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DOES INFLATION INSTABILITY CAUSE ENVIRONMENTAL POLLUTION IN TÜRKİYE? EVIDENCE FROM THE FOURIER-WAVELET CAUSALITY TEST

Türkiye'de Enflasyon İstikrarsızlığı Çevre Kirliliğine Neden Olur mu? Fourier-Wavelet Nedensellik Testinden Kanıtlar

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Keywords:
Inflation Instability, Environmental Quality, Fourier TY Causality Analysis, Turkiye.

JEL Codes:
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Abstract

The Turkish economy has faced many macroeconomic problems in terms of GDP stability, inflation stability, growth rate, and exchange rate. This situation has become even more noticeable in recent times, especially with the negative effects of the Covid 19 epidemic and the Russia-Ukraine war. Thus, inflation in Turkiye has increased and has a more unstable outlook. However, environmental problems have also increased. In light of this information, the aim of the study is to examine the causality relationship between inflation instability and environmental pollution for the period 1990-2021 by considering growth, energy consumption, and financial development as control variables in Turkiye. For this purpose, firstly, the series was subjected to wavelet transform. Afterwards, the transformed series were analyzed with the Fourier TY and Fractional Fourier TY causality tests as short, medium, and long term. Findings from the Fourier causality test show that inflation instability promotes environmental pollution in the short, medium, and long term. According to the Fractional Fourier causality test, which I used to test whether the shocks are permanent, there is persistence from inflation instability to environmental pollution only in the medium term. This study is the first to examine the subject in the case of Türkiye.

Anahtar Kelimeler:
Enflasyon Istikrarsızlığı, Çevresel Kalite, Fourier TY Nedensellik Analizi, Türkiye.

JEL Kodları:
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Öz

Türkiye ekonomisi GSYH'nın istikrarı, enflasyon istikrarı, büyüme oranı ve döviz kuru konusunda birçok makroekonomik sorunla karşı karşıya kalmıştır. Bu durum son dönemlerde özellikle Covid 19 salgını ve Rusya- Ukrayna savaşı gibi olumsuzluklarla daha da hissedilir hale gelmiştir. Böylelikle Türkiye'de enflasyon artmış ve daha istikrarsız bir görünüme sahip olmuştur. Bununla birlikte çevresel sorunları da giderek artmıştır. Bu bilgiler ışığında çalışmanın amacı Türkiye'de büyüme, enerji tüketimi ve finansal gelişmeyi kontrol değişkeni olarak dikkate alarak enflasyon istikrarsızlığı bağlamında CO2 emisyonları arasındaki nedensellik ilişkisini 1990-2021 dönemi için incelemektedir. Bu amaç için öncelikle seriler dalgacık dönüşümüne tabi tutulmuştur. Sonrasında dönüştürülmüş seriler Fourier TY ve Fractional Fourier TY nedensellik testleri ile kısa, orta ve uzun vadeli olarak analiz edilmiştir. Fourier nedensellik testinden elde edilen bulgular, enflasyon istikrarsızlığının kısa, orta ve uzun vadede çevre kirliliğini teşvik ettiğini göstermektedir. Şokların kalıcı olup olmadığını test etmek için kullanılan Kesirli Fourier nedensellik testine göre ise sadece orta vadede, enflasyon istikrarsızlığından çevre kirliliğine kalıcılık söz konusudur. Bu çalışma Türkiye örneğinde konuyu ele alan ilk çalışmadır.

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1. Introduction

Global warming is a problem that both developing and developed countries are dealing with today. One of the most serious issues confronting the world in recent decades has been the rapid increase in greenhouse gas emissions, such as CO_2 emissions (Ahmad et al., 2021). Because of their efforts to achieve economic growth while maintaining environmental quality, developing economies, in particular, face two major challenges. In terms of economic growth, one of the most significant challenges that poses a fundamental problem is environmental degradation in developing countries (Mughal et al., 2021; Ullah et al., 2021). Similar issues exist in Turkiye, which is a developing country. For example, CO_2 emissions per capita increased from 2.79 tons in 1990 to 5.26 tons in 2021 (Our World in Data, 2022).

Furthermore, the Turkish economy faced numerous macroeconomic issues during the relevant period, including GDP stability, inflation stability, growth rate, and exchange rate. When we examine the Turkish economy's evolution process, we can see that there have been many periods of contraction and recession since the 1970s. In short, the country has experienced significant macroeconomic insecurity, high and volatile inflation rates, significant production slowdowns, and poor economic growth performance (Doruk and Yavuz, 2018). This situation has become even more pronounced in recent years, owing to the negative consequences of the Covid 19 epidemic and the Russia-Ukraine war. Turkiye's inflation rate rose as a result of this situation. Thus, according to TUIK October 2022 data, Turkiye has one of the highest inflation rates in the world, at 85.51 percent. All of these macroeconomic disturbances have an impact on environmental pollution (Khan, 2019; Ahmad et al., 2021; Tahir et al., 2022). Because of the increased environmental degradation, many scientists are concerned in determining the fundamental determinants of pollution emissions at the macro and micro levels. Numerous studies have extensively discussed the determinants of pollution emissions (such as human development, trade, energy use, corruption, governance, urbanization, FDI, industrialization, and transportation) in the past literature (Ahmad et al., 2021).

Generally, in these studies, CO2 emissions have been used as a determinant of environmental pollution, as it is a major component of greenhouse gases (Khan et al., 2022). Undoubtedly, these variables play a significant role in environmental deterioration. However, negativities such as the Covid 19 epidemic and the Russia-Ukraine war have increased the uncertainties in the economic systems recently.

Uncertainty or instability refers to features of the economy that may have an impact on the macroeconomic conditions. In general, macroeconomic instability or uncertainty is characterized by uncertainty in inflation, which stifles economic growth by lowering total factor productivity and investments (Fischer 1993; Khan, 2019; Tahir et al., 2022).

As a result, the literature contends that inflation stability (instability) has a dual (positive and negative) effect on reducing pollutants. The first of these asserts that inflation stability has both positive and negative environmental consequences. This viewpoint holds that inflation stability can boost growth and reduce CO2 emissions by allocating more economic resources to environmentally friendly initiatives. The stability in the macroeconomy may restrict the use of nonrenewable energy by companies that generate more waste (Ullah et al., 2020; Tahir et al., 2022).

Furthermore, by providing incentives against further global warming, a macroeconomic environment may act an important role in deputy the supply side of green substructure. Although inflation stability is beneficial to the environment, it also has some negative consequences. As a result, macroeconomic resilience makes it easier for consumers to purchase carbon-emitting automobiles, appliances, air conditioners, and household durable goods and services (Khan, 2019). Furthermore, by allowing low temperatures to harm finance and increase production security, an economic system's financial sector can contribute to energy consumption and CO_2 emissions (Baloch et al., 2018).

According to another piece of literature, inflation instability has both negative and positive effects on the environment. According to this viewpoint, inflation instability is a resource of pollution because fiscal and monetary issues incline to be key issues for these countries. As a result, increased inflationary uncertainty may postpone long-term investment projects, including those aimed at transitioning from non-renewable to renewable energy generation. Because investments are inherently exact, investors in an uncertain environment may prefer a wait-and-see policy (Khan, 2019).

Furthermore, inflation instability may lead to a reduction in R&D funding required for the market entry of energy-efficient devices, resulting in environmental degradation. Although macroeconomic insecurity has a negative effect on the environment, it may also have a positive effect in certain circumstances. As a result, inflation uncertainty restricts firm market entry and leads to lower production with lower carbon emissions. As a result, it contributes to environmental quality (Rousseau and Wachtel, 2002).

Inflationary instability reduces consumers' purchasing power. As a result, the economy's environmental quality improves (Ahmad et al., 2021). All of these discussions show that inflation instability (instability) may have a positive and negative effect on economic activity and environmental pollution via direct and indirect channels (Khan, 2019; Ullah et al., 2020).

While inflation instability has (positive or negative) environmental consequences, it can also cause inflation instability as a result of climate change and environmental degradation. Therefore, a loss in the domestic or global product supply chain, as well as a variety of productivity shocks brought on by climate change events like floods, storms, droughts, and rise levels of sea, may result in some inflationary stress. Such climate change activities may cause significant monetary losses, reduce of wealth, and slow of economic growth. Therefore, inflationary stress decreases countries' economic prosperity, depletes income, and may impede growth and development (Khan et al., 2022). A high inflation rate is therefore detrimental to the economy. High inflation is a financial issue that must be resolved in every nation (Deka et al., 2022).

Numerous studies have been conducted around the world to investigate various aspects of carbon emissions. The majority of empirical studies look at the various determinants of carbon emissions (variables like urbanization, trade, FDI, transportation, industrialization, energy consumption, corruption, human development, and governance), with the links between energy-GDP and GDP-environment being extensively discussed. These indicators are well known to act an significant role in the economy and are required for inflation stability (Tahir et al., 2022).

These indicators are also important in determining environmental quality. As a result, inflation stability (instability) has a serious effect on environmental pollution emissions (Ullah et al., 2020). Despite this information, there is considerable disagreement about whether inflation instability benefits or harms environmental degradation (Tahir et al., 2022).

As previously stated, the study of CO_2 emissions and their determinants has been a major topic of discussion among researchers in recent years. However, inflation instability, which is an important determinant of CO_2 emissions, has received insufficient attention in the literature. For example, there are studies for Pakistan (Khan 2019; Ullah et al., 2020) and for the United States (USA) (Tahir et al., 2022). However, previous studies in Turkiye do not emphasize how inflation instability affects environmental quality in Turkiye. In this way, the aim of this study is to examine the causality relationship between inflation instability and carbon emissions in Turkiye from 1990 to 2021. For this purpose, wavelet-based Fourier TY and Fractional Fourier TY causality tests were used. This approach applies a regression-based causality test that considers the Fourier and wavelet transforms to explain various characteristics of the series. For instance, smooth changes in causal links are taken into account by Fourier functions. Wavelet transforms make it possible to examine causal relationships over the short, medium, and long terms. It also enables consideration of the frequency domain characteristics of series.

The chosen economy provides a potential testing ground for this relationship. Because Turkiye experienced high inflation volatility and environmental degradation during the chosen sampling period. While the relationship between environmental pollution and infilation uncertainty can be confirmed through a variety of other channels, to the best of our knowledge, the current literature has not directly tested this link. The study's contribution is to fill this gap in the empirical literature on the Turkish economy.

The rest of the work is listed below. A literature review is a summary of the literature. Data and method describes a detailed data description as well as the econometric method methodologically. The Findings section summarizes the empirical findings, while the Conclusions section sum ups the findings and offer specific policy implications.

2. Literature Review

The connection between inflation instability and growth has been extensively addressed in both theoretical and empirical literature. Various viewpoints on the matter are developed through theoretical studies, with the predominate stance suggesting an inverse link between the two variables. To that end, Lucas (1973) hypothesizes that price instability causes production elements to become less efficient, resulting in shocks in macroeconomic variables and, as a result, an increase in environmental quality. Friedman (1977) presents the basic idea that the resource allocation mechanism is based on adverse disruption due to unanticipated changes in inflation when investigating the direct impact of inflation uncertainty on growth. As a result of uncertainty about inflation, the growth rate is slowing down. According to Bernanke (1983), high volatility may lead to lower investment if investment plans are inherently irreversible. However, he claims that if agents have a precautionary motive to save, higher uncertainty can lead to increased savings and investment. Similar inconsistencies can be found in empirical literature findings. Empirical studies were examined using time series analysis with a single country as a sample or panel data analysis with more than one country included in the sample. These studies, which are classified as both time series and panel studies, are also divided into developing and developed countries and are presented below.

Khan's (2019) study for Pakistan, which is in the group of developing countries where only one country is examined, discovered a relationship between CO_2 emissions, macroeconomic instability, financial development, GDP, and GDP^2 from 1971 to 2016. The relationship is being investigated. The findings suggest that the variables studied have a long-run relationship, and that macroeconomic instability increases pollution emissions. Furthermore, financial development factors improve environmental degradation. Based on these findings, the study recommends that macroeconomic stability play a significant role in meeting pollution reduction targets. In another study for Pakistan, Ullah et al. (2020) use an Autoregressive Distributed Lag (ARDL) methodological approach to investigate the empirical relationship between inflation instability, economic growth volatility, and environmental pollution from 1975 to 2018. According to research, both positive and negative inflationary shocks have various impacts on environmental pollution. In long-term, CO_2 and N_2O emissions are positively impacted by negative inflation instability shocks, whereas positive inflation instability shocks have negligible effects. Varied GDP growth volatility effects have different effects on CO_2 and N_2O emissions. Additionally, the short-term consequences of positive and negative shocks to GDP growth and inflation volatility and pollutant emissions vary. Again for Pakistan, the asymmetrical effects of monetary and fiscal policies on environmental degradation made by Ullah et al. (2021) were examined for the period 1985-2019 with a Nonlinear Autoregressive Distributed Lag (NARDL) approach. The findings indicate that both negative and positive shocks to monetary policies increase CO_2 emissions in the short run, while positive shocks decrease CO_2 emissions in the long run. A short-term increase in carbon emissions and a long-term decrease in environmental pollution are the result of a positive and negative shock to fiscal policies. As a result, while mitigating environmental pollution, policymakers should take into account the employment of fiscal and monetary policy tools. The study conducted by Setyadharma et al. (2021) examined the empirical relationship between inflation and air pollution in Indonesia throughout the time frame spanning from 1981 to 2017. The findings of the research indicate that there exists a negative correlation between high levels of inflation and air pollution, both in the short and long run. The study's findings suggest that governments should prioritize inflation stability as a means to effectively achieve air pollution reduction targets. Rakshit and Neog (2021) conducted an empirical analysis to examine the influence of macroeconomic uncertainty on environmental deterioration in India from 1971 to 2016. The results indicate that there is a significant correlation between macroeconomic uncertainty and carbon emissions. Additionally, it is shown that high levels of inflation volatility, which serve as a measure of macroeconomic uncertainty, negatively affect the environmental quality in India. It is imperative for policymakers and government stakeholders to take into account the ecological consequences of macroeconomic policies during the formulation of strategies aimed at fostering economic expansion and ensuring stability. For Brazil, which is in the group of developing countries, Deka et al. (2022), the ARDL model used to analyze the relationship between the consumption of renewable energy, the exchange rate, and the inflation rate. The utilization of renewable energy has a detrimental short-term effect on the currency rate. Additionally, the increased usage of renewable energy results in an rise in the exchange rate. The exchange rate and renewable energy have a reciprocal relationship over the long term. This demonstrates how both the use of renewable energy and the exchange rate are impacted by them. Renewable energy sources and exchange rates are impacted by inflation. Long-term outcomes have a negative effect on the exchange rate of using renewable energy, while inflation and the exchange rate have a beneficial impact.

In a study conducted for the USA, which is in the group of developed countries, Tahir et al. (2022) examined the symmetrical and asymmetrical effects of macroeconomic volatility on environmental pollution for the period 1970-2019 with the help of ARDL and NARDL. The findings reveal that inflation uncertainty and volatility of GDP have both short- and long-term impact on pollution emissions. For Germany, which is in the group of developed countries, By using inflation dynamics, as a control variable, Khan et al. (2022) investigate the impact of alternative energy sources on environmental pollution in Germany. According to the findings, alternative energies, government spending, and inflation all have a negative relationship with environmental quality, whereas economic growth has a positive relationship with it. Thus, policymakers; it encourages the removal of subsidies for domestic coal production, the promotion of cost-effective ecological policy designs, the pricing of environmental resources, the intensification of the green budget, the separation of economic growth from harmful emissions, and the stabilization of inflation through a sustainable monetary policy.

In studies examining more than one country, Fountas and Karanasos (2007) investigate the causal effects of nominal and real macroeconomic uncertainty on growth and inflation, as well as the effect of inflation on inflation uncertainty for G7 countries from 1957 to 2000. A number of conclusions have been reached. The first is that inflation predicts inflation uncertainty positively. Second, uncertainty about output growth predicts output growth rate positively. Third, the effect of inflation uncertainty on economic growth and inflation is mixed. As a result, uncertainty about inflation rates isn't always bad for the economy. This situation suggests that inflation uncertainty has an indirect impact on environmental quality in developed economies. Alola et al. (2019) used the ARDL approach to investigate the effect of a high inflation regime on the environmental quality of 16 Mediterranean countries with low carbon emission coastlines from 1995 to 2014. The researchers discovered that using renewable energy reduces CO_2 emissions, increasing food production (a move toward food security) rises environmental risk, and a high inflation regime causes low CO_2 emissions, particularly in the long run. Ahmad et al. (2021) investigated the relationship between inflation instability and pollution emissions in 40 Asian economies from 1990 to 2018. According to the findings, inflation instability advances environmental quality by causing uncertainties that hinder consumption and investment, thus improving environmental quality. But the findings show that financial development increases pollution emissions and worsens environmental conditions. The study provides novel insights for policymakers based on these findings in order to promote a powerful role for economic stability in achieving pollution reduction goals. Mughal et al. (2021) conducted a study in Association of Southeast Asian Nations (ASEAN) countries to investigate the impact of monetary and fiscal policy on environmental quality during the period spanning from 1990 to 2019. The findings indicate that the implementation of contractionary monetary policy is associated with a decrease in CO_2 emissions, whereas the adoption of expansionary monetary policy is linked to an increase in CO_2 emissions over an extended period of time. Furthermore, it substantiates the notion that over an extended period, the implementation of expansionary fiscal policy leads to a reduction in CO_2 emissions within the ASEAN. In the specific setting of OPEC countries in Africa, Djedaiet (2023) employs the panel NARDL approach to investigate the manner in which the environment, as shown by CO_2 emissions, reacts to asymmetric shocks in inflation and unemployment rates during the timeframe spanning from 1990 to 2019. The research paper reveals two noteworthy findings. Initially, it is important to note that there exists an inverse relationship between CO_2 emissions and both unemployment and inflation rates. This implies that the pursuit of environmental preservation entails the occurrence of two undesired outcomes, namely the reduction in employment opportunities and the decrease in purchasing power. Furthermore, the examination of asymmetry reveals that both adverse unemployment shocks and favorable inflation shocks exert a more substantial influence on the levels of CO_2 emissions. In their study, Mbassi et al. (2023) investigated the correlation between inflation targeting (IT) and environmental degradation within a dataset comprising 22 Developed Market Economies and 25 Emerging Market Economies. The study period spanned from 1980 to 2017. The results indicate that in both study groups, IT has a considerable impact in reducing the emission of polluting gases. Şanlı and Gülbay Yiğiteli (2023) conducted a study to investigate the unequal impact of economic complexity and macroeconomic stability on CO_2 within the context of OECD nations during the period spanning from 1995 to 2020. The results demonstrate a positive relationship between macroeconomic stability and instability and long-term CO_2.

In contrast to the aforementioned studies, Semenova (2023) conducts an analysis on the influence of climate change on inflation. Semenova (2023) emphasizes the importance of climate change as a consistent, systematic, and durable catalyst for inflation. The projected rise in global temperatures and the growing frequency and intensity of extreme weather events are expected to exacerbate the inflationary impacts of climate change. Furthermore, the considerable ability of the corporate sector to influence prices has the capacity to exacerbate these impacts. Moreover, one could contend that the adoption of the growth-oriented Green New Deal and its accompanying fiscal measures may not adequately tackle the issues presented by climate change or properly offset its inflationary ramifications. Overall, the discussion presented above demonstrates that the impact on inflation instability and CO_2 emissions varies, and the findings in empirical and theoretical studies are mixed.

Studies on inflation instability and the environment are generally in the context of developing countries; There are studies on Pakistan (Khan, 2019; Ullah et al., 2020), monetary and fiscal policies and environment (Ullah et al., 2021); inflation and air pollution (Setyadharma et al., 2021) for Indonesia; macroeconomic uncertainty on environmental degradation (Rakshit and Neog 2021) for India; renewable energy, exchange rate and inflation instability (Deka et al., 2022) for Brazil. In the context of developed countries, studies for the USA (Tahir et al., 2022) and Germany (Khan et al., 2022). In studies conducted for more than one country; There are studies for G7 countries (Fountas and Karanasos, 2007), 16 Mediterranean countries (Alola et al., 2019) and 40 Asian economies (Ahmad et al., 2021), ASEAN countries (Mughal et al., 2021), African OPEC countries (Djedaiet, 2023), 22 Developed Market Economies and 25 Emerging Market Economies (Mbassi et al., 2023), OECD countries (Sanlı and Gulbay Yigiteli, 2023) and global (Semenova, 2023). As far as I know, there is no study for Turkiye. Thus, it is expected that the present study will conduce to the literature.

3. Data and Methods

3.1. Data

This study aim to investigate the causality relationship between economic growth (EG), financial development (FD), energy consumption (EC) and environmental pollution (EP) in the context of inflation instability (INF) for Turkiye. The study is based on the work of (Ahmad et al., 2021). The natural logarithm of the data excluding INF and FD rate is taken. Explanations these data are given in Table 1.

Table 1. The Details of the Variables

Variable Name	Description	Source
EP	CO_2 emisyon (kt)	Our World in Data (2022)
EG	GDP per capita (Constant 2010 US$)	World Bank (2022a)
FD	Domestic credit to private sector by banks (% of GDP)	World Bank (2022b)
EC	Energy use (kg of oil equivalent) per $1,000 GDP (constant 2017)	World Bank (2022c)
INF	Inflation variation from its mean values	Author’s calculations

EP is measured by CO2 emissions in kilotonnes. EG is measured as GDP per capita in constant 2010 USD, FD is measured as domestic credit to the private sector as a ratio of GDP, and EC is measured as kg of oil equivalent per capita. INF is measured as the deviation of inflation from its average values. Therefore, firstly, the mean is calculated and secondly, the difference from the original value is subtracted. Descriptive statistics are shown in Table 2. Additionally, the graphics of the series are shown in Figures 1,2,3 and 4 in the appendix.

Table 2. Descriptive Statistics

	ln EP	lnEC	lnEG	INF	FD
Mean	8.429711	4.190867	4.147541	3.99E-17	33.71671
Median	8.436763	4.186534	4.143904	-0.195682	24.72349
Maximum	8.649534	4.348307	4.371845	0.698921	70.92024
Minimum	8.180884	4.017971	3.974130	-0.290719	14.01066
Std. Dev.	0.147208	0.106264	0.125316	0.321571	19.91467
Skewness	-0.114802	-0.022631	0.248316	0.676591	0.648148
Kurtosis	1.694817	1.728691	1.696330	1.913033	1.777067
Jarque-Bera	2.341626	2.157699	2.594933	4.016802	4.102269
Probability	0.310115	0.339986	0.273223	0.134203	0.128589
Sum	269.7507	134.1077	132.7213	2.19E-15	1045.218
Observations	32	32	32	32	31

3.2. Method

The causality test approach was used to investigate the causality relationship between EG, EC, FD, and EP in the context of INF for Turkiye. In empirical studies, most researchers have examined causal relationships using the causality test of Granger (1969) and Toda and Yamamoto (1995). However, these tests ignore the structural breaks that can become in the variables in cases where structural changes such as INF are experienced. In short-term samples with structural changes, Nazlıoğlu et al. (2016) and Enders and Jones (2016) suggested the Fourier based Granger causality test.

Granger (1969) pioneered the use of causal analysis to investigate whether a variable provides useful information in estimating the future value of another variable. Over time, numerous time-series-based causality tests have been developed (Granger, 1969; Toda and Yamamoto, 1995). But, structural changes are frequently overlooked in traditional causality tests. According to a 2008 study in Monte Carlo simulations by Ventosa-Santaulària and Vera-Valdés, when there are structural shifts in the seri generation process, the null causal relationship may be rejected even though the two series have a causal relationship. Enders and Jones (2016) use Monte Carlo simulations to achieve a similar result. When structural breaks in a VAR model are ignored, this results in a misidentification error. As a result, Granger shows that the causality test biases the true null hypothesis toward rejection. Furthermore, Granger causality tests may over-reject the absence of causality if breaks are not properly modeled. As a result, if structural breaks are ignored or incorrectly considered, deductions from traditional Granger causality analysis can be illusory. These findings emphasize the significance of accounting for structural changes. It is also critical to consider how fractures are captured (Nazlioglu et al., 2016).

Dummy variables with sharp shifts are traditionally used to model structural breaks. The soft transition approach is also used to control for structural shifts. Because structural shifts may be slow. Both approaches require information of the number, functional forms, and dates of shifts. Enders and Jones (2016) proposed a new approach to causality tests that incorporates a Fourier function into the VAR model to account for the probability of plural uniform shifts (Nazlıoğlu et al., 2016). As is known, stationary series must be used to test causality in VAR.

In other words, in order to use non-stationary variables in the VAR model, their difference must be calculated. Otherwise, taking the difference results in information loss in the long term (Cagri et al., 2021). As a result, Nazlioglu et al. (2016) employ the Fourier TY causality test in this study, which was created by combined Fourier functions into the TY causality test. Furthermore, as stated by Nazlolu et al. (2016), it can be used in both short-term samples and structural changes.

The VAR model's assumption that shear terms are constant over time is relaxed to account for structural breaks, and the VAR model is modified. Equation 1 includes the revised VAR model.

$$y_t = \alpha(t) + \beta_1 y_{t-1} + \cdots + \beta_{p+d} y_{t-(p+d)} + \epsilon_t \quad (1)$$

Here, the intercept terms (t) are time functions that represent any structural shift in "y_t" To record structural changes as a progressive duration with an obscure start date, number of fractures, and mode of fracture, it defines the Fourier expansion, α(t), as follows:

$$\alpha(t) = \alpha_0 + y_1 \sin\left(\frac{2\pi kt}{T}\right) + y_2 \cos\left(\frac{2\pi kt}{T}\right) \quad (2)$$

In Eq. (2) k shows the approximation frequency. By putting Equation (2) in Equation 1, Equation 3 is obtained.

$$y_t = \alpha_0 + y_1 \sin\left(\frac{2\pi kt}{T}\right) + y_2 \cos\left(\frac{2\pi kt}{T}\right) + \beta_1 y_{t-1} + \cdots + \beta_{p+d} y_{t-(p+d)} + \epsilon_t \quad (3)$$

In this specification, the standard VAR model is used to test the Granger null hypothesis of non-causality. Lütkepohl (2005) recommends using the F statistic rather than the Wald test. Recent studies with Granger causality employ critical value bootstrapping to rise the power of the test statistic in small samples while remaining resistant to the unit root and cointegration properties of the data. The bootstrapping method is used to obtain the bootstrap distribution of F-statistics.

3.2.1. Wavelet Analysis

The existence of causal linkages over the study period can be examined using a time series causality test. However, taking into account various time periods will allow for a more thorough examination. In this study, wavelet decomposition was employed to examine the causality between the series for the purpose of verification.

Wavelet analysis has been employed often in economic research during the past few years as a result of its appealing characteristics (for instance, Pata, et al., 2022; Pata et.al., 2023; Gorus et al., 2023). Wavelets include information from the time and frequency domains, offering wavelet analysis to study the dynamic interaction between series at various time scales.

In this study, I decompose the time series into different frequencies using the discrete wavelet transform (DWT). The following is a representation of the DWT orthogonal approximation:

$$Y(t) = S_j(t) + D_j(t) + D_{j-1}(t) + \cdots + D_1(t) \tag{4}$$

$S_j(t)$ and $D_j(t)$ can be written in detail below.

$$S_j(t) = \sum_k s_{j,k}\, \varphi_{j,k}(t) \tag{5}$$

Where $\varphi_{j,k}$ is the scaling function that represent a series low frequency component and captures long term behavior. Also $s_{j,k}$ shows smoothing coefficients that capture information about trend components.

$$D_j(t) = \sum_k d_{j,k}\, \theta_{j,k}(t) \text{ for } j = 1, 2, \dots, log2(N) \tag{6}$$

The wavelet function represented by the notation $\theta_{j,k}$ reflects the high frequency components of a series and captures short term behavior. Also $d_{j,k}$ shows detail coefficients that capture information about short term components.

As proposed by Walden (2001), it uses the maximal overlapping discrete wavelet transform (MODWT) to divide the series under consideration into orthogonal components and assess causality at various frequencies. Because as the wavelet number and scaling coefficients fall, DWT becomes less and less capable of doing statistical analysis. The following definitions apply to the MODWT representation of the original series:

$$w_{j,k}(t) = \sum_{l=0}^{L-1} \frac{2^{-j/2}\varphi\left[\left(t - 2^j l\right)/2^j\right]}{2^{j/2}} Y_{t-L} modN \tag{7}$$

and

$$v_{j,k}(t) = \sum_{l=0}^{L-1} \frac{2^{-j/2}\theta\left[\left(t - 2^j l\right)/2^j\right]}{2^{j/2}} Y_{t-L} modN \tag{8}$$

In equation, wavelet ($w_{j,k}$) and scaling ($v_{j,k}$) show coefficients of the MODWT. Also Y_t (t=0,1,2,….., L-1) shows the time series. By implementing the advice provided by Gencay et al. (2010), it uses Daubechies Least Asymmetrical as wavelet filter and eight as wavelet length (LA8). It followed the suggestions of (Andersson, 2016; Ha et al., 2018) and combined the orthogonal components of Y_t taking into account three different time frequencies: short-term (2-8 years), mid-term (8-32 years), and long-term (over 32 years).

3.2.2. Empirical Findings

There are several time series methods that can be used, depending on the stochastic characteristics of the data. Many causality tests (such as the Fourier causality test) require variables to be stationary. Therefore, the series must be stationary at the level or stationary by taking the difference. However, in causality tests based on the Toda and Yamamoto causality approach, there is no need to take the difference of the data in the integrated variables. The first thing to do for the Fourirer causality test and the Fourirer Toda and Yamamoto causality test (FTY) test used in the study is to determine the maximum integration degree (dmax) of the variables in the first step. Therefore, before running these tests, I tested the stationarity of the variables and determined the dmax. For this purpose, I conducted the FADF and ADF unit root tests, and I report the findings in Table 3.

Table 3. ADF and FADF Test Results

Original series Variables	**Opt. Freq.**	**F-stat**	**Opt. Lag Length**	**FADF Test Stat**	**Result: (dmax=1) ADF Test Stat**
lnEP	4	0.841358	0.000000	-0.767004	-5.6649***
Inf	1	2.616299	8.000000	-2.702495	-5.0099***
FD	1	10.84784*	9.000000	-2.747462	-4.2977**
lnEC	3	2.796866	1.000000	-0.507463	-6.8979***
lnEG	4	4.265547	1.000000	0.079378	-5.5200***
Decomposed Series: Short Term					**Result: (dmax=null)**
Variables	**Opt. Freq.**	**F-stat**	**Opt. Lag Length**	**FADF Test Stat**	**ADF Test Stat**
lnEP	5	0.083513	9.000000	-4.440043	-5.0331***
Inf	4	3.424712	9.000000	-3.034527	-7.7267***
FD	5	0.177764	9.000000	-4.279084	-4.9941***
lnEC	4	0.473444	9.000000	-4.698238	-5.2713***
lnEG	5	0.198972	9.000000	-4.182963	-5.3057***
Decomposed Series: Medium Term					**Result: (dmax=1)**
Variables	**Opt. Freq.**	**F-stat**	**Opt. Lag Length**	**FADF Test Stat**	**ADF Test Stat**
lnEP	3	5.790231**	9.000000	-3.571144**	-4.3578**
Inf	2	17.19481*	9.000000	-5.651806*	-5.2721**
FD	3	10.37087*	9.000000	-6.603972*	-3.9377**
lnEC	3	4.500734	9.000000	-3.815504	-4.8169***
lnEG	3	2.466008	9.000000	-2.976707	-5.2910***
Decomposed Series: Long Term					**Result: (dmax=1)**
Variables	**Opt. Freq.**	**F-stat**	**Opt. Lag Length**	**FADF Test Stat**	**ADF Test Stat**
lnEP	1	17.55747*	9.000000	-5.632968*	-8.8189***
Inf	1	8.602624*	9.000000	-1.548299	-4.3889**
FD	1	18.99621*	9.000000	-5.710031*	-3.8387***
lnEC	1	23.00804*	9.000000	-6.505914*	-9.7892***
lnEG	1	14.90392*	9.000000	-5.206904*	-5.2910***

Note: ***, **, and * shows 1, 5, and 10 percent level of statistical significance, respectively

Before interpreting the FADF test results, I tested the significance of trigonometric terms with the F-test. According to the F test, the Fourier function is significant only in the original FD, medium-term disaggregated lnEP, INF and long-term decomposed series with FD. I used the FADF unit root test for these series and the ADF unit root test for the remaining series.

According to the FADF test findings, the medium-term disaggregated lnEP, INF and FD series and the long-term disaggregated lnEP, FD, lnergy and lnEG series are stationary at level and I(0). Except for these series, the ADF test results are taken into account for the remaining series. According to these test findings; Original series, medium-term and long-term series contain unit root and are stationary at first difference. Short-term series, on the other hand, are stationary at level. Thus, for all VAR model specifications with the exception of the decomposed short-term series, dmax can be given as "1". In order to test for causal links between variables, an additional lag length is introduced to the VAR models taking into account the findings of the unit root test. In the second step, Fourirer causality and FTY tests are applied to the original and decomposed series according to their dmax values in a multivariate framework. The results of these tests are presented in Table 4 and Table 5.

Table 4. Fourier and Fourier TY Causality

Original	Test Stats.	Boostrap Prob.	p	k	Short Term (< 8 years)	Test Stats.	Boostrap Prob.	p	k
EG=>EP	0.026	0.873	1	1	EG=> EP	0.670	0.712	2	3
EP=>EG	0.405	0.534	1	1	EP=>EG	2.459	0.313	2	3
EC=> EP	1.072	0.314	1	1	EC=> EP	5.444	0.094	2	3
EP=>EC	0.029	0.870	1	1	EP=>EC	0.740	0.689	2	3
FD=> EP	10.60***	0.004	1	1	FD=> EP	20.037	0.001	2	3
EP=>FD	0.765	0.400	1	1	EP=>FD	2.207	0.357	2	3
Inf=> EP	0.142	0.704	1	1	Inf=> EP	5.437	0.096	2	3
EP=>Inf	0.150	0.704	1	1	EP=>Inf	1.819	0.414	2	3
EC=>EG	0.431	0.523	1	1	EC=>EG	8.881	0.028	2	3
EG=>EC	0.009	0.922	1	1	EG=>EC	0.329	0.848	2	3
FD=>EG	5.795**	0.026	1	1	FD=>EG	15.863	0.003	2	3
EG=>FD	0.051	0.822	1	1	EG=>FD	2.959	0.261	2	3
FD=>EC	3.450*	0.082	1	1	FD=>EC	15.769	0.003	2	3
EC=>FD	1.175	0.303	1	1	EC=>FD	10.511	0.018	2	3
Inf=>EC	0.189	0.671	1	1	Inf=>EC	7.486	0.042	2	3
EC=>Inf	0.233	0.626	1	1	EC=>Inf	4.094	0.158	2	3
Inf=>FD	0.308	0.585	1	1	Inf=>FD	8.254	0.035	2	3
FD=>Inf	7.110**	0.017	1	1	FD=>Inf	0.826	0.663	2	3
Inf=>EG	1.241	0.281	1	1	Inf=>EG	5.154	0.107	2	3
EG=>Inf	0.261	0.610	1	1	EG=>Inf	0.358	0.843	2	3

Table 4. Continued

Medium term (8–16 years)	**Test Stats.**	**Boostrap Prob.**	**p**	**k**	**Long Term (> 16 years)**	**Test Stats.**	**Boostrap Prob.**	**p**	**k**
EG=> EP	8.825	0.041	2	1	EG=>EP	2.616	0.309	2	3
EP=>EG	9.007	0.039	2	1	EP=>EG	17.047	0.005	2	3
EC=> EP	11.940	0.017	2	1	EC=>EP	2.436	0.336	2	3
EP=>EC	26.591	0.001	2	1	EP=>EC	19.981	0.003	2	3
FD=> EP	29.222	0.000	2	1	FD=>EP	61.179	0.000	2	3
EP=>FD	11.905	0.019	2	1	EP=>FD	26.961	0.001	2	3
Inf=> EP	16.313	0.007	2	1	Inf=>EP	7.824	0.053	2	3
EP=>Inf	36.912	0.000	2	1	EP=>Inf	23.654	0.002	2	3
EC=>EG	1.983	0.400	2	1	EC=>EG	3.833	0.197	2	3
EG=>EC	10.192	0.029	2	1	EG=>EC	2.972	0.264	2	3
FD=>EG	15.533	0.007	2	1	FD=>EG	65.650	0.000	2	3
EG=>FD	15.140	0.007	2	1	EG=>FD	2.929	0.269	2	3
FD=>EC	25.709	0.002	2	1	FD=>EC	61.439	0.000	2	3
EC=>FD	3.166	0.253	2	1	EC=>FD	15.819	0.007	2	3
Inf=>EC	22.976	0.001	2	1	Inf=>EC	5.587	0.098	2	3
EC=>Inf	52.487	0.000	2	1	EC=>Inf	9.012	0.036	2	3
Inf=>FD	17.195	0.005	2	1	Inf=>FD	23.366	0.001	2	3
FD=>Inf	13.902	0.013	2	1	FD=>Inf	27.155	0.001	2	3
Inf=>EG	9.690	0.031	2	1	Inf=>EG	7.262	0.062	2	3
EG=>Inf	13.442	0.014	2	1	EG=>Inf	12.289	0.016	2	3

Note: p: Appropriate delay, k: Appropriate frequency, ***, **, and * denotes 1, 5, and 10 percent level of statistical significance, respectively

According to the findings of the Fourier TY causality test, in the original series; There is a unidirectional causality termning from FD to EP, EG, EC and INF. No causality was found for other variables. While there was no causal relationship between some variables in the original version of the series; causality relationship can be found in the transformed version of the series. Therefore, the results obtained are remarkable.

In the short term; There is a bidirectional causality relationship between FD and energy, INF and FD. There is unidirectional causality; from energy, FD and INF to EP; from energy and FD to EG and from INF to EC. In the medium term, there is only unidirectional causality from EG to EC and from FD to EC. There is bidirectional causality for all other variables. In the long term; There is bidirectional causality between FD and EP, INF and EP, EC and FD, INF and EC, INF and FD, and INF and EG. There is unidirectional causality running from EPto EG and EC, from FD to EG. Also fractional Fourier TY causality test was performed to test whether the shocks were permanent. The results regarding this are shown in Table 5.

According to the results obtained from the fractional Fourier TY causality test, in the original series; As in the Fourier TY causality test, only unidirectional causality was found from FD to EG, EP, EC and INF. No causality was found for other variables. In the fractional causality analysis, there is no causality relationship between some variables in the original version of the series; causality relationship can be found in the transformed version of the series. The findings obtained in this respect are remarkable. Similarly to Fourier causality in the short term; There is a bidirectional causality relationship between FD and EC, INF and FD. There is unidirectional causality; from EC and FD to EP, from EC and FD to EG and from INF to EC. However, unlike the Fourier causality, there is no causal relationship from INF to EP. This shows that the causality relationship between the two variables is temporary in the short term.

Table 5. Fractional Fourier and Fractional Fourier TY Causality

Original	Test Stats.	Boostrap Prob.	p	k	Short Term (< 8 years)	Test Stats.	Boostrap Prob.	p	k
EG=>EP	1.500	0.495	1	1.3	EG=> EP	0.536	0.764	2	2.9
EP=>EG	0.407	0.824	1	1.3	EP=>EG	2.260	0.345	2	2.9
EC=> EP	2.790	0.295	1	1.3	EC=> EP	5.453	0.097	2	2.9
EP=>EC	0.185	0.909	1	1.3	EP=>EC	0.703	0.715	2	2.9
FD=> EP	11.313**	0.021	1	1.3	FD=> EP	18.547	0.002	2	2.9
EP=>FD	4.418	0.155	1	1.3	EP=>FD	1.907	0.404	2	2.9
Inf=> EP	0.980	0.634	1	1.3	Inf=> EP	4.927	0.112	2	2.9
EP=>Inf	4.751	0.135	1	1.3	EP=>Inf	1.810	0.416	2	2.9
EC=>EG	1.852	0.423	1	1.3	EC=>EG	8.941	0.027	2	2.9
EG=>EC	1.654	0.465	1	1.3	EG=>EC	0.248	0.883	2	2.9
FD=>EG	11.914**	0.017	1	1.3	FD=>EG	14.491	0.005	2	2.9
EG=>FD	1.122	0.590	1	1.3	EG=>FD	2.794	0.265	2	2.9
FD=>EC	7.898*	0.053	1	1.3	FD=>EC	13.998	0.006	2	2.9
EC=>FD	3.757	0.204	1	1.3	EC=>FD	10.253	0.020	2	2.9
Inf=>EC	1.760	0.436	1	1.3	Inf=>EC	6.702	0.059	2	2.9
EC=>Inf	3.134	0.253	1	1.3	EC=>Inf	4.432	0.142	2	2.9
Inf=>FD	0.268	0.873	1	1.3	Inf=>FD	7.683	0.042	2	2.9
FD=>Inf	6.215*	0.090	1	1.3	FD=>Inf	0.793	0.676	2	2.9
Inf=>EG	0.437	0.801	1	1.3	Inf=>EG	4.803	0.121	2	2.9
EG=>Inf	0.886	0.652	1	1.3	EG=>Inf	0.428	0.799	2	2.9
Medium term (8-16 years)	**Test Stats**	**Boostrap Prob.**	**p**	**k**	**Long Term (> 16 years)**	**Test Stats**	**Boostrap Prob.**	**p**	**k**
EG=> EP	7.291	0.060	2	0.6	EG=>EP	0.787	0.679	2	2.8
EP=>EG	8.869	0.039	2	0.6	EP=>EG	13.441	0.012	2	2.8
EC=> EP	10.909	0.023	2	0.6	EC=>EP	2.579	0.315	2	2.8
EP=>EC	23.940	0.001	2	0.6	EP=>EC	6.338	0.083	2	2.8
FD=> EP	23.878	0.002	2	0.6	FD=>EP	69.091	0.000	2	2.8
EP=>FD	11.289	0.020	2	0.6	EP=>FD	9.622	0.032	2	2.8
Inf=> EP	11.010	0.025	2	0.6	Inf=>EP	3.644	0.215	2	2.8
EP=>Inf	18.767	0.004	2	0.6	EP=>Inf	47.026	0.000	2	2.8
EC=>EG	2.684	0.301	2	0.6	EC=>EG	2.994	0.266	2	2.8
EG=>EC	7.687	0.055	2	0.6	EG=>EC	1.087	0.599	2	2.8
FD=>EG	11.417	0.020	2	0.6	FD=>EG	91.814	0.000	2	2.8
EG=>FD	14.721	0.008	2	0.6	EG=>FD	0.775	0.688	2	2.8
FD=>EC	17.770	0.004	2	0.6	FD=>EC	41.495	0.000	2	2.8
EC=>FD	3.673	0.203	2	0.6	EC=>FD	1.955	0.408	2	2.8
Inf=>EC	15.080	0.010	2	0.6	Inf=>EC	3.667	0.204	2	2.8
EC=>Inf	37.799	0.000	2	0.6	EC=>Inf	56.624	0.000	2	2.8
Inf=>FD	12.201	0.017	2	0.6	Inf=>FD	11.464	0.019	2	2.8
FD=>Inf	8.156	0.049	2	0.6	FD=>Inf	65.219	0.000	2	2.8
Inf=>EG	6.757	0.069	2	0.6	Inf=>EG	2.324	0.352	2	2.8
EG=>Inf	8.597	0.043	2	0.6	EG=>Inf	10.516	0.023	2	2.8

Note: p: Appropriate delay, k: Appropriate frequency, ***, **, and * denotes 1, 5, and 10 percent level of statistical significance, respectively

In the middle term, there is only unidirectional causality from EG to EC and from FD to EC, as in Fourier causality. There is bidirectional causality for all other variables. It shows that the causality relationship between the variables continues in the medium term. This shows that the causal relationship between the variables is permanent.

In the long term, there is bidirectional causality between FD and EP and INF and FD. There is unidirectional causality running from EPto EG and EC, from FD to EG. Since this situation continues in the fractional Fourier causality analysis, it implies that the shocks are permanent. Unlike Fouirer causality, the bidirectional relationship between INF and EP, INF and EC, EC and FD, INF and EG has disappeared. In the new situation, it has evolved into a unidirectional causality relationship from EP to INF, from EC to INF, from FD to EC, and from EG to INF. This shows that the causality relationship will be permanent in the long term.

4. Conclusion

While CO2 emissions are increasing globally and the negativities that will trigger this increase (especially the Covid 19 epidemic and the Russia-Ukraine war) have increased in the last few years. This is also true for Turkiye. In contrast, previous studies have examined CO2 emissions through many other channels, but not, to our knowledge, in the context of inflation instability. In the light of this information, the study is to examine the causality between Financial development, growth, energy consumption and environmental pollution in the context of inflation instability for Turkiye in the period of 1990-2021. For this aim, the series were subjected to wavelet transform. Thus, the transformed series were analyzed as short, medium and long term by Fourier TY and Fractional Fourier TY causality tests. According to the results obtained from both tests, only FD; A unidirectional causality is found towards EP, EG, EC and INF. No causality was found for other variables.

While there was no causal relationship between some variables in the original version of the series; causality relationship was found in the transformed version of the series. In the short term; There is a bidirectional causality relationship between FD and EC, INF and FD. From EC, FD and INF to EP; There is unidirectional causality from EC and FD to EG and from INF to EC. In the medium term, there is only unidirectional causality from EG to EC and from FD to EC. There is bidirectional causality for all other variables. In the long term; There is bidirectional causality between FD and EP, INF and EP, EC and FD, INF and EC, INF and FD, and INF and EG. There is unidirectional causality running from EP to EG and EC, from FD to EG.

The findings obtained from the fractional Fourier TY causality test, which was used to test whether the shocks are permanent or not, show that the causality relationship continues in the original series. In the short term, unlike the Fourier causality, there is no causality from INF to EP. This shows that the causality relationship between the two variables is temporary in the short term. In the middle term, there is only unidirectional causality from EG to EC and from FD to EC, as in Fourier causality. There is bidirectional causality for all other variables. It shows that the causality relationship between the variables continues in the medium term. In the long term, unlike Fouirer causality, the bidirectional relationship between INF and EP, INF and EC, EC and FD, INF and EG has disappeared. In the new situation, it has evolved into a unidirectional causality relationship from EP to INF, from EC to INF, from FD to EC, and from EG to INF. This shows that the causality relationship will be permanent in the long term. The findings support their work (Ullah et al., 2020; Ahmad et al., 2021; Ullah et al., 2021; Rakshit and Neog, 2021; Setyadharma et al., 2021; Tahir et al., 2022; Djedaiet, 2023; Sanlı and Gulbay Yigiteli, 2023). In these studies, there is a relationship between macroeconomic indicators and environmental quality. Furthermore, the present study not only corroborates the conclusions of previous research about the influence of inflation on the environment, but also incorporates an analysis of the reciprocal relationship between environmental degradation and inflation, which was not explored in such studies. It is important to highlight that the causal association between environmental deterioration and inflation is expected to persist in long run. The aforementioned observation is in alignment with the outcomes of a previous study conducted by Semenova (2023). According to Semenova (2023), the escalating occurrence of exceptional climatic events, attributed to the progressive degradation of the environment, is anticipated to exert a lasting influence on inflation.

These findings show that inflation instability in the Turkish economy triggers environmental deterioration in the short, medium and long term. However, it reveals that shocks disappear in the long term and are temporary. This empirical study also offers recommendations to policymakers and researchers. It shows that inflation instability does not only have a negative effect on economic indicators, but may also affect environmental indicators in the short and medium term. In this direction, the study encourages policymakers to review the policy structure related to inflation. Future research can explore the effects of other variables, especially inflation instability, on environmental pollution by adding different variables and using asymmetric or different econometric techniques.

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
I am a single author of this paper. My contribution is 100%.

Declaration of Researcher’s Conflict of Interest
There is no potential conflicts of interest in this study.

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Appendix

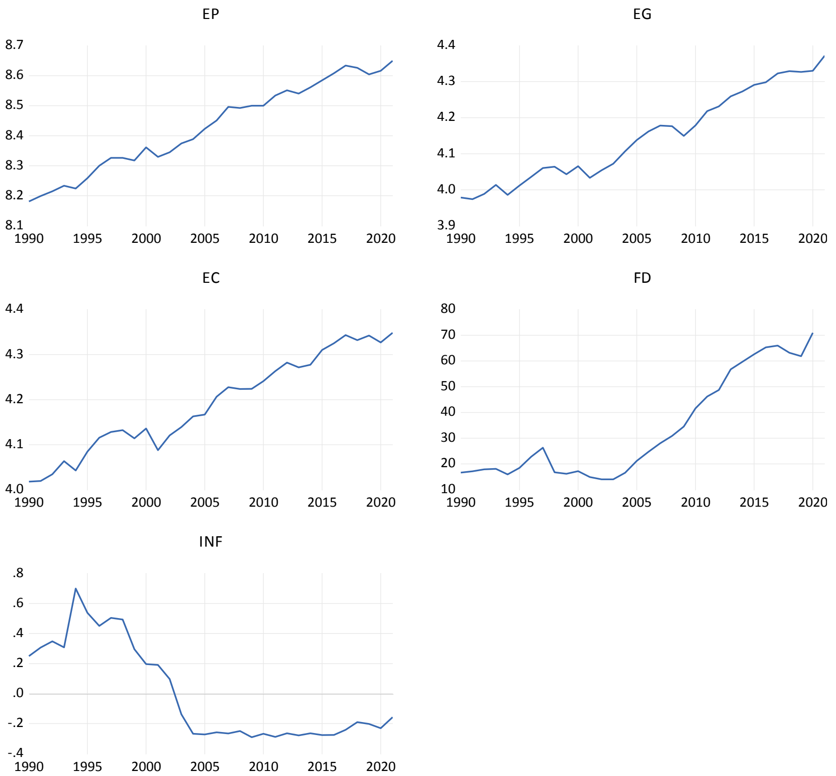

Figure. 1. Graphical Flow of Original Series

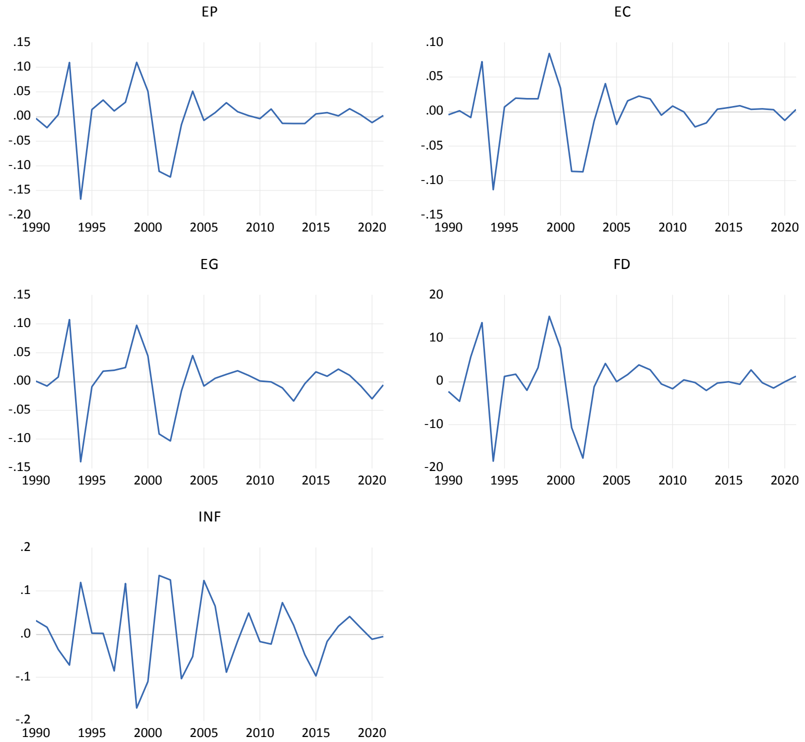

Figure 2. Graphical Flow of Short Term Series

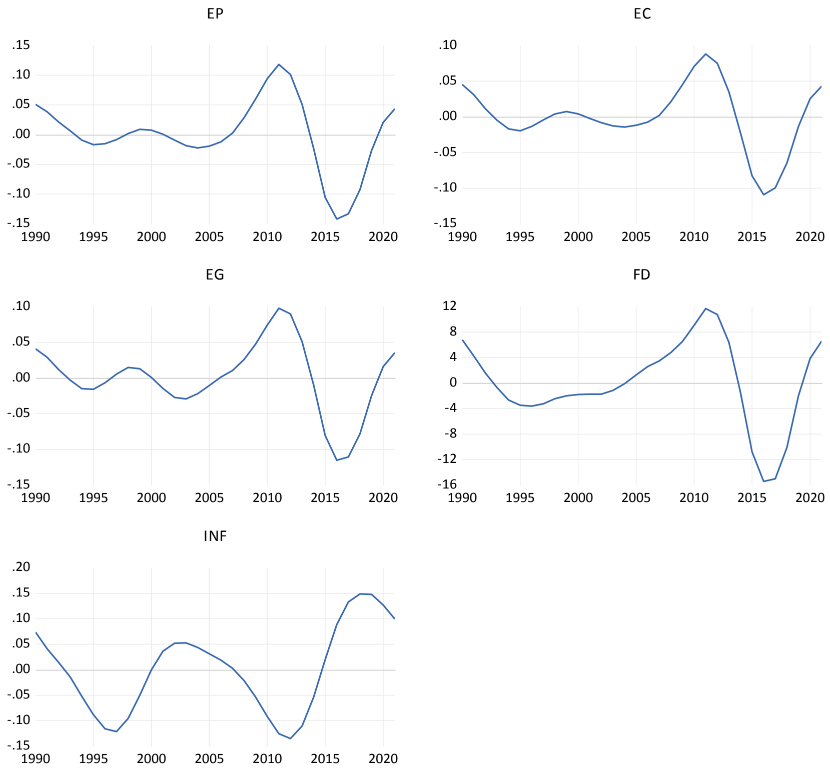

Figure 3. Graphical Flow of Medium Term Series

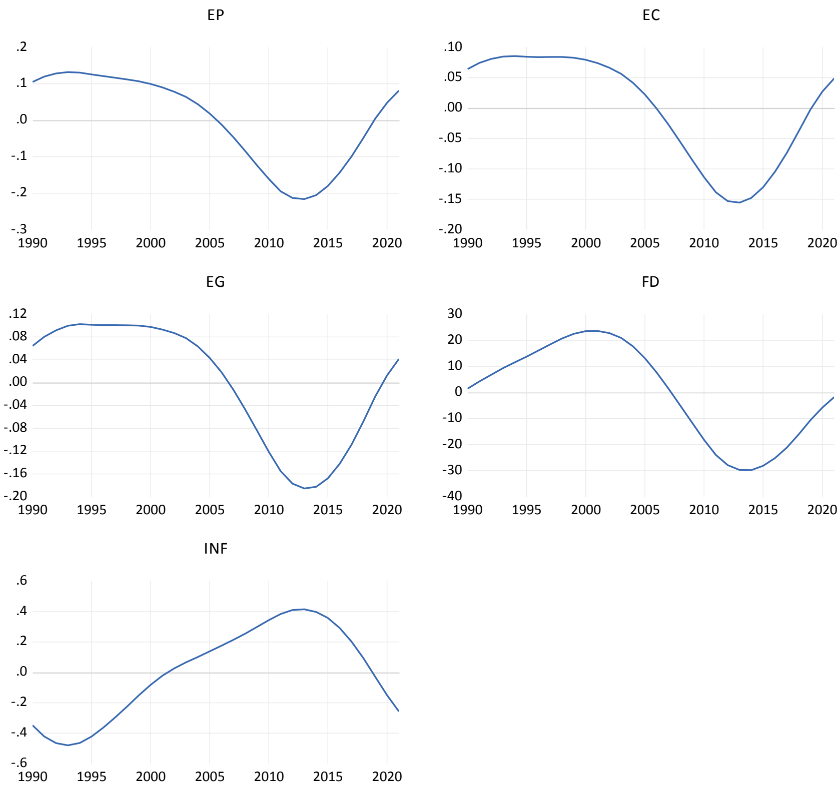

Figure 4. Graphical Flow of Long Term Series