



# BULLETIN OF ECONOMIC THEORY AND ANALYSIS

Journal homepage: <https://dergipark.org.tr/tr/pub/beta>

## Public Debt and Economic Growth: Does One Size Fit All? Evidence from Fourier-based Empirical Analysis

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**To cite this article:** Bozatlı, O. (2026). Public debt and economic growth: does one size fit all? evidence from fourier-based empirical analysis. *Bulletin of Economic Theory and Analysis*, 11(1), 437-465.

**Received:** 28 Oct 2025

**Accepted:** 23 Jan 2026

**Published online:** 28 Feb 2026



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## *Bulletin of Economic Theory and Analysis*

Volume 11, Issue 1, pp. 437-465, 2026

<https://dergipark.org.tr/tr/pub/beta>

Original Article / Araştırma Makalesi

Received / Alınma: 28.10.2025 Accepted / Kabul: 23.01.2026

Doi: <https://doi.org/10.25229/beta.1812157>

### **Public Debt and Economic Growth: Does One Size Fit All? Evidence from Fourier-based Empirical Analysis**

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#### **Abstract**

While public debt is vital for economic growth and development, a heavy debt burden has adverse effects. Therefore, there is a debate about how public debt will affect economic growth. This study investigates the public debt and economic growth nexus in Türkiye using the Fourier-Augmented ARDL methodology over the years 1968-2019. Although Türkiye has a moderate level of public debt, it has significantly lost its fiscal space because of geopolitical risks, irregular migration, natural disasters, inaccurate economic policies, and the economic crises it has frequently faced in the last decade. Our analysis demonstrates that public debt has a detrimental impact on economic growth, as evidenced by linear and nonlinear models. These findings remain consistent even after conducting robustness checks. However, our nonlinear model differs from the majority by indicating a U-shaped relationship between public debt and economic growth, featuring a 61-63% threshold. Therefore, increasing public debt to stimulate growth is not a viable policy. Instead, policymakers should prioritize borrowing to fund productive investments that increase output and employment rather than financing budget deficits and increasing the debt burden. For Türkiye, these initiatives can increase the welfare of present and future generations and make both public debt and economic growth sustainable.

#### **Keywords**

Public Debt,  
Economic Growth,  
Fourier-Augmented  
ARDL

#### **JEL Classification**

E62, H63, C32

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**Citation** Bozatlı, O. (2026). Public debt and economic growth: does one size fit all? evidence from fourier-based empirical analysis. *Bulletin of Economic Theory and Analysis*, 11(1), 437-465.



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## Kamu Borcu ve Ekonomik Büyüme: Her Duruma Uyan Tek Bir Model Mümkün mü? Fourier Tabanlı Ampirik Bulgular

### Öz

Kamu borcu ekonomik büyüme ve kalkınma için hayati öneme sahip olsa da aşırı borç yükü olumsuz etkiler yaratmaktadır. Bu nedenle, kamu borcunun ekonomik büyümeyi nasıl etkileyeceği konusunda süregelen bir tartışma bulunmaktadır. Bu çalışma, Türkiye’de kamu borcu ile ekonomik büyüme arasındaki ilişkiyi 1968-2019 dönemi için Fourier-Artırılmış ARDL yöntemiyle incelemektedir. Türkiye’nin kamu borcu seviyesi genel olarak orta düzeyde olmasına rağmen, son on yılda sıkça karşılaşılan jeopolitik riskler, düzensiz göç, doğal afetler, hatalı ekonomik politikalar ve ekonomik krizler nedeniyle mali alanını önemli ölçüde kaybetmiştir. Analizimiz hem doğrusal hem de doğrusal olmayan modellerde kamu borcunun ekonomik büyüme üzerinde olumsuz bir etki yarattığını göstermektedir. Bu bulgular, sağlamlık testleri sonrasında da tutarlılığını korumaktadır. Bununla birlikte, doğrusal olmayan modelimiz çoğu çalışmadan farklı olarak, kamu borcu ile ekonomik büyüme arasında %61–63 eşiği bulunan U şeklinde bir ilişki olduğunu ortaya koymaktadır. Bu nedenle, büyümeyi teşvik etmek amacıyla kamu borcunu artırmak uygulanabilir bir politika değildir. Bunun yerine, politika yapıcıların borçlanmayı bütçe açıklarını finanse etmek veya borç yükünü artırmak yerine, üretimi ve istihdamı artıran verimli yatırımların finansmanına yönlendirmeleri gerekmektedir. Türkiye açısından bu tür girişimler hem mevcut hem de gelecek kuşakların refahını artırabilir ve kamu borcu ile ekonomik büyümeyi sürdürülebilir hale getirebilir.

**Anahtar Kelimeler**  
Kamu Borcu,  
Ekonomik Büyüme,  
Fourier-Augmented  
ARDL

**JEL Kodu**  
E62, H63, C32

### 1. Introduction

The first quarter of the 21st century was a period of exciting developments regarding public debt (PD). In two decades on a global scale, PD has increased nominally fourfold, while GDP has only risen threefold (UNCTAD, 2023). Sharp accumulation of PD coincided with a period of the lowest interest rates in recent history (Wolf & Zessner-Spitzenberg, 2024). The 10-year nominal interest rates for PD remained below the expected inflation for many developed countries. This situation resulted in negative-real interest rates (Blanchard, 2023). Additionally, for many developing and developed countries, the net PD-to-GDP ratio exceeded 100% (IMF, 2024), and budget deficits reached significant levels, particularly after COVID-19. During this period, extreme conditions such as the 2008 Great Financial Crisis and the COVID-19 pandemic also resulted in significant fluctuations in economic growth (EG). The increases in PD on a global scale and the slowdown in EG have brought the interaction of these two variables to the forefront. Determining whether PD is an effective tool or a heavy burden for EG and economic development is the first step in a long-term academic debate. Does low EG lead to high PD, or does high PD slow EG, or is there hysteria (see Bozatli et al. 2024). Although academic discussions initially defined PD as a

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conundrum and focused solely on its probable impacts, it has evolved into a central focus of macroeconomic debates with the help of novel econometric techniques.

The study of macroeconomics provides insights into how the occurrence of PD could impact EG. The theoretical discussions focus on the positive effects of PD through the aggregate demand channel in the short run from a Keynesian perspective. The neo-classical approach discusses the negative effects, such as tax pressure (Égert, 2015a), crowding-out effect, policy restrictiveness, ineffective governments (Turan & Yanikkaya, 2021), and debt overhang effect (Krugman, 1988), in the long run (Checherita-Westphal & Rother, 2012; Woo & Kumar, 2015). Once more, Diamond (1965) remarked that the accumulation of PD activates a dynamic market failure, restricts the accumulation of physical capital, negatively affects the EG, and increases the burden of intergenerational debt. On the other hand, the Barro-Ricardo equivalence hypothesis exemplifies the neutrality of PD in terms of EG with households being aware of future tax increases (Barro, 1974). Researchers have extensively discussed and thoughtfully considered this intricate issue but have not yet reached a consensus.

The groundbreaking paper by Reinhart and Rogoff (2010) is a milestone in the PD-EG nexus debate, providing evidence for an inverted U-shaped relationship. Reinhart and Rogoff (2010) presented a comparative analysis with data covering approximately two centuries for 44 countries and claimed that the PD-to-GDP ratio exceeding the 90% threshold negatively affects EG. A significant body of empirical literature has concentrated on testing nonlinear relationships and estimating thresholds. Nevertheless, findings indicate the presence of heterogeneous thresholds ranging from 20% to 132% (Baum et al., 2013; Caner et al., 2010; Chirwa & Odhiambo, 2020; Ibanez Martin et al. 2024; Law et al., 2021; Yolcu Karadam, 2018). Contrary to the common view that the nonlinear relationship is in the form of an inverted U-shape Augustine and Rafi (2023); Bentour (2021); Okwoche & Nikolaidou (2022); Minea and Parent (2012) show that the PD-EG nexus can also be U-shaped. Equally important, several investigators underlined that one size does not fit all, so it is impossible to determine a universally acceptable threshold. Even if there is a threshold, the results are not robust (Amann & Middleditch, 2020; Arčabić et al., 2018; Kourtellos et al., 2013; Presbitero, 2012; Panizza and Presbitero, 2013). Using linear empirical models, we can separate the answers given to the PD-EG puzzle into positive (Akram, 2015; Fincke & Greiner, 2015; Owusu-Nantwi & Erickson, 2016) and negative (Bal & Rath, 2014; Gómez-Puig et al., 2022; Onofrei et al., 2022).

Empirical investigations occasionally disregard the effect of low EG on PD, which is the other half of the debate (Dafermos, 2015). Correspondingly, PD can positively impact EG if it is at a sustainable level or under the country's safe debt ceiling. Thus, PD is not obligatory to have a negative effect on EG. The relationship between PD and EG can differ between countries due to the probability of changes in the debt coefficient at the threshold. This implies that policies effective in one country may not be suitable for another (Eberhardt & Presbitero, 2015). Considering the heterogeneous findings and critiques within the extant literature of the PD-EG nexus, it is imperative to note that a singular resolution that can address all encountered contradictions remains elusive.

A considerable amount of empirical literature explores the relationship between PD and EG through panel data techniques, systematically assessing the inferences drawn from this relationship. However, it is crucial to understand the nuanced macroeconomic performance of individual countries to design appropriate policies and interventions. In this study, we empirically investigate the PD-EG nexus in Türkiye for 1968-2019. During this period, Türkiye experienced several episodes of economic turbulence caused by many endogenous and exogenous factors. The oil crises in the early 1970s, the public financial crises arising from state economic enterprises in the 1980s, the national financial crises in the 1990s, and the global/national financial crises in the 2000s illustrate economic hard times. Türkiye, which has experienced a sudden increase in PD and the loss of EG momentum, is again faced with an economic bottleneck. Consequently, understanding the complexity of the PD-EG relationship is crucial for designing precise policies to maintain macroeconomic stability and foster sustainable economic development.

Our research is expected to make a significant contribution to the current body of literature by tackling four major areas of discussion related to the results. (a) It presents country-specific results about Türkiye, a fragile developing country that has not been adequately examined in the literature. (b) The Fourier Augmented ARDL method presents an innovative and cutting-edge technique that provides a sophisticated approach to modeling smooth breaks. This methodology, which allows modeling the economic side effects of crises occurring in certain periods, has not been previously used in the literature. Thus, adopting this method in a sample exposed to financial, political, and economic crises, such as Türkiye, will provide a different insight into the nature of the PD-EG relationship. (c) The nonlinear model revealed a rare yet significant U-shaped relationship between PD-EG. (d) This study reveals that no single solution can address all the

contradictions that will be encountered regarding the PD-EG connection; in other words, one size does not fit all in the PD-EG relationship.

The organization of the study is as follows: The second part provides a comprehensive review of empirical literature, while the following part includes detailed explanations of the data, method, and model. The fourth section includes empirical results. The fifth section discusses the PD-EG nexus, offering some insights into this topic. The final section includes policy recommendations.

## 2. Empirical Literature Review

We organize the empirical literature into two groups: those employing linear models and those employing non-linear models. We first consider studies that examine the PD-EG nexus in the context of "impact" with linear models.

Employing the ARDL method for exploring different countries and periods Akram (2011), Bal and Rath (2014), Barik and Sahu (2022), Gómez-Puig and Sosvilla-Rivero (2018), Mhlaba and Phiri (2019), and Owusu-Nantwi and Erickson (2016) have uncovered evidence indicating a negative impact of PD on EG. Likewise, with the Panel-ARDL method Asteriou et al. (2021), Chirwa and Odhiambo (2020), and Onofrei et al. (2022) confirmed a negative relationship between PD and EG. Additionally, Woo and Kumar (2015), Gunarsa et al. (2020), and Gómez-Puig et al. (2022) utilized different panel data techniques, which support the findings of negative effects of PD on EG. Equally important, Albu and Albu (2021), using wavelet analysis and Gómez-Puig and Sosvilla-Rivero (2025), using time-varying panel data techniques, discovered robust evidence for a negative PD-EG nexus. Similarly, a limited number of linear estimations for Türkiye indicate that PD has a negative effect on EG (Dogan & Bilgili, 2014; Turan, 2019).

According to Abubakar and Mammam (2021), in OECD countries, PD had a short-term positive and temporary impact on EG, but a long-term negative and permanent effect that was greater than the temporary positive effect. Lof and Malinen (2014) discovered that PD had no significant impact on EG; however, they did identify a significant negative effect of EG on PD. It is also important to acknowledge studies that demonstrate a positive relationship between PD and EG, even though much of the prior research has indicated negative associations. Akram (2015) and Fincke and Greiner (2015) reported that PD has a positive impact on EG, but the source of PD is significant.

In the second step, we focus on examining empirical literature that utilizes quadratic models, and we discuss whether a specific threshold can be found at which PD begins to affect the EG. We also aim to determine whether this threshold value is valid for economies with similar conditions. Numerous studies using diverse empirical techniques and nonlinear models have demonstrated a curvilinear relationship between PD and EG, revealing an inverted U-shaped pattern. However, in these studies, the estimated threshold values vary widely.

Presbitero (2012) points out that PD has a negative impact on EG until PD-to-GDP reaches 90%, beyond which there is no significant relationship. However, Checherita-Westphal and Rother (2012) detected an inverted U-shaped PD-EG connection with a threshold value ranging from 90-100%. Moreover, Mencinger et al. (2014) examined 25 EU member countries between 1980 and 2010. They revealed a non-linear relationship, with the threshold value between 80% and 94% in the former (new) EU member states. In contrast, Šulíková et al. (2015) found that the threshold value for 13 EU was 64%. Baum et al. (2013) analyzed data from 12 Eurozone countries from 1990 to 2019 and reported a threshold of 67%. However, Afonso and Alves (2015) argued that from 1970, through 2012, the threshold value for 14 European countries was in the range of 74 to 75%.

Caner et al. (2010) scrutinized 101 countries and specified threshold values as 77% for developed countries and 64% for developing countries. Cecchetti et al. (2011) pointed out that the threshold value could be around 85% in the developed and developing countries they examined. Lee et al. (2017) found a threshold effect occurring at 30% between PD and median GDP growth, for developing countries. If the threshold had been surpassed, the median real GDP growth experienced a sharp decline. Arčabić et al. (2018) analyzed data from 178 countries across the periods 1880-2009 and 1960-2009 and found statistically insignificant results. They concluded that establishing a definitive debt threshold is impossible due to the sensitivity of their estimated values, which ranged from 14% to 105%. Additionally, Law et al. (2021) analyzed 71 developing countries from 1984 to 2015, revealing that the threshold is 51.65%. Finally, Ibañez Martín et al. (2024) investigate 47 developing countries and found inverted U-shaped relation for the external PD-to-GDP threshold value at 42%, with the relationship turning negative above the threshold.

Égert (2015a) examine 20 OECD countries from 1790 to 2009 and found that a central (general) government PD-to-GDP ratio exceeding 30% (50%) weakened EG but did not indicate any such relationship for the 60% and 90% threshold values. Additionally, Égert (2015b) analyze

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29 OECD countries from 1946 to 2009 and found evidence that the threshold value that starts negatively affecting EG could be as low as 20-60%.

Some studies have also employed procedures that enable smooth transition and threshold regression modeling in the examined series. Yolcu Karadam (2018) examined 135 developed and developing countries, finding public debt thresholds for economic growth at 59.6% (total), 63.2% (short-run), and 56.2% (long-run). The study also revealed that public debt negatively impacts economic growth until a per capita income of \$1,603.59, beyond which it has a positive effect. Ndoricimpa (2020) reported that in 39 African countries, the threshold at which public debt negatively impacts economic growth is between 62% and 66%, with a neutral relationship observed below this threshold. Bal (2025) analyzed India between 1970 and 2019 and revealed an inverted U-shaped relation with a threshold of 61-64%. Shah et al. (2025) examined 38 developing countries and found that an inverted-U-shaped PD-EG relationship exists and the threshold varies from 50% to 62%.

Kourtellos et al. (2013) investigated 82 countries and found that institutional quality determines the relationship. They emphasize that there is no robust evidence of nonlinearity. Gómez-Puig and Sosvilla-Rivero (2025) also underlined the moderating effect of institutional quality. Additionally, Afonso and Jalles (2013) found a negative relationship between PD and EG with a threshold value of 59% in their study of 155 countries from 1970 to 2008, noting that the quadratic debt coefficients were not statistically significant and thus failed to support an inverted-U shaped relationship. Alsamara et al. (2024) investigated how energy moderates the relationship between public debt and economic growth in 14 MENA countries during the period from 1980 to 2021, identifying a nonlinear relationship with thresholds of 90% for the full sample, 46% to 69% for oil countries, and 74% to 80% for non-oil countries.

Minea and Parent (2012) point out that PD-to-GDP ratios below 115% have a negative effect on EG. Eberhardt and Presbitero (2015) found a negative PD-EG nexus in their study of 118 countries; however, no significant evidence supporting a common threshold was found, and there are examples of inverted-U and U-shape relations. In addition, Bentour (2021) examined 20 developed countries and found that the relationship between PD and EG can differ depending on the country, with some countries exhibiting a consistently negative or positive connection, while others exhibit a U-shaped or inverted U-shaped pattern. Okwoche and Nikolaidou (2022) examined

a large sample of developing and developed countries and identified a U-shaped relationship. They used per capita income as a threshold variable with a predicted threshold value of \$9,862. Augustine and Rafi (2023) examined 39 developed and developing countries and reported that the PD-EG connection varies according to country. They found both U-shaped and inverted U-shaped relationships, and the PD-to-GDP threshold value varies between 24% and 132%.

The hot debate about the PD-EG nexus persists alongside the rapid expansion of PD around the world. This section seeks to unveil the potential frameworks of relationships that are supported by empirical literature. The literature is built on a diverse foundation that includes numerous models for panel data and a range of techniques for analyzing time series data. Based on primary studies in empirical literature, we have constructed Table 1, which includes empirical results derived from linear and quadratic models. However, the outcomes are negative for linear models and show an inverted U-shape pattern for nonlinear models. Although Reinhart and Rogoff (2010), which triggered the discussion of the nonlinear PD-EG connection, points to a 90% value, there is a vast spectrum of threshold values in the empirical literature, ranging from 20% to 106%. The variations in the estimated results can be primarily attributed to differences in assumptions regarding factors such as the frequency of data, time dimension, sample size, minimum number of observations required in each nonlinear regime, preferred econometric methodology, and macroeconomic dynamics of the countries included in the sample.

The threshold value findings and effects of PD on EG for developed economies are more consistent than those for developing economies. It is important to note that no universal threshold value applies to all countries when examining the connection between PD and EG. This means that country-specific analysis is necessary, as a "one size fits all" approach will not be accurate.

Table 1

*Empirical Literature Review*

	<b>Authors(Year)</b>	<b>Sample</b>	<b>Period</b>	<b>Method</b>	<b>Findings</b>	
<b>Testing Linear Models</b>	Akram(2011)	Pakistan	1972-2009	ARDL	Negative	
	Bal and Rath (2014)	India	1980-2011	ARDL	Negative	
	Woo and Kumar (2015)	Selected C. (60)	1970-2018	Sys-GMM	Negative	
	Owusu-Nantwi and Erickson (2016)	Ghana	1970-2012	Johansen	Positive	
	Gómez-Puig and Sosvilla-Rivero (2018)	Euro Area (11)	1961-2013	ARDL	Negative	
	Mhlaba and Phiri (2019)	South Africa	2002-2016	ARDL	Negative	
	Asteriou et al. (2021)	Asia C. (11)	1980-2012	P-ARDL	Negative	

	Chirwa and Odhiambo (2020)	Euro Area (10)	1970-2018	P-ARDL	Negative	
	Gunarsa et al. (2020)	Asian C. (25)	1970-2015	Diff-GMM	Negative	
	Albu and Albu (2021)	Euro Area (19)	2000-2019	Wavelet coherence	Negative	
	Barik and Sahu (2022)	India	1980-2018	ARDL	Negative	
	Gómez-Puig et al. (2022)	Selected C. (115)	1995-2016	GFE	Negative	
	Onofrei et al. (2022)	European Union (28)	1995-2019	ARDL	Negative	
	Abubakar and Mamman (2021)	OECD (37)	1980-2018	PDA	Negative	
	Lof and Malinen (2014)	Developed C. (20)	1905-2008	P-VAR	Negative	
	Akram (2015)	Philippines	1975-2010	ARDL	Negative	
	Fincke and Greiner (2015)	Developing C. (8)	1980-2012	PDA	Positive	
	<b>Authors(Year)</b>	<b>Sample</b>	<b>Period</b>	<b>Method</b>	<b>Findings</b>	<b>Threshold</b>
Researchers Testing Quadratic Models	Presbitero (2012)	Selected C. (92)	1990-2007	Sys-GMM	Inverted-U	90%
	Checherita-Westphal and Rother (2012)	Euro Area (12)	1970-2008	LS&GMM	Inverted-U	90-100%
	Mencinger et al. (2014)	European Union (15)	1980-2010	GMM-IV	Inverted-U	80-94%
	Šulíková et al. (2015)	European Union (13)	1993-2013	Dynamic IV	Inverted-U	64%
	Caner et al. (2010)	Selected C. (111)	1980-2008	PTR	Inverted-U	77%
	Minea and Parent (2012)	Developed C. (20)	1945-2009	PSTR	U	115%
	Lee et al. (2017)	Developed C. (20)	1946-2009	TR	Inverted-U	28%
	Baum et al. (2013)	Euro Area (12)	1990-2010	DPTR	Inverted-U	67%
	Arčabić et al. (2018)	Selected C. (178)	1880-2009	DPTR	Inverted-U	-
	Law et al. (2021)	Developing C. (71)	1984-2015	PTR	Inverted-U	51%
	Ibañez Martín et al. (2024)	Developing C. (47)	1970-2019	DPTR & PTR	Inverted-U	42%
	Égert (2015a)	OECD (29)	1946-2009	N-PTR	Inverted-U	20-60%
	Égert (2015b)	OECD (20)	1790-2009	TR	Inverted U	30-50%
	Yolcu Karadam (2018)	Selected C. (135)	1970-2012	PSTR	Inverted U	88-106%
	Ndoricimpa (2020)	African C. (39)	1980-2012	PSTR	Inverted U	62-66%
	Bal (2025)	India	1970-2019	ARDL	Inverted-U	61-64%
	Afonso and Jalles (2013)	Selected C. (155)	1970-2008	Sys-GMM	Inverted-U	59%
	Alsamara et al. (2024)	MENA C. (14)	1980-2021	CS-ARDL	Inverted-U	46-91%
	Eberhardt&Presbitero (2015)	Selected C. (118)	1961-2012	PDA	Inverted-U	60-90%
	Okwoche&Nikolaidou(2022)	Selected C. (87)	1988-2015	DPTR	U	\$9,862per capita
Shah et al. (2025)	Developing C. (38)	1990-2020	DPTR	Inverted-U	50-62%	
Bozatli and Serin (2025)	G-7	1984-2019	PDA	U and Inverted-U	13-34%	
Cecchetti et al. (2011)	OECD (18)	1989-2010	PTR	Inverted-U	85%	

Note. ARDL: Autoregressive Distributed Lag; P-ARDL: Panel Autoregressive Distributed Lag; GFE: Grouped Fixed Effects; Diff-GMM: Difference Generalized Method of Moments; PDA: Panel Data Analysis; P-VAR: Panel Vector Autoregression; PSTR: Panel Smooth Threshold Regression.

### 3. Methods

#### 3.1. Data and the Model

The main empirical objective of this investigation was to test PD's probable effects on EG in Türkiye. In the study, due to data availability, two models, linear and quadratic, were designed using data from 1968 to 2019, which is approximately half a century. Table 2 provides details about the variables used in the econometric models, which are presented in equations (1) and (2).

Table 2

*Description of Variables*

Variable	Symbol	Criterion	Source
Economic Growth	<i>gdp</i>	Per Capita (2015 \$ Constant Prices)	WDI
Public Debt	<i>debt</i>	% GDP	IMF
Gross Fixed Capital Formation	<i>gf</i>	% GDP	WDI
Human Capital	<i>hc</i>	Index (based on years of schooling and returns to education)	Penn World Table

$$\ln gdp_t = \beta_0 + \beta_1 \ln debt_t + \beta_2 \ln gf_t + \beta_3 \ln hc_t + \varepsilon_t \quad (1)$$

$$\ln gdp_t = \beta_0 + \beta_1 \ln debt_t + \beta_2 \ln debt_t^2 + \beta_3 \ln gf_t + \beta_4 \ln hc_t + \varepsilon_t \quad (2)$$

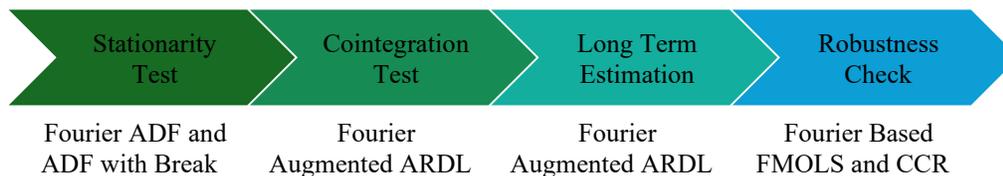
In Equations (1) and (2), *debt* represents PD, *gf* represents gross fixed capital investments, *hc* represents human capital, and *debt2* represents the square of PD. The first model analyzes the linear relationship between PD and EG by considering fixed capital investments and human capital. The former is included in the EG model to represent capital, and the latter to represent labor. In the second quadratic model, the square of the PD is included to reveal whether there is a turning point between PD and EG, and if so, what form this relationship takes. In both models,  $\beta_0$  and  $\varepsilon_t$  represent the constant and error term coefficients, respectively. The term “ln” implies that a logarithmic transformation has been applied to the series.

There are some theoretical and empirical grounds for such an approach. Considering the literature review in Table 1, some researchers have tested linear relationships, and others have tested nonlinear relationships. However, estimating both linear and nonlinear models will allow for a clearer understanding and comparison of the PD-EG relationship. The purpose of estimating the linear model (equation 1) is motivated by the theoretical arguments that the relationship between PD-EG can be positive or negative. A Keynesian perspective implies that PD will positively affect EG in the short run through the aggregate demand channel. On the other hand, the neo-classical perspective considers the PD-EG relationship to be potentially negative (Checherita-Westphal & Rother, 2012; Woo & Kumar, 2015) in the presence of tax pressure (Égert, 2015a), crowding-out effect, policy restrictiveness, ineffective governments (Turan & Yanikkaya, 2021; Serin & Ünlükaplan, 2022), and debt overhang effect (Krugman, 1988). Again, Diamond (1965) argues that PD accumulation negatively affects EG by restricting the accumulation of physical capital and increasing the intergenerational debt burden. However, the Barro-Ricardo equivalence hypothesis of Barro (1974) implies neutrality in this relationship. Therefore, the PD-EG relationship may differ from country to country, as it is a theoretical issue that remains unresolved.

The pioneering paper by Reinhart and Rogoff (2010) is a milestone in the PD-EG nexus debate and provides evidence of an inverted U-shaped relationship. They present a comparative analysis with data for 44 countries spanning nearly two centuries and argue that a PD/GDP ratio exceeding the 90 percent threshold negatively affects EG. A significant part of the empirical literature has focused on testing non-linear relationship and estimating thresholds. However, as seen from the findings presented in Table 2, we believe this ratio cannot be generalized, and even the opposite relationship may exist. Therefore, depending on the institutional and economic structures of the countries, it is possible that there is a U-shaped or inverted U-shaped relationship between PD-EG. Finally, the inclusion of gross fixed capital formation and human capital in both models is due to the fact that these are the main determinants of EG. These two are expected to positively affect EG in the long run.

### 3.2. Methodology

It is a methodological necessity to explore the stationarity properties of a series, examine the long-run relationship, and estimate coefficients using appropriate empirical techniques. The term structural breaks refers to shocks that occur within a time series during a specific period. These shocks may arise from endogenous causes, such as economic crises and political fluctuations, and from uncontrollable exogenous causes such as natural disasters. Disregarding these structural breaks may produce biased results (Aydin & Bozatli, 2023). Therefore, a Fourier-based econometric methodology was used in this study. The econometric application process in this study is summarized in Figure 1.



*Figure 1. Empirical Strategy*

The empirical research process consists of four phases. First, the stationarity properties of the series are investigated, and the degree of integration is determined. Then, the existence of a long-term relationship is tested. If the long-term relationship is identified, the long-term coefficients are calculated in the next phase. In the last phase, the results obtained are subjected to robustness analysis to demonstrate their validity.

### 3.2.1. Fourier ADF and ADF with Break Tests

Enders and Lee (2012) developed the Fourier ADF unit root test by adding Fourier terms (*sine* and *cosine*) as deterministic terms to the conventional ADF equation, which makes it possible to model smooth structural breaks in a time series. Thus, the Fourier ADF test considers structural changes neglected by the conventional ADF unit root test. The principal model for the question test is introduced in Equation 3.

$$\alpha(t) = \alpha_0 + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) \quad (3)$$

The Fourier ADF test is obtained by adding Fourier terms (represented by  $k$ ) to the ADF equation:

$$\Delta y_t = \alpha_1 + \delta t + \beta y_{t-1} + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + \sum_{i=1}^p \theta_i \Delta y_{t-i} + u_t \quad (4)$$

The implementation of the Fourier ADF test occurs in two stages: first, it involves estimating the range of  $1 \leq k \leq 5$  and selecting the optimal model with the lowest sum of residual squares, followed by a significance test for the deterministic terms using an F-test in the second phase. When the Fourier terms are statistically significant, the Fourier ADF test is applied to interpret the results. If the Fourier terms are insignificant, the ADF unit root test should be used. However, as stated by Perron (1989), traditional unit root tests lead to biased results in the presence of structural changes. Accordingly, conducting unit root tests by including structural breaks in the traditional ADF test is a more accurate approach.

### 3.2.2. Fourier Augmented ARDL Bounds Test

It is essential that the dependent variable be integrated of order  $I(1)$  for the ARDL method developed by Pesaran et al. (2001) to ensure the validity of the F and t-bounds tests, thus avoiding unreliable outcomes (Sam et al., 2019). Hence, the ARDL method was further developed by McNown et al. (2018) and Sam et al. (2019), who introduced some changes to the application process. They suggested the inclusion of an F-test for independent variables to supplement the general F-test and t-test as a means of improving the method's effectiveness. Three test statistics can be expressed as follows:

$$a) F\text{-overall} | H_0 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$$

$$b) t\text{-dependent} | H_0 : \beta_1 = 0$$

$$c) F\text{-independent} | H_0 : \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$$

The initial two tests (a and b) mentioned here refer to the standard tests put forth by Pesaran et al. (2001), while the third test is the F-independent test suggested by McNown et al. (2018) and Sam et al. (2019). It is important to ensure that the cointegration relationship is valid and requires all computed test statistics to exceed their respective critical values. Otherwise, issues relating to degenerate case 1 and case 2 can arise during analysis (Sam et al., 2019; Bozatli and Akca, 2024). Consequently, Pesaran et al. (2001) ARDL model to investigate the long-run relationship stated in Equations (1) and Equation (2):

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{p-1} \alpha_i \Delta y_{t-i} + \sum_{i=1}^{p-1} \gamma_i \Delta x_{t-i} + \sum_{i=1}^{p-1} \delta_i \Delta z_{t-i} + \sum_{i=1}^{p-1} \nu_i \Delta \ln w_{t-i} + \sum_{i=1}^{p-1} \delta_i \Delta \ln q_{t-i} + \beta_1 y_{t-1} + \beta_2 x_{t-1} + \beta_3 z_{t-1} + \beta_4 w_{t-1} + \beta_5 q_{t-1} + v_t \quad (5)$$

In Equation (5)  $v_t$  and  $\alpha_0$  denote the error term and constant, respectively. Additionally, short-run coefficients are represented by  $\alpha_i, \gamma_i, \delta_i, \nu_i, \delta$  and long-term coefficients are represented by  $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ . While the augmented ARDL method addresses the issues mentioned earlier, it has a notable limitation in that it doesn't account for structural changes. However, Sam et al. (2019) state that structural breaks can be modeled by adding a sharp break to the Augmented ARDL equation. On the other hand, these breaks are sharp, and require a priori information about their date and number, which poses an important disadvantage. To address this shortcoming, Syed et al. (2023) and Aydin et al. (2024) have proposed the inclusion of Fourier terms in the augmented ARDL model, which effectively models smooth structural breaks.

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{p-1} \alpha_i \Delta y_{t-i} + \sum_{i=1}^{p-1} \gamma_i \Delta x_{t-i} + \sum_{i=1}^{p-1} \delta_i \Delta z_{t-i} + \sum_{i=1}^{p-1} \nu_i \Delta \ln w_{t-i} + \sum_{i=1}^{p-1} \delta_i \Delta \ln q_{t-i} + \beta_1 y_{t-1} + \beta_2 x_{t-1} + \beta_3 z_{t-1} + \beta_4 w_{t-1} + \beta_5 q_{t-1} + \beta_6 \sin\left(\frac{2\pi kt}{T}\right) + \beta_7 \cos\left(\frac{2\pi kt}{T}\right) + e_t \quad (6)$$

Accordingly, the Fourier Augmented ARDL methodology is preferred because it allows modeling smooth structural breaks and there is no need for a priori information on their date/number. As Jones and Enders (2014) emphasized, conducting analyses by estimating an appropriate number of frequencies instead of numbers, dates, and break structures makes Fourier-based tests more reliable and preferred.

### 3.2.3. Robustness Check

If a cointegration relationship is detected, the Fourier Augmented ARDL method will estimate the long-term coefficients. Additionally, to ensure reliable results, the Fourier-based Fully Modified Least Squares (FMOLS) and Canonical Cointegration Regression (CCR) methods are used to estimate the cointegration equation. This approach aims to leverage the strengths of various estimators and ensure parameter stability by overcoming the instabilities that may arise in recursive estimation.

## 4. Empirical Results

At the outset of the empirical research process, a crucial task is to determine the level of integration of the series. In this regard, the series was subjected to the Fourier ADF test, and the results are presented in Table 3.

Table 3  
Unit Root Test Results

Variables	Fourier ADF					ADF with Break			
	I(0)	p/k	I(1)	p/k	F-test	I(0)	Prob.	I(1)	Prob.
<i>gdp</i>	-4.165***	3/1	---	---	5.479	-3.512	0.684	-7.427*	0.000
<i>debt</i>	-3.633	3/1	-4.543*	4/3	1.081	-2.654	0.971	-6.927*	0.000
<i>debt</i> <sup>2</sup>	-3.619	3/1	-4.594*	4/3	1.081	-2.619	0.975	-7.231*	0.000
<i>gf</i>	-3.052	4/2	-4.445**	4/3	3.913	-3.954	0.399	-7.688*	0.000
<i>hc</i>	-4.398**	4/1	---	---	5.090	-7.170*	0.000	---	---

Note. \*, \*\*, and \*\*\* denote that the null hypothesis was rejected at the 1%, 5%, and 10% significance levels, respectively. p and k represent lags and frequency, respectively. The optimal lag length was selected on the basis of AIC.

Table 3 displays that according to the Fourier ADF unit root test, the variables human capital and GDP show stationary behavior at level, whereas the rest of the variables demonstrate stationary behavior only after taking the first difference. The application of the F-constraint test by Enders and Lee (2012), indicated that deterministic terms were insignificant, whereas the ADF test with conventional breaks revealed that all variables except for human capital is stationary at first

difference. The main reason for the GDP series being stationary in the Fourier ADF test, but at first difference in the ADF test with breaks, is that the methodology takes into account a smooth break in the Fourier ADF test and a sudden break in the ADF test. In other words, the unit root process is carried out by considering one specified frequency in the first test and one specified time break in the second test. Although Enders and Lee (2012) recommend the use of the conventional ADF test when deterministic terms are insignificant, we rely on the findings of the ADF test with breaks based on Perron's (1989) view that unit root tests that do not take into account structural changes may be biased. Based on these observations, models 1 and 2 were examined using the Fourier Augmented ARDL method, which allows different variables to be stationary at varying degrees of integration, provided that the dependent variable is stationary at the first difference.

Table 4

*Fourier Augmented ARDL Cointegration Test Results*

Dependent Variable: GDP			Diagnostic Tests				
Model	Statistics	Value	$X_{SC}$	$X_H$	$X_N$	$X_{FF}$	C/CSQ
$gdp = f(debt, gf, hc)$	$F_{general}$	7.77*	0.154 (0.85)	0.961 (0.478)	2.035 (0.361)	1.176 (0.284)	Stable Stable
	$t_{dependent}$	-4.29**	<b>Cointegration (✓) Diagnostic Check (✓)</b>				
	$F_{independent}$	10.35*					
$gdp = f(debt, debt^2, gf, hc)$	$F_{general}$	6.30**	3.800 (0.05)	1.212 (0.360)	0.502 (0.777)	3.865 (0.071)	Stable Unstable
	$t_{dependent}$	-4.87*	<b>Cointegration (✓) Diagnostic Check (✓)</b>				
	$F_{independent}$	7.87*					

Note. \* and \*\* denote statistical significance at 1% and 5% significance levels, respectively. Probability values are reported in parentheses.

Table 5

*Critical Values*

Test	Lower Bound I(0)			Upper Bound I(1)		
	10%	5%	1%	10%	5%	1%
$F_{general}$	2.87	3.50	4.86	3.97	4.70	6.36
$t_{dependent}$	-2.57	-2.86	-3.43	-3.46	-3.78	-4.37
$F_{independent}$	2.23	2.83	4.29	3.99	4.94	7.07

Note. Critical values for F-general, t-dependent, and F-independent statistics are taken from Narayan (2005), Pesaran et al. (2001), and Sam et al. (2019), respectively.

The results for the cointegration relationship in Table 4 show that the validity of a long-term relationship cannot be rejected in either model. This is because all test statistics surpass the critical thresholds provided in Table 5 for both the lower and upper bounds. Moreover, both models meet the assumptions of the ARDL test. In other words, the linear and quadratic models do not suffer from autocorrelation and heteroscedasticity problems, the series is normally distributed, and the models fit well in terms of functional form. The iterative forecasts (C/CSQ) presented in the appendix indicate stability. Although there is instability in the CSQ within the quadratic model, the coefficient stability is ensured by the empirical procedure through the use of various estimators. Accordingly, the results of both models were estimated using the Fourier Augmented ARDL method, and the findings are presented in Table 6.

Table 6

*Fourier Augmented ARDL Long-Run Estimations*

Variables	Model 1 Linear		Model 2 Quadratic	
	Coefficient.	P-value	Coefficient.	P-value
<i>debt</i>	-0.187*	0.006	-1.287*	0.000
<i>debt</i> <sup>2</sup>	---	---	0.148*	0.001
<i>gf</i>	0.235**	0.025	0.192*	0.006
<i>hc</i>	1.5219*	0.000	1.614*	0.000
<i>sin</i>	-0.088*	0.000	-0.071*	0.000
<i>cos</i>	0.092*	0.000	0.083*	0.000

Note. \* and \*\* denote statistical significance at 1% and 5% significance levels, respectively.

When the findings in Table 6 are evaluated, the following inferences can be drawn: First, according to the linear model, there is a negative relationship between PD and EG. In other words, an increase in PD decreases EG. On the other hand, the findings of the quadratic model indicate a U-shaped relationship between PD and EG. Accordingly, PD negatively affects EG until a certain turning point, after which this effect reverses. Although the PD-EG relationship seems negative, empirical findings suggest that, when the threshold relationship is considered, the relationship may vary depending on the level of PD. In addition, both models find that human capital and fixed capital investments are important determinants of EG. Although both variables positively affect EG, human capital has a greater effect than fixed capital investments. This result is consistent with endogenous growth models that emphasize the role of human capital in economic growth.

#### 4.1. Robustness Results

To test the robustness of the obtained results in respect of the preferred long-run estimator, and to avoid the parameter instability implied by the recursive estimates, both models are re-estimated with Fourier-based FMOLS and CCR estimators. The linear and quadratic model results are presented in Tables 7 and 8, respectively.

Table 7

##### *Robustness Check (Linear Model)*

Variables	FMOLS			CCR		
	Coefficient	Standard Error	P-value	Coefficient	Standard Error	P-value
debt	-0.105*	0.038	0.009	-0.103**	0.041	0.015
gf	0.229*	0.063	0.008	0.236*	0.071	0.001
hc	1.611*	0.083	0.000	1.596*	0.096	0.000
sin	-0.025	0.017	0.154	-0.026	0.017	0.145
cos	0.099*	0.012	0.000	0.097*	0.014	0.000

Note. \* and \*\* denote statistical significance at 1% and 5% significance levels, respectively.

Table 8

##### *Robustness Check (Quadratic Model)*

Variables	FMOLS			CCR		
	Coefficient	Standard Error	P-value	Coefficient	Standard Error	P-value
debt	-0.850*	0.305	0.007	-0.828*	0.287	0.006
debt <sup>2</sup>	0.103**	0.042	0.019	0.100**	0.039	0.015
gf	0.238*	0.055	0.001	0.239*	0.061	0.000
hc	1.623*	0.071	0.000	1.612*	0.082	0.000
sin	-0.021	0.015	0.171	-0.022	0.015	0.143
cos	0.100*	0.010	0.000	0.098*	0.012	0.000

Note. \* and \*\* denote statistical significance at 1% and 5% significance levels, respectively.

The results of FMOLS and CCR estimators for both models confirm the Fourier Augmented ARDL findings. Therefore, under the structural changes, although there is a negative relationship between PD and EG at first glance, the existence of a nonlinear relationship between both variables implies another point of view. Again, in line with expectations, empirical evidence supports the notion that human capital and fixed investments play an undeniably important role in the formation of economic welfare in the long run.

## 5. Discussion

This study investigated the effect of PD on EG for Türkiye during the 1968-2019 period using the Fourier Augmented ARDL method with both linear and non-linear models. First, the Fourier ADF and ADF with break unit root tests were applied to determine the series' integration degrees. The findings imply that human capital is  $I(0)$  and the others are  $I(1)$ . The Fourier Augmented ARDL bound test was performed because the condition of not  $I(2)$  of the variables, including the dependent variable, was met. According to the bound test findings, it was determined that all three statistical values (General F-test, T-test, and F-independent variables test) were greater than the critical values at the 1% and 5% significance levels. Therefore, the cointegration relationship between the series is valid. In other words, the series moves together in the long run. Fourier Augmented ARDL long-term coefficient findings are as follows: The public debt (debt) and the square of the public debt (debt2) have significant negative and positive effects on EG, respectively. Such a finding indicates that PD negatively affects EG to a certain level. After this point, it has a positive effect on EG. In other words, a U-shaped relationship was determined between PD and EG. This result does not support an inverted U-shaped relationship, as Reinhart and Rogoff (2010) suggested. In addition, in researching the threshold effect between PD and EG (Caner et al. 2010; Cecchetti et al. 2011; Cecherita-Westphal and Rother 2012; Baum et al. 2013; Afonso and Jalles 2013; Mencinger et al. 2014; Suliková et al. 2015; Égert, 2015a; Égert, 2015b; Afonso and Alves 2015; Lee et al. 2017; Yolcu Karadam, 2018; Ighodalo Ehikioya et al. 2020; Ndoricimpa 2020; Liu and Lyu 2021; Law et al. 2021), a different result was reached. On the other hand, a U-shaped relationship between PD and EG coincides with the findings of Bentour (2021), Minea and Parent (2012), and Okwoche and Nikolaidou (2022).

However, it is important to highlight that the panel data technique, which does not consider heterogeneity, was used in these studies, investigating the PD-EG relationship. The threshold values changed from 20% to 132%. Presbitero (2012) suggested reevaluating the results obtained, because the techniques did not consider heterogeneity in the PD-EG relationship. Therefore, reaching such a relationship using novel time series techniques that consider country heterogeneity is quite meaningful. In addition, Eberhardt and Presbitero (2015) argue that in linear specifications with various predetermined thresholds, the probability of the change in the debt coefficient at the threshold being either positive or negative is so crucial that it cannot be neglected. In this context, we underline that regardless of the shape and form of the PD-EG relationship, these findings may

differ between countries, so policies suitable for one country may be seriously inappropriate in another.

In addition to PD, investment and labor have been found to have a positive and statistically significant effect on EG. Therefore, gross capital formation and human capital are important channels for determining the effect of PD on EG. To control the robustness of the results obtained within the scope of the study, estimations were made using FMOLS and CCR methods. The robustness checks support our findings.

The possible benefits of providing additional resources can offset the negative effects of a debt surplus in developing countries. Country-specific factors change the way PD affects EG (Presbitero, 2012). In addition, in light of the findings of some studies (Presbitero, 2012; Panizza and Presbitero, 2013; Kourtellis et al., 2013; Lof & Malinen, 2014; Chudik et al., 2017; Arčabić et al., 2018; Amann & Middleditch, 2020; Turan & Yanikkaya, 2021), it should be noted that there cannot be a universal or country-based threshold value in the PD-EG relationship; even if such a threshold, the results are not strong, and the findings remain weak. However, institutional quality is important in determining whether the relationship between PD and EG is positive, negative, or neutral. A low level of institutional quality (*ceteris paribus*) leads to lower economic growth. In contrast, if the institutions are of sufficient quality, the PD-EG relationship is neutral (Kourtellis et al., 2013). Also, the impact of financial sector policies or the level of financial development on PD should not be neglected. Financial development is likely to affect PD positively or negatively through the EG channel. Less stringent financial sector policies and large-scale financial reforms increase PD (Agnello & Sousa, 2015). Accordingly, financial restructuring is an important tool for bringing the PD to the desired level.

## **6. Conclusion and Policy Recommendations**

Our study aims to investigate the relationship between PD-EG and other variables in Türkiye during the 1968-2019 period, which was marked by multiple economic, political, and social crises. In this context, we estimate two models, one linear and one quadratic, using the Fourier Augmented ARDL method, which is one of the most up-to-date time series techniques. While making our empirical predictions, we include gross PD, which is central in empirical studies, in the EG model. Our findings provide robust evidence that the PD-EG connection is negative for

the linear model, whereas it is positive for the quadratic model. The results obtained in the quadratic model indicate a threshold value varying between 61% and 63%.

For Türkiye, this finding is highly rational. While the average PD to GDP ratio of developing countries worldwide is 68%, this ratio for Türkiye is 31% (UNCTAD, 2023). The historical development of PD in Türkiye is generally aimed at financing budget deficits, and the clearest indicator of this is that the PD stock has always increased before economic crises. In other words, public borrowing has long been a political choice in Türkiye. The threshold value we calculated (61-63%) was exceeded during the 2001 economic crisis. The average annual EG rate between 1996 and 2000 was 4.2%. The annual EG rate was 7.5% from 2002 to 2006 (WDI, 2024). Moreover, the coefficients obtained in the linear and quadratic models also show that the negative effect of PD is more dominant than its positive effect. For Türkiye, after the 61-63% threshold is exceeded, a 10% increase in PD increases EG by 1%.

Although our initial empirical findings suggest that additional PD could lead to greater EG, this is not the case. Owing to its macroeconomic fragilities, Türkiye will increase its PD stock, resulting in higher costs than present levels. The economic crises experienced in Türkiye during the review period and the public borrowing used in this process, created short-term solutions. In the 1990s, the PD to GDP ratio was approximately 80%. PD exceeding the threshold value increased EG in the short term, as demonstrated by the empirical results. However, in the long term, the sustainability of PD was lost, and the share of GDP allocated to interest payments on PD increased to 15% on an annual basis (IMF, 2024). In other words, PD, which was initially seen as a blessing, turned into a heavy burden in a short time.

Therefore, borrowing 10% more to achieve 1% economic growth is not a rational public policy. Awareness of the risks of PD should be prioritized in debt reduction during the fiscal austerity process. Thus, the EG profile to be achieved will create an environment that is effective in terms of resource allocation and income distribution, and more sustainable in terms of public finance. Furthermore, it will be possible to balance the distribution of the intergenerational burden of PD. In addition to the positive effect of reducing debt, there will also be benefits of increasing physical capital formation, reducing the crowding out effect (Serin & Demir, 2023), and strengthening the fiscal space. Additionally, in Türkiye PD is preferred, especially for financing public deficits, rather than for productive investments. In other words, it serves as a tool to

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eliminate deviations from fiscal targets. In addition, it should not be forgotten that low-cost and long-term borrowing opportunities are limited in Türkiye.

One of the main conditions that policymakers should consider is that the negative effect of borrowing is greater than its positive effect. In other words, the channels of the negative impact of borrowing come from the interest and tax burden of borrowing at high costs, the crowding-out of the private sector, and the financing of budget deficits through inefficient expenditures for populist political reasons. Therefore, our main policy recommendation in this article is to maintain the PD in Türkiye at a moderate level and minimize its distorting effects. Moreover, rather than economic growth guided by fiscal policy, it is necessary to expand the private sector, rather than the public sector, by adopting incentive policies that enable the private sector to access resources at lower costs. In this way, fiscal space will expand, fiscal policies will become more flexible, and resilience will increase to guard against possible hard times. Moreover, initiatives to reduce PD will reduce sustainability risk, allowing debt-risk premiums to decline and enabling borrowing at lower costs.

Within the scope of our study, we had to exclude some of the alternative channels that affect EG and borrowing costs, such as institutional quality, financial development, and market regulations, from the model due to a lack of data. In addition, obtaining consistent datasets for the early periods of the Republic of Türkiye was impossible. Although the model we chose is a new technique not previously used in the empirical literature, future research using frequency-domain-based techniques that have not been utilized before and that enable the examination of the relationships at the lower frequencies of the series with time-varying analyses may provide exciting results.

### **Declaration of Research and Publication Ethics**

This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

### **Researcher's Contribution Rate Statement**

Since the author is the sole author of the article, his contribution rate is 100%.

### **Declaration of Researcher's Conflict of Interest**

There are no potential conflicts of interest in this study.

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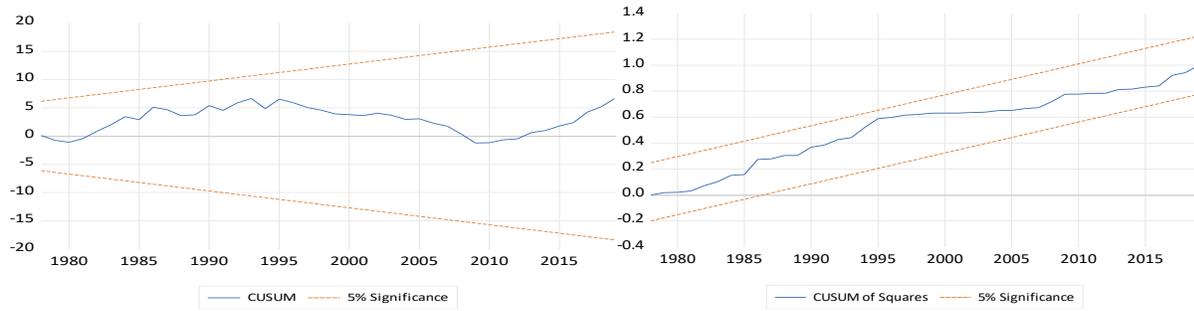
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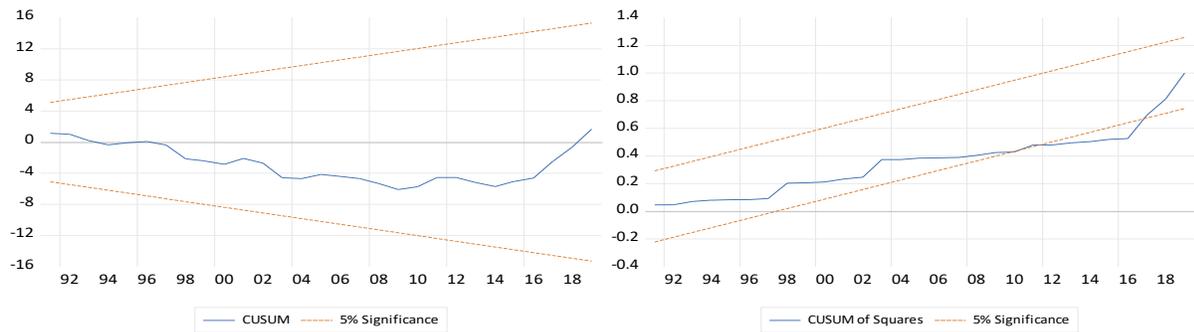
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### Appendix 1. Recursive Estimates



Recursive Estimates (Linear Model)



Recursive Estimates (Quadratic Model)