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Effects of Fiscal and Monetary Policies, Energy Consumption and Economic Growth on CO_2 Emissions in the Turkish Economy: Nonlinear Bootstrapping NARDL and Nonlinear Causality Methods

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Abstract: Governments use fiscal and monetary policies to direct the economy toward economic expansion. However, both policies could have impacts on the environment. The study investigates the effects of fiscal and monetary policy, energy consumption and economic growth on carbon dioxide emissions for the Turkish economy from 1978 to 2021 with novel nonlinear bootstrapping NBARDL and nonlinear NBVARDL for nonlinear causality testing. The methods are robust to degenerate cointegration. By differentiating between expansionary and contractionary fiscal and monetary policies, the results determined the presence of long-run cointegrated relationships between the analyzed variables and emissions. The positive effects of both economic policies on emissions cannot be rejected, which become particularly pronounced for expansionary policies in addition to emission enhancing effects of energy consumption and growth. The effects of contractionary monetary policy are also positive in contrast to a set from the literature. Nonlinear causality tests favor one-way causality from energy consumption and from growth to emissions. The one-way causality from energy consumption and economic growth to emissions suggest non-existent feedback effects, leading to concerns for the environment. Expansionary and recessionary fiscal policies have one-way causal impacts on energy, leading to further environmental degradation. The findings highlight the severity of environmental problems caused by economic policies. Important policy recommendations are generated.

Keywords: monetary policy; fiscal policy; environmental sustainability; nonlinear econometrics; cointegration; bootstrap; ARDL; business cycles; expansionary and contractionary economic policies

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1. Introduction

Environmental issues on a global scale, such as warming temperatures and unusual weather patterns, are getting worse. The rise in carbon dioxide emissions (CO2e) is one of the most critical environmental problems confronting the world today. Burning fossil fuels is the main cause of CO2e. The environmental degradation (ED) brought on by increasing energy consumption (EC) has been another problem for the global economy in addition to positive effects of continuing of economic growth (EG) unless coupled with efficient environmental policies.

A graphical presentation of the conceptual framework is given in Figure 1. Economic policies, namely, fiscal policy (FP) and monetary policy (MP), have an important influence on the environment and ED. Both policies are the main policy tools of the policymakers to influence economic activity. While policies generally favor expansions overs contractions, generated economic prosperity also necessitates an incline in energy consumption. Hence, economic policies aiming at growth has adverse effects on the environmental sustainability.

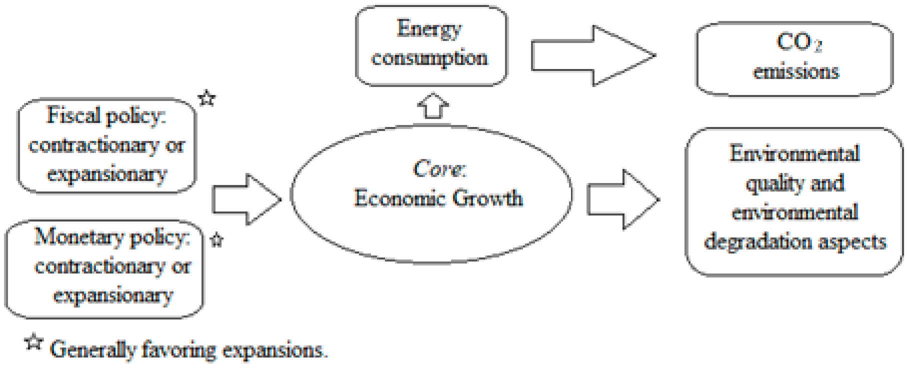

Figure 1. Conceptual Framework.

In practice, economic business cycles are subject to relatively longer durations for expansions compared to recessions, a finding occurring due to the intention of the policy maker to achieve economic growth to avoid recessions and to encourage economic growth. In the case of recessions, the policies also aim at expansion to achieve recovery from these recessions advocating FP and MP policies to shift the economy back to the phase of growth. However, from an environmentalist perspective, growth generates greenhouse gases. Therefore, achieving environmental sustainability and economic growth simultaneously leads to a dilemma for many economies between growth and environment unless growth policies cannot be coupled with a solid commitment to smart solutions which counterbalance the negative effects of expansionist policies on the environment.

These smart solutions include a strong commitment to renewable energy including solar, wind and various other forms, the greening of manufacturing and distribution channels, strong social awareness of green and circular economy and avoiding such consumption habits, application of carbon tax policies in FP and green and sustainable financial markets' policies under MP, subsidies for investments to carbon-capture technologies and great commitment net-zero policies with great commitment. Though this is the case, the motivation of the economic policies is mainly growth based, hindering the commitment to smart solutions given above since they are either considered as being costly or taken with a lack of willingness, since such measures could slow down economic expansions. Political motives also lead to political cycles generally aiming at the achievement of longer-lasting economic expansions. However, in the long run, the ongoing climate change with the continuing trend of CO2e shows a lack of commitment and leads to questioning the sustainability of economic policies environmentally and economically. FP and MP should work together to implement adaptation and mitigation solutions to reverse climate change and global warming. Therefore, the investigation of the long-run nexus between FP and MP policies and the CO_2 emissions necessitates nonlinear analyses which take the asymmetric nature of policies and the nonlinear response of ED to economic policies.

At present, the recent literature points to the finding that the net effect of MP and FP is towards contributing to environmental damage. Ensuring sustainability is vital in this context as it brings to light important concerns about maintaining a balance between EG and environmental sustainability in FP and MP. Central banks may contribute to environmental change by implementing MP by managing interest rates and controlling inflation and by affecting the quantity of money in the economy [1]. Among other things, interest rate changes have an impact on how much energy is consumed and how much pollution is produced. Industrialists choose conventional technology over green investments in reaction to contractionary MP, and as a result, pollutant emissions rise as a result of greater usage of less ecologically friendly technologies. FP has the potential to enhance environmental quality. Environmental quality and overall energy usage are directly and indirectly correlated with FP instruments. Government expenditure changes may end up either from an expansionary (EFP) or from a contractionary (CFP) fiscal policy. To boost industrial production, EFP also causes less eco-friendly technology to use more fossil fuels and CO2e [1–3]. Moreover, tax incentives in the FP have positive and a considerable outcome on CO2e [4,5]. Yuelan et al., in the Chinese case, and Halkos and Paizanos, in the US case, both study fiscal instruments and obtain results, which stress that economic policies have significant effects on CO2e and environmental degradation [6,7].

Recent studies investigated how fiscal decentralization could transform the pace of ED. Accordingly, fiscal decentralization is noted to enhance the efficiency of public spending, which leads to improved resource allocation and increase in allocative efficiency leads to lowering the CO2e [8]. According to Oates, who focused on economic development and fiscal decentralization, decentralization occurs as GDP per capita incline and governments are fiscally more centralized for developing nations compared to the developed nations [9]. It has been found that increased government size and regulatory red tape speed up economic activity, which, as a result, speeds up CO2e [10]. Millimet examines the effects of decentralized environmental policy making in the USA and show that decentralization leads to race-to-top, the empirical findings of the paper show increasing hazardous emissions at low levels of GDP, and the process is reversed at higher development levels [11]. Accordingly, fiscal decentralization is considered as aiding regional governments in improving the effectiveness of resource allocation, which is also anticipated to aid in environmental sustainability [11]. Cheng et al. highlight fiscal policy efficiency in terms of decentralization and how it might improve environmental quality [12]. According to evidence at the micro level, firms' environmental performance improves after fiscal decentralization [13]. Therefore, the above-mentioned field links the concept of fiscal decentralization occurring at high levels of income and development possibly leading to improvement in environment.

Recent studies examined the relationship between MP and ED as well as FP simultaneously [1,14,15]. Among these, Chishti et al. emphasized the importance of additional variables in this research [15]. The association between MP, fossil fuel and CO2e is emphasized [16]. Noureen et al. study the effects of monetary and fiscal policies with the CS-ARDL model in addition to renewable energy, fossil fuel consumption and GDP for development economies [16]. In their study, an important conclusion is the environmental degradation effect of both monetary and fiscal policies pursued to achieve economic expansions [16]. Therefore, recent research has taken the impacts of both MP and FP on ED simultaneously. However, the nonlinear and asymmetric relationships in addition to the asymmetric long-run associations between MP, FP and environmental degradation have not been investigated, not to mention the bootstrapping to ARDL techniques to avoid spurious cointegration relations. Although a set of papers aimed at investigating nonlinear associations between fiscal and monetary policies and emissions, the nonlinear causal links in addition to bootstrapping cointegration to evaluate the existence of non-spurious cointegration relations is another field that has not yet been addressed.

In this work, we will use the nonlinear bootstrapping ARDL method and nonlinear causality approach to jointly examine MP and FP's impacts on the Turkish economy's environmental pollution between 1978 and 2021. In addition to these variables under investigation, the paper includes economic growth (EG) and energy consumption (EC) as control variables following the literature to avoid omitted variables biases in estimation. This research also contributes by investigating how MP and FP may lessen the ED by using Nonlinear Bootstrapping ARDL (NBARDL) and Asymmetric Granger causality methods. It is shown that NBARDL method results produce more reliable results in addition to providing detailed insights into cointegrated relations [17,18]. Further, one of the main contributions of the paper is to extend the BARDL [19,20] to nonlinear NARDL to achieve the NBARDL. The proposed nonlinear bootstrapping ARDL (NBARDL) method benefits from the BARDL method in the implementation and investigation of cointegrated relations and in testing the existence of a single cointegration vector with a single dependent variable under nonlinearity. After the determination of cointegrated relations, nonlinear causality analyses are conducted. The determination of the causal links between FP, MP, EC, EG and CO2e under asymmetry is utilized to identify policy recommendations. For comparative purposes, traditional Granger causalities are reported and evaluated. In the case of confirming causality and its directions with both nonlinear and linear methods, the determined causality link is accepted for policy recommendations.

Literature review is given in Section 2. Section 3 focuses on data and methods for econometric analysis. Results and analysis are handed over in Section 4, which addresses the connection between monetary and FP instruments and environmental quality. The Section 5 provides the conclusion and any potential policy considerations.

2. Literature Review

The recent literature has drawn attention to the effects of MP and FP economic policies on the environment and various methods had been employed empirically including econometric techniques allowing investigation of long-run dynamics. Further, a selected set of research to be given below investigated the relation between the economic policies and ED with nonlinear methods which include the nonlinear autoregressive distributed lag model (NARDL). A separate set from the literature points at the necessity of bootstrapping ARDL (BARDL) to avoid degenerate cases of cointegration in linear ARDL due to factors to be discussed in the methodology section. To our knowledge, our paper is the first that investigates the FP-MP-ED nexus with the novel nonlinear bootstrapping ARDL (NBARDL) method. NBARDL method integrates nonlinearity defined as in the NARDL model to control for degenerate cases as proposed for BARDL modeling. Further, the paper extends the investigation of FP-MP-ED nexus with the vector autoregressive type generalization of NBARDL to NBVARDL method to investigate nonlinear causality. If an overlook is provided, a consensus of the literature showed that expansionary economic policies affect the environment negatively while contractionary policies affect the environment in the opposite direction. By extending nonlinear NARDL to bootstrapping, our paper fills the research gap regarding degenerate cases under nonlinear cointegration and if an overlook is provided to findings, the paper contributes by not only confirming environmental effects of expansionary policies, findings determining such effects existing at relatively low levels also for contractionary policies. Further, in addition to confirmation of cointegration (if exists) with bootstrapping, the findings achieved with asymmetric causality tests under bootstrapping NBVARDL in this paper are of crucial importance to govern the direction of causality under different policy settings for economic policymakers.

Given the above-mentioned focus, the literature is reviewed below. The first strand of the literature focuses on MP policy and its environmental impacts. As typical, by centering on MP policies, Annicchiarico and Di Dio have explored the influence of the central bank on ED in a set of papers [21]. In their study, the New Keynesian (NK) model is integrated with MP policies, and they extended the NK model to NK-ED model, which assumes MP being unneutral to environmental degradation [22]. Inflation instability is a challenge as it has both short-term benefits in preventing environmental harm and long-term implications for MP. When there are MP shocks, the discount rate increases, reducing aggregate demand and EG, which leads to lesser ED due to decreased economic activity resulting in lowered CO2e. To successfully address ED, an extremely countercyclical MP strategy is desired. The central bank is showing a growing interest in green finance, as evidenced by two recent articles by Pan et al. and Chen et al. [23,24]. These studies propose a model called environmental dynamic stochastic general equilibrium (E-DSGE) that takes into account both MP and ED. Qingquan et al. investigate the impact of MP on CO2e from 1990 to 2014 by incorporating CO2e and MP in addition to including several control variables such as human capital, income, urbanization, remittances and fossil fuels [1]. Their findings highlight a long-lasting positive relationship between EMP and CO2e by using panel dynamic least squares (LS), panel fully modified LS estimators and Kao and Pedroni cointegration tests [1].

A recent study that investigated the effect of MP shows that higher discount rates applied by the MP authority incentivize individuals to reduce consumption and increase savings; as a result, MP policy discourages producers' decisions on new capital investments [24]. During this process, MP stabilizes the level of CO2e [24]. Among the papers that differentiate between contractionary and expansionary MP (henceforth CMP and EMP), Fu et al. use quantile regressions with the method of moments to demonstrate that CMP policy at its major quantiles effectively reduces ED while moderate fiscal expansion speeds up emissions [25]. Chan uses the DSGE approach to inquire about the possibility that macroeconomic policies are more effective at limiting environmentally dangerous gases. Their conclusions suggested that the CMP, when combined with inclined interest rates, would successfully lower economic activity and, as a result, aggregate demand and ED [26]. It is emphasized that tight MP (CMP) at high levels could help on cutting CO2e, but also lower societal well-being while pursuing environmental sustainability [26]. The overall evaluation of the previous two studies suggests an effective reduction in emissions if high levels of contraction are achieved with CMP; however, this policy, if pursued, necessitates very high levels of it, which would infer negative effects on the societies.

A second set of the literature centered on FP policies. By focusing on the nexus between FP and ED, López et al. provided evidence that the level of government expenditures affects ED [27]. Abbass et al. investigate the effects of FP with different FP variables including health and education expenditures in addition to overall government expenditures in Pakistan for 1976–2018 period with the VAR model under five FP scenarios [28]. Their findings indicated mitigation effects on CO2e of health and education expenditures while tax revenues led to inclines in CO2e [28]. Adewuyi found an adverse association among public spending and CO2e, both directly and indirectly [29]. Halkos and Paizanos compared the differences of the indirect and direct effects of public expenditures on ED [7]. According to an analysis by Katircioglu and Katircioglu on the Turkish economy, it is obtained that public spending has a long-term and significantly negative outcome on environment and air quality. [30]. Using a dataset on an urban level, Zhang et al. demonstrated the effects of public expenditures as a proxy to FP on the environmental damages [31]. By concentrating on sulfur dioxide levels as pollutants, Huang highlighted the nexus between government expenditures, the main tool to generate EG through FP and environmental protection policies using spatial econometric approaches [32]. By inspecting the connection between FP and ED in China, FP is found to increase environmental worsening; vertical fiscal imbalance is found to have strong implications on ED [33]. Ullah et al. assess the nonlinear impacts of MP and FP measures on ED in Pakistan for the 1985–2019 period with the NARDL method [34]. Their results emphasize the implications on CO2e of both positive and negative FP shocks which also highlight the positive impacts of policies in the short-run, while producing negative implications on ED in the long-run [34]. The authors conclude that monetary and fiscal shocks have good long-term environmental effects but have negative short-term environmental effects [34]. Chishti et al. explore the potential consequences of expansionary and contractionary FP (henceforth EFP and CFP) [15]. Their findings indicated that CFP affects CO2e in the BRICS economies as well as EMP and CMP by using robust techniques of cointegration [15]. They displayed that EFP intensifies the negative effects of CO2e; CFP mitigates the adverse impacts of CO2e, EMP weakens and CMP increases the negative effects on CO2e [15]. In the context of effects of macroeconomic policies, Yu et al. showed that economic policy uncertainty has strong effects on CO2e and they highlighted the role of energy intensity and fuel mix channels on the negative effects of economic policies on the ED with the use of provincial level data [35].

The level of fiscal decentralization has been covered in several research. The regional ED level is lower in high-level fiscal autonomy regions; because they have appropriate budgets for environmental governance and rigorous environmental regulations [8,36–41]. The fact that fiscal decentralization significantly raises the regional ED level is another persuasive factor [33]. Fiscal decentralization would cause local administrations to loosen environmental laws to attract foreign investment and to achieve increases in tax revenue; however, the process degrades the environment due to bad environmental governance [41].

Nevertheless, there are studies in the literature that specify that the connection between the Chinese decentralization model of FP and its relation to ED is not linear [8,36].

Recently, NARDL modeling of nonlinear cointegration has gained relevance in the environmental economics literature. In the context of MP and energy consumption (EC) nexus, similar to the focus of our study, the contrasting results from linear and nonlinear ARDL are highlighted. By providing comparative results with linear ARDL and nonlinear NARDL, Sohail et al. explore asymmetric MP uncertainty and asymmetric effects of MP on non-renewable and renewable EC [42]. Sohail et al. underline contrasting results between those achieved by linear ARDL relative to nonlinear NARDL and by omitting nonlinearity, the linear ARDL analysis reveals no significant effect of MP uncertainty on the consumption of fossil fuel energy in either the short or the long term [42]. With NARDL, in contrast, increasing (lessening) MP uncertainty in the US has adverse (positive) impacts on fossil-fuel energy [42]. Within a panel setting of a selected developing country, Noureen et al. explore the dynamic links from MP and FP policy, economic growth, EC, fossil fuel and renewable energy and three different ED proxies for confirmatory reasons with Westerlund cointegration, cross-sectional dependence ARDL (CS-ARDL) method to control the bias in panel ARDL settings due to cross-sectional dependence, and the asymmetric effects of MP and FP are underlined [16]. In terms of these effects, the expansionary MP and FP are found to be increasing ED while contractionary policies are effective to mitigate ED [16]. Further, according to causality test results of [16], ED causally impacts economic policies and they underline macroeconomic policies as being sensitive to ED [16].

In addition to the literature that showed that both MP and FP have consequences on the environment, various studies integrated the effects of the additional variables with a developing and developed country perspective. Bletsas et al. integrate institutional quality and bureaucratic quality in the public sector to the relation of MP, FP and CO2e [43]. Their empirical results, which were based on a sample of 95 economies, demonstrated that GDP, public expenditures and central bank dependence are the primary causes of ED in addition to negative effects of institutional quality and government inefficiency [43]. They underline that the central bank result is one of the important ones. It has been demonstrated that achieving an effective decrease in emissions requires central bank independence and a reduction in governmental influence over central banks [43]. By examining the roles of climate-related green financial policy instruments with panel quantile regressions on CO2e, the significance of financial development and the positive effects of EC on CO2e in the higher quantiles are highlighted [44]. With their findings, D'Orazio and Dirks demonstrate that green financial instruments have negative coefficient estimates in the long- and short-term, therefore reducing CO2e [44]. For a sample of ASEAN countries from 1990 to 2019, Mughal et al. analyze these implications of economic policy [2]. According to their results, increasing interest rates in line with CMP lowers CO2e; however, EMP has the reverse effect, it causes emissions to increase; regarding FP, government spending increases CO2e in the long-term, but in the short-term, both EFP and CFP produce same outcome, despite the limited impact of contractionary measures [2]. Bhowmik et al. assess the connection between trade policy, FP and MP uncertainty and emissions and the so-called environmental Phillips Curve hypothesis [45]. They demonstrate that MP uncertainty raises CO2e, but a surprising outcome is that FP uncertainty works in the other direction, with no short-term emission impacts of uncertainty in economic policies and long-term emission consequences of economic policies [45]. Mahmood et al. investigate the influences of MP and FP on consumption-based CO_2 in GCC nations and highlight the long-run benefits of MP in addition to scale benefits, as well as long-run and short-run benefits of FP on achieving sustainability [46].

As seen above, the simultaneous impacts of FP and MP on ED were examined in recent empirical papers and nonlinear associations has been a new area of research. Differentiation between expansionary and contractionary policies also provides important distinction. Overall investigation suggests negative effects of expansionary policies on the environment. Within a nonlinear setting, the paper aims at differentiation between the effects of expansionary and contractionary FP and MP both in the long-run and short-run on CO2e. Further, the paper applies nonlinear bootstrapping ARDL (NBARDL) and causality to avoid degenerate cases of cointegration. To our knowledge, this paper is the first to integrate bootstrapping ARDL (BARDL) and particularly to nonlinear NBARDL to investigate the nexus between FP-MP-ED. The novel NBARDL method will be evaluated in the next section and the method will be generalized to causality testing with the NBVARDL.

3. Methodology and Proposed Model

The ARDL method of Pesaran et al. [47] permits researchers to examine long-run associations among time series variables [47]. The method includes bounds for cointegration testing with lower and upper critical values provided by PSS. Critical values are later generalized by Narayan [48] to achieve correction for small sample biases in critical values to avoid over acceptance of cointegrated relations [48]. More recently, McNown et al. introduced bootstrapping to ARDL to achieve the BARDL method to overcome the so-called degenerate cases. Through bootstrapping, a set of F, t, F*, t* critical test values are generated to be tested to avoid degenerate cases and incorrect acceptance of cointegrated long-run associations [19]. In all papers above, the model architectures maintain linearity in long-run and short-run equations. In another strand, Shin et al. extend the PSS model architecture to nonlinear ARDL (NARDL) [49]. Our paper integrates the bootstrapping ARDL to the NARDL and further extends the proposed model to vector form to achieve Granger causality tests robust to degenerate cases and nonlinearity.

3.1. Linear and Nonlinear ARDL Methods

For theoretical framework of linear ARDL model, readers are referred to Pesaran et al. [47] (henceforth, PSS) and for asymmetric NARDL, Shin et al. [49]. We introduce bootstrapping to control degenerate and spurious cointegration given by [19]. A linear bivariate ARDL is.

$$\Delta Y_t = \alpha_0 + \phi Y_{t-1} + \theta X_{t-1} + \sum_{i=1}^{m-1} \alpha_i \Delta Y_{t-i} + \sum_{i=0}^{m} \beta_i \Delta X_{t-i} + \varepsilon_t \tag{1}$$

with a first part resembling the first stage long-run equation $\Delta Y_t = \phi Y_{t-1} + \theta X_{t-1} + \eta_t$ of [50]. Equation (1) permits testing long-run cointegrated relations with F_{PSS} test of PSS [47] testing no cointegration under null hypothesis of $H_0 : \theta = \phi = 0$, which jointly examines significance of ϕ and θ against the alternative of $H_1 : \theta \neq \phi \neq 0$ cointegrated associations. PSS method allows testing cointegrated relations for series to be $I(d)$, with order of integration at d = 0, 1 and to avoid degenerate cointegration, it is necessary to ascertain that $Y_t \sim I(1)$ with unit root tests under linearity. If confirmation of cointegration is achieved for a single cointegration vector only, restricted second-step form is,

$$\Delta Y_t = \alpha_0 + \lambda ecm_{t-1} + \sum_{i=1}^{m-1} \alpha_i \Delta Y_{t-i} + \sum_{i=0}^{m} \beta_i \Delta X_{t-i} + \varepsilon_t \tag{2}$$

ecm_{t-1} representing the mechanism for error correction, and, the form of Equation (2) is similar to second-stage short-run model of [50]. Necessary conditions for error correction are $-1 < \lambda < 0$ and statistical significance of λ. Under these conditions, λ defines how rapid convergence to the long-run equilibrium occurs. $1/\lambda$ is the duration of convergence following a shock. Equation (2) is extended to nonlinearity by NARDL [49]. To achieve asymmetry, by rewriting Equation (1) with positive and negative innovations, long-run relation differentiates among negative and positive variations in X_t

$$Y_t = \theta^+ X_{t-1}^+ + \theta^- X_{t-1}^- + u_t \tag{3}$$

with θ^+ and θ^- asymmetric long-run parameters. Again, it is conventional to expect Y_t ~I(1) integrated of 1st order process to avoid degenerate cointegration solution and it is still necessary to check the existence of single cointegration vector [17,20]. In a most simple form, the independent variable X_t is decomposed into $X_t = X_0 + X_t^+ + X_t^-$, X_0 is the initial value of X_t, and the remainder are positive and negative occurrences. Cumulative sums of negative X_t are calculated [49] as $X_t^- = \sum_{j=1}^{t} \Delta X_j^- = \sum_{j=1}^{t} \min(\Delta X_j, 0)$ and positive values are cumulated as $X_t^+ = \sum_{j=1}^{t} \Delta X_j^+ = \sum_{j=1}^{t} \max(\Delta X_j, 0)$.

By integrating the asymmetric long-run structure defined above to Equation (1), NARDL model is,

$$\Delta Y_t = \alpha_0 + \phi Y_{t-1} + \theta^+ X_{t-1}^+ + \theta^- X_{t-1}^- + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \sum_{i=0}^{m} \beta_i \Delta X_{t-i} + \varepsilon_t \tag{4}$$

By also augmenting with asymmetric short-run terms, it is convenient to write nonlinear NARDL model with asymmetry in long and short terms as,

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \sum_{i=0}^{n} (\beta_i^+ \Delta X_{t-i}^+ + \beta_i^- \Delta X_{t-i}^-) + \phi Y_{t-1} + \theta^+ X_{t-1}^+ + \theta^- X_{t-1}^- + \varepsilon_t \tag{5}$$

Equation (5) allows long-run and short-run asymmetric relationships by ΔX_t^+, ΔX_t^- with their relevant parameters β_i^+ and β_i^-. In Equations (1) and (5), the residuals are i.i.d. normal white noise processes. Further, long-run elasticities defining the long-run impact of a variation in X_t on Y_t are calculated for ARDL and NARDL are,

$$\phi = \sum_{i=1}^{m} \delta_{i-1},\ \theta_i = -\sum_{j=i+1}^{m} \vartheta_j \text{for } i = 1, \ldots\ldots, m-1 \tag{6}$$

$$\vartheta^+ = \sum_{i=0}^{n} \vartheta_i^+,\ \vartheta^- = \sum_{i=0}^{n} \vartheta_i^-,\ \varphi_0^+ = \vartheta_0^+,\ \varphi_i^+ = -\sum_{j=i+1}^{n} \vartheta_i^+ \text{ for } i = 1, \ldots\ldots, n-1 \tag{7}$$

$$\varphi_0^- = \vartheta_0^-,\ \varphi_i^- = -\sum_{j=i+1}^{n} \vartheta_i^- \text{ for } i = 1, \ldots\ldots, n-1 \tag{8}$$

for the asymmetric long-run parameters given as $\beta^+ = -\vartheta^+/\delta$, $\beta^- = -\vartheta^-/\delta$. In Equation (5), the short and/or the long run relations could also be tested for rigidities. The H_0 of no-cointegration is $H_0: \ \delta = \vartheta^+ = \vartheta^- = 0$ tested against $H_1: \ \delta \neq \vartheta^+ \neq \vartheta^- \neq 0$ which assumes cointegrated associations under H_1. Our paper aims at testing three cases which could exist as possible solutions by testing the following cases,

$$\text{Case} - 1: \ H_0: \ \delta_1 = \delta_2 = 0 \text{ vs. } H_1: \ any\ \delta_1,\ \delta_2 \neq 0 \text{ with an F test,} \tag{9}$$

$$\text{Case} - 2: \ H_0: \ \delta_1 = 0 \text{ vs. } H_1: \ \delta_1 \neq 0 \text{ with a } t \text{ test,} \tag{10}$$

$$\text{Case} - 3: \ H_0: \ \vartheta^+ = \vartheta^- = 0 \text{ vs. } H_1: \ \vartheta^+ \neq \vartheta^- \neq 0 \text{ with an F test.} \tag{11}$$

If error correction is established, NARDL below is achieved,

$$\Delta Y_t = \omega_0 + \lambda ecm_{t-1} + \gamma \Delta Y_{t-1} + \sum_{j=1}^{q} (\varphi_j^+ X_{t-j}^+ + \varphi_i^- X_{t-j}^-) + \sum_{j=1}^{q} (\varphi_j^+ \Delta X_{t-j}^+) + \tau_t \tag{12}$$

The model in Equation (12) is known as a conditional or unrestricted error correction model [49]. Long-run asymmetry is tested with H_0 null hypothesis assuming negative and positive parameters in long and short-run relationships by the use of conventional F to test the parameter equality, $(\theta^+/p)' = (\theta^-/p)'$, where mechanism for error correction ecm_{t-1}

is transformed from the residuals, $ecm_{t-1} = Y_{t-1} - \beta^{+'} X^{+}_{t-1} + \beta^{-'} X^{-}_{t-1}$ with X^{-}_{t-1} and X^{+}_{t-1} are partial sums for negative and positive X_t as before. Asymmetric long-run parameters are obtained as $\beta^{-} = -(\theta^{-}/p), \beta^{+} = -(\theta^{+}/p)$.

The calculation of long-run multipliers are $L^{+}_{op} = \vartheta^{+}/-\delta$, $L^{-}_{op} = \vartheta^{-}/-\delta$ and the long-run reaction symmetry is evaluated by testing the restriction of $\vartheta^{+} = \vartheta^{-} = \vartheta$ with a Wald test. Another test for no-long-run asymmetric association is by testing $\delta = 0$. Testing the parameter equality of $L^{+}_{op} = L^{-}_{op}$ leads to long-run symmetry.

The conditional nonlinear error correction model is as written as,

$$\Delta Y_t = \omega_0 + \sum_{i=1}^{m-1} \beta_i \Delta Y_{t-1} + \sum_{i=0}^{n-1} (\pi_j^{+'} \Delta X^{+}_{t-1} + \pi_i^{-'} \Delta X^{+}_{t-1}) + \psi ecm_{t-1} + e_t \tag{13}$$

with ψ error correction parameter again expected to be in the range of $-1 < \psi < 0$ to achieve adjustment to long-run equilibrium within $1/\psi$ periods. $\pi_0^{-} = \delta_0^{-} + w$, $\pi_0^{+} = \delta_0^{+} + w$, $\pi_i^{+} = \varphi_i^{+} - w'\Lambda_i$ and $\pi_i^{-} = \varphi_i^{-} - w'\Lambda_i$ for $i = 1, \ldots\ldots, n-1$. Adjustment towards the long-run equilibrium in the short-run is modeled with the model. Therefore, symmetry in the adjustment towards equilibrium is tested with $H_0 : \pi_i^{+} = \pi_i^{-}$ and $H_0 : \sum_{i=0}^{n-1} \pi_i^{-} = \sum_{i=0}^{n-1} \pi_i^{+}$ for all $i = 0, \ldots, n-1$.

3.2. Augmented Nonlinear Granger Causality Model

The construction of the Augmented Nonlinear Granger Causality model is as follows:

$$\Delta Y_t = \alpha_{10} + \sum_{i=1}^{m} \alpha_{1i} \Delta Y_{t-i} + \sum_{i=0}^{m} (\varpi_i^{+} \Delta X^{+}_{t-i} + \varpi_i^{-} \Delta X^{-}_{t-i}) + \psi_1 ecm_{t-1} + \varepsilon_{1t} \tag{14}$$

$$\Delta X_t = \alpha_{20} + \sum_{j=1}^{m} \alpha_{2j} \Delta X_{t-i} + \sum_{i=0}^{n} (\zeta_i^{+} \Delta Y^{+}_{t-i} + \zeta_i^{-} \Delta Y^{-}_{t-i}) + \psi_2 ecm_{t-1} + \varepsilon_{2t} \tag{15}$$

In the vector autoregressive model presented in Equations (14) and (15), the error correction term ecm_{t-1} is obtained from the long-run equilibrium [51]. The parameters ψ_1, ψ_2 in vectors 1 and 2 denote the speed of adjustment towards the equilibrium after a shock and the duration of adjustment is calculated as $1/\psi_v$ for v = 1, 2. Similarly, ψ_v should be between $-1 < \psi_v < 0$, in addition to the requirement of being statistically significant and non-positive $\psi_v < 0$. Residuals are Gaussian white noise $\varepsilon_{1t} \sim N(0, \delta_1^2)$, $\varepsilon_{2t} \sim N(0, \delta_2^2)$ processes.

Nonlinear Granger causality is tested with applying zero restrictions on the asymmetric terms. In Vector 1 given in Equation (14), short-run Granger causality, or in other words, weak Granger causality could be tested following [52]. Due to generalization of the ARDL model to NBARDL model and Granger VARDL presentation to Granger nonlinear causality model with bootstrapping (NBVARDL), nonlinear Granger causality is examined by the null with zero restrictions on the parameters of $\Delta X^{+}_{t-i}, \Delta X^{-}_{t-i}$ as $H_0 : \varpi_i^{-} = \varpi_i^{+} = 0$ so that, both asymmetric coefficients are no different than zero for $2m$ number of coefficients. The alternative hypothesis of the existence of Granger causality is $H_1 : \varpi_i^{-} \neq \varpi_i^{+} \neq 0$. The test is conducted with $\chi^2(q)$ Chi square distribution with number of restrictions $q = 2m$. For small samples, F test statistic follows an F distribution of $F(q, (n-3m-2))$. Similarly, in Vector 2 given in Equation (15), the null of non-causality and the asymmetric Granger causality alternative hypotheses are $H_0 : \zeta_i^{-} = \zeta_i^{+} = 0$ and $H_1 : \zeta_i^{-} \neq \zeta_i^{+} \neq 0$. Further, one could extend the test to regime-specific Granger causality testing by also testing the following hypotheses in Vector 1, by applying two restrictions instead of a single restriction under the null hypothesis $H_0 : \varpi_i^{-} = 0, \varpi_i^{+} = 0$. As a result, regime-specific asymmetric Granger causalities are tested under the alternative hypothesis, $H_1 : \varpi_i^{-} \neq 0$ and $\varpi_i^{+} \neq 0$. Likewise, in Vector 2, the hypotheses for nonlinear asymmetric Granger causality testing are, $H_0 : \zeta_i^{-} = 0, \zeta_i^{+} = 0, H_1 : \zeta_i^{-} \neq 0, \zeta_i^{+} \neq 0$.

3.3. Proposed Model in This Study

The paper seeks to examine the claim that impacts of MP and FP on CO2e are nonlinear. The proposed error-correction model aims at assessing the impacts of MP and FP in the long and short-run simultaneously. The effects in the short term are represented by the sections below with first-differenced variables denoted as Δ, while the long-term effects are estimated using variables in levels for which the parameter set of w_1 to w_4, which are normalized on w_0 in the Equation (16) below,

$$\begin{aligned}\Delta CO_t = \alpha_0 + \sum_{i=1}^{m} \beta_i \Delta CO_{t-i} + \sum_{i=0}^{k} \chi_i \Delta Y_{t-i} + \sum_{i=0}^{k} \varphi_i \Delta C_{t-i} + \sum_{i=0}^{p} \lambda_i \Delta R_{t-i} \\ + \sum_{i=0}^{z} \delta_i \Delta G_{t-i} + w_0 CO_{t-1} + w_1 Y_{t-1} + w_2 C_{t-1} + w_3 R_{t-1} + w_4 G_{t-1} + \varepsilon_t\end{aligned} \quad (16)$$

The NARDL specification tested in this paper is,

$$\begin{aligned}&\Delta CO_t = \alpha_0 + \sum_{i=1}^{m} \beta_i \Delta CO_{t-i} + \sum_{i=0}^{k} \chi_i \Delta Y_{t-i} + \sum_{i=0}^{l} \phi_i \Delta C_{t-i} + \sum_{i=0}^{p} \varphi_i^+ \Delta R^+_{t-i} + \sum_{i=0}^{n} \varphi_i^- \Delta R^-_{t-i} \\ &+ \sum_{i=0}^{n-1} \delta_i^+ \Delta G^+_{t-i} + \sum_{i=0}^{z} \delta_i^- \Delta G^-_{t-i} + w_0 CO_{t-1} + w_1 Y_{t-1} + w_2 C_{t-1} + w_3{}^- R^-_{t-1} + w_4{}^+ R^+_{t-1} \\ &+ w_5{}^- G^-_{t-1} + w_6{}^+ G^+_{t-1} + \varepsilon_t.\end{aligned} \quad (17)$$

In Model given in Equation (17), series under investigation are decomposed into positive and negative occurrences denoting inclines and declines in MP and FP tools, namely, policy rates R_t, and government expenditures, G_t. It should be noted that the inclines in MP policy tool correspond to policy rate increases, which is contractionary MP (CMP) in nature, while the opposite denotes expansionary MP (EMP) characterized with declines in policy rates. For FP, increases in G_t characterize expansionary FP (EFP) and declines in G_t correspond to contractionary FP (CFP). For CMP and EMP, cumulative sums are calculated as $R_t^+ = \sum_{j=1}^{t} \Delta R_j^+ = \sum_{j=1}^{t} \max(\Delta R_j, 0)$ and $R_t^- = \sum_{j=1}^{t} \Delta R_j^- = \sum_{j=1}^{t} \min(\Delta R_j, 0)$ are the partial sums of relevant policy rates. For EFP, $G_t^+ = \sum_{j=1}^{t} \Delta G_j^+ = \sum_{j=1}^{t} \max(\Delta G_j, 0)$ and for CFP, $G_t^- = \sum_{j=1}^{t} \Delta G_j^- = \sum_{j=1}^{t} \min(\Delta G_j, 0)$.

In vector form, the following equations denote vectors used to test nonlinear Granger causality with bootstrapping. Given that the model has five variables, the model in VAR form is below,

$$\begin{aligned}&\Delta CO_t = \alpha_{1,0} + \sum_{i=1}^{m} \beta_i \Delta CO_{t-i} + \sum_{i=0}^{k} \chi_i \Delta Y_{t-i} + \sum_{i=0}^{l} \phi_i \Delta C_{t-i} + \sum_{i=0}^{p} \varphi_{1,i}^+ \Delta R^+_{t-i} + \sum_{i=0}^{n} \varphi_{1,i}^- \Delta R^-_{t-i} \\ &+ \sum_{i=0}^{n-1} \delta_{1,i}^+ \Delta G^+_{t-i} + \sum_{i=0}^{z} \delta_{1,i}^- \Delta G^-_{t-i} + \lambda_1 ECM_{t-1} + \varepsilon_{1,t}\end{aligned} \quad (18)$$

$$\begin{aligned}&\Delta C_t = \alpha_{2,0} + \sum_{i=1}^{m} \phi_i \Delta C_{t-i} + \sum_{i=0}^{k} \gamma_i \Delta Y_{t-i} + \sum_{i=0}^{l} \eta_i \Delta CO_{t-i} + \sum_{i=0}^{p} \varphi_{2,i}^+ \Delta R^+_{t-i} + \sum_{i=0}^{n} \varphi_{2,i}^- \Delta R^-_{t-i} \\ &+ \sum_{i=0}^{n-1} \delta_{2,i}^+ \Delta G^+_{t-i} + \sum_{i=0}^{z} \delta_{2,i}^- \Delta G^-_{t-i} + \lambda_2 ECM_{t-1} + \varepsilon_{2,t}\end{aligned} \quad (19)$$

$$\begin{aligned}&\Delta Y_t = \alpha_{3,0} + \sum_{i=1}^{m} \kappa_i \Delta Y_{t-i} + \sum_{i=0}^{k} \nu_i \Delta CO_{t-i} + \sum_{i=0}^{l} o_i \Delta C_{t-i} + \sum_{i=0}^{p} \varphi_{3,i}^+ \Delta R^+_{t-i} + \sum_{i=0}^{n} \varphi_{3,i}^- \Delta R^-_{t-i} \\ &+ \sum_{i=0}^{n-1} \delta_{3,i}^+ \Delta G^+_{t-i} + \sum_{i=0}^{z} \delta_{3,i}^- \Delta G^-_{t-i} + \lambda_3 ECM_{t-1} + \varepsilon_{3,t}\end{aligned} \quad (20)$$

$$\Delta R_t^{+} = \alpha_{4,0} + \sum_{i=1}^{m} \pi_i \Delta R_{t-i}^{+} + \sum_{i=0}^{p} \vartheta_i \Delta Y_{t-i} + \sum_{i=0}^{k} \varpi_i \Delta CO_{t-i} + \sum_{i=0}^{l} \theta_i \Delta C_{t-i} + \sum_{i=0}^{n} \varphi_{4,i}^{-} \Delta R_{t-i}^{-} + \sum_{i=0}^{n-1} \delta_{4,i}^{+} \Delta G_{t-i}^{+} + \sum_{i=0}^{z} \delta_{4,i}^{-} \Delta G_{t-i}^{-} + \lambda_4 ECM_{t-1} + \varepsilon_{4,t} \quad (21)$$

$$\Delta R_t^{-} = \alpha_{5,0} + \sum_{i=1}^{m} \rho_i \Delta R_{t-i}^{-} + \sum_{i=0}^{p} \sigma_i \Delta Y_{t-i} + \sum_{i=0}^{k} \varsigma_i \Delta CO_{t-i} + \sum_{i=0}^{l} \tau_i \Delta C_{t-i} + \sum_{i=0}^{n} \varphi_{5,i}^{+} \Delta R_{t-i}^{+} + \sum_{i=0}^{n-1} \delta_{5,i}^{+} \Delta G_{t-i}^{+} + \sum_{i=0}^{z} \delta_{5,i}^{-} \Delta G_{t-i}^{-} + \lambda_5 ECM_{t-1} + \varepsilon_{5,t} \quad (22)$$

$$\Delta G_t^{+} = \alpha_{6,0} + \sum_{i=1}^{m} \upsilon_i \Delta G_{t-i}^{+} + \sum_{i=0}^{p} \omega_i \Delta Y_{t-i} + \sum_{i=0}^{k} \xi_i \Delta CO_{t-i} + \sum_{i=0}^{l} \phi_i \Delta C_{t-i} + \sum_{i=0}^{n} \varphi_{6,i}^{-} \Delta R_{t-i}^{-} + \sum_{i=0}^{n} \varphi_{6,i}^{+} \Delta R_{t-i}^{+} + \sum_{i=0}^{z} \delta_{6,i}^{-} \Delta G_{t-i}^{-} + \lambda_6 ECM_{t-1} + \varepsilon_{6,t} \quad (23)$$

$$\Delta G_t^{-} = \alpha_{7,0} + \sum_{i=1}^{z} \eta_i \Delta G_{t-i}^{-} + \sum_{i=0}^{p} \kappa_i \Delta Y_{t-i} + \sum_{i=0}^{k} \eta_i \Delta CO_{t-i} + \sum_{i=0}^{l} \theta_i \Delta C_{t-i} + \sum_{i=0}^{n} \varphi_{7,i}^{-} \Delta R_{t-i}^{-} + \sum_{i=0}^{n} \varphi_{7,i}^{+} \Delta R_{t-i}^{+} + \sum_{i=0}^{z} \delta_{7,i}^{+} \Delta G_{t-i}^{+} + \lambda_7 ECM_{t-1} + \varepsilon_{7,t} \quad (24)$$

The model is constituted of 7 vectors for a 5-variate model since the model allows the FP and MP variables to be asymmetric. Further, the model also allows testing the effects of individual variables on expansionary and contractionary EMP and CMP policies. Similar to previous specifications given in this paper, the mechanism for error correction, $ecm_{t-1,}$ is obtained by the residuals of the long-run model, in each of 7 vectors in Equations (18)–(24), parameters for error correction are λ_i for i = 1, 2, . . . , 7; as a result, length of duration of error correction towards the long-run equilibrium in each vector is calculated as $1/\lambda_i$. In addition to the PSS method that advocates bounds testing with F and t test statistics [47], the study assumes bootstrapping tests with F, t, F* and t* test statistics with bootstrapped critical values following the methodology given in [19,20]. In the empirical section, both linear BARDL and nonlinear NBARDL tests will be conducted to confirm and to compare the results under linear and nonlinear methods.

4. Data and Results

4.1. Data

The dataset consists of yearly data covering 1978–2021 period for the Turkish Economy. Environmental pollution is proxied with carbon dioxide emissions (CO) in kilotons obtained from World Bank Development Indicators (WDI) database. Energy consumption (C) is in quadrillion Btu and is from WDI database. Government expenditures (G) are given in billions of USD and are taken from World Bank. The monetary policy rate (R) of the Central Bank of the Republic of Türkiye (CBRT) is the weighted average policy interest rate of CBRT and is denoted as R. This variable is considered as the policy rate by the Central Bank. Data are available from CBRT electronic database. Income variable is the real GDP in 2005 constant prices in billion USA dollars and is taken from World Bank. All variables are subject to natural logarithms. In case of first differencing, the variables will be denoted with Δ. The descriptive statistics are conveyed in Table 1.

Before model estimations, the time series given in Table 1 will be evaluated for stationarity with augmented Dickey–Fuller (ADF) and Kapetanios–Shin–Snell (KSS) unit root tests. The former assumes linear, the latter assumes a STAR type nonlinear extension of the ADF model to control for nonlinearity. According to the test findings given in Table 2, all variables in levels follow integrated or order 1 processes, i.e., series are stationary once first differenced at conventional significance levels. Hence, the order of integration d = 1 for all series investigated. For NARDL strategy, determination of integration order and especially having $I(1)$ processes is an important step, similar to ARDL models.

Table 1. Descriptive Statistics.

	C	CO	Y	R	G
Mean	3.059780	5.298193	11.86956	3.419446	8.879920
Median	3.055697	5.291634	11.84656	3.416246	9.355086
Max	3.314193	5.618989	12.30308	4.474957	11.49382
Min	2.845344	4.924279	11.48849	1.791759	5.144263
Sd	0.134400	0.211330	0.244733	0.720331	2.015051
Skew	0.124677	−0.058888	0.107599	−0.299467	−0.362831
Kur	2.014054	1.795928	1.873017	1.148695	1.773650
JB [1]	1.896157	2.683377	2.413403	1.986309	3.722618

[1] All variables are in natural logarithms. JB is the Jarque-Bera normality test statistic, SD, Skew., Kur. denote standard deviation, skewness and kurtosis, respectively.

Table 2. ADF and KSS Unit Root Tests.

Variables in Levels:	ADF	KSS
C	0.6711	1.2175
CO	−1.319	−1.275
Y	0.702	0.472
R	−2.0182	−2.0384
G	−1.803	0.3078
Variables in 1st Differences [1]:	**ADF**	**KSS**
ΔC	−7.428 **	−3.9115 *
ΔCO	−6.8074 **	−5.2518 **
ΔY	−6.5178 **	−5.8702 **
ΔR	−5.8037 **	−3.95071 *
ΔG	−5.669 **	−5.3131 **

[1] Δ denotes first difference, ADF and KSS are the augmented Dickey–Fuller linear unit root test, KSS is Kapetanios–Shin–Snell nonlinear unit root test. * and ** reflect acceptance of the alternative hypothesis of stationarity at 5% and at 1% significance levels.

As a component of the econometric methodology adopted in this research, we utilized the BDS test to determine whether linear or nonlinear modeling is suitable for the analysis and the results are reported in Table 3. The BDS tests for each variable are conducted to ensure that the data generating processes (DGP) of the variables are of nonlinear nature. In Table 3, the BDS test results with a variety of dimensions indicate that the underlying time series structures are nonlinear. This finding also reinforces the usage of NBARDL.

Table 3. BDS Test Results.

	Y		CO		C		R		G
Dim. [1]	z	Dim.	z	Dim.	z	Dim.	z	Dim.	z
2	28.87473	2	16.85073	2	30.83350	2	24.24751	2	24.51408
3	29.66092	3	16.76458	3	32.24502	3	24.84212	3	23.55804
4	31.35926	4	17.13008	4	34.37437	4	26.08052	4	22.73981
5	34.02293	5	18.10567	5	37.53553	5	28.59864	5	22.31449
6	38.06674	6	20.19769	6	42.10963	6	32.40821	6	22.30536

[1] Dim. represent the dimension in BDS test and z is the z statistic.

4.2. Bootstrapping ARDL (BARDL) and Nonlinear Bootstrapping NARDL (NBARDL) Results

Bound testing for cointegration is performed with bootstrapping BARDL and its nonlinear counterpart, nonlinear NBARDL tests. The results are reported in Table 4 below.

Table 4. Linear and Nonlinear Bootstrapping Bounds Tests.

Dep. var. ∣ Indep. var.	F	F*	Fin-dep	F*in-dep	t	T*	Verdict
Linear BARDL Bounds Test Results							
CO ∣ C,G,R,Y	8.582	7.11	5.48	4.55	−3.42	−1.21	Cointegration
C ∣ G,R,Y,CO	0.987	3.05	2.22	2.98	−2.59	−3.72	No-Cointegration
G ∣ R,Y,CO,C	2.991	4.28	4.27	4.96	−4.77	−3.97	No-Cointegration
R ∣ Y,CO,C,G	3.507	3.41	3.48	4.36	−5.46	−3.26	Degenerate-1
Y ∣ CO,C,G,R	4.26	3.69	2.28	5.72	−5.79	−4.03	Degenerate-1
Nonlinear NBARDL Bounds Test Results							
CO ∣ C,G^+,G^-,R^+,R^-,Y	5.66	4.22	4.81	3.96	−2.88	−2.64	Cointegration
C ∣ G^+,G^-,R^+,R^-,Y,CO	1.47	2.19	2.75	3.01	−1.82	−2.88	No-Cointegration
G^+ ∣ G^-,R^+,R^-,Y,CO,C	3.69	4.83	3.26	2.89	−3.14	−3.09	No-Cointegration
G^- ∣ G^+,R^+,R^-,Y,CO,C	5.27	4.68	3.44	4.62	−5.81	−3.71	Degenerate-1
R^+ ∣ G^-,G^+,R^-,Y,CO,C	4.76	2.55	2.87	3.66	−4.41	−3.81	Degenerate-1
R^- ∣ G^+, R^+,G^-,Y,CO,C	3.33	4.65	2.78	2.76	−3.16	−3.55	No-Cointegration
Y ∣ G^+,R^+,G^-,R^-,CO,C	2.48	2.99	3.18	2.65	−3.48	−3.22	No-Cointegration

The testing cycle allows determination of the dependent variable, determination of degenerate cases and confirmation of cointegration with the BARDL method. Its nonlinear extension in our study, the NBARDL method allows testing the above-mentioned relations under nonlinearity. We performed the BARDL test to determine the dependent variable to be selected under the existence of, if not statistically rejected, single cointegration vector. After the determination of the dependent variable with BARDL test results, we will those to the results obtained by the NBARDL nonlinear bounds test. The two methods will be evaluated within a comparative perspective in terms of the determination of dependent variable in the cointegrated relations.

Simultaneous investigation of cointegration under BARDL and NBARDL aims providing a comparative perspective. If overlook is presented, the findings for BARDL and NBARDL tests determine carbon dioxide emissions as the dependent variable, conditional on energy consumption and GDP in addition to FP and MP. NBARDL test confirms this finding also under asymmetry between EMP and CMP and between EFP and CFP policies. Therefore, the findings obtained with BARDL method are confirmed with NBARDL results, which also led to determining CO2e as the dependent variable in both BARDL and NBARDL methods. Additionally, our NBARDL method confirms evidence of cointegration under expansionary and contractionary FP and MP economic policies.

By setting each time series as the dependent variable conditional on the remaining variables, the long-cointegration tests are repeated by employing the nonlinear bounds test for the vectors reported in Equations (18)–(24). According to the findings in Table 4, a single cointegration vector cannot be rejected for the model with CO, representing the carbon dioxide emissions, taken as the dependent variable at conventional significance levels.

4.3. NBARDL Model Estimation Results

Following BARDL and NBARDL cointegration test results reported in Table 4, the long and short-run associations are assessed with NARDL model. The parameter estimates in addition to descriptive statistics are given in Table 5.

Before interpreting the estimation results, robustness of the model to misspecification, to heteroskedasticity, to serial correlation and to structural breaks is tested. Further, asymmetry testing in long-run and short-run parameters is conducted. The results are presented in the last section of Table 5. In terms of overall fit of the model, F test suggests significance of the model parameters, RESET test of model misspecification suggests no model misspecification LM test of structural break test that tests the remainder for structural break innovative and additive forms suggests non-existence of such breaks at conventional significance level. Further, following methodology, asymmetry is tested with F tests both for long- and short-term parameters of FP and MP. Accordingly, both contractionary and expansionary MP and FP have long-run consequences on CO2e since the calculated asymmetry test statistics are $F_{LR\text{-}G}$ = 7.642 and $F_{SR\text{-}G}$ = 4.74 for long-run symmetry and short-run symmetry in government expenditures, i.e., equality of the effect of EFP and CFP policies, since both $W_{LR\text{-}G}$ and $W_{SR\text{-}G}$ are higher than critical F at 5%. The calculated $F_{LR\text{-}R}$ and $F_{SR\text{-}R}$ also lead to statistical finding that, at 5% significance level, expansionary and contractionary MP policies, i.e., EMP and CMP, have asymmetric effects on CO_2 emissions both in the long and short-term. Breusch–Pagan–Godfrey test of homoskedasticity also favored that the residuals are homoscedastic, Jarque–Bera test of normality of residuals suggested normality, Breusch–Godfrey LM test of no serially correlated residuals favored no autocorrelated residuals at 5%. The overall results favor effectiveness of the NARDL model in modeling the impacts of the policy variables in addition to robustness to various factors including structural breaks, autocorrelation, heteroskedasticity and model misspecification.

Table 5. Model Estimation Results.

Variable	Long-Run Coef.	t	Variable	Short-Run Coef.	t
Y_t	−0.2499	−1.50571	ΔY_t	−0.15835	−2.84414
R_t	0.116403	3.165412	ΔR_t^-	−0.07944	−2.25956
R_t^-	0.145588	3.540646	ΔR_{t-1}^-	0.067637	2.45831
R_t^+	0.006494	1.791	ΔR_{t-2}^-	0.01127	2.67931
G_t	0.04267	1.374899	ΔR_t^+	0.000869	2.117452
G_t^-	−0.06845	−1.96234	ΔR_{t-1}^+	0.007553	1.920468
G_t^+	0.033197	2.247271	ΔR_{t-2}^+	−0.00998	−2.29996
C_t	0.601363	3.100095	ΔG_t^+	0.025019	1.782294
intercept	0.189529	2.862624	ΔG_{t-1}^+	−0.00692	−2.60297
			ΔG_{t-2}^+	−0.02926	−1.83958
			ΔG_t^-	0.108058	2.14479
			ΔG_{t-1}^-	−0.07173	−3.10279
			ΔG_{t-2}^-	−0.01256	−2.08596
			ΔC_t	0.630617	3.048868
			ecm_{t-1}	−0.2135	−2.0458

Diagnostic Tests:

Goodness of fit:		Policy Asymmetry Tests:			
R-square	0.89684		Long-run asymmetry test results:		
Adj.R-square	0.795787	$F_{LR\text{-}G}$ [1]	7.642	$F_{LR\text{-}R}$	8.462
AIC	−5.67613		Short-run asymmetry test results:		
BIC	−5.21639	$F_{SR\text{-}G}$	4.74	$F_{SR\text{-}R}$	5.012
LL	127.3607				
F-overall	46.488				
LM, BG	24.672				
LM, sb	1.471				
RESET	0.631				

[1] $F_{LR\text{-}G}$ and $F_{SR\text{-}G}$ denote F test statistics for testing symmetry under the null for long and for short-term in G, the FP variable. $F_{LR\text{-}R}$ and $F_{SR\text{-}R}$ are their policy interest rate counterpart for MP. Note that R^+ and G^+ show inclines in R and G. However, inclines in R, i.e., R^+, are "contractionary" MP in nature. Inclines in G, i.e., G^+, correspond to "expansionary" FP policy. LL is the log-likelihood, RESET is Ramsey's Reset test of model misspecification. LM, sb is the F stat. for Bai-Peron test of structural break, LM, BG is the F stat. for LM type test of Breush–Godfrey serial correlation. AIC and BIC are Akaike and Bayesian information criteria.

Following the tests discussed above, the parameter estimates for EFP, CFP, EMP and CMP with expansionary and contractionary policy distinctions are evaluated. It is clear that the effects are asymmetric depending on the type of policy and depending on being contractionary or expansionary. At the first section of Table 5, according to the long-run associations, influence of MP is relatively larger if compared to FP considering the size of coefficients. Further, it is evident that both FP and MP policies have positive effects on

CO2e. If MP is taken into the center, by remembering that R^+ and R^- signify the inclines and the declines in policy rates and that R^+ and R^- correspond to contractionary and expansionary MP, it is evident that the expansionary MP policy clearly has a larger impact on the CO2e and environmental degradation. Though relatively, the parameter estimate is close to zero, it is still positive and significant at 10% level of significance, signifying MP to have positive effects at 10% significance level even though it would be applied as a contractionary MP policy. According to the results, a 1% point increase (decrease) in policy rates result in a 0.146% point increase (0.0065% decrease) in CO2e, but the latter is accepted only with a 10% significance level, while the former is at 5%. To test the overall effect of *R*, we also estimated a single parameter without the asymmetric specification, which yielded a parameter estimate for R_t equal to 0.116, statistically significant at 5%, suggesting a 0.116% point increase in CO2e due to a 1% point increase in policy rates. Overall, the NBARDL specification led to important findings by differentiating the effects of MP types between EMP and CMP compared to the BARDL result of 0.116% and the BNARDL provided additional results in specifying asymmetric effects and most importantly, severity of the MP policy and its effects on emissions given that the size of parameter estimate is 0.146, relatively higher than the one obtained with linear BARDL. The overall sum is, in Table 4, NBARDL confirmed the BARDL result in terms of MP. Avoiding nonlinearity and asymmetry would lead to estimation of the effect of the MP on CO2e relatively less, i.e., less severe, than it is. Hence, nonlinear method provided important insights over its linear counterpart.

If the effects of FP policy on CO2e are evaluated for the long-run, the asymmetric effects in addition to signs of the parameter estimates provide a striking point in terms of EFP and CFP policy. G^- denote declines, G^+ denote inclines, corresponding to contractionary and expansionary, CFP and CFP. Similar to MP, the parameter estimate of *G* is provided for linear effects of FP. However, the *t* statistic for its parameter is 1.37, is statistically insignificant, if would assume linearity and focus on linear effects of FP only, this would lead to an incorrect conclusion that FP would have no effect on CO2e, though the opposite holds under nonlinear results. It is clear that neglecting asymmetry leads to biased findings, and hence, to inefficient policy recommendations. In terms of nonlinear long-run results, findings show that a 1% point increase in G^+, as an expansionary EFP, results in a 0.033% point increase in CO2e, showing that, expansionary FP increase environmental pollution. On the other hand, a 1% point decrease in G^-, a contractionary FP, results in a 0.068% point decrease in CO2e. Both parameters of G^+ and G^- are statistically significant at 5%. Therefore, expansionary FP increases environmental pollution, while contractionary FP does the opposite. However, if we compare sizes of parameter estimates, the positive effect dominates given the size of parameter estimates and the share of periods with expansions relative to contractions. The investigation of data showed that a larger share of the sample consists of expansionary instead of contractionary FP policies. Hence, the positive effects of FP on CO2e cannot be rejected for the Turkish economy.

In the short-run dynamics, in terms of expansionary MP policy, ΔR_t^-, ΔR_{t-1}^- and ΔR_{t-2}^- are included and these dynamic effects cannot be rejected at 5% significance level. The parameter estimates are estimated as -0.079, 0.068 and 0.011, the former as negative, the latter two are positive. A 1% negative policy rate shock at period *t* has substantial beneficial impact on CO2e; however, at lags 1 and 2, such effects in the short-run are overtaken by the positive effects on CO2e, canceling out the initial negative effect of policy rates on emissions. If we evaluate the effects of MP with contractionary characteristics, parameters of ΔR^+, ΔR_{t-1}^+ and ΔR_{t-2}^+ are estimated as 0.0009 (significant at 5%), 0.008 (significant at 10% only) and -0.001 (significant at 5%) clearly suggesting significant effects of MP on CO2e; however, these effects of negligible since the parameter estimates are too close to zero, compared to the dominance of the parameter estimates for contractionary MP. The overall results suggest evidence that expansionary MP is emission creating in the short-run, while the contractionary MP has almost no effect on emissions in the short-run.

In the next stage, the short-run effects of FP are evaluated. The short-run dynamics of CFP are modeled with ΔG_t^-, ΔG_{t-1}^- and ΔG_{t-2}^- and their parameter estimates are estimated as 0.108, −0.072 and −0.013, all with statistically significant parameters at 5%, suggesting an almost 0.11% point increase in CO2e due to a 1% point increase in contractionary policy at period *t*. If a 1% point increase is given to government expenditures in contractionary characteristics at lags 1 and 2, the parameter estimates are clearly negative, but relatively less dominant compared to the initial parameter estimate for period *t*. Therefore, in the short-run, though the CO2e acceleration effect of FP is lessened if one assumes an accumulated response, still the positive effect on CO2e dominates. In contrast to significant effects of CFP, for the EFP, the parameters of ΔG_t^+, ΔG_{t-1}^+ and ΔG_{t-2}^+ provide differentiated results. The parameters of two out of three are statistically insignificant at 5% significance level in the short-run, though they show positive effects of EFP at 10% significance level. The parameter of ΔG_{t-1}^+ is −0.0069, and is significant at 5% suggesting a 0.007% point decline in CO2e due to a G increase by 1% point in the short-run. However, this CO2e mitigation effect of FP is very close to zero and if evaluated together with the long-run effects of FP, it is more convenient to conclude that expansionary FP has CO2e increasing effects. However, we should keep the mitigation effect of FP restricted to short-run dynamics only in our considerations.

Overall investigation of results shows that both fiscal and monetary measures could be used as effective tools for improving the environmental degradation. However, such effects also would require an amount of economic growth to be forgone to achieve environmental sustainability. EFP with inclined G aims at boost economic activity, capital accumulation, but at the same time, it leads to acceleration in energy consumption (C) levels within the economy. If parameter estimates of C are evaluated in Table 5, a 1% increase in C leads to 0.60% increase in CO2e in the long-run and a 1% increase in C in the short-run also has a 0.63% positive effect on CO2e. It is clear that mitigation of CO2e requires reductions in C which is impossible to achieve with expansionary economic policies. Such results clearly show a dilemma of between economic prosperity and environmental sustainability. However, environmental quality may result from FP if FP instruments prioritize air quality by encouraging greening of fiscal policies with green tax policies and subsidies given to sectors which achieve greening standards. FP could encourage forestation green EG through the use of clean and/or significantly low pollution generating energy sources to mitigate CO2e. In terms of MP, the positive shocks in policy rates have both negative and positive long-term effects on CO2e in our results in the context of Turkish economy. Chan observed that a positive MP shock might reduce CO2e, while a negative MP shock may raise CO2e [26]. In our results, at the 5% level, the finding of Chan is confirmed in expansionary MP only. On the other hand, the parameter of CMP is insignificant, suggesting no effects on CO2e. However, we cannot neglect the further finding at 10% significant level that the effect of CMP exists and is positive on CO2e. Though the effect is close to zero, at very high levels of policy rate cuts, the findings suggest that 90% of cases, MP would have positive effects on CO2e.

Last but not least, the parameter estimates for ecm_{t-1} is calculated as −0.2135, statistically significant and achieving the necessary non-positivity conditions. Hence, 21.35% of the deviations from the equilibrium relation is reverted within 1 period and the adjustment towards the long-run equilibrium takes 4.68 years after which the disequilibrium is reverted back to the long-term equilibrium.

4.4. Causality Results

Causality results are presented in Table 6. The causality test findings led to important results regarding the direction of causality between the analyzed variables.

Table 6. Nonlinear Granger Causality results.

Tested causality direction:						
$\Delta C \rightarrow \Delta CO$	$\Delta Y \rightarrow \Delta CO$	$\Delta R^{-} \rightarrow \Delta CO$	$\Delta R^{+} \rightarrow \Delta CO$	$\Delta Y \rightarrow \Delta C$	$\Delta R^{-} \rightarrow \Delta C$	$\Delta R^{+} \rightarrow \Delta C$
$\Delta CO \rightarrow \Delta C$	$\Delta CO \rightarrow \Delta Y$	$\Delta CO \rightarrow \Delta R^{-}$	$\Delta CO \rightarrow \Delta R^{+}$	$\Delta C \rightarrow \Delta Y$	$\Delta C \rightarrow \Delta R$-	$\Delta C \rightarrow \Delta R^{+}$
2.079	2.269	8.95	2.156	2.136	2.901	1.762
0.342	0.49	0.36	0.239	10.804	0.929	2.735
Results:						
$\Delta C \rightarrow \Delta CO$	$\Delta Y \rightarrow \Delta CO$	$\Delta R^{-} \rightarrow \Delta CO$	$\Delta R^{+} \rightarrow \Delta CO$	$\Delta C \rightarrow \Delta Y$, $\Delta Y \rightarrow \Delta C$	Δ R- $\rightarrow \Delta C$	$\Delta C \rightarrow \Delta R^{+}$
Tested causality direction:						
$\Delta G^{-} \rightarrow \Delta CO$	$\Delta G^{+} \rightarrow \Delta CO$	$\Delta R^{-} \rightarrow \Delta Y$	$\Delta R^{+} \rightarrow \Delta Y$	$\Delta G^{-} \rightarrow \Delta C$	ΔG+ $\rightarrow \Delta C$	$\Delta R^{+} \rightarrow \Delta R^{-}$
$\Delta CO \rightarrow \Delta G^{-}$	$\Delta CO \rightarrow \Delta G^{+}$	$\Delta Y \rightarrow \Delta R^{-}$	$\Delta Y \rightarrow \Delta R^{+}$	$\Delta C \rightarrow \Delta G$-	$\Delta C \rightarrow \Delta G^{+}$	$\Delta R^{-} \rightarrow \Delta R^{+}$
11.96	5.427	7.723	0.0628	15.421	2.542	0.47
0.287	0.287	1.542	6.37	0.325	0.12	0.17
Results:						
$\Delta G^{-} \rightarrow \Delta CO$	$\Delta G^{+} \rightarrow \Delta CO$	$\Delta R^{-} \rightarrow \Delta Y$	$\Delta Y \rightarrow \Delta R^{+}$	ΔG- $\rightarrow \Delta C$	$\Delta G^{+} \rightarrow \Delta C$	None
Tested causality direction:						
$\Delta G^{+} \rightarrow \Delta R^{+}$	$\Delta G^{+} \rightarrow \Delta R^{-}$	$\Delta G^{-} \rightarrow \Delta Y$	$\Delta G^{+} \rightarrow \Delta Y$	$\Delta G^{-} \rightarrow \Delta R^{-}$		
$\Delta R^{+} \rightarrow \Delta G^{+}$	$\Delta R^{-} \rightarrow \Delta G^{+}$	$\Delta Y \rightarrow \Delta G^{-}$	$\Delta Y \rightarrow \Delta G^{+}$	$\Delta R^{-} \rightarrow \Delta G^{-}$		
12.343	14.18	12.299	2.5207	0.774		
0.256	0.01	1.095	3.46	0.298		
Results:						
$\Delta G^{+} \rightarrow \Delta R^{+}$	$\Delta G^{+} \rightarrow \Delta R^{-}$	$\Delta G^{-} \rightarrow \Delta Y$	$\Delta G^{+} \rightarrow \Delta Y$, $\Delta Y \rightarrow \Delta G^{+}$	None		

The findings are listed as follows. According to the findings, there is the evidence of,

- One-way causal link from Y to CO;
- One-way causal link from C to CO; however, causal links from C and EG to CO further exaggerate the effect on CO;
- One-way causal link from EFP and CFP to CO. Both expansionary and contractionary FP having causal effects on emissions;
- One-way causal link from EMP to C and from C to CMP. Expansionary MP accelerating energy consumption which has causal effects on contractionary MP policies.
- One-way causal link from EFP and CFP policies to C;
- C has one-way causal links on CO. In addition to the causal effects of MP and FP which affect energy consumption, energy consumption has causal effects on CO_2 emissions.

Table 7 presents the traditional Granger causality test results for comparison purposes. The findings show unidirectional causalities running from Y to CO and from C to CO, which is consistent with the nonlinear Granger causality results. The traditional causality tests yielded similar results in terms of C, indicating that C and EG are the Granger causes of CO. Additionally, a one-way causal link from FP to CO_2 emissions and a one-way link of causality from MP to CO2e cannot be rejected just similar to the observations from the traditional method. The findings confirm the findings stated above for the nonlinear causality tests. In addition, the nonlinear tests revealed important findings regarding the asymmetric causal effects which are confirmed for expansionary and contractionary MP and FP policies.

Table 7. Traditional Granger Causality results.

Tested causality direction:				
ΔEC → ΔCO ΔCO → ΔEC 5.62391 1.3496	ΔY → ΔCO ΔCO → ΔY 2.49985 0.70674	ΔG → ΔCO ΔCO → ΔG 3.12273 1.46275	ΔR → ΔCO ΔCO → ΔR 6.17801 0.91331	ΔG → ΔEC ΔEC → ΔG 1.36671 2.47312
Result:				
ΔEC → ΔCO	ΔY → ΔCO	ΔG → ΔCO	ΔR → ΔCO	ΔEC → ΔG
Tested causality direction:				
ΔY → ΔEC ΔEC → ΔY 8.18159 0.44052	Δ R → ΔEC ΔEC → ΔR 0.94355 6.01860	ΔG → ΔY ΔY → ΔG 0.36107 3.40919	ΔR → ΔY ΔY → ΔR 0.16206 6.83005	
Result:				
ΔY → ΔEC	Δ R → ΔEC	ΔY → ΔG	ΔY → ΔR^+	

5. Discussion

Recent studies underline nonlinear cointegration based on NARDL in environmental economics. As typical, nonlinear cointegrated relations are shown between production, employment and extractive resource industries [53] and between extractive industries, employment and economic growth [54]. Without NARDL but by utilizing Fourier transformations within cointegration and causality methods, Pata and Samour showed the existence of environmental impacts in the context of environmental Kuznets curve (EKC) from renewable and nuclear energies to the environmental variables including CO2e [55]. Findings showed an inverted U shaped EKC relation with nuclear energy helping in mitigation of CO2e in the long-run [55]. According to [56], pollution haven hypothesis holds for OECD nations that achieved EKC type reduction at high levels of GDP. Therefore, a global perspective is necessary to consider transfer of pollution to countries with lower restrictions on environmental damages. The findings of [56] confirm Bildirici and Ersin [56], who showed with nonlinear methods based on neural networks integrated Markov-switching models with sensitivity analyses that EKC is not validated after controlling nonlinearity with regime-switching neural networks and international transfer of pollution through multinational production should be taken into consideration [56].

By integrating the nonlinear NARDL [49] method with bootstrapping BARDL [19,20], our study suggested novel NBARDL model to model asymmetric effects of MP and FP on CO2e by also controlling and testing cointegration under degenerate cointegration cases. Our findings produced important results in terms of FP and MP. We confirm Lopez et al. [27] and Ullah et al. [34] in terms of the positive impacts of FP in the context of G on CO2e and positive effects of MP on CO2e with asymmetric effects similar to [42]. However, our study provided additional insights through the identification of significant asymmetric effects of contractionary FP on CO2e at different time lags. Specifically, a 1% increase in negative shocks reduces emissions, but the opposite is true for positive shocks. This result could be taken as being consistent with Chen et al.'s [24] suggestion at first sight that CFP reduces demand for final goods by reducing public and private investments, private consumption to decline CO2e.

In contrast, our study revealed significant CO2e mitigation effect for CFP at 5% significance level. EFP is found to lead to emission increases, but at 10% significance level only in the context of the Turkish economy. The findings established asymmetric effects of positive and negative FP shocks, i.e., EFP and CFP leading to differentiated effects on environmental degradation. According to our findings for MP, EMP has positive effects on CO2e confirming the papers investigating effects of expansionary MP policies. However, in contrast to the literature suggesting negative effects of CMP on emissions, CMP is found to affect CO2e positively at conventional significance levels. This provides a deviation from the literature; however, due to low size of the parameter estimate, CO2e increasing effects of CMP exists but at low levels especially for low levels of changes in policy interest rates. Given the economic history with economic crises that led to sharp inclines in policy rates such as those after 1994 crisis, the policy rates could reach three-digit values three decades ago. In such cases, though the parameter estimates are low in size, they become legitimate under very high inclines in policy rates.

In addition to model estimates, causality results determined Granger causality from contractionary and expansionary fiscal policies to CO_2 emissions. FP instruments, affecting expenditures, have a key role in environmental quality if policies are used by considering the environment. In terms of policy effects, the findings in our study clearly showed the implications of FP and MP and the interlinkages between both policies. The causal links between MP and FP provide important insights if used in coordination to achieve sustainability of the environment. Hence, both EMP and CMP increase CO2e in the long-run, though at different levels. Based on these results, it is recommended that governments conduct thorough assessments of the long-term impact of policies on greenhouse gas emissions. Furthermore, policymakers should be aware of the susceptibility of financial systems to climate-related shocks. Central banks should also utilize MP to promote environmentally friendly lending practices among commercial banks.

One strategy suggested for commercial banks is to charge higher credit rates to enterprises that use non-renewable energy in majority of their energy consumption, another strategy would be to internalize the emission awareness to combine the level of emission goals to achieve net-zero in say 10 years gradually by offering government subsidies to encourage greening of manufacturing, distribution, transportation, marketing and pricing processes to reduce their reliance on fossil-fuel energy and cut CO2e. This shift towards decarbonization will necessitate the alteration of MP instruments to achieve mitigation of CO2e. The implementation of MP can help improve the accessibility to green finance schemes for both public and private banks. The green finance incentives would be formulated to provide subsidies for investment projects that combine forms of CO2e mitigation.

Financial policy instruments alone may not be sufficient to achieve environmentally quality finances unless MP policies are used in conjunction. To promote environmentally friendly finance, governments should analyze long-term sources of emissions and policymakers should take into account the financial system's susceptibility to climate-related shocks. In the achievement of sustainability of economic policies, funding of public and corporate-level initiatives that promote sustainable consumption deserves attention. Policymakers should consider and establish coherence among the policy tools, sectors or industries and actors or social groups to achieve environmental sustainability. Additionally, reducing fossil-fuel consumption is crucial in environmental policies. A green monetary and fiscal policy program is suggested to be developed to maintain atmospheric temperatures and prevent climate-induced instability. To achieve it, green fiscal policies, alternative green financial and monetary policies, and regulatory interventions should be needed in addition to integrating MP and FP policies with net-zero targets.

6. Conclusions

This research aims at contributing by investigating how MP and FP applications may lessen or worsen ED by using the Nonlinear Bootstrapping ARDL method and asymmetric Granger causality method between 1978–2021 for the Turkish economy. This study is one of the first to inspect the linkage between monetary and fiscal policy and environmental degradation along with evaluating the effects of energy consumption and economic growth. To this purpose, the paper investigates expansionary and contractionary policies and their effects on emissions, the study utilized the nonlinear extension of the Bootstrapping ARDL method to Nonlinear ARDL to achieve the Bootstrapping Nonlinear ARDL model. Further, the paper also benefited from causality testing with nonlinear and linear Granger causality tests. For the former, the study used the method developed by Shin et al. for NARDL models applied to VAR type Nonlinear VARDL model.

The study yielded significant results in the field of environmental economics, indicating, (a) one-way causality running both from EFP and CFP to CO2e, as well as from EMP to energy consumption and from energy consumption to contractionary monetary policies; (b) positive and significant impacts of EG on CO2e; both MP and FP policies could be utilized to reduce EG and afterward, reduce CO2e; (c) the study determined that CMP had a positive impact on CO2e in the long-run, in addition to positive impacts of EMP on CO2e; these results deviate from the literature, especially in terms of the former; (d) expansionary fiscal policies, EFP, have favorable long-term implications for CO_2 emissions if used in conjunction with green tax policies; however, the findings suggested no such CO_2 mitigation effects so far; (e) Hence, both fiscal contraction and expansionary policies have a considerable impact on CO_2 emissions.

According to the findings, governments must increase their environmental spending within their fiscal and monetary policies to transition towards more equitable and sustainable economies with low-emission activities. The increase in G would be selective to promote environmental protection, education schemes, increasing awareness of health implications and encouraging green infrastructure in manufacturing. Therefore, governments should apply policies to transform the existing infrastructure of fossil fuel plants and gradually, convert the energy production capacity towards renewable energy sources including hydro, wind, solar and thermal energies.

In sum, for environmental sustainability, though our study derived important conclusions on the effects of MP and FP on CO2e, solely focusing on FP and MP policies with the ongoing policy tools and without societal and social behavior on environmental concerns would not provide a complete solution to environmental degradation; however, the strong commitment of MP and FP simultaneously with environmental concerns would require commitment by the producers and the consumers to achieve environmental quality process in the economy.

From a societal perspective, given the largest share of consumption within the GDP, expansionary policies established by monetary and fiscal authorities aim at encouraging economic growth through aggregate expenditures. The awareness towards green products with green manufacturing, and green distribution channels, in addition to encouraging net-zero emissions in manufacturing, is among policy recommendations. From a policy perspective, internalizing emissions by society should be aimed with policies including carbon taxes, subsidizing and encouraging carbon-capture technologies and updating curricula in education with environmental aspects are among the tools to help on mitigation of negative effects of economic policies on the environment.

The paper has two limitations, first is the sample size due to availability of data and second is the number of variables utilized. To save loss in degrees of freedom, we assumed asymmetry in the policy rate variable for MP and in the government expenditures variable for FP. After extending the number of observations in the future, it is suggested to model the asymmetric effects of additional policy variables including FP variables such as carbon tax, domestic debt, and MP variables including required reserve ratios and endogenous money created. In the future, after the establishment of long data sets, integration of carbon taxes to the model is suggested for future work.

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