustainability in the groups of countries under study were made after conducting Pedroni's cointegration test and Dumitrescu and Hurlin's Granger causality test.

Descriptive Statistics

Before we begin presenting the calculations of unit roots, cointegration, and Granger causality, we can examine the descriptive statistics of individual groups of countries, where special attention was paid to the arithmetic mean and standard deviation. In Table 1, we can observe that, during the study period, the group of European countries recorded the highest value of the arithmetic mean in budget revenues, budget expenditures, and public debt.

For budget revenues and budget expenditures, this difference is relatively high, as European countries have more than a 10 percentage point higher share of budget expenditures and revenues as a percentage of GDP than the group of countries from Asia and Oceania, which has the second-highest arithmetic mean value of these two fiscal variables. The arithmetic mean of public debt as a percentage of GDP for European countries compared to other groups is not significantly higher, as African countries have a lower arithmetic mean value of public debt as a percentage of GDP by 1.2 percentage points. The highest average value of the primary budget balance as a percentage of GDP is recorded by the group of countries from Asia and Oceania, which, like European countries and the group of countries from Latin America, the Caribbean, and North America, have an average primary budget balance as a percentage of GDP in surplus. Only the group of countries from Asia and Oceania has an average value of the primary budget balance as a percentage of GDP in deficit. The lowest average value of budget revenues and budget expenditures as a percentage of GDP can be found in the group of African countries, while the group of countries from Asia and Oceania recorded the lowest average value of public debt as a percentage of GDP during the study period.

The highest standard deviation of the variables of budget revenues, budget expenditures, and the primary budget balance was recorded in the group of countries from Asia and Oceania, indicating that this group of countries had the highest variability around the average for these variables. This suggests relatively the most volatile and diverse fiscal policy among the countries studied. Public debt as a percentage of GDP had the highest standard deviation in the group of African countries. On the other hand, the group of countries from Latin America, the Caribbean, and North America had the relatively lowest standard deviation for the variables of budget revenues and the primary budget balance, while the relatively

lowest value of the standard deviation for budget expenditures and public debt was recorded in the group of European countries.

Table 1

Descriptive statistics of examined fiscal variables

Europe	Government revenue (% of GDP)	Government expenditure (% of GDP)	Primary budget balance (% of GDP)	Public debt (% of GDP)
Mean	42.73741	44.86787	0.479833	59.67061
Median	42.67662	45.36931	0.213939	53.73911
Maximum value	59.67470	66.82280	20.57039	212.4489
Minimum value	22.29026	24.26086	-28.17485	3.764939
Standard deviation	7.140171	7.092167	4.077183	34.20736
Asia and Oceania	Government revenue (% of GDP)	Government expenditure (% of GDP)	Primary budget balance (% of GDP)	Public debt (% of GDP)
Mean	30.95163	32.22020	0.723899	47.44849
Median	26.64701	30.28318	-0.233833	39.64523
Maximum value	153.3713	137.3595	47.76756	262.4920
Minimum value	3.487907	8.392471	-24.52537	1.561886
Standard deviation	18.31017	16.29593	7.108267	35.20019
Africa	Government revenue (% of GDP)	Government expenditure (% of GDP)	Primary budget balance (% of GDP)	Public debt (% of GDP)
Mean	21.01225	23.47001	-0.715881	58.55503
Median	18.40130	21.53123	-1.221664	48.98661
Maximum value	62.66851	141.5014	31.24285	263.3720
Minimum value	2.764126	7.380385	-117.6795	0.488086
Standard deviation	9.646273	10.66361	6.409674	40.20173
Latin America, the Caribbean, and North America	Government revenue (% of GDP)	Government expenditure (% of GDP)	Primary budget balance (% of GDP)	Public debt (% of GDP)
Mean	22.76766	25.30024	0.103356	55.23910
Median	22.76704	25.02865	0.063303	46.78176
Maximum value	60.12687	67.93982	14.41452	319.0883
Minimum value	4.300100	9.311014	-30.27498	3.901890
Standard deviation	6.947125	7.336462	3.917408	34.31300

Source: Authors' calculation

First-Generation Panel Unit Root Tests

First-generation unit root tests that account for cross-sectional independence are the first step in verifying fiscal sustainability under the considered approach. Special attention needs to be paid to the first difference of public debt, which, by testing for the presence of a unit root, allows for the verification of the solvency condition in the groups of countries under study when the unit root process of the first difference of public debt is rejected. Checking for the presence of a unit root in the time series of budget expenditures and revenues will provide initial findings regarding fiscal sustainability before testing for cointegration. Table 2 shows the results of the LLC unit root test, which assumes a common unit root process, while Table 3 presents the results of the IPS unit root test, which assumes an individual unit root process. Both tests assume the presence of a unit root process. The calculations included automatic lag selection based on the Schwarz Information Criterion, and spectral estimation was based on the Newey-West selection of bandwidth using Bartlett's kernel, assuming asymptotically normal distribution. Rejecting the null hypothesis of both tests, which means rejecting the presence of a unit root and confirming stationarity, we can only assert that stationarity is present in at least one member of the panel. Thus, rejection of the null hypothesis does not provide information on which countries or how many countries exhibit stationarity for the variable under consideration (Afonso & Rault, 2010).

Table 2

Results of the Levin, Lin & Chu panel unit root test

	Europe	Asia and Oceania	Africa	Latin America, the Caribbean, and North America
Constant				
Government revenue (% of GDP)	-1.48554*	-0.99788	-4.02057***	-2.76902***
Government expenditure (% of GDP)	-5.96116***	-1.95857**	-3.21325***	1.04700
Primary budget balance (% of GDP)	-4.63160***	-5.51647***	-9.35805***	-4.20592***
First Difference of the Public debt (% of GDP)	-14.6232***	-16.4158***	-16.3197***	-2.72034***
Constant and trend				
Government revenue (% of GDP)	0.59797	-5.48746***	-4.47286***	-3.55502***
Government expenditure (% of GDP)	-4.46873***	-2.17942**	-5.46798***	-1.71347**
Primary budget balance (% of GDP)	-4.18343***	-5.32131***	-11.3642***	-3.63310***
First Difference of the Public debt (% of GDP)	-13.9821***	-15.0000***	-12.5220***	-11.2574***

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level
Source: Author's calculation

When considering the group of European countries, it can be determined that both first-generation unit root tests confirm the stationarity of the first difference of public debt both with a constant and with a constant and trend. The same applies to the variables of budget expenditures and the primary budget balance. For the variable of budget revenues, the presence of a unit trend cannot be rejected with a constant and trend using the LLC and IPS tests, while budget revenues are stationary at a 1% risk of rejecting the null hypothesis with the IPS test and show stationarity at 10% in the case of the LLC test. In accordance with the empirical literature, fiscal sustainability for the group of European countries can indeed be confirmed, but there is some deviation in rejecting the unit root for budget revenues with the LLC test. In this case, it is necessary to compare the results with Pesaran's unit root test, which is presented in the following subsection.

Similarly, for the group of Asia and Oceania countries, the solvency condition can be confirmed, as the first difference of public debt is stationary at less than a 1% risk. According to the results of the LLC test, budget revenues have a unit root present at the constant, while they are stationary at less than a 1% level of significance when considering both constant and trend. On the other hand, the IPS test rejects the presence of a unit root in budget revenues both at the constant and with the constant and trend. Budget expenditures and the primary budget balance show stationarity, as both the LLC and IPS tests for these variables in the Asia and Oceania sample, indicate the absence of a unit root at least at a 5% level of significance. Similarly to European countries, it is not possible to conclusively assert fiscal sustainability for the group of Asia and Oceania countries using first-generation unit root tests, as the variable of budget revenues in the LLC test showed the presence of a unit root at the constant.

African countries have demonstrated the highest level of fiscal sustainability among all four groups of countries considered, according to the LLC and IPS tests. We can observe that the solvency condition is met with the integration of the first difference of public debt at the order of zero, while the variables of budget revenues and expenditures and the primary budget balance are stationary both at the constant and with the constant and trend. The absence of a unit root in the variables of budget revenues and expenditures is an important indicator of fiscal sustainability, which needs to be further confirmed with additional tests.

Table 3

Results of the Im, Pesaran & Shin panel unit root test

	Europe	Asia and Oceania	Africa	Latin America, the Caribbean, and North America
Constant				
Government revenue (% of GDP)	-2.37418***	-2.25532**	-4.18798***	-2.32613**
Government expenditure (% of GDP)	-7.93940***	-2.53763***	-2.88627***	-0.02365
Primary budget balance (% of GDP)	-6.53505***	-6.48067***	-10.1247***	-6.09916***
First Difference of the Public debt (% of GDP)	-15.1903***	-16.2201***	-16.3579***	-11.3466***
Constant and trend				
Government revenue (% of GDP)	-0.82741	-4.30719***	-5.86603***	-3.03362***
Government expenditure (% of GDP)	-5.04862***	-3.87034***	-6.27277***	-2.32041**
Primary budget balance (% of GDP)	-6.09060***	-6.21848***	-11.1666***	-5.64099***
First Difference of the Public debt (% of GDP)	-13.8302***	-13.8185***	-16.5893***	-14.8464***

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level.
Source: Author's calculation

Similarly, the solvency condition was also met in the group of Latin America, the Caribbean, and North American countries, as the stationarity of the first difference of public debt can be confirmed with both first-generation unit root tests. At a significance level of more than 5%, budget revenues are statistically significantly stationary, which does not apply to budget expenditures, as we cannot reject the unit root at the constant for both the LLC and IPS tests. When considering both constant and trend, at a 5% significance level, we can reject the unit root in budget expenditures using both unit root tests. The primary budget balance is stationary in both first-generation unit root tests, with no significant difference in statistical significance when considering the constant and the constant and trend. Based on the obtained unit root results, we can draw similar conclusions as for the group of European and Asian countries and Oceania. While considering both constant and trend allows us to confirm fiscal sustainability in the group of Latin America, the Caribbean, and North American countries, the presence of a unit root at the constant for the variable of budget expenditures reveals some deviation from the criteria of fiscal sustainability in stationarity tests.

Second-Generation Pesaran's Panel Unit Root Test

Considering cross-dependence is crucial in evaluating groups of countries that are closely interconnected in trade and capital flows and participate in economic integrations (Afonso & Coelho, 2022). These characteristics will be considered in the analyzed country panels, as we will assess fiscal sustainability using Pesaran's second-generation unit root test, which allows for cross-dependence in its assumptions. The results of the first-generation unit root tests confirmed the solvency condition for all groups of countries, as the existence of a unit root could be rejected. When testing the stationarity of the variables of government revenues and expenditures, we could only reject the unit root process in Africa, while in the other three groups of countries, we did not manage to confidently accept the condition of fiscal sustainability or the intertemporal budget constraint. The results of the Pesaran's panel unit root test are presented in Table 4. In the calculations, a lag of one was considered, consistent with the approach used by Afonso & Coelho (2022) in their Pesaran's unit root test calculations. Pesaran's test evaluates the null hypothesis describing the presence of a unit root process in the examined variable.

Table 4

Results of the Pesaran panel unit root test of second generation (CIPS statistic)

	Europe	Asia and Oceania	Africa	Latin America, the Caribbean, and North America
Constant				
Government revenue (% of GDP)	-1.50839	-1.89822	-2.07310*	-2.32487***
Government expenditure (% of GDP)	-1.99239	-1.89657	-2.01572	-2.17183**
Primary budget balance (% of GDP)	-1.99674	-1.97427	-2.73163***	-2.38550***
First Difference of the Public debt (% of GDP)	-3.04459***	-2.82710***	-3.72472***	-2.63125***
Constant and trend				
Government revenue (% of GDP)	-1.82415	-2.14902	-2.98306***	-3.07941***
Government expenditure (% of GDP)	-2.52028	-2.15562	-2.62638*	-2.42289
Primary budget balance (% of GDP)	-2.45800	-2.43191	-3.18237***	-2.58841
First Difference of the Public debt (% of GDP)	-3.48148***	-2.99060***	-4.05814***	-3.13240***

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level.
Source: Author's calculation

In the group of European countries, we can again accept the solvency condition, as the first difference of the public debt as a percentage of GDP is stationary both with a constant and with a constant and trend. Unlike the first-generation unit root tests, we cannot reject the null hypothesis of the presence of a unit root process for all three remaining fiscal variables. The non-stationarity of government revenues and expenditures with a constant and with a constant and trend requires further examination of fiscal sustainability of European countries in the studied period using a cointegration test of both fiscal variables.

Similar findings to those for European countries can be concluded for the group of Asia and Oceania countries, which also meet the solvency condition, as the first difference of public debt is stationary with both a constant and a constant and trend. Calculated CIPS statistics compared to the corresponding critical values show that government expenditures, government revenues, and primary budget balance are non-stationary. The hypotheses regarding the presence of a unit root process could not be rejected both with a constant and a constant and trend. The first-generation unit root tests only rejected the unit root for government revenues when considering a constant, thus showing some deviation from Pesaran's second-generation unit root test. A conclusion regarding the fiscal sustainability

of the group of Asia and Oceania countries will need to be made after examining the cointegration between government expenditures and revenues, as well as between the primary budget balance and public debt.

In the group of African countries, it was possible to confirm the stationarity of all examined fiscal variables, so we were interested in whether similar results would be obtained when considering cross-dependence in the unit root calculations. The first difference of public debt is statistically significantly stationary at less than 1% risk of rejecting the existence of a unit root process with both a constant and a constant and trend. For government revenues, the null hypothesis of a unit root process can be rejected at a 10% statistical significance level when considering a constant, while this variable is statistically significant at less than 1% with both a constant and trend. Government expenditures in African countries are stationary only at a 10% statistical significance level when considering both a constant and trend, which cannot be claimed when considering only a constant, as the null hypothesis of the presence of a unit root process cannot be rejected. On the other hand, the primary budget balance is stationary both with a constant and with a constant and trend. Pesaran's unit root test provided completely different results in assessing fiscal sustainability compared to first-generation unit root tests. Considering a constant in Pesaran's unit root test,

it can be stated at a 5% significance level that African countries are fiscally unsustainable. However, considering both a constant and trend in the second-generation unit root test, at a 10% risk, we can accept the first-order integration for government expenditures and revenues. These findings will also need to be verified with cointegration tests of fiscal variables.

The group of Latin American, Caribbean, and North American countries has confirmed the stationarity of government revenues, primary budget balance, and the first difference of public debt in the unit root tests, while for government expenditures, the unit root process could not be rejected. Considering both a constant and trend in Pesaran's unit root test, we cannot reject the null hypothesis of a unit root process for government expenditures. However, when considering only a constant, it can be observed that the government expenditure variable is stationary at a 5% statistical significance level. At less than 1% risk of rejecting the null hypothesis, we can reject the unit root process with a constant for government revenues, primary budget balance, and the first difference of public debt. Similarly, this applies to government revenues and the first difference of public debt when considering both a constant and trend, while in this case, the primary budget balance is not stationary. Although the condition of

solvency is met, fiscal sustainability will need to be verified with the Pedroni cointegration test. Fiscal sustainability can be examined with a cointegration test since government revenue and expenditure variables are statistically significantly stationary at 5% when considering a constant.

Pedroni Cointegration Test and Dumitrescu and Hurlin Panel Causality Test

In accordance with the procedure for testing fiscal sustainability used by Afonso & Coelho (2022), we employed the Pedroni Cointegration Test to examine the cointegration of the following pairs of fiscal variables: government revenue and government expenditure, primary budget balance and lagged public debt, and public debt and lagged primary budget balance. In the calculations of the Pedroni test, spectral estimation was based on Newey-West bandwidth selection using the Bartlett kernel, while assuming one lag. The Pedroni test assesses the null hypothesis that there is no cointegration among the variables. Additionally, among these pairs, we investigated Granger causality using the Dumitrescu and Hurlin test, with one lag and assuming normal distribution, following the procedure and selection of fiscal variable pairs as conducted by Afonso & Coelho (2022).

Table 5
Pedroni's cointegration test for the panel of European countries

	Relation	Revenues and expenditures		Primary balance and lagged debt		Debt and lagged primary balance	
		No trend	Trend	No trend	Trend	No trend	Trend
Within-dimension	Panel *v*	2.7336***	0.9668	5.4697***	1.2454	-1.9001	-1.5977
	Panel *rho*	-4.4083***	-2.9014***	-5.2502***	-2.5690***	2.0231	2.5752
	Panel PP	-4.7124***	-4.7496***	-5.0737***	-4.6190***	1.2594	1.3138
	Panel ADF	-2.5964***	-2.4213***	-4.4421***	-4.1597***	1.5255	2.1041
Between-dimension	Group *rho*	-1.9961**	0.0852	-3.4038***	-0.6964	3.2782	3.6709
	Group PP	-3.7939***	-2.7154***	-5.3489***	-5.7932***	1.7615	1.5730
	Group ADF	-2.3389***	-1.7747**	-5.6678***	-5.8454***	2.4094	3.8105

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level.
Source: Author's calculation

If we proceed from the Pedroni Cointegration Test, we can continue examining the fiscal sustainability of European countries, as both government revenue and government expenditure are integrated of the first order. In Table 5, the results of the Pedroni Cointegration Test for the three pairs of fiscal variables of the group of European countries are presented. Considering the

constant term, government revenue and government expenditure are statistically significantly cointegrated at least at the 5% level, allowing us to infer the presence of fiscal sustainability among the group of European countries. Similarly, the primary budget balance and lagged public debt are also cointegrated at the constant term, indicating a long-term stable relationship between

these fiscal variables. However, for public debt and lagged primary budget balance, we cannot confirm cointegration, and it is also not possible to conclude cointegration when considering both constant and trend for the pairs of government revenue and government expenditure and primary budget balance and lagged public debt in the calculation of cointegration test statistics in the Pedroni test.

With the Dumitrescu and Hurlin Granger causality test, we examined the causal relationship between different pairs of fiscal variables. The results of the Dumitrescu and Hurlin causality test for the group of European countries are presented in Table 6. We observe that there is no statistically significant impact of government revenue on

government expenditure, as also found by Afonso & Coelho (2022) in the case of European Union countries. The absence of this relationship implies that governments do not adjust government expenditures based on collected government revenues. On the other hand, we can confirm a statistically significant impact of government expenditure on government revenue, indicating that governments of European countries adjust government expenditures based on collected government revenues. Similarly, there is a causal relationship between lagged public debt and primary budget balance, as well as lagged primary budget balance and public debt, although these latter two variables are not cointegrated.

Table 6
Dumitrescu and Hurlin causality test for the panel of European countries

Null Hypothesis:	W-statistic	Z bar-statistic	p-value
Government expenditures does not homogeneously cause government revenues	2.65652	5.13080	0.0000***
Government revenues does not homogeneously cause government expenditures	1.35938	0.86804	0.3854
Lagged debt does not homogeneous cause primary budget balance	2.63264	4.99154	0.0000***
Lagged primary budget does not homogeneous cause debt	2.21041	3.61797	0.0003***

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level.
Source: Author's calculation

For the group of countries in Asia and Oceania, based on the results of the Pedroni Cointegration Test presented in Table 7, we can confirm the cointegration of lagged primary budget balance and public debt, as well as lagged public debt and primary budget balance, considering the constant term. Government revenue and government expenditure are cointegrated at a 10% level of statistical significance, indicating that we cannot

assert strong fiscal sustainability within the group of Asia and Oceania countries. However, when both constant and trend are considered in the cointegration test, due to the panel and group rho statistics, we cannot confirm cointegration between government revenue and government expenditure, primary budget balance and lagged public debt, and public debt and lagged primary budget balance.

Table 7
Pedroni's cointegration test for the panel of Asian and Oceanian countries

	Relation	Revenues and expenditures		Primary balance and lagged debt		Debt and lagged primary balance	
		No trend	Trend	No trend	Trend	No trend	Trend
Within-dimension	Panel *v*	1.4067*	-1.8887	4.4484***	0.4223	1.9976**	-1.9420
	Panel *rho*	-6.3402***	-4.8120***	-6.3416***	-3.6158***	-7.7650***	-6.6870***
	Panel *PP*	-6.4326***	-7.1902***	-6.3288***	-6.0432***	-7.3727***	-10.458***
	Panel *ADF*	-3.3050***	-3.0541***	-3.2786***	-4.1080***	-4.9865***	-7.5389***
Between-dimension	Group *rho*	-3.1217***	-1.1213	-3.7260***	-1.2645	-4.1364***	-2.6190***
	Group *PP*	-5.3293***	-4.9665***	-5.8870***	-5.7312***	-6.0841***	-7.5438***
	Group *ADF*	-4.0284***	-3.9036***	-4.8495***	-6.0189***	-3.9415***	-4.7847***

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level.
Source: Author's calculation

The results of the Dumitrescu and Hurlin causality test for fiscal variables of Asian and Oceanian countries are presented in Table 8. At less than a 1% level of statistical significance, we can confirm the causal relationship among all examined links between fiscal variables. This implies bidirectional causality between government revenue and government expenditure, as well as lagged public debt affecting the primary budget balance and lagged primary budget balance affecting public debt. Unlike European countries, in the group of Asia and Oceania countries, the influence of government expenditure on government revenue can be detected.

Table 8

Dumitrescu and Hurlin causality test for the panel of Asian and Oceanian countries

Null Hypothesis:	W-statistic	Z bar-statistic	p-value
Government expenditures does not homogeneously cause government revenues	2.11584	3.71803	0.0002***
Government revenues does not homogeneously cause government expenditures	3.67707	9.40926	0.0000***
Lagged debt does not homogeneous cause primary budget balance	2.37614	4.61114	0.0000***
Lagged primary budget does not homogeneous cause debt	1.84447	2.68889	0.0072***

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level.
Source: Authors' calculation

For the group of African countries, using the Pesaran unit root test, we found that government revenue is integrated of order zero at a 10% level of statistical significance, while we failed to reject the null hypothesis of a unit root process for government expenditure. Given these results of the unit root test at a 10% level of significance, further testing of fiscal sustainability is precluded as it cannot be confirmed. The Pedroni Cointegration Test for the group of African countries can only be continued at a lower level of statistical significance and considering only the estimates with constant and trend. From Table 9, displaying the results of the Pedroni Cointegration Test for Africa, we can infer that there is cointegration among all examined pairs of fiscal variables when the constant term is considered. The obtained results of the statistical significance of the cointegration test enable similar conclusions to those of the Asia and Oceania group. Based on these results, fiscal sustainability can be confirmed in the studied group of African countries. However, considering both the constant and trend, cointegration among the examined pairs of fiscal variables cannot be confirmed due to differing results of the test statistics, as all cases of the panel t-statistics are statistically insignificant. These results are not representative when considering a 5% level of statistical significance, as government revenue and government expenditure are not integrated of the same order.

Table 9

Pedroni's cointegration test for the panel of African countries

	Relation	Revenues and expenditures		Primary balance and lagged debt		Debt and lagged primary balance	
		No trend	Trend	No trend	Trend	No trend	Trend
Within-dimension	Panel *v*	10.5484***	4.9245***	4.1592***	-0.3197	5.3668***	0.5598
	Panel *rho*	-17.081***	-14.1906***	-7.1144***	-4.8442***	-13.461***	-11.2900***
	Panel PP	-24.133***	-22.891***	-7.6486***	-8.0184***	-13.867***	-16.098***
	Panel *ADF*	-4.1920***	-2.1541***	-3.8303***	-3.4768***	-4.4789***	-4.9332***
Between-dimension	Group *rho*	-5.0910***	-2.5941***	-4.8307***	-2.8620***	-5.9721***	-4.4017***
	Group PP	-7.7680***	-7.3456***	-8.0491***	-8.9015***	-9.3700***	-13.4063***
	Group *ADF*	-3.6312***	-3.7432***	-5.0920***	-6.3710***	-5.0074***	-7.1234***

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level.
Source: Authors' calculation

In Table 10, the results of the Dumitrescu and Hurlin causality test for the examined pairs of fiscal variables for the group of African countries are presented. Government expenditure influences government revenue at a 5% level of statistical significance. At less than a 1% level of statistical significance, we can assert that government revenue influences government expenditure and lagged primary budget balance affects public debt. However, it is not possible to confirm the statistically significant influence of lagged public debt on the primary budget balance.

Table 10

Dumitrescu and Hurlin causality test for the panel of African countries

Null Hypothesis:	W-statistic	Z bar-statistic	p-value
Government expenditures does not homogeneously cause government revenues	1.74687	2.21165	0.0270**
Government revenues does not homogeneously cause government expenditures	2.88079	6.06024	0.0000***
Lagged debt does not homogeneous cause primary budget balance	1.26892	0.56870	0.5696
Lagged primary budget does not homogeneous cause debt	2.27819	3.96653	0.0000***

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level.
Source: Authors' calculation

In Table 11, the results of the Pedroni Cointegration Test for various pairs of fiscal variables for the group of Latin American, Caribbean, and North American countries are presented. To assess the fiscal sustainability of this group of countries using the Pedroni Cointegration Test, we can focus solely on the results that consider the constant term, as government revenue and government expenditure are integrated of different orders. Government revenue and government expenditure are statistically significantly cointegrated at less than a 1% level, thus confirming the existence of fiscal sustainability in the group of Latin American, Caribbean, and North American countries.

Additionally, according to Table 10, it can be observed that primary budget balance and lagged public debt are cointegrated at a statistically significant level of at least 1%, while public debt and lagged primary budget balance are not cointegrated.

The Dumitrescu and Hurlin causality test, presented in Table 12, for the group of Latin American, Caribbean, and North American countries, confirms bidirectional causality between government expenditure and government revenue at a 1% level of statistical significance. The influence of lagged public debt on the primary budget balance is statistically significant at 5%. At less than a 1% level of statistical significance, lagged primary budget balance affects public debt, although this relationship cannot be meaningfully interpreted due to the absence of cointegration between the variables.

Table 11

Pedroni's cointegration test for the panel of Latin American, Caribbean, and North American countries

	Relation	Revenues and expenditures		Primary Balance and Lagged debt		Debt and Lagged Primary balance	
	Statistics	No trend	Trend	No trend	Trend	No trend	Trend
Within-dimension	Panel *v*	3.5936***	0.9500	4.6691***	1.9395**	0.0048	-2.3152
	Panel *rho*	-5.5552***	-4.7446***	-5.4492***	-4.4167***	-1.0918	2.6602
	Panel PP	-5.5923***	-6.9991***	-5.6296***	-6.9183***	-1.0467	1.6554
	Panel *ADF*	-3.6845***	-3.8260***	-4.4653***	-6.2860***	3.5636	5.0459
Between-dimension	Group *rho*	-2.8065***	-1.2102	-2.9859***	-1.1272	2.9249	2.3692
	Group *PP*	-4.3463***	-4.3599***	-4.7215***	-4.9284***	2.2347	0.5067
	Group *ADF*	-2.2467**	-2.7065***	-4.1719***	-4.7827***	4.6787	3.4666

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level.
Source: Authors' calculation

Table 12

Dumitrescu and Hurlin causality test for the panel of Latin American, Caribbean, and North American countries

Null Hypothesis:	W-statistic	Z bar-statistic	p-value
Government expenditures does not homogeneously cause government revenues	2.23502	3.61863	0.0003***
Government revenues does not homogeneously cause government expenditures	2.41521	4.19070	0.0000***
Lagged debt does not homogeneous cause primary budget balance	1.77436	2.11971	0.0340**
Lagged primary budget does not homogeneous cause debt	4.86224	11.8436	0.0000***

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level.

Source: Authors' calculation

Conclusions

We examined fiscal sustainability in the groups of European, Asian and Oceanic, African, and Latin American, Caribbean, and North American countries. These four groups of countries represented separate panel data, on which we verified the presence of fiscal sustainability. Fiscal sustainability of the four groups of countries was examined over the period 1995-2021. The panel data consisted of fiscal variables such as government revenue, government expenditure, primary budget balance, and public debt, with all analyzed variables expressed as a percentage of GDP. The methodology for examining fiscal sustainability followed the procedure of Afonso & Rault (2010) and Afonso & Coelho (2022).

We tested the fiscal variables for the presence of a unit root using the Levin, Lin, and Chu test and the Im, Pesaran, and Shin test, both of which confirmed the solvency condition in all four groups of countries. Government expenditure and government revenue showed different orders of integration when considering the constant term in European countries, Asian and Oceanic countries, and the group of Latin American, Caribbean, and North American countries. Considering both the constant and trend in both first-generation unit

root tests confirmed the stationarity or the same order of integration of fiscal variables, except for European countries. Given the emphasis on cross-dependencies by many authors, recent research on the fiscal sustainability of countries often employs only second-generation unit root tests. From this group of unit root tests, we used the Pesaran unit root test, which accounts for cross-dependencies, to obtain the basis for further examining fiscal sustainability. The Pesaran unit root test again confirmed the solvency condition, as we were able to reject the unit root process for the first difference of public debt. However, the Pesaran unit root test yielded different results than first-generation unit root tests. Government revenue and government expenditure showed first-order integration when considering the constant term at a 5% level of statistical significance. Considering both the constant and trend in the Pesaran unit root test and a 5% level of statistical significance, the same order of integration was present only in European countries and the group of Asian and Oceanic countries.

Based on the findings presented, we can accept the hypothesis set before the research. Despite confirming the solvency condition and fiscal sustainability for all groups of countries at a 10% level of statistically significant cointegration of government expenditure and government revenue when considering the constant term, the results showed some deviations. These were mainly present when examining other pairs of fiscal variables and when considering both the constant and trend in both cointegration tests and unit root tests. In the review of the empirical literature, we mostly found studies that confirmed fiscal sustainability, albeit in a weak form. While the groups of countries under study were larger than those in previous research, we found alignment with the findings of these studies. For a more detailed examination, it would be reasonable to further divide countries into smaller and economically more homogeneous groups in future research. Moreover, it would be reasonable to incorporate structural break tests, which would provide us with more accurate and robust results regarding assessment of the fiscal sustainability using unit root tests. However, these tests are out of the scope of this study.

Based on the findings presented, we can accept the hypothesis set before the research. Despite confirming the solvency condition and fiscal sustainability for all groups of countries at a 10% level of statistically significant cointegration of government expenditure and government revenue when considering the constant term, the results showed some deviations. These were

mainly present when examining other pairs of fiscal variables and when considering both the constant and trend in both cointegration tests and unit root tests. In the review of empirical literature, we mostly found studies that confirmed fiscal sustainability, albeit in a weak form. While the groups of countries under study were larger than those in previous research, we found alignment with the findings of these studies.

For a more detailed examination, it would be reasonable to further divide countries into smaller and economically more homogeneous groups in future research. Moreover, it would be reasonable to incorporate structural break tests, which would provide us with more accurate and robust results regarding assessment of the fiscal sustainability using unit root tests. However, these tests are out of the scope of this study. Additionally, individual cross-sectional units or countries were not examined, which could have enabled the identification of the characteristics of fiscal sustainability of each country in the corresponding group. Based on the available data, it would also be sensible to form smaller groups of countries with longer time series of fiscal data.

Furthermore, it would be necessary to estimate fiscal reaction functions, which could provide additional information on fiscal sustainability. Assessment of the fiscal sustainability with panel unit root and cointegration tests has a major informational drawback from its methodological approach, as it only provides us the information about the state of fiscal sustainability in the analyzed group of countries. The extension of the analysis with the employment of fiscal reaction functions would provide us with necessary information about determinants of fiscal sustainability that would enable us to develop usable policy implications.

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Appendix 1. List of countries covered in the study

Europe	Asia and Oceania	Africa	Latin America, the Caribbean, and North America
Austria	Australia	Algeria	Antigua and Barbuda
Belgium	Azerbaijan	Benin	Argentina
Bulgaria	Bahrain	Burkina Faso	Aruba
Croatia	Bangladesh	Burundi	Grenada
Cyprus	Bhutan	Cape Verde	Bahamas
Czechia	Cambodia	Central African Republic	Barbados
Denmark	China	Chad	Bolivia
Estonia	Fiji	Comoros	Chile
Finland	Georgia	Congo	Dominica
France	India	Djibouti	Dominican Republic
Germany	Indonesia	Equatorial Guinea	Nicaragua
Greece	Israel	Eswatini	Ecuador
Hungary	Japan	Ethiopia	Costa Rica
Iceland	Jordan	Gabon	Honduras
Ireland	Kiribati	Ghana	Guatemala
Italy	Kuwait	Guinea	Jamaica
Luxembourg	Kyrgyzstan	Guinea-Bissau	Colombia
Moldova	Malaysia	Kenya	Mexico
Netherlands	Maldives	Lesotho	Panama
Norway	Marshall Islands	Madagascar	Paraguay
Poland	Micronesia	Morocco	Peru
Portugal	Mongolia	Namibia	El Salvador
Romania	New Zealand	Niger	Suriname
Slovakia	Oman	Nigeria	Saint Lucia
Slovenia	Pakistan	Rwanda	Saint Kitts and Nevis
Spain	Papua New Guinea	Senegal	Saint Vincent and the Grenadines
Sweden	Philippines	Seychelles	Trinidad and Tobago
Switzerland	Qatar	South Africa	Venezuela
Ukraine	Saudi Arabia	Sudan	
United Kingdom	Solomon Islands	Tanzania	
	South Korea	Togo	
	Sri Lanka	Tunisia	
	Thailand		
	Turkey		
	United Arab Emirates		
	Vanuatu		
	Yemen		

Ocenjevanje fiskalne vzdržnosti s panelnimi testi enotskega korena, kointegracije in Grangerjeve vzročnosti: ugotovitve za širše skupine držav

Izvleček

Vprašanje fiskalne vzdržnosti držav je postala ena izmed osrednjih tem ekonomske politike, zlasti v času naraščajočega javnega dolga. Eden od načinov ocenjevanja fiskalne vzdržnosti je preverjanje skladnosti z medčasovno proračunsko omejitvijo, kar vključuje preverjanje stacionarnosti javnofinančnih prihodkov in izdatkov, primarnega proračunskega salda in prve diference javnega dolga. Del tega pristopa je tudi testiranje kointegracije in vzročnosti med različnimi pari spremenljivk. V okviru tega pristopa se članek osredotoča na prvo in drugo generacijo panelnih testov enotskega korena, kointegracijo in Grangerjev test vzročnosti. Ta članek se osredotoča na ocenjevanje fiskalne vzdržnosti štirih panelov držav, razdeljenih po celinah: Evropa, Azija in Oceanija, Afrika ter Latinska Amerika, Karibi in Severna Amerika. Ugotovljeno je bilo, da je fiskalna vzdržnost prisotna v vseh obravnavanih širših skupinah držav, vendar v šibki obliki. Fiskalna vzdržnost je bila potrjena, ko je bila v izračunih upoštevana konstanta, medtem ko so bila med skupinami držav opažena odstopanja, če sta bila upoštevana tako konstanta kot trend. Študija služi kot izhodišče za obsežnejšo analizo fiskalne vzdržnosti. Za natančnejše ugotovitve bi bilo treba države razvrstiti v manjše in ekonomsko bolj homogene skupine ter jih analizirati tudi z uporabo drugih metod fiskalne vzdržnosti.

Ključne besede: testi kointegracije, fiskalna vzdržnost, Grangerjev test vzročnost, medčasovna proračunska omejitev, testi enotskega korena.