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Fiscal regimes and debt sustainability in Colombia

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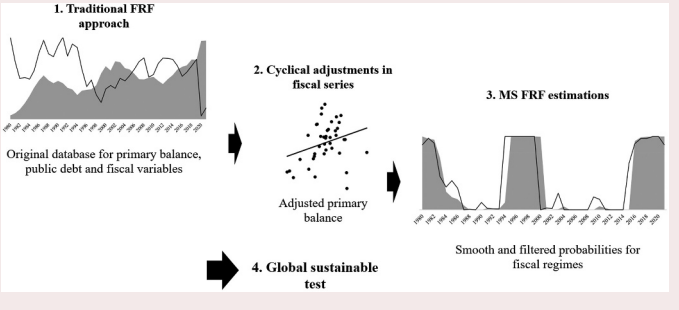
ABSTRACT

This paper evaluates Colombia's debt sustainability for the period 1980–2021, using a nonlinear fiscal reaction function approach. We employ a Markov-Switching model with annual data to identify sustainable and unsustainable fiscal regimes. According to this model, we identified an unsustainable fiscal regime during three periods with an average duration of six years – 1980–1985, 1993–1999, and 2015–2021 – while the other periods are identified as a sustainable regime. Although we find evidence of asymmetric behaviour in fiscal responses and the presence of pro-cyclical fiscal policy, Colombia's long-term fiscal sustainability is verified based on a globally-based fiscal sustainability test. In this context, the government reacts appropriately to increases in debt only in the sustainable regime, but the fiscal response is sufficiently robust to stabilise public debt throughout the entire period. Finally, we also highlight concerns regarding the current state of the global economy, particularly due to an inflationary trend and escalating interest rates, which can compromise long-term fiscal sustainability.



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Fiscal regime; debt sustainability; asymmetric response

1. Introduction

The analysis of debt sustainability is essential to identify the macroeconomic vulnerabilities of a country, especially in the fiscal structure, as well as the risks to which it is exposed in the long term (Celasun et al., 2006; Ghosh et al., 2013; Mendoza & Ostry,

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

2008). Recent global events have amplified concerns regarding escalating fiscal deficits and public indebtedness, mainly due to the recent crisis caused by the coronavirus disease 2019 pandemic (Covid-19). Such conditions raise concerns about design and implementation of fiscal policy and its long-term sustainability because a high level of debt affects the government's solvency and increases uncertainty in financial markets, affecting therefore a country's economic stability. For instance, by 2020 the fiscal deficit of the central national government (CNG) in Colombia reached 8.2% of GDP and the debt level as an exceeded 60%, whereas by 2021 a slight correction in the deficit is identified, although debt remained the same, as shown in Figure 1. This state has generated a budgetary imbalance that has worsened the fiscal dynamics during the last decade. Although the debt level increased by nearly 10 percentage points (pp) over the period 2010–2019,[1] by 2020, the increase was 12 pp. Figure 1 shows public debt during this period, and we highlight its increase since the 1980s, when it reached levels close to 10%, as well as some corrections in the early of 1990s and before the 2014–2015 oil shock.

Otherwise, the analysis of debt sustainability should not only consider a government's response to increases in debt or in the debt-to-GDP ratio but also verify whether the degree of adjustment or response is timely and strong enough to stabilize the debt level in the long term. Hence, under a high level of indebtedness and a historical fiscal deficit, such as the current one, a government's response must be strong to return to a level that guarantees its long-term sustainability. Recent literature on debt sustainability has confirmed the presence of an asymmetric government response to debt increases (Cassou et al., 2017; Coccia, 2017; Ghosh et al., 2013; Magazzino & Mutascu, 2022; Magazzino et al., 2019) as well various fiscal regimes, both sustainable and unsustainable (Adeosun et al., 2021; Afonso & Jalles, 2017; Aldama & Creel, 2019; Chua et al., 2021; Owusu et al., 2023). Nevertheless, this analysis departs somewhat from the extensive international literature that evaluates the response of the government's primary balance to changes

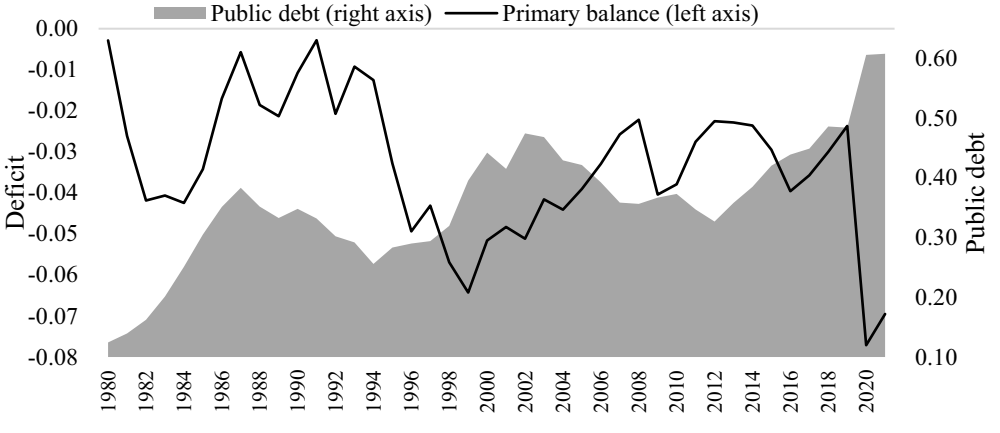

Figure 1. Public debt and fiscal deficits in Colombia. Source: Banco de la República de Colombia (BanRep). Own elaboration.

[1]This increase in debt is mainly due to the shocks originated by the fall in oil prices in the years 2014–2015.

in the public debt-to-GDP ratio based on the fiscal reaction function (FRF) (Bohn, 1995, 1998; Mendoza & Ostry, 2008; Ostry et al., 2010).

Bohn (1995, 1998) pioneered an approach to assessing debt sustainability through the FRF. He found that if government actively adjusts its balance sheet by generating a primary surplus when debt increases, fiscal policy is sustainable fiscal policy is considered sustainable. For instance, previous works by Lozano and Julio (2019) and Zapata and Chamorro (2022), carried out for Colombia and based on Bohn's FRF approach, verified the conditions of fiscal sustainability until 2019. However, this conventional FRF approach fails to account for government's asymmetric reaction, as it only considers a uniform dynamic fiscal policy response, as claimed by Afonso and Jalles (2017), Cassou et al. (2017), and Aldama and Creel (2019). Cassou et al. (2017) and Afonso and Jalles (2017) confirmed the presence of these asymmetric responses as a function of the debt-to-GDP ratio, as well as frequent changes from one regime to another, which are related to the economic state. The authors found that under weak economic conditions, fiscal sustainability is not met, whereas it is met when economic conditions are stable and/or strong.

Therefore, analysis of this asymmetry is necessary for an overall assessment of long-term debt sustainability. In this regard, distinguishing between sustainable and unsustainable fiscal regimes can provide a far more comprehensive framework for sustainability analysis. For example, Aldama and Creel (2019) find that under an unsustainable regime, a government's response is weak or even negative, which can increase the debt-to-GDP ratio and thereby trigger an unsustainable long-term outcome.

In this context, this paper evaluates long-term debt sustainability in Colombia. To achieve that, we extend the standard Bohn FRF approach with a Markov-switching (MS) model to identify sustainable and unsustainable fiscal regimes. Based on the MS model for a non-linear FRF, we identified: i) an unsustainable fiscal regime during three periods with an average duration of six years –1980–1985, 1993–1999, and 2015–2021; and ii) a sustainable fiscal regime during the other periods with an average duration of 12 years. Furthermore, the results indicate that in the sustainable regime, an increase in debt has a positive effect on the primary balance, with a parameter of 0.0612 associated with this response, while in the non-sustainable regime the response is negative and equal to −0.0244. It is important to note that the presence of these fiscal regimes does not guarantee *per se* long-term sustainability. Therefore, it is crucial to identify the conditions under which fiscal policy is globally sustainable. To do that, we complement our analysis with a Bai – Perron structural change model, considering that an empirical test based on FRF approach may yield inconclusive results regarding long-term sustainability. The globally sustainable test allows us accounting for i) frequency and duration of unsustainable periods in the short term and ii) the time delay and magnitude of the government's response in implementing the necessary fiscal adjustment to ensure long-term sustainability.

The results confirm the presence of long-term fiscal sustainability in Colombia. In that context, we found that the government reacts appropriately to increases in debt only in the sustainable regime, but the fiscal response is sufficiently robust to stabilise public debt throughout the entire period. The paper contributes to the literature on the analysis of fiscal sustainability in emerging economies when analysing asymmetric effects of fiscal policy confirms the benefits and scope of the global sustainability test that considers the differences between sustainable and unsustainable fiscal regimes.

The paper is organized into five sections, including this introduction. The second section shows a review of the literature, highlighting some theoretical and empirical elements for the fiscal sustainability test based on the FRF estimation. The third section describes an extension of this framework to incorporate asymmetries in the fiscal response, whereas the fourth section presents model results from different empirical formulations. Finally, the fifth section presents the paper's conclusions and policy implications.

2. Literature review

International literature on public debt sustainability is large and diverse. Theoretical and empirical studies focus on the long-term effects of the intertemporal budget constraint (IBC). The IBC approach considers the government budget constraint, taking into account the response of a government's primary balance, pb (as a percentage of GDP), to changes in public debt, d (as a percentage of GDP), and proves the public debt sustainability (Blanchard, 1990). Following the IBC approach, the dynamics of d at time t can be expressed as follows:

$$d_t = \left(\frac{1+r_t}{1+g_t}\right) d_{t-1} - pb_t \tag{1}$$

where r_t is the real interest rate, g_t is the growth rate of real GDP, and d_{t-1} is the debt at time $t-1$. Thus, if r_t exceeds g_t, then d increases because the growth of an economy is not enough to compensate for the cost of debt unless interest payments are financed by own revenues. Therefore, a primary surplus, that is, when $bp_t > 0$, can help to reduce debt level to ensure its sustainability. Otherwise, the primary deficit ($bp_t < 0$) further increases debt level. Thus, primary deficits must be offset by surpluses in the balance. If this condition is satisfied, then:

$$d_t = \sum_{n=0}^{\infty} \frac{E_t(bp_{t+n})}{(1+r_t)^n}. \tag{2}$$

Equation 2 is equivalent to

$$\lim_{n\to\infty} \frac{E_t(d_{t+n})}{(1+r_t)^n} = 0. \tag{3}$$

Equation 2 denotes the IBC, while Equation 3 represents the transversality condition (TC), which means that the government cannot continuously issue new debt to pay current debt, and therefore, the initial debt equals the expected present value of future pb if the discounted future of d converges to 0.

The literature review follows the IBC approach and is divided into three different empirical tests. The first approach assesses debt sustainability using stationarity and cointegration conditions, which were developed in the 1980s and 1990s (J. Hamilton & Flavin, 1985; Quintos, 1995; Trehan & Walsh, 1991). This is followed by Bohn's FRF approach, which was developed in the late 1990s and early 2000s (Bohn, 1995, 1998, 2007). Finally, in the last decade, extensions of the FRF have been introduced under the third approach, which considers fiscal regimes and asymmetries in fiscal policy (Aldama & Creel, 2019; Cassou et al., 2017).

2.1. Stationarity and cointegration tests based on the IBC approach

Based on the IBC approach, the sustainability of debt can be tested empirically using standard unit-root tests on ratios like debt-to-GDP and primary balance-to-GDP or considering cointegration test between public expenditure and revenue. In this context, we found the studies of J. Hamilton and Flavin (1985), Trehan and Walsh (1991), Hakkio and Rush (1991), and Quintos (1995).

J. Hamilton and Flavin (1985) provided an empirical framework for testing the IBC considering the present value of the government's budget surpluses[2] or the present value of the budget constraint (PVBC), where they tested analytically the fiscal sustainability using standard unit-root tests on fiscal variables such as debt-output ratio and surpluses-output ratio. Additionally, it is also possible to evaluate sustainability through the cointegration between government of the debt and the primary balance or between public revenues and expenditures. Since the seminal paper of J. Hamilton and Flavin (1985), tests of debt sustainability based on the IBC have increased substantially.

Trehan and Walsh (1991) showed that, if the debt and the primary balance are not stationary, solvency is satisfied if both series move together, that is, if they are cointegrated. Hakkio and Rush (1991) stated that the stationarity test is equivalent to testing the cointegration relationship between government expenditure and revenues, and they showed that cointegration is a necessary condition for the government to obey its PVBC. Finally, Quintos (1995) proved that if revenues and expenditures are cointegrated, then the fiscal deficit is strongly sustainable. Similarly, Brady and Magazzino (2018) and Magazzino et al. (2019) provided different approaches to assess the sustainability of fiscal policy in European Union countries by applying panel unit root tests and cointegration tests. They found that government debt series are stationary, indicating that the solvency or sustainability conditions are satisfy.

On the other hand, Bohn (1998, 2007) found some limitations in stationarity and cointegration tests for testing sustainability conditions. He showed that cointegration tests of government revenues and expenditures, or in the primary budget balance and debt series, do not provide sufficient evidence and are therefore not appropriate methods for testing debt sustainability.

2.2. Bohn's FRF approach to testing debt sustainability

Bohn (1995) proposed a sustainability test based on a relationship between pb and d, known as the FRF (shown in Equation 4), under the assumption that government must generate primary surpluses ($pb > 0$) in response to an increase in d.

$$pb_t = \rho d_{t-1} + \mu + \varepsilon_t \tag{4}$$

where μ relates a set of determinants of pb such as the GDP gap and the cyclical component of public spending, whereas ε_t is the error term with zero mean. Thus, Bohn (1998) found that a government reacts actively through a dynamic fiscal policy that allows it to generate primary surpluses when the debt-to-GDP ratio increases. Therefore, the level of debt can be considered sustainable in the long run. Later, Bohn

[2]This positive response is related to the absence of Ponzi games. That is, if a government acts responsibly, it avoids a vicious state of issuing new debt to pay the issued debt.

(2007) showed that a stable and strictly positive relationship between pb and d, that is, if $\rho > 0$, is consistent with the IBC and TC. Conversely, Equation 4 can be rewritten to reflect an empirical formulation of the FRF, as shown in Equation 5:

$$pb_t = \alpha + \rho d_{t-1} + \gamma \boldsymbol{Z_t} + \varepsilon_t \tag{5}$$

where $\boldsymbol{Z_t}$ is a vector of other determinants of primary balance with γ parameters. Additionally, Bohn's FRF can be extended to incorporate nonlinear components such as quadratic and cubic terms for d_{t-1}, as well as other determinants, as shown in Equation 6

$$pb_t = \alpha + \rho d_{t-1} + \varphi d_{t-1}^2 + \vartheta d_{t-1}^3 + \gamma \boldsymbol{Z_t} + \varepsilon_t \tag{6}$$

Mendoza and Ostry (2008), Ostry et al. (2010), Ghosh et al. (2013), and Mackiewicz-Łyziak and Łyziak (2019) extended this model by incorporating other determinants of fiscal balance, as well as other measures associated with sustainability analysis such as fiscal space and debt limit.

According to Ghosh et al. (2013) the Bohn's FRF has drawbacks given that the model considers a constant interest rate. However, it deviates randomly from the long-term average. To overcome this problem, Ghosh et al. (2013) incorporated endogeneity of the interest rate into the FRF by including the risk premium as a positive function of a government's default probability vis-à-vis the debt. Therefore, with an endogenous interest rate, $\rho > 0$ is not a sufficient condition to confirm the sustainability of debt.[3] Moreover, they found that when debt level reaches the limit, risk premium rises indefinitely, and thus, debt becomes unsustainable. The difference between the debt limit and the observed debt defines the fiscal space for a government. This relationship modifies Bohn's FRF, as shown in Equation 7

$$pb_t = f(d) + \mu + \varepsilon_t \tag{7}$$

where the term $f(d)$ represents a continuous and differentiable function that explains the response of primary balance to lagged debt. The condition of debt sustainability requires that besides being positive, ρ must be larger than the spread between i and y, that is, $\rho > r - g$. Thus, they found empirical evidence of this nonlinear relationship, according to which, for low levels of debt, the relationship between pb and d is small or even negative, but as debt increases, the relationship becomes positive and, for excessively high levels of debt, the curve flattens.

Under the Bohn's FRF approach, there are several studies applied to both developed and emerging economies, in which different formulations for FRF are implemented. For instance, Mackiewicz-Łyziak and Łyziak (2019) incorporated effects of interest rate dynamics and country risk premia, which allow for assessing the conditions under which emerging economies face higher borrowing costs along with high country risk premia. Additionally, Afonso and Alves (2023) evaluated the impact of government spending efficiency on fiscal sustainability and FRF coefficients for OECD countries. They obtained

[3]Additionally, Mendoza (2017) found that although the FRF allows testing the sustainability condition and provides information on historical and projected debt and primary balance adjustments, it presents a strong limitation as it does not incorporate macroeconomic and welfare effects under a fiscal adjustment.

government spending efficiency scores through which found that countries' fiscal balance and fiscal sustainability is directly improved using fewer public resources.

Briceño and Perote (2020) found similar results for Eurozone countries. Based on an integrated viewpoint based on financial, social and governance or institutional factors, they found that the COVID-19 pandemic lead Eurozone countries to increase dramatically their current public debts, to such an extent that they could fall into unsustainable paths and, therefore, substantial reforms are necessary conditions to ensure public debt sustainability amid COVID-19 pandemic.

Finally, we found some studies in Colombia. Lozano and Julio (2019) adopted a nonlinear FRF following Ghosh et al. (2013), and they used the spline technique to estimate a FRF with an endogenous risk premium. This application is also extended to several emerging economies. Later, Zapata and Chamorro (2022) performed linear and nonlinear estimates of FRF using the two-stage least squares technique and the generalized method of moments. Although these authors identified some concerns about high levels of debt in Colombia, as well as its reduced fiscal space, which affects the government's solvency, they followed a uniform response approach when assessing debt sustainability.

However, these models are based on conventional econometric techniques, particularly panel data, which have difficulty capturing the asymmetric effects of government responses, as suggested by Cassou et al. (2017) and Aldama and Creel (2019). In addition, Afonso and Jalles (2017) showed that the empirical FRF introduced by Bohn (1998) can be extended to account for asymmetries in fiscal policy and changes in the size of shocks, by introducing sources of nonlinearity.

2.3. Fiscal regimes and asymmetries in fiscal policy

Cassou et al. (2017) and Aldama and Creel (2019) found that previous tests based on the FRF approach do not consider the government's asymmetric responses to rising public debt. They interpret the asymmetric response as the absence of fiscal sustainability during times of distress or crisis given that policy makers are more concerned about economy recover and temporarily ignore sustainability. Additionally, they found evidence that fiscal policy is countercyclical during bad economic times and becomes less countercyclical during good times. Therefore, fiscal policy is not always sustainable. In that sense, the reaction of primary balance changes depending on the state of the debt-to-GDP ratio. Ghosh et al. (2013), introducing the notion of fiscal fatigue, found a different behaviour in the response of primary balance to a debt-to-GDP ratio, as a government's response depends on how high or low this ratio is.

Cassou et al. (2017) found that in periods with a low debt-to-GDP ratio, the response is different from that in periods with a high debt-to-GDP ratio. Later, Adeosun et al. (2021) showed that fiscal policy authorities' reactions are asymmetric for high levels of public debt and the response is linked with a pro-cyclical fiscal policy, especially, in emerging economies. Additionally, the asymmetric behaviour in the response of governments is more frequent in crises and episodes of shocks, such as, for example, in oil shocks or in the recent COVID-19 pandemic. The presence of this asymmetric behaviour defines different types of fiscal regimes, taking into account the government's response to increases in public debt. Firstly, if the government's response is positive, i.e., if it responds

by generating primary surpluses as Bohn argued, a sustainable fiscal regime is found. Otherwise, if the answer is negative, the fiscal regime is temporarily unsustainable. In this line, Afonso et al. (2018), and Aldama and Creel (2019) found that the government response in developed economies has been asymmetric in episodes of wars and international shocks. For instance, based on a Markov-switching (MS) model, Afonso et al. (2018) found unsustainable periodic regimes for the U.S. economy and for European countries. Similarly, Aldama and Creel (2019) found that a government response in sustainable periods can be strong enough to stabilize long-term debt, and therefore, the long-run stabilization condition is met, which can be re-expressed by

$$\rho_S > |\rho_{NS}| \frac{d_{NS}}{d_S} \frac{i-y}{1+y} \frac{d_S + d_{NS}}{d_S} \tag{8}$$

where ρ_S and ρ_{NS} correspond to the primary balance response parameters in the sustainable and unsustainable periods or regimes and d_S and d_{NS} correspond to their average duration, respectively. The MS model, following J. D. Hamilton (1989), is determined by fitting the basic empirical model defined in Equation 6, starting from an unobserved state variable (s_t). Thus, we have:

$$bp_t = \alpha(s_t) + \rho(s_t) d_{t-1} + \gamma(s_t) \boldsymbol{Z_t} + \varepsilon_t(s_t) \tag{9}$$

With $\varepsilon_{s_t,t} \tilde{n}(0, \sigma_2(s_t))$ and s_t takes values of $0, 1, \ldots, k$ for k states or regimes within the model.

From a MS model of fiscal regime changes, Afonso et al. (2018) found unsustainable periodic regimes for the U.S. economy and for European countries. In the same line, Brady and Magazzino (2017) analysed the sustainability of Italian public debt by using a MS model and they found the existence of two persistent states for both public debt and deficit. Additionally, Aldama and Creel (2019) found that a government's reaction may be weak and infrequent to changes in debt; therefore, the debt-to-GDP ratio may not decrease, affecting its long-term sustainability. Using their MS model of fiscal regime changes for the U.S. economy, they discovered multiple unsustainable regimes for the period 1940–2016. Later, Owusu et al. (2023) assessed debt sustainability in the euro area by analysing the reaction of the primary balance to changes in public debt, using annual data for the 2000–2019 period within a panel framework. They analysed non-linearities in debt sustainability by using both the MS model and the panel smooth transition regression. According to their findings, a threshold exists in the behaviour of the FRF, indicating two distinct regimes: a high deb regime and a low debt regime.

In addition to these studies on developed economies, which consider asymmetric reactions of governments to changes in debt, there have also been several applications for emerging economies, including the works of Adeosun et al. (2021), Chua et al. (2021), and Olaoye and Olomola (2022). Adeosun et al. (2021) implemented various specifications of the fiscal policy rule using MS fiscal models to assess fiscal sustainability conditions in Nigeria. They confirmed the presence of asymmetries in the fiscal policy authorities' reactions to public debt and identified evidence for a violation of the IBC, as well as a pro-cyclical response of the fiscal policy to the improvement of the primary fiscal balance. Similarly, Chua et al. (2021) applied a MS model to test fiscal sustainability in Sri Lanka for the period 1961–2017. They identified a non-sustainable fiscal regime in two periods – 1978–1983 and 1986–1990, while the other periods are defined as

sustainable regimes. Based on their results, which were derived from regime-specific feedback coefficients of the fiscal policy rule and the average durations of fiscal regimes, they concluded that Sri Lanka's fiscal policy adheres to the No-Ponzi game condition.

Despite international evidence of asymmetric behaviour in fiscal responses and the presence of pro-cyclical fiscal policy, only a few studies have considered the combined use of MS models and tests for structural changes, such as the Bai-Perron structural change models (Aldama & Creel, 2019). Besides, their implementation has primarily focused on the US economy. This joint approach to testing has not yet been applied extensively to emerging economies. Research in these economies has mainly focused on identifying sustainable and non-sustainable fiscal regimes and on verifying the TC or the No-Ponzi Game condition.

Therefore, it is necessary to take a comprehensive approach to evaluate fiscal sustainability in emerging economies, such as Colombia. We propose a globally-based fiscal sustainability test to identify the empirical conditions that ensure a strong enough fiscal response to stabilize public debt. Additionally, we consider the recent effects of the COVID-19 pandemic and the oil shock on Colombia, which has significant This latest shock has significant implications given the importance of oil revenues for the country.

3. Methodological framework and data

3.1. Data

This study uses annual series of variables for the period 1980–2021 provided by MFPC, BanRep, and Bloomberg.[4] The fiscal variables correspond to the CNG accounts of Colombia for the series of primary balance (bp), public debt (d), public expenditure without interest payments (g), and debt interest payments (i), all of them are measured as a percentage of GDP. Government expenditure is measured in levels as well macroeconomic variables such as nominal and real GDP, and GDP growth rate (y), inflation rate (π), real interest rate (r), and changes in oil prices (ΔOil), terms of trade index (ti). The variables were selected following to Bohn (1998, 2008) and Aldama and Creel (2019) and are in line with the empirical literature. Table 1 presents descriptive statistics of the data used and their source.

Additionally, the output gap ($\tilde{y}_t$) is calculated by taking the log difference between nominal GDP and the trend obtained by using the Hodrick – Prescott filter, as suggested by Bohn (2008). Similarly, the cyclical component of government expenditure ($\tilde{g}_t$) is calculated by taking the difference of the seasonally adjusted series of noninterest expenditure and its trend obtained by using the Hodrick – Prescott filter. Figure 2 shows the results.

3.2. Bohn FRF-based sustainability test

Bohn (1995, 1998) found that a government reacts actively through a dynamic fiscal policy that allows it to generate primary surpluses when the debt-to-GDP ratio increases.

[4]All data is available on the sources' web portals: Ministry of Finance and Public Credit Republic of Colombia (MFPC). https://www.minhacienda.gov.co/webcenter/portal/Estadisticas and Central Bank of Colombia (BanRep). https://www.banrep.gov.co/es/estadisticas. Although the authors make available, upon request, the complete and consolidated database available to readers.

Table 1. Descriptive statistics of the data – period 1980–2021.

Variable	Mean	Median	Std. Dev.	Min.	Max.	Skewness	Kurtosis	Source
Percentage (%) of GDP								
pb	−0.0122	−0.0095	0.015	−0.0509	0.0104	−0.6520	−0.31	MHCP, 2022
d	0.3601	0.3572	0.1036	0.1244	0.608	−0.0083	0.8	MHCP, 2022
g	0.134	0.135	0.0292	0.0795	0.2037	0.2203	−0.18	MHCP, 2022
i	0.0218	0.0257	0.0109	0.0055	0.0381	0.1444	−1.57	MHCP, 2022
Annual growth rate								
y	0.0341	0.0367	0.0289	−0.076	0.106	−1.3539	5.49	BanRep, 2022
π	0.1316	0.0807	0.097	0.0159	0.3337	0.3798	1.48	BanRep, 2022
r	0.0804	0.0620	0.0508	0.0228	0.2332	0.9914	−0.11	BanRep, 2022
ΔOil	0.0491	0.0228	0.2601	−0.4422	0.717	0.2705	−0.10	Bloomberg, 2022
Levels								
ti	117.53	110.68	30.42	75.79	183.74	0.7124	−0.36	BanRep, 2022
ln(GDP)	11.7	12.3	1.9	7.7	14	−0.7125	−0.77	MHCP, 2022
ln(G)	9.63	10.24	2.13	5.27	12.37	−0.586	−1.00	MHCP, 2022

Source: MHCP, BanRep, IMF, Bloomberg. Own elaboration.

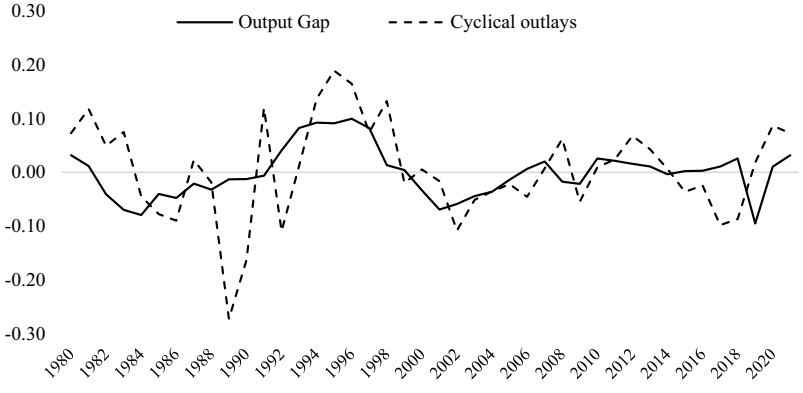

Figure 2. Output gap and cyclical component of spending. Source: BanRep. Own elaboration.

We considered the empirical formulation of the Bohn's FRF as indicated Equation 5 and Equation 6, and we defined four models considering linear and nonlinear components such as quadratic and cubic terms for d_{t-1}, as well as other determinants: $\tilde{y}_t$, $\tilde{g}_t$, π_t, ti_t, and ΔOil_t. In that sense, the extended FRF are:

$$pb_t = \mathrm{a}_0 + \rho d_{t-1} + b_1\tilde{y}_t + b_2\tilde{g}_t + \varepsilon_t, \tag{10}$$

$$pb_t = \mathrm{a}_0 + \rho d_{t-1} + b_1\tilde{y}_t + b_2\tilde{g}_t + b_3\pi_t + b_4 ti_t + b_5\Delta Oil_t + \varepsilon_t, \tag{11}$$

$$pb_t = \mathrm{a}_0 + \rho d_{t-1} + \varphi d_{t-1}^2 + \vartheta d_{t-1}^3 + b_1\tilde{y}_t + b_2\tilde{g}_t + \varepsilon_t, \tag{12}$$

$$pb_t = a_0 + \rho d_{t-1} + \varphi d_{t-1}^2 + \vartheta d_{t-1}^3 + b_1\tilde{y}_t + b_2\tilde{g}_t + b_3\pi_t + b_4 ti_t + b_5\Delta Oil_t + \varepsilon_t, \tag{13}$$

Now, to implement the MS model considering the base Bohn's FRF, we defined two different fiscal regimes, then Equation 10 can be restated as follows:

$$bp_t = a_1 + \rho_S d_{t-1} + b_{11}\tilde{y}_t + b_{21}\tilde{g}_t + \varepsilon_{1,t}, \tag{14}$$

$$bp_t = a_2 + \rho_{NS} d_{t-1} + b_{11}\tilde{y}_t + b_{21}\tilde{g}_t + \varepsilon_{2,t}, \tag{15}$$

and the Markov transition probability matrix for these two regimes is determined by:

$$P(s_t = j|s_{t-1} = i) = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}, \tag{16}$$

where p_{ij} is the transition probability from regime i at time $t-1$ to regime j at t. In this regard, $y_t = (y_1, y_2, \ldots, y_t)$ represents the set of observations and $\theta = \left(a_1, a_2, \rho_1, \rho_2, b_{11}, b_{12}, b_{21}, b_{22}, \sigma_1, \sigma_2, p_{11}, p_{22}\right)$ the vector of all model parameters, which are obtained from the Hamilton filter (see J. D. Hamilton, 1989, for more details), as indicated using Equation 17 and Equation 18.

$$\xi_{jt} = P(s_t = j|y_t; \theta) \tag{17}$$

$$\xi_{jt} = \frac{\sum_{i=0}^{1} \xi_{i,t-1} p_{ij} \eta_{ij}}{f(y_t|y_{t-1}; \theta)} \tag{18}$$

where $\xi_{i,t-1} = P(s_{t-1} = i|y_{t-1}; \theta)$, η_{ij} is the density of the two regimes at t, and $f(y_t|y_{t-1}; \theta)$ is the conditional density at t. Thus, the unobserved Markovian state variable generates periodic changes in the model structure and its transition probabilities determine the persistence and duration of each regime. In this sense, the asymmetric response of a government on its primary balance to increases in the debt-to-GDP ratio, as well as its probabilities and duration, can be estimated. The empirical estimation of the MS model is presented in the next section.

4. Empirical results

This section presents empirical tests for debt sustainability in Colombia. To achieve this, we estimate proposed models and perform sustainability tests based on the FRF approach.

4.1. Empirical findings and discussions

To estimate the linear and nonlinear FRF, we use the residual component of the primary balance adjusted by the cyclical components of GDP ($\tilde{y}_t$) and expenditure ($\tilde{g}_t$), given the resulting nonsignificant relationship between primary balance and (lagged) debt, as shown in Figure 3a.

We used an ordinary least square (OLS)[5] of primary balance pb against output gap $\tilde{y}_t$ and cyclical government spending $\tilde{g}_t$. The model specification is given by:

$$u_t = pb_t - \alpha_0 + \alpha_y \tilde{y}_t + \alpha_g \tilde{g}_t. \tag{19}$$

From this adjustment, a positive linear relationship is found as shown in Figure 3b. Now, considering the previous series and using the OLS method, we proceed to estimate the FRF. Additionally, all models are fitted using the Cochrane – Orcutt method to correct for serial correlation of errors (see Hansen, 1990, for more details). In that sense, we

[5]All models were implemented using R software. The codes and data used are available to the reader upon request.

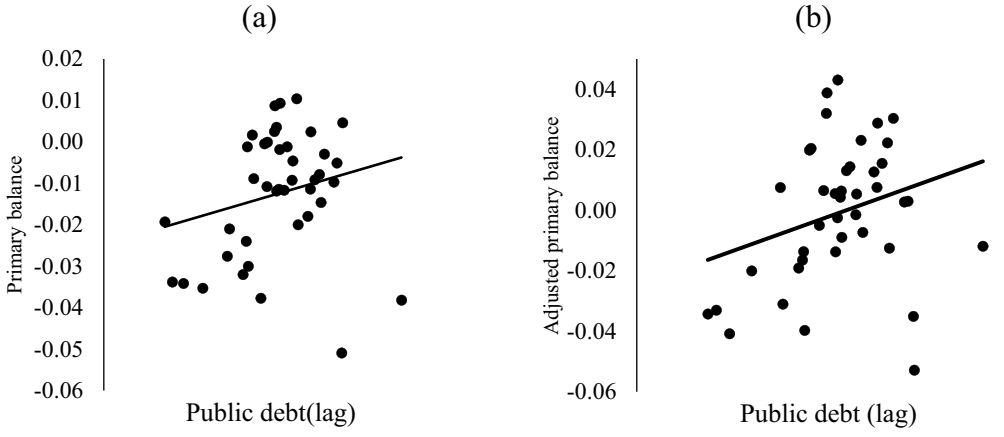

Figure 3. Relationship between fiscal balance and debt (1980–2021). Source: Own elaboration.

formulated a different specification for the FRF indicated above, as well as the linear and nonlinear components, shown in Table 2.

Table 2 summarizes the estimation results of four models. Model 1 considers only $\tilde{y}_t$ and $\tilde{g}_t$ with the debt-to-GDP ratio (d_{t-1}). Model 2 incorporates the other linear components such as π_t, ti_t, and ΔOil_t. Model 3 considers the same variables of model 1 and the quadratic and cubic components of debt (d^2_{t-1} and d^3_{t-1}). Finally, model 4 considers all variables. According to the above results, no significant evidence of debt sustainability in the analysed period is found in any model. Moreover, only the variables $\tilde{y}_t$ and $\tilde{g}_t$ are

Table 2. Results of linear and nonlinear FRF estimations.

	Linear FRF		Nonlinear FRF	
	(1)	(2)	(3)	(4)
Constant	−0.0183	−0.0479	−0.1461	−0.0179
	(0.0181)	(0.0369)	(0.0872)	(0.0086)
d_{t-1}	0.0413	0.0918	0.7198	0.107
	(0.0389)	(0.0437)	(0.6277)	(0.0665)
$\tilde{y}_t$	0.3331	0.3779	0.388	0.4355
	(0.0416)***	(0.0519)***	(0.0431)***	(0.0557)***
$\tilde{g}_t$	−0.2151	−0.217	−0.2017	−0.207
	(0.0198)***	(0.019)***	(0.019)***	(0.0193)***
d^2_{t-1}			−0.976	−1.84
			(1.523)	(1.61)
d^3_{t-1}			0.2634	0.988
			(1.204)	(1.287)
π_t		−0.0767		−0.0841
		(0.0625)		(0.0602)
ti_t		−0.0001		−0.0001
		(0.0001)		(0.0002)
ΔOil_t		0.0065		−0.0004
		(0.0044)		(0.004)
R^2	0.8249	0.8429	0.849	0.8521
Statist. DW	1.64	1.82	2.01	1.989

Statistical significance level at 1% (***), 5% (**), and 10% (*).
Standard errors are in parentheses.
Source: Own elaboration.

significant for all models. Cassou et al. (2017), Aldama and Creel (2019) and Owusu et al. (2023) found similar results for the US economy and some Euro area countries. They suggested that these shortcomings are driven by the non-linear properties of fiscal policy rules. However, these results contrast with previous studies for Colombia applied by Lozano and Julio (2019) and Zapata and Chamorro (2022) and reflect the concerns generated by the incorporation of the COVID-19 pandemic crisis period until 2021.

Then, we proceed to the implementation of the MS model for the FRF, as indicated in Equation 8–Equation 10. For this purpose, the specification given in model 1 is taken as the base model, since all other variables including the nonlinear components of the debt turned out to be nonsignificant. Table 3 presents the estimation results for both regimes: sustainable (regime 1) and unsustainable (regime 2).

Unlike models 1–4 in Table 2, we now identify a sustainable fiscal regime (regime 1), which confirms the positive response of the primary balance to the increase in debt ($\rho_S = 0.0612$), whereas the response in regime 2 is negative and equal to $\rho_{NS} = -0.0244$. This result confirms the presence of periods in which the debt-to-GDP ratio is sustainable depending on the response of the primary balance (pb) and the cyclical behaviour of the variables $\tilde{y}_t$ and $\tilde{g}_t$ and those periods that are unsustainable.

Figure 4 allows us to identify those unsustainable periods by showing the estimated probability of the unsustainable state, as well as the filtered probability. Three periods of unsustainable fiscal regimes are identified corresponding to 1980–1985, 1993–1999, and 2015–2021, with an average duration of 6 years for each period. The unsustainable regimes incorporate the periods of (i) the debt crisis in Latin America in the early 80s, (ii) the 1998–1999 crisis, and (iii) the ex-post period of the 2014–2015 oil shock and the-19 pandemic crisis. We also identify two periods of sustainable fiscal regimes (1986–1994 and 2000–2014) with an average duration of 12 years.

Given the strong impact of the debt crisis of the 1980s and the 1998–1999 crisis, the country experienced strong increases in the debt level corresponding to 23 pp and 10 pp, respectively, as well as sharp drops in the growth rate of the economy. Likewise, in the period of the recent COVID-19 pandemic crisis, with the 2014–2015 oil shock, the country again experienced negative growth rates accompanied by a notable increase in the debt-to-GDP ratio. Moreover, in this last period, a probability that persists at its

Table 3. MS model for the FRF.

	Regime 1	Regime 2
Constant	−0.0136	−0.0019
	(0.0084)	(0.0047)
d_{t-1}	0.0612	−0.0240
	(0.0230)***	(0.0112)**
$\tilde{y}_t$	0.3513	0.3063
	(0.0352)***	(0.0294)***
$\tilde{g}_t$	−0.1885	−0.3472
	(0.0165)***	(0.0219)***
R^2	0.8977	0.9575
	Regimen probabilities	
$s = 1$	0.8572	0.1428
$s = 2$	0.0863	0.9137

Statistical significance level at 1% (***), 5% (**), and 10% (*).
Standard errors are in parentheses.
Source: Own calculations.

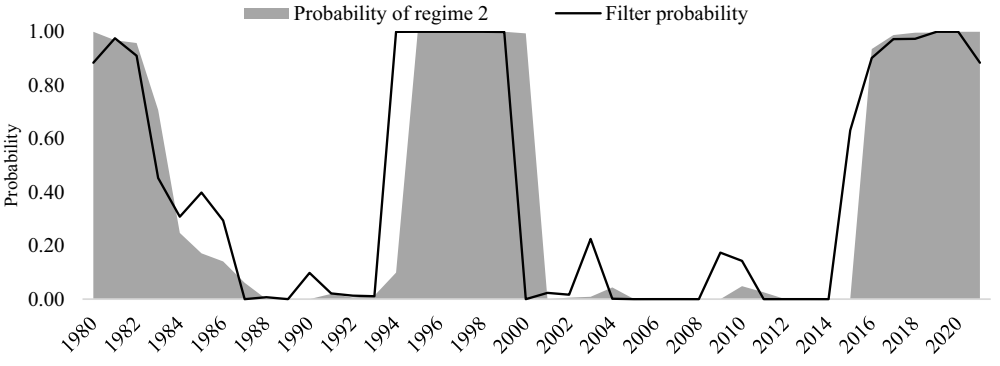

Figure 4. Probability and filtered probability for unsustainable regime. Source: Own elaboration.

highest level is identified, which indicates that the final duration of this will depend on the magnitude of the response that the CNG continues to give to stabilize the budget imbalance, as well as the outcome in economic matters for the coming years.

Now, considering that the debt stabilization condition (DSC) is determined by using Equation 1 and how it depends exclusively on the relationship between bp and d, its verification requires the use of the growth-adjusted average real interest rate (r^{ay}), as stated by Bohn (2008). Thus, we have $r^{ay} = \frac{r-g}{1+g}$. For the estimation of the r^{ay} rate, it is proposed to use a Bai – Perron regression to introduce structural changes, as shown in Equation 13:

$$r_t^{ay} = \nu + \varepsilon_t \tag{20}$$

where ν represents its average value. Based on this estimate, three different rates were identified for the analysis period, which are obtained from the structural changes determined in the previous model.[6] Figure 5 shows the behaviour of the historical growth-adjusted rate r^{ay} and its average estimate in each period of structural change: i) 1990–1997, ii) 1998–2002, and iii) 2003–2021.

Finally, the results of the test for the DSC defined in Equation 8 are presented in Table 4, using the rate υ for each period and for the entire period of analysis. These tests allow us to conclude that the estimated MS FRF satisfy the DSC.

Furthermore, despite periodic unsustainable regimes, evidence of an overall sustainable fiscal policy is found. Sustainable regimes are sufficiently strict and frequent to ensure that public debt is backed by the expected present value of primary balance, as indicated in Equation 8 However, the presence of an unsustainability fiscal regime shows a pro-cyclical response of the primary balance of the Colombian government and therefore the debt stabilization policy rule does not operate within an adequate long-term adjustment path. The asymmetric adjustment of primary balance to positive and negative debt shocks is recurrent with a duration of six years. The result of the globally test is like Aldama and Creel (2019) for the US economy. However, they contrast with the results obtained by Chua et al. (2021) and Adeosun et al. (2021), who verify no evidence in the global test of fiscal sustainability in emerging economies.

[6]For this estimation, all coefficients are found to be significant at a 95% confidence level.

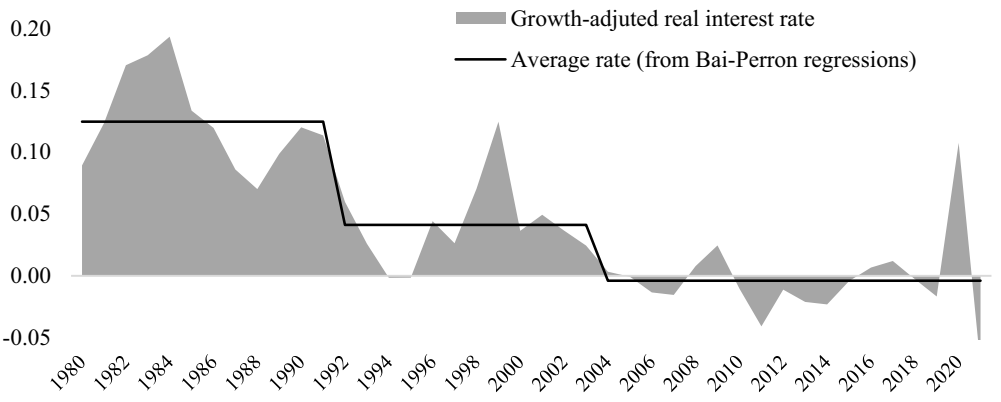

Figure 5. Growth-adjusted real interest rate. Source: Own elaboration.

Table 4. Global sustainability test with $\rho_S = 0.0612$.

1980–1991	1992–2003	2004–2021	All periods
0.0441	0.0316	−0.0494	0.0289

Source: Own elaboration.

4.2. Model diagnostics and robustness checks

To test the internal validity of the MS model, we checked for diagnostics and robustness of the model. To do that, we applied statistical diagnostic tests, where the assumption of the error term was found not have been violated. Additionally, we tested for serial correlation of the error term in the for both regimes: sustainable (regime 1) and unsustainable (regime 2) and we concluded that the error terms are not serially correlated.

On the other hand, we implemented an additional check to assess the sensitivity of the MS model with additional control variables such as π, *ti* and, ΔOil, following the second formulation of the FRF. We found the statistically significant coefficients and confirmed the sustainable fiscal regime (regime 1) with a positive response of the primary balance to the increase in debt ($\rho_S = 0.1104$) and a negative the response in regime 2 with $\rho_{NS} = -0.0938$. These new results confirm the same previous conclusions of the proposed MS model.

5. Conclusions and policy implications

In this paper, the fiscal sustainability condition for Colombia was evaluated, extending the standard Bohn FRF approach by using a MS model and a Bai – Perron structural change model. To do so, we identified different sustainable and unsustainable fiscal regimes throughout the period 1980–2021, where we found asymmetric responses of the government's primary balance to face increases in public debt, especially during the last crisis. Particularly, we identified three unsustainable periods that incorporate the debt crisis in Latin America in the early 1980s, the 1998–1999 crisis, and the ex-post period of the 2014–2015 oil shock and the COVID-19 pandemic crisis. Based on the proposed models, we corrected the problems and limitations identified in the use of empirical tests

that follow the conventional Bohn's FRF since the presence of periodic fiscal shocks may lead to the nonfulfillment of the public debt sustainability condition. On that basis, we implemented a global sustainable test to verify the DSC, where the real interest rate was adjusted under structural changes following the Bai – Perron structural model.

Although evidence of asymmetric behaviour in fiscal responses and the presence of pro-cyclical fiscal policy was found, the sustainable regime has been adequate in stabilizing public debt for longer periods than the non-sustainable regime since 1980. The average duration of sustainable periods (twelve years) has been longer than that of unsustainable ones (six years) and incorporates a robust reaction of the primary balance towards the lagged public debt. If the government implements a fiscal policy aimed at reducing the current level of debt with credible measures, it can reduce the possibility of experiencing new unsustainable periods. This will help maintain a path of long-term fiscal adjustments. However, it is important to remember that the government has limited fiscal space. Therefore, implementing weak adjustment measures in the next few years could lead to longer periods of unsustainability and destabilize the path of fiscal adjustment needed to correct the current high debt.

Additionally, concerns arise due to the inflationary processes experienced by all economies and the global uncertainty caused by recent armed conflicts. All this has triggered a significant increase in debt interest rates and depreciation of the Colombian peso against the US dollar, which has increased the cost of debt and consequently has limited the availability of national budget resources to perform all social and productive public investment as well as the economic reactivation packages. Moreover, this can lead to lower growth rates in the medium and long terms, putting the government's solvency and the country's macroeconomic stability at risk.

Based on that, it is recommended that these concerns and the effects of the recent tax reform be addressed in future work. Further research should examine the degree in which Colombia is exposed to such risk. Additionally, for future extensions, the sustainability condition may be evaluated using much more robust methodologies, not only considering the fiscal policy, but also its interrelation with the dynamics of inflation and monetary policy, under an integrated framework. In the direction of the solution, it can be analysed by using a dynamic general equilibrium model (DSGE) that incorporates endogeneity of fiscal policy in the macroeconomic context.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

All the data, models, and R code that support the findings of this study are available from the corresponding author on reasonable request.

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