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Tax Revenues and Inflation Relationship: A Century-Long Application with Fourier-Based Approaches for Türkiye

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Abstract

Chronic high inflation periods have several disadvantages for a country's economy. One of the most significant drawbacks is the erosion of the real value of public revenues. It is impossible to completely isolate the relationship between tax revenues and inflation. Taxes are mandatory monetary obligations collected by the state to finance public services, whereas inflation is an economic phenomenon characterized by sustained increases in the general price level, which impacts the purchasing power of money. Therefore, understanding the relationship between these two concepts is vital for developing an inflation-resilient tax system. In this study, we use Fourier-based novel empirical methods to examine the relationship between total tax revenues and inflation in the Republic of Türkiye from 1924 to 2023. The long-run estimation results indicate that inflation negatively affected tax revenues in the first century of the Republic of Türkiye. Our empirical findings supporting the validity of the Olivera-Tanzi hypothesis highlight the importance of the issue, the policies that can be applied, and their importance in managing tax revenues in an inflationary environment in Türkiye.

Keywords
Tax Revenue, Inflation, Tax Erosion, Olivera-Tanzi Effect

JEL Classification
E31, H20, H21

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Vergi Gelirleri ve Enflasyon İlişkisi: Türkiye için Fourier Temelli Yaklaşımlarla Yüzyıllık Döneme İlişkin Bir Uygulama

Öz

Kronik yüksek enflasyonist koşullar bir ülke ekonomisi için çeşitli dezavantajlar yaratmaktadır. En önemli dezavantajlardan biri de kamu gelirlerinin reel değerinin aşınmasıdır. Vergi gelirleri ile enflasyon arasındaki ilişkiyi tamamen ayrıştırmak mümkün değildir. Vergiler, kamu hizmetlerini finanse etmek için devlet tarafından toplanan zorunlu parasal yükümlülüklerdir; enflasyon ise genel fiyat düzeyindeki sürekli artışlarla karakterize edilen ve paranın satın alma gücünü etkileyen bir ekonomik olgudur. Bu nedenle, bu iki kavram arasındaki ilişkiyi anlamak enflasyon-dirençli bir vergi sistemi oluşturmak için hayati öneme sahiptir. Bu çalışmada, Fourier tabanlı güncel ampirik yöntemleri kullanarak Türkiye Cumhuriyeti'nde 1924'ten 2023'e kadar toplam vergi gelirleri ile enflasyon arasındaki ilişki incelenmektedir. Uzun vadeli tahmin sonuçları, enflasyonun Türkiye Cumhuriyeti'nin ilk yüzyılında vergi gelirleri üzerinde olumsuz bir etkiye yol açtığına işaret etmektedir. Olivera-Tanzi hipotezini destekleyen ampirik bulgularımız, konunun önemini ve Türkiye'de enflasyonist bir ortamda vergi gelirlerinin yönetilmesindeki başvurulabilecek politikaları ve bunların önemini vurgulamaktadır.

Anahtar Kelimeler
Vergi Gelirleri,
Enflasyon,
Vergi Erozyonu,
Olivera-Tanzi Etkisi

JEL Kodu
E31, H20, H21

1. Introduction

The impact of inflation on a country's economy continues to be a topic of ongoing debate, especially concerning its effects on the government's fiscal structure. Despite extensive theoretical and empirical studies, a consensus has yet to be reached. It is clear that inflation can substantially diminish the real value of public revenues and expenditures, leading to a detrimental effect on the budget balance. Academicians have held comprehensive discussions throughout the history of economic thought regarding the rationales of inflation, how it interacts with the economic system, and the costs it brings about. One of these discussion topics concentrates on the fiscal consequences of inflation. This scope of studies investigates how inflationary processes impact key fiscal indicators, including budget balance, public expenditures, and public revenues. In fact, in theoretical discussions in the 1980s, the Chicago school's monetarist approach to the determination of the price level was criticized, and alternative models, such as the fiscal theory of the price level (Cochrane, 2023) and the unpleasant monetarist arithmetic (Sargent & Wallace, 1981), were introduced. These approaches address the interaction between fiscal policy and inflation with a critical glance at the traditional approach. However, prior to these approaches, several theoretical studies analyzed the fiscal consequences of inflation (Bailey, 1956; Cagan, 1956; Olivera, 1967). These early works particularly emphasized the potential effects of monetizing deviations from the budget balance as an initial focal point. Accordingly, an answer is sought as to whether inflation

tax, which can be obtained from increasing cash balances due to monetization in financing the budget balance, or taxation as a fiscal tool, should be used. On a theoretical scale, Bailey (1956) suggested that tax revenues could be more effective than inflation taxes in ensuring budget balance. Conversely, Phelps (1973) argued that creating an optimal combination of inflation tax and tax revenues is feasible. A wider group accepts the first of these theses within the framework of modern economic policies.

However, Tanzi (1977; 1978), who took these propositions one step further, pointed out that inflation may affect the real value of tax revenues, depending on the elasticity of the tax system and the collection period stipulated (lags) in the tax laws. According to Tanzi (1977) defined t*ax elasticity* as a concept related to tax system designs and income during the period in which tax liability occurs. Moreover, Tanzi does not consider real economic growth and explains the concept of elasticity only through price changes (Şen, 2003: p.4). Since the studies of Tanzi (1977; 1978) are based on a logic similar to that of Olivera (1967); the idea that inflation will erode the real value of tax revenues is called the Olivera-Tanzi effect in literature.

The Olivera-Tanzi erosion effect can occur during periods of high and persistent inflation. Nevertheless, moderate inflation may result in increased tax revenues for an economy. In this context, assuming that other variables remain constant, moderate inflation is likely to boost overall tax collection by broadening the base of taxable events. If companies can effectively manage their inventory costs during inflation, they can convert rising product and service prices into profits, leading to higher corporate tax revenues. Similarly, revenues from proportional consumption taxes can also increase as consumer goods prices rise. In addition, appreciation of real estate and other assets may result in higher taxes on wealth. Finally, if wage increases in labor markets occur in parallel with inflation, there will be an increase in tax revenues collected on wages without experiencing a fiscal drag/tax bracket shift. However, realizing all these positive scenarios is possible with a moderate level of inflation that is kept under control, allows markets to adapt, and does not change the direction of expectations (Musgrave & Musgrave 1989).

However, high and chronic inflation can negatively affect the budget balance by reducing the real value of public revenues. Understanding the most significant effects is crucial for developing a tax system that is resilient to inflation. However, the existing empirical literature on the fiscal implications of inflation in Türkiye appears to lack consensus. This divergence can be

attributed to the fact that various studies have analyzed distinct time periods using different empirical methodologies. Despite numerous studies conducted in Türkiye that affirm the validity of the Olivera-Tanzi effect (Demir, 2023; Gürbüzer, 1997; Karadeniz, 2022; Şen, 2003), some researchers argue that there may be no statistically significant link between inflation and tax revenues (Abdioğlu & Terzi, 2009; Biçen et al., 2015; Özmen & Koçak, 2012; Yalçın, 2020).

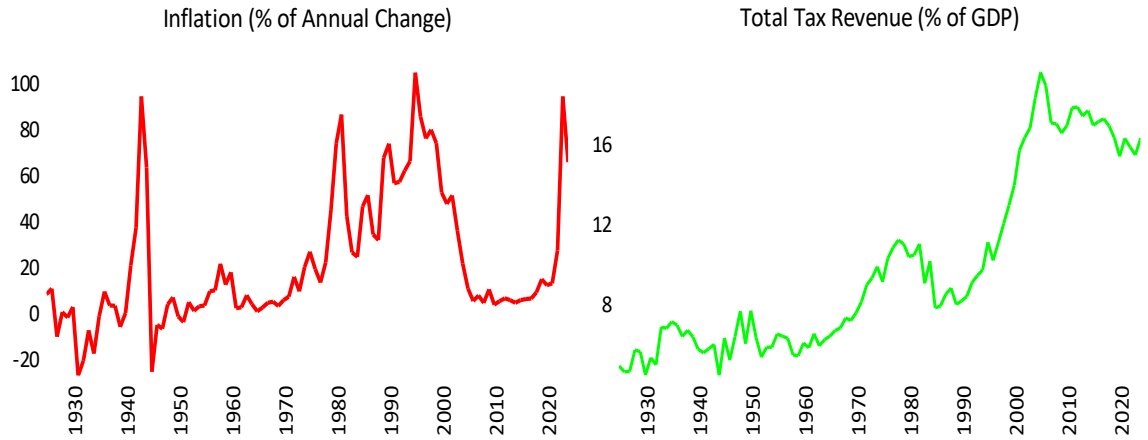

Figure 1. Inflation and Tax Revenue: (1924-2023) *Reference*: T.R. Ministry of Treasury and Finance (2024); T.R. Presidential Strategy and Budget Directorate (2024)

Figure 1 depicts the historical development of the indicators of tax revenues (% of real GDP) and inflation represented by the GDP deflator (% of annual change) in Türkiye as a time path graph. The 100-year average inflation and total tax revenues are 23% and 10%, respectively. In this manner, the fiscal consequences of inflation have become a remarkable concern for Türkiye, notoriously known for its historically high and chronic structure. Türkiye created a significant solution to the inflation problem both in the early periods of the Republic and the 2000s. Regarding both periods, it is possible to note that the initial disruptions in public finance gave rise to a subsequent spiral of inflation. A low level of total tax revenues also plays an important negative role in this regard. Furthermore, according to Gürkaynak et al. (2023: p.233), not every outbreak of inflation in Türkiye led to a public finance crisis. Nonetheless, every interval when public finance becomes unsustainable has resulted in inflation.

As we celebrate the second century of the Republic of Türkiye, we are facing a troubling situation where inflation is once again spiraling out of control. This has raised questions about how inflation affects tax revenues, especially since there are differing views on this topic in existing research. It highlights the importance of re-examining the relationship between inflation and tax

income. This study can contribute to the literature in several ways: (1) To our knowledge, no study examines Türkiye's 100-year history in a holistic manner, and studies in the literature can only date back to 1975 at most. (2) Moreover, at all stages of empirical application, novel Fourier-based empirical methods, which allow internal modeling of smooth structural breaks and have not been used before in the empirical literature, were used. (3) Since the study is based on a historical data set, it will allow the overall effect to be determined despite the changes in the tax system and the inflation path.

This study has four-parted design: The first section discusses the theoretical background of the relationship between inflation and tax revenues. The second section reviews empirical literature. The following section introduces the model, data, and methodology. The study then reports empirical results. In the last section, the findings and institutions of the Turkish Tax System are discussed, and some policy recommendations are included.

2. Inflation and Tax Revenues Relationship: Theoretical Background

Numerous theoretical studies support the notion that inflation can diminish the real value of tax revenues. This impact is influenced by various factors, such as the underlying causes of inflation (Cagan, 1956), its severity (Nowotny, 1980), the responsiveness of the tax system, and the time lag between taxable event and collection (Anušić & Švaljek, 1996; Beer et al., 2023; Choudhry, 1990; Mansfield, 1980; Olivera, 1967; Tanzi, 1978). Relevant studies indicate that inflation erodes real tax revenues, and they often evaluate them under the Olivera-Tanzi effect.

Cagan (1956) made significant contributions to the theoretical development of the Olivera-Tanzi effect. However, it was shaped by Olivera (1967) by monetizing fiscal deficits and basing the real change in tax revenues on a monetarist approach through this channel. In this context, Olivera (1967: p.260) stated that price changes are reflected more quickly in public expenditures, whereas public revenues take time to adjust. Furthermore, the author notes that certain tax revenues are linked to previous revenue figures. Some public revenues are influenced by exchange rates; however, adjustments to these rates occur with a delay in relation to changes in local currencies. Consequently, inflationary trends can lead to revenue reduction due to legal and delinquency delays (Çavuşoğlu, 2005: p. 38).

In other words, lags in the fiscal system (*ceteris paribus*) will result in a budget deficit problem due to inflation. To the best of our knowledge, the discussion surrounding this topic first

emerged in the work of Cagan (1956) and Olivera (1967), but it truly reached its peak when Tanzi (1977) provided a comprehensive analysis that significantly contributed to the literature on the subject. In addition to the inflation tax obtained through the monetization of public deficits, Tanzi (1977; 1978) offered a framework to the fundamental proposition of Olivera (1967) by approaching it from a fiscal perspective regarding lags in tax collection. In terms of developing economies, Tanzi (1978) stated that (a) tax bases are not suitable to bear the high tax burden; (b) tax administrations are inefficient even if their tax bases are suitable for high tax burdens; (c) public revenues may be insufficient due to political preferences and keeping the tax burden low. According to Tanzi (1977; 1978), if the price elasticity of a tax system is inelastic (*elastic*) and the collection lag period is long (*short*), inflation will negatively (*positively*) affect the real value of tax revenues. Figure 2 illustrates the relationship between these two factors.

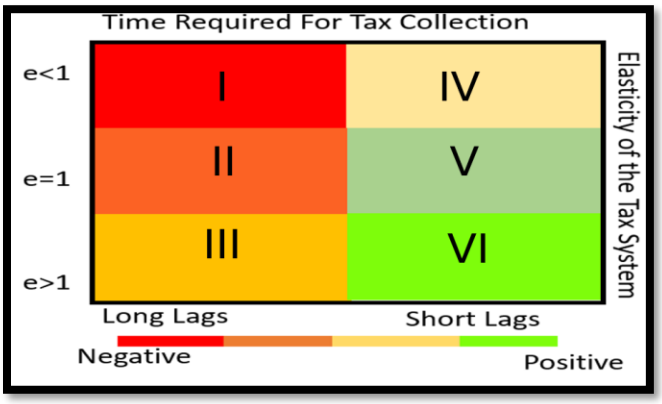

Figure 2. Effects of Inflation Corresponding to Elasticity and Lags. *Reference*: Regenerated by the authors basis of the data given by Tanzi (1978: p.424).

In Figure 2, inflation further erodes the real value of tax revenues as we move from green (minimum erosion area VI) to red (maximum erosion area I), with lags in tax collection on the horizontal axis and tax system elasticity (price elasticity of tax revenues (e)) on the vertical axis. Accordingly, regions I and II generally express the status of the tax systems of underdeveloped or developing countries. In contrast, regions V and VI typically describe developed economies' tax systems. Regions III and IV are transition stages that may occur depending on total economic activity. Figure 3 presents the hypothetical effect of the relationships in Figure 2 on real tax revenues.

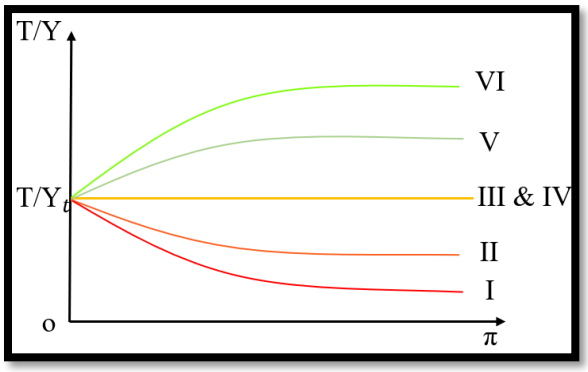

Figure 3. Relationship Between Inflation and Real Tax Revenue. *Reference*: Regenerated by the authors on the basis of the data given by Tanzi (1978: p.424).

Figure 3 shows variations in real tax revenues with inflation, elasticity of tax system, and collection lag. The area notations used in Figure 3 also represent the regions in the box diagram in Figure 2. In Figure 3, the basic multiplier in the form of $\frac{1}{(1+\pi_m)^{cl}}$ was used to calculate the inflation level's effect on tax revenues (Tanzi, 1977: p.157), where π_m is the monthly inflation level and *cl* is the tax collection lag. Tanzi (1978: p.426) calculated the erosion in the real value of tax revenues, assuming that the price elasticity of the tax system is unit, as shown in Equation 1.

$$T^{\pi} = \frac{(\frac{T}{Y})}{(1+\pi_m)^{cl}} = \frac{(\frac{T}{Y})}{(1+\pi)^{cl/12}} \tag{1}$$

The increase in the $[(1+\pi)^{cl/12}]$ value in the denominator in Equation 1, while $(\frac{T}{Y})$ constant, will cause the real value of tax revenues to decrease. Regarding these conditions, Tanzi (1978) argued that the inflationary financing process was unsustainable and that the inflation level should be reduced as an essential policy. However, Phelps (1973) and Dixit (1991) claimed that an optimal combination could be achieved by compensating for the negative effects of the inflationary financing process on tax revenues through an inflation tax or seigniorage. However, this proposition was also criticized by Tanzi (1992) for not being applicable in terms of tax technique and policymakers' preferences (Çavuşoğlu, 2005: p.38).

The elasticity of a tax system is influenced by several factors, including the overall level of economic activity, distribution of income, taxation methods, range of the tax base, efficiency of tax administration, and dynamics of international tax competition. Therefore, robust tax system elasticity, steeply progressive taxation, effective tax administration, and deterrent tax penalty

practices are essential to minimize the erosion explained by the Olivera-Tanzi effect. At this stage, it would be useful to identify tax policies that exacerbate the Olivera-Tanzi effect. The degree of progressiveness in the tax system, i.e. low differences in the height and width of the tax schedule) will have a reducing effect on the flexibility of the tax system. Another extremely important issue is the indexation or adjustment of tax brackets in an inflationary environment. In an inflationary environment, nominal wage increases can result in individuals moving into higher brackets of progressive tax schedules. This situation exemplifies fiscal drag, also referred to as bracket creep, in taxation terminology (Banerjee, 2024: p.3). Additionally, the existence of flat-rate taxes diminish flexibility in the tax system (Ünlükaplan & Canıkalp, 2016: p.327). Other factors contributing to this issue include prolonged collection delays, insufficient penalties for non-compliance with tax obligations, and an inefficient tax administration system.

3. Review of Empirical Literature

The empirical literature on the fiscal effects of inflation focuses on indicators such as tax revenues. However, there is no consensus on the nature of this relationship. The examination of causal connections can provide partial insight into this confusion. The research findings on Türkiye regarding fiscal indicators shows either bidirectional (Çetintaş, 2005; Günaydın, 2001; İpek & Akar, 2016) or unidirectional causal relationships (Bayrak & Kanca, 2013; Doğru, 2014). Hence, we can assume that the available evidence supports the concept that the variables of inflation and fiscal indicators interact in at least one direction.

It is possible to investigate the connection between public revenue and inflation by classifying the studies conducted in terms of the fiscal costs of the inflation phenomenon on a variable basis. Among these techniques, valuable studies offer quantitative analyses based on Tanzi's (1978) methodology. Gürbüzer (1997) conducted a quantitative study on the Olivera-Tanzi effect in Türkiye, finding that inflation significantly reduced the real value of tax revenues from 1988 to 1996. During this time, the erosion rate of total tax revenues as a percentage of GDP varied between 1.6% and 2.5%. Another quantitative research by Şen (2003) covering the period 1987-2000 calculated that the reduction rate in the real value of tax revenues (% of GDP) varied between 1.4% and 2.0%. Remarkably, in both studies, the tax erosion values defined as the Olivera-Tanzi effect exceed 10% of total tax revenues.

On the other hand, Çavuşoğlu (2005) used the Johansen Cointegration method and predicted the erosion of tax revenues and public expenditures due to inflation within 1987: Q1-2003: Q4 for Türkiye and reported that the loss of value in public expenditures due to inflation was more dominant than the decrease in tax revenues. In addition, Beşer (2007) used the Bootstrap-VAR method to estimate the relationship between tax revenues and inflation for Türkiye during the 1987-2005 period and obtained results that supported the validity of the Olivera-Tanzi effect. Additionally, Ünlükaplan and Canıkalp (2016) found bidirectional Granger causality between inflation and tax revenues in Türkiye from 2006: M1 to 2016: M3, interpreting this as evidence of the Olivera-Tanzi effect.

Using Johansen cointegration and the VAR technique, Durmaz and Kılınç Savrul (2017) found that a 1% increase in inflation would reduce tax revenues (% of GDP) by 0.12%, supporting the validity of the Olivera-Tanzi effect during the 2003: M1-2016: M10 period. Akduğan (2020) used the ARDL method to examine the link between indirect tax revenues and inflation for Türkiye during the 2004-2019 period and found evidence supporting the validity of the Olivera-Tanzi effect. Akgül (2022) utilized the Hatemi-J asymmetric causality technique to examine indirect tax and inflation in Türkiye during 2010: M1-2021: M6 and found empirical evidence supporting the Olivera-Tanzi effect. In addition, Demir (2023) used the Maki cointegration technique to examine the link between Türkiye's budget balance and inflation for Türkiye during the 1960-2022 period and found that a 1% change in inflation created a 0.14% increase in the budget deficit, indirectly supporting the validity of the Olivera-Tanzi effect.

Conversely, Abdioğlu and Terzi (2009) declared that the Olivera-Tanzi Effect was invalid for Türkiye during 1975-2005. According to researchers, a 1% increase in inflation resulted in a 0.11% reduction in budget deficits (% of GDP). Similarly, Biçen et al. (2015) reported that their analysis of Türkiye from 1999: Q1-2014: Q1 did not reveal any evidence for the validity of the Olivera-Tanzi effect, which is consistent with the results of Özmen and Koçak (2012). Additionally, using the SVAR technique, Yalçın (2020) investigated the period 2006: Q1-2019: Q4 for Türkiye and support that the Olivera-Tanzi effect is invalid.

On the other hand, Karadeniz (2022) used the Maki Cointegration method for the 1975-2019 period to determine a quadratic relationship between inflation and tax revenues for Türkiye, revealing that the Olivera-Tanzi Effect can be observed until annual inflation exceeds the 74%

threshold value. In addition, Erdoğan and Erdoğan (2018) utilized the VAR technique to analyze Türkiye from 2006: M1 to 2017: M2. They found that while no statistically significant relationship existed in the short run, inflation had a negative effect on tax revenues in the long run.

After providing an overview of the empirical literature on Türkiye that has predominantly relied on time series techniques, reviewing the findings of studies based on panel data analysis and international samples would be beneficial to gain a broader understanding of the possible associations between inflation and fiscal variables. Özmen (2016) examined the determinants of tax revenues for the BRIC-T sample during the 1996-2013 period and found that a 1% increase in inflation would lead to a 0.09% decrease in tax revenues. Additionally, Çalcalı and Altıner (2019) found that inflation negatively affects tax revenues in Germany, Greece, Hungary, Mexico, Switzerland, and Türkiye based on their investigation of tax revenue determinants in 16 OECD countries from 1991 to 2015. Afonso and Jalles (2019) demonstrated that a 1% decrease in inflation during the historical period of 1870-1914 for 17 selected countries resulted in a 0.02% increase in real tax revenues, indicating that the Olivera-Tanzi effect can also work in terms of deflation. Tülümce et al. (2021) found that a 1% increase in inflation during 1995-2020 for 16 countries in the Eurozone with panel cointegration techniques resulted in a 0.19% decrease in budget deficits, leading to the argument that the Olivera-Tanzi Effect is valid.

Table 1 summarizes the empirical literature, highlighting how the timeframe was analyzed, and the chosen methodologies significantly impact the findings. This indicates that studies employing various techniques to investigate the same period may yield different results.

Table 1

Empirical Literature Review

Author (Year)	**Sample**	**Period**	**Method**	**Olivera-Tanzi Effect**
Gürbüzer (1997)	Türkiye	1988–1996	Quantitative analysis	✓
Şen (2003)	Türkiye	1987–2000	Quantitative analysis	✓
Çavuşoglu (2005)	Türkiye	1987: Q1–2003: Q4	Johansen Cointegration	✓
Beşer (2007)	Türkiye	1987–2005	Bootstrap VAR	✓
Abdioğlu & Terzi (2009)	Türkiye	1987–2005	ARDL	×
Özmen & Koçak (2012)	Türkiye	1994–2011	ARDL	×

Biçen et al. (2015)	Türkiye	1991: Q1–2014: Q1	ARDL	×
Ünlükaplan & Canıkalp (2016)	Türkiye	2006: M1–2016: M3	Granger Causality	✓
Özmen (2016)	Türkiye	1996–2013	Panel Cointegration	✓
Durmaz & Kılınç Savrul (2017)	Türkiye	2003: M1–2016: M10	Johansen Cointegration VAR	✓
Erdoğan & Erdoğan (2018)	Türkiye	2006:M1–2017:M2	VAR	✓
Çalcalı & Altıner (2019)	16 OECD	1991–2015	Panel Cointegration	✓
Afonso & Jalles (2019)	17 Country	1870–1914	GMM	✓
Yalçın (2020)	Türkiye	2006: Q1–2019: Q4	SVAR	×
Akduğan (2020)	Türkiye	2004–2019	ARDL	✓
Tülümce et al. (2021)	16 Euro Area	1995–2020	Panel Cointegration	✓
Karadeniz (2022)	Türkiye	1975–2019	Maki Cointegration	✓
Akgül (2022)	Türkiye	2010: M1–2021: M6	Hatemi-J Asymmetric Causality	✓
Demir (2023)	Türkiye	1960–2022	Maki Cointegration	✓

Note. (✓) represents that the validity of the relevant hypothesis is supported, (×) represents that it is not supported.

Furthermore, our findings regarding some exceptional cases in the empirical literature can be summarized as follows: (I) Several studies provide evidence of inflation's erosive effect on tax revenues, supporting the validity of the Olivera-Tanzi effect in Türkiye. (II) Many empirical studies assess the Olivera-Tanzi effect but often focus on legal delays and overlook delinquency lags because of limited data availability. (III) In a context like Türkiye, characterized by frequent structural changes, there are few studies that apply methods suitable for addressing these unique dataset features. (IV) Finally, even when examining the same time period, the findings on the fiscal effects of inflation can vary significantly depending on the empirical techniques used in different studies.

4. Data, Model, and Methodology

4.1. Data and Model

This study used a 100-year historical dataset of tax revenues compiled by the Republic of Türkiye Ministry of Treasury and Finance (2024). The dataset comprises total tax revenues (% of real GDP) and the GDP deflator (%of annual change).

Table 2

Description of Data

Variable	Symbol	Unit	Source
Total Tax Revenue	*Tax*	% of real GDP	T.R. Ministry of Treasury and Finance (2024)
GDP Deflator	*Def*	% Annual Change	T.R. Presidency of Strategy and Budget (2024)

This preference stems from the fact that price level data other than the GDP deflator exist for the early periods of the Türkiye and that the GDP deflator is more inclusive than other price metrics. We derive the GDP deflator from the T.R. Presidency of Strategy and Budget Economic and Social Indicators (2024).

Table 3 presents the descriptive statistics of the variables. The average total tax revenue (*Tax*) (% of real GDP) from 1924 to 2023 was 10.05%. The maximum value of 19.8% of *taxes* corresponds to the period after 2004, and the minimum value of 4.6% corresponds to 1926. The average value of the inflation indicator (*Def*) between 1924 and 2023 was 23.5%, demonstrating that inflation is a chronic problem for Türkiye. The maximum value was 106.4% in 1994. The minimum value of the series is -25.4%, corresponding to 1930, which was the beginning of both World War I and the Great Depression.

$$Tax_t = \beta_0 + \beta_1 Def_t + \epsilon_t \quad (2)$$

Equation 2 outlines the model to be estimated, focusing on the various factors influencing total tax revenues. It is important to note that incorporating these factors into a model that analyzes the impact of inflation on tax revenues could alter both the direction and strength of their relationship. Therefore, it is appropriate to directly examine the relationship between inflation and tax revenues without additional variables.

Table 3

Descriptive Statistics

Variables	Average	Max	Min	Std. Dev.
Tax	10.05	19.806	4.645	4.495

Def	23.513	106.450	-25.400	29.144

Based on the theoretical proposition that long-run high inflation levels will lead to erosion in tax revenues, the primary expectation for the β_1 coefficient in Equation 2 is that it is statistically significant and has a negative sign.

4.2. Empirical Methodology

This study conducts an empirical analysis comprising three stages. To provide a clear overview, Figure 4 illustrates the empirical methodology employed in the study. Accordingly, the stationarity structure of the series was examined using the Fourier KPSS stationary test. Then, the cointegration relationship between the series is investigated using Tsong et al. (2016) Fourier–Shin cointegration methodology.

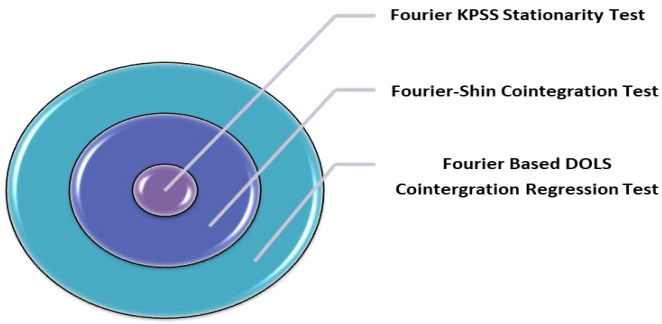

Figure 4. Empirical Methodology

After establishing the cointegration relationship among the series, we proceed to perform diagnostic tests and estimate the long-run coefficients. In the final phase, following the approach of Stock and Watson (1993), we employ Fourier-based DOLS to derive the long-run coefficients.

4.2.1. Fourier KPSS Stationary Test

The initial phase of the time series analysis involves assessing the stationarity characteristics of the series. For this purpose, we will utilized Becker et al. (2006) Fourier KPSS stationarity test. It is possible to discuss many internal and external shocks, such as economic crises, political instabilities, and natural disasters in Türkiye. Hence, the use of Fourier terms in testing stationarity provides an advantageous opportunity to forecast smooth structural breaks in the series without prior knowledge of them or external addition to the model, thereby preventing the model from weakening (Aydın & Bozatlı, 2023: p.41289). Equation 3 presents the data generation process within the scope of Becker et al. (2006) Fourier KPSS test.

$$y_t = \alpha_0 + \beta_t + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + r_t + \varepsilon_t \quad (3)$$

In Equation 3 r_t can be defined as follows:

$$r_t = r_{t-1} + u_t \quad (4)$$

In Equation 3 ε_t, are stationary errors, and in Equation 4 u_t, are independent and identically distributed (*i.i.d.*) with variance σ_u^2. Under the null hypothesis σ_u^2=0, the defined processes in Equations 3 and 4 are stationary. In contrast, $(\sin\left(\frac{2\pi kt}{T}\right) + \cos\left(\frac{2\pi kt}{T}\right))$ is chosen because a Fourier expression can approximate absolutely integrable functions to any desired degree of accuracy (Chang, 2011; p.2209). Equations 3 γ_1 and γ_2 measure the amplitude and displacement of the frequency component, respectively, and *k* represents the frequency selected for the approximation. A desirable feature of Equation 3 is that the standard linear specification emerges as a particular case by setting $\gamma_1 = \gamma_2 = 0$. If a structural break occurs, at least one frequency component must be present. Becker et al. (2004) leveraged this characteristic of Equation 3 to create a test with greater power to detect breaks of the unknown form than the standard Bai and Perron (1998) test. Since the data generating process in Equation 3 encompasses the one used for the standard KPSS test, Becker et al. (2006) stationary test with a Fourier function requires only a minor adjustment of the KPSS statistic (Chang, 2011; p.2210). The first step involves obtaining residuals from Equations 5 and 6:

$$y_t = a_0 + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + v_t \quad (5)$$

$$y_t = a_0 + \beta_t + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + v_t \quad (6)$$

Equation 5 examines the null hypothesis of level stationarity, whereas Equation 6 examines the null hypothesis of trend stationarity. The test statistic for testing the null hypothesis of stationarity in the series against the nonstationary alternative hypothesis is calculated as follows:

$$\tau_{KPSS}(k) = \frac{1}{T^2} \frac{\sum_{t=1}^{T} \tilde{S}_t(k)^2}{\tilde{\sigma}^2} \quad (7)$$

The term is defined as $\tilde{S}_t(k) = \sum_{j=1}^{t} \tilde{v}_j$ in Equation 7, $\tilde{v}_j$ indicates the residuals obtained from Equations 5 and 6. In line with the KPSS framework and using a Phillips-Perron type approach, Becker et al. (2006) recommended obtaining a nonparametric estimate of σ^2 by selecting a truncation lag parameter l and a set of weights: $w_j, j = 1, 2, \ldots, l$.

$$\sigma^2 = \tilde{\alpha}_0 + 2\sum_{j=1}^{l} w_j \tilde{\alpha}_j \tag{8}$$

In Equation 8 $\tilde{\alpha}_j$ is represents j_{th} sample autocovariance of the residuals $\tilde{v}_t$ from Equations 5 and 6 respectively. Becker et al. (2006) suggested that the frequencies in Equations 5 and 6 should be obtained by minimizing the sum of the squared residuals.

4.2.2. Fourier-Shin Cointegration Test

Shin (1994) assessed the cointegration relationship between variables using KPSS stationarity test and developed a long-run relationship test. Arai and Kurozumi (2007) later designed a test that allows for internal structural breaks, but evaluations of long-run relationships must consider both sudden and gradual structural breaks between series. Tsong et al. (2016) proposed a new test that incorporates Fourier functions into Shin (1994) cointegration test to address this concern. The fundamental model of this test is presented in Equation 9.

$$y_t = d_t + x_t'\beta + n_t, t = 1, 2, \ldots, T, \tag{9}$$

In Equation 9 $\eta_t = \gamma_t + \upsilon_{1t}$, $\gamma_t = \gamma_{t-1} + u_t$ with γ_0 =0 and $x_t = x_{t-1} + \upsilon_{2t}$. Here u_t is an independent and identically distributed process (*i.i.d.*) with zero mean and variance σ_u^2=0. For this reason, γ_t is a random walk with mean zero (Tsong et al., 2016: p.1087). In addition, in Equation 9 d_t represents the deterministic terms defined as follows:

$$d_t = \sum_{i=0}^{m} \delta_i t^i + f_t \ with\, m = 0 \ or \ m = 1 \tag{10}$$

In Equation 11, f_t shown as follows:

$$f_t = \alpha_k \sin\left(\frac{2\pi kt}{T}\right) + \beta_k \cos\left(\frac{2\pi kt}{T}\right) \tag{11}$$

The scalar v_{1t} and p-vector v_{2t} are stationary, and hence, y_t and x_t are all I(I) processes. And, if σ_u^2=0, $\eta_t = v_{1t}$ is a stationary process, implying that y_t and x_t are cointegrated. Thus, the null hypothesis of cointegration can be defined as follows:

$$H_o: \sigma_u^2 = 0 \text{ versus } H_1: \sigma_u^2 > 0 \tag{12}$$

In Equation 12, the null hypothesis, which asserts the presence of cointegration, is tested against the alternative hypothesis, which asserts the absence of cointegration. The test statistic used to evaluate these hypotheses is defined in Equation 13:

$$CI_F^m = T^{-2}\hat{\omega}_1^{-2}\sum_{t=1}^{T} S_t^2 \, , S_t = \sum_{t=1}^{T} \hat{v}_{1t} \tag{13}$$

In Equation 13, $\hat{\omega}_1$, $\hat{v}_{1t}$ are the partial sum of the error terms and the long-run variance estimator, respectively. At this stage, the test statistics calculated following the methodology developed by Tsong et al. (2016) are compared with the critical values. If the calculated test statistics are smaller than the critical value, the null hypothesis implying the existence of cointegration cannot be rejected. Furthermore, Tsong et al. (2016) stated that the significance of Fourier terms should be assessed using the F-test.

5. Empirical Results [1]

The first step in defining the empirical results is to report on stationarity structures of the series obtained from Becker et al. (2006) Fourier KPSS test results. According to the Fourier KPSS results, *Tax* and *Def* series are stationary at I(1). For the Fourier KPSS test to be valid, the F-constraint test applied to the Fourier terms must also be statistically significant. When Table 4 is examined, the F-constraint tests are considered significant. Moreover, to compare the results obtained from the Fourier KPSS test with the coefficients, the critical values for the relevant

[1] For Fourier KPSS test estimation, Gauss 10, Fourier Shin cointegration, F test statistics of Fourier-based analysis and Fourier based DOLS cointegration estimator were estimated using EViews 12 package programs.

frequencies and the F-constraint test critical values presented in Becker et al. (2006) are also presented in Table 4.

Table 4

Fourier KPSS Stationarity Test Results

Fourier KPSS (Break in Level & Trend)					
Variables	**I (0)**	**I (1)**	**Min SSR**	**k**	$F_t(\hat{k}) - trend$
Tax	0.234	0.027***	63.132	3	4.460*
Def	0.365	0.024***	31197.41	2	5.154**
$\tau_\tau(k)$ *−trend Critical Values*					$F_\tau(\hat{k})$ *−trend Critical Values*
	k (2)	k (3)			
%1	0.202	0.210			6.873
%5	0.132	0.142			4.972
%10	0.103	0.114			4.162

Note. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. (k) denotes the frequency.

Table 5 presents the results of Fourier Shin cointegration analysis. Tsong et al. (2016) stated that the null hypothesis of Fourier Shin cointegration test is that cointegration exists between the series. According to the test statistics ($CI^m{}_f$) presented in Table 5, the hypothesis that the series are cointegrated cannot be rejected at any level. Furthermore, according to the F-test, the Fourier terms were significant at the 1% level.

Table 5

Fourier Shin Cointegration Results

	$CI^m{}_f$	(k)	Min SSR
Tax= f(Def)	0.039	1	159.51
Table critical values	%1	%5	%10
	0.063	0.048	0.042
	$F^m(k^*)$		
***Tax= f(Def)* F-test**	29.974***		
Table Critical Values	%1	%5	%10
	5.860	4.019	3.306

Note. *** denotes significance at the 1% level.

Table 5 provides evidence of a cointegration relationship between the series. The coefficients of the series are estimated in the next stage using Fourier-based DOLS cointegration regression. In the DOLS cointegration tests, lags were automatically determined according to the Akaike information criterion. Tsong et al. (2016: p.1091) stated that if the strict exogeneity assumption is violated, the cointegration vector will not be effective, the asymptotic distribution of the $CI^m{}_f$ test will depend on unknown nuisance parameters, and the use of a DOLS estimator is appropriate for this problem.

Table 6

Long Run Results

Fourier Based DOLS		
Variable	**Coefficient**	**t-statistic**
Def	-0.060***	(-3.246)
Sin	1.285***	(2.708)
Cos	-1.716*	(-1.966)
C	5.197***	(4.320)
Trend	0.129***	(6.439)
R^2	0.91	
Adj. R^2	0.90	
Jarque-Bera (prob)	5.635(0.060)	

Note. *** and * indicate statistical significance at the 1% and 10% levels. sin and cos represent sine and cosine as trigonometric terms.

Fourier-based DOLS regression results show that inflation has a negative impact on tax revenues. Moreover, trend models are preferred in predictions for all processes that observe trends in inflation and tax revenues. The trend coefficient is statistically significant. In addition, the coefficients related to the Fourier terms were found to be statistically significant and in line with expectations. Considering that the average inflation (% of annual change) level in the 1924-2023 period was 23.6%, tax revenues for Türkiye are being eroded by inflation, which is significantly consistent with theoretical expectations. Subsequently, our findings point to results akin to the Olivera-Tanzi hypothesis that inflation may lead to an erosion of tax revenues for Türkiye. This finding, indicated by both theoretical expectations and descriptive data, also reconfirms the result indicated by many empirical investigations using a historical data set and Fourier novel time series analysis. In other words, the findings of previous studies indicating the erosionist effects of the Olivera-Tanzi effect (Akduğan, 2020; Beşer, 2007; Demir, 2023; Gürbüzer, 1997; Özmen, 2016; Şen, 2003) on specific periods are consistent with the results obtained in this study.

6. Conclusion and Discussion

It is a matter of consensus that inflation is a continuous increase in the general level of prices, and high inflation negatively affects the economic system in numerous ways. However, different views on the effects of inflation on fiscal policy tools are possible. Therefore, research on the interaction between inflation and the fiscal system continues to expand. Therefore, within the scope of this study, the connection between tax revenues and inflation during the first century of the Republic of Türkiye is examined through novel empirical techniques. In this context, predictions using a combination of historical datasets and Fourier-based empirical techniques reveal that total tax revenues and inflation variables have a cointegration relationship. However, the results indicate that inflation erodes total tax revenues. Therefore, our study provides similar evidence for the validity of the Olivera-Tanzi effect, consistent with many previous empirical studies for Türkiye (Akduğan, 2020; Akgül, 2022; Demir, 2023; Karadeniz, 2022; Ünlükaplan & Canıkalp, 2016).

However, at present, it is impossible to directly state that the modern Turkish tax system does not consider inflation risk. There are many inflation protection institutions in the Turkish Tax System. As explained in the previous sections, a determinant of the erosional effect of inflation is

the lags in tax collection periods stipulated by law. Within the scope of the Turkish tax system, wages and interest income are taxed by deduction (withholding) from the income tax at source. Tax receivables are taxed quarterly through provisional tax returns. Moreover, withholding agents report the tax bases deducted from wage earners to the tax office monthly through withholding tax declarations (Income Tax Code, art. 84). In addition, if the tax liability is not accrued within the legal periods (Tax Procedure Code, art.112), lag interest; If the tax debt is not paid within the legal periods (Law for Collection of Public Revenue, art. 51), late payment charge applications come into force.

These structures are implemented at rates equal to or higher than the inflation rate to prevent tax debt from being used as a loan. However, these measurements remain below the inflation rate during periods such as 2018. Again, to provide an inflation-resilient tax structure, a revaluation rate is established to protect the rights of both the taxpayer and the tax administration. Despite the existence of these tax institutions that protect against inflation, such as provisional tax, withholding at source, revaluation rate, lag interest, and late payment charges, the validity of the Olivera-Tanzi effect can be explained in many respects. (1) Given that our 100-year average inflation rate is 23% and exceeds 100% in some periods, high inflation levels create an erosion for every tax type whose average legal payment period exceeds one month. (2) Inflation protection institutions are generally included in the scope of income taxes, but a significant part of tax revenues in Türkiye are obtained from indirect taxes. Moreover, inflation in Türkiye may also erode the revenue of indirect taxes over time. (3) Although it has a limited portion in total tax revenues, the average collection period for wealth taxes is very long and is heavily exposed to erosion. (4) This context also highlights the prevalence of the informal economy in Türkiye and the theoretical propositions suggesting that tax avoidance has become more widespread during periods of high inflation.

To minimize the erosion in tax revenues and make the Turkish tax system an inflation-resilient structure, focusing primarily on tax collection periods may be helpful. The infrastructure provided by advanced financial systems will enable the reduction of declaration-based transactions. By doing so, the lag in tax applications based on accrual and collection of expenditure-based indirect taxes can be reduced. In addition, time-based regulations in wealth taxes, which have incredibly long tax collection periods, can decrease the erosion of tax receivables due to inflation. Increasing the effectiveness of tax administration audits for taxes that are within the scope of

income tax and assessed based on declarations, as well as increasing alternative time costs due to delinquency lags by aggravating tax penalties and sanctions, is also necessary.

Like any empirical study, this research has significant limitations that must be acknowledged. One of the main challenges is the lack of comprehensive datasets on various tax revenues and price indices for past periods in Türkiye. In addition, our analysis spanning a century limits our ability to distinguish the time-varying effects of inflation. Future studies can use time-varying models to improve the analysis. Moreover, the model estimated in this paper is relatively simple, suggesting room for improvement. Including control variables for tax revenues can increase the model's explanatory power. In this context, it would be helpful to investigate how institutional factors such as central bank independence, political stability, and financial development can reduce the negative effects of inflation on tax revenues. Addressing these limitations and investigating the potential asymmetric aspects of the relationship can contribute significantly to the literature in this area.

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

Seref Can Serin contributed 60% and Murat Demir contributed 40% to this study.

Declaration of Researcher’s Conflict of Interest

There are no potential conflicts of interest in this study.

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