Revisiting the role of renewable and non-renewable energy consumption on Turkey's ecological footprint: Evidence from Quantile ARDL approach

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Abstract

The current study re-investigates the impact of renewable and non-renewable energy consumption on Turkey's ecological footprint. This study applies Quantile Autoregressive Lagged (QARDL) approach for the period of 1965Q1-2017Q4. We further apply Granger-causality in Quantiles to check the causal relationship among the variables. The results of QARDL show that error correction parameter is statistically significant with the expected negative sign for all quantiles which confirm an existence of significant reversion to the long-term equilibrium connection between the related variables and ecological footprint in Turkey. In particular, the outcomes suggested that renewable energy decrease ecological footprint in long-run on each quantile. However, the results of economic growth and non-renewable energy impact positively to ecological footprint in long-short run period at all quantiles. Finally, we tested the Environmental Kuznets Curve (EKC) hypothesis and the results of QARDL confirmed the EKC in Turkey. Furthermore, the findings of causal investigation from *Granger*-causality in quantiles evident the presence of a bi-directional causal relationship between renewable energy consumption, energy consumption and economic growth with ecological footprint in the Turkish economy.

Keywords: renewable energy; EKC; ecological footprint; Turkey; QARDL

1. INTRODUCTION

When a nation tries to traverse along the path to achieve economic growth, it has to rely on its resource pool, which includes the natural and intellectual resources. During the earliest phases of this economic growth, a nation relies on the pool of natural resources, as it is easier to utilize and consume. Consumption of the natural resources helps the nations to grow, while this pattern of consumption deteriorates the environmental quality of these nations. Continuous consumption of natural resources gradually raises the level of environmental degradation, and this is the time, when the nations start to embrace the intellectual resources in pursuit of alternate energy sources. However, owing to the high implementation cost, it might not always be possible for the nations to carry out the implementation of alternate energy sources, as the implementation cost might have implications on the economic growth pattern itself. Therefore, in order to boost the industrialization in a nation, majorly fossil fuel consumption takes place in pursuit of energy generation. Because of the environmental degradation caused by the consumption of fossil fuel-based solutions, the biocapacity of the nation is hampered, as the absorptive capacity of the land, water, and air of the nation might not be sufficient for the waste generated in the due course of economic growth. This carrying capacity of the nation is generally referred to as the "Ecological footprint". In general, ecological footprint is "the aggregate area of land and water that is claimed by participants in this economy to produce all the resources they consume and to absorb all their wastes they generate on a continuous basis, using prevailing technology" [1]. Now, as the world has ushered in the regime of Sustainable Development Goals (SDGs), it is gradually turning out to be more important for the nations around the globe to comply with the SDG objectives by 2030. Therefore, the nations are in pursuit of redesigning their energy and environmental policies, so that they can create the basis for addressing the SDG objectives by having a control over the environmental degradation created by them, by means of the ecological footprint.

Now, when we discuss about having a control over the ecological footprint being created by the nations, we are fundamentally referring to the economic growth pattern being attained by those nations. In such a situation, it should be remembered that giving preference to fossil fuel based solutions over the alternate energy solutions might be a likely character of the emerging nations, as achievement of economic in the primary preference of these nations, rather than retaining the environmental quality. Turkey is a nation, which demonstrates such characteristic traits. According to [2], the present economic growth pattern in Turkey is creating a problem in the way of implementing the objectives of SDG 13 (by high ambient GHG discharges), SDG 14 (poor fortification of Black Sea ecosystem), and SDG 15 (poor fortification of land quality). These SDGs collectively represent the ecological footprint of a nation, and in case of Turkey, addressing the objectives of these SDGs has turned out to be an issue, owing to their growth pattern. In order to address this issue, the policymakers are striving to reduce the dependence on fossil fuel-based energy solutions, by means of discovering and designing alternate renewable energy solutions. Even though Turkey has made substantial progress in the amount of renewable energy production after 2009, the usage of renewable energy is still far less than the non-renewable energy. In 2018, approximately 32% of Turkey's total electricity energy is produced from renewable sources. The hydropower takes the major share of Turkey's renewable energy portfolio. Because of its geographical location, Turkey has a comparative advantage in terms of renewable energy generation (i.e., solar, wind). Therefore, it has the potential which may turn the environmental threats to opportunities. However, inefficiency of the educational infrastructure in Turkey might turn out to be a predicament in the way of renewable energy implementation. A reflection of this condition can be visualized in terms of the inability of Turkish policymakers in attaining the objectives of SDG 9 (inadequate R&D and patents) and SDG 4 (poor academic outcome in science) [2]. Therefore, while on one hand, the fossil fuel-driven economic growth is deteriorating the environmental quality by augmenting the ecological footprint, on the other hand, full potential of renewable energy generation is yet to be realized. There lies the focus of the study.

The present study takes a cue from the famous "Limits to Growth" approach, according to which the natural resource-driven economic growth pattern in the nations is constrained and unsustainable [3]. Continuous dependence on fossil fuel energy solutions might provide Turkey a short run economic benefit, but it might cause ecological unsustainability. Turkey was one of the 197 signatories of the 2015 Paris climate agreement, and they are also one of the 10 nations, which did not ratify with the accord [4]. In 2019 COP21 Barcelona Convention, several issues have been pointed out regarding the problems of climatic shift in Turkey [5]. Legislative obstacles have been identified as one of the reasons behind these issues, alongside the failure to diffuse the innovations across the nation. In order to assess these issues at a deeper level, the COP22 International Convention on the Protection of the Mediterranean Marine Environment and Coastline in 2021 will be organized in Turkey, and the major focus of this summit will be to look into the governance-climatic shift nexus, with special attention on Turkey. These recent developments on the sustainable policy design front calls for an analysis on the impact of economic growth and its drivers on ecological footprint.

For a country characterized by the problems of implementing sustainable development, it is necessary to assess the role of various forms of energy consumption on environmental quality. Although it can be understood that renewable energy consumption can help in improving the environmental quality, it might not be possible for the nation to implement it, as it might harm the economic growth pattern. Moreover, the social setting of the nation might not be ready to complement the nation-wide diffusion of the alternate energy technologies. Therefore, impact of the renewable energy solutions on the environmental quality might not be as per the expected standard, as the socio-economic caveats might be the hindrances on the way of implementing these solutions. In such a scenario, the nation has to rely on the existing fossil fuel-based energy resources, and experience the gradual deterioration in the environmental quality. In case of Turkey, the roles of renewable and non-renewable energy solutions in determining the level of ecological footprint need to be analyzed, as the socio-economic obstructions on the way of implementing the renewable energy solutions are not allowing these solutions to reach their full potential in tackling the environmental degradation issues, which are possibly being aggravated by the use of non-renewable energy solutions. The reason for choosing ecological footprint as an indicator of environmental degradation is motivated by the fact that it denotes the carrying capacity of earth, and therefore, it is a more inclusive indicator of environmental degradation, compared to any single pollutant. This association needs to be analyzed from the perspective of the SDGs, as Turkey is presently facing issues in attaining the SDG objectives, and the results to be obtained from this study might bridge the policy-level gaps existing in Turkey. There lies the policy-level contribution of the study.

While saying this, it also needs to be remembered that various levels of income growth, and renewable and non-renewable energy solutions might not have similar impacts on all the levels of ecological footprint. At the same time, this association needs to be analyzed for both short-run and long-run scenarios, as the results to be obtained by means of the analysis will be utilized for policy making. In this pursuit, Quantile Autoregressive Distributed Lag (QARDL) approach of Cho et al [6] has been employed. There are various advantages of QARDL technique vis-a-vis alternative methods. First, the QARDL approach allows analyzing the long-term relationship simultaneously with short-run dynamics throughout a span of quantiles of the conditional distribution of the explained variable [7]. Second, it allows for locational asymmetry between the variables in accordance with the location of the explained variable within its conditional distribution [8]. Finally, the QARDL approach lets the cointegrating coefficients to change over the innovation quantile originated from shocks [9]. Now, from the policymaking perspective, this methodological application complements the policy-level contribution. It is likely that different levels of income growth, renewable and non-renewable energy solutions might have different levels of impact on ecological footprint, as the technology diffusion is a characteristic problem in Turkey, owing to low penetration in R&D and additional scientific developments. Therefore, the application of QARDL process complements the contextual development, and thereby contributing to the literature of environmental economics from the contextually-driven methodological perspective.

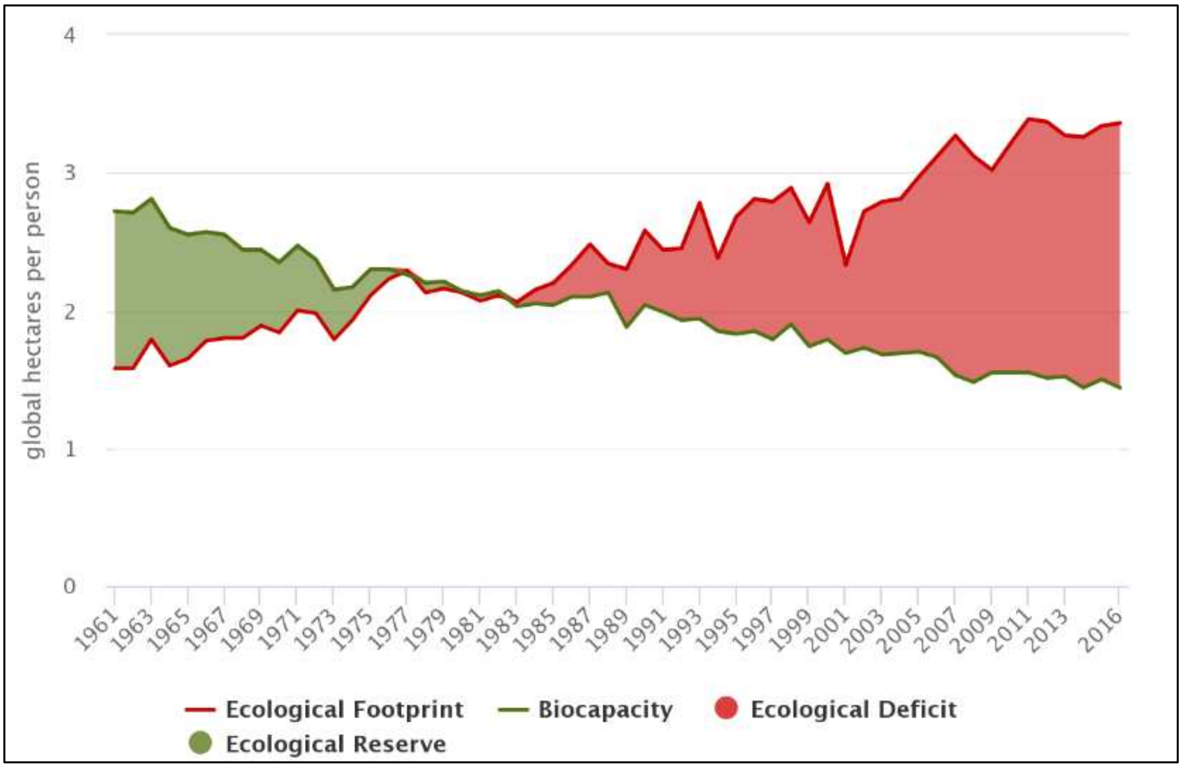
The contextual scenario in Turkey follows in section 2. In Section 3, the empirical literature is viewed. In Section 4, the data set and the econometric methodology are presented. Empirical results are discussed in Section 5. In Section 6 a brief summary of the study and suggestions are discussed.

2. CONTEXTUAL SCENARIO IN TURKEY

2.1. Ecological Footprint in Turkey

Turkey's ecological footprint of consumption per person was 3.36 gha while biocapacity per person was 1.44 gha in 2016. The ecological footprint is measured more than twice of biocapacity that year in Turkey. This means that people need more than 2 years to wait for the reproduction of natural resources they consume in 1 year and to keep the CO_2 released into the atmosphere. This value also indicates that there are an unsustainable lifestyle and requirement of biocapacity import in Turkey [10]. The ecological footprint and biocapacity rate of Turkey is given in Graph 1.

Graph 1: Ecological Footprint and Biocapacity in Turkey (1961-2016)

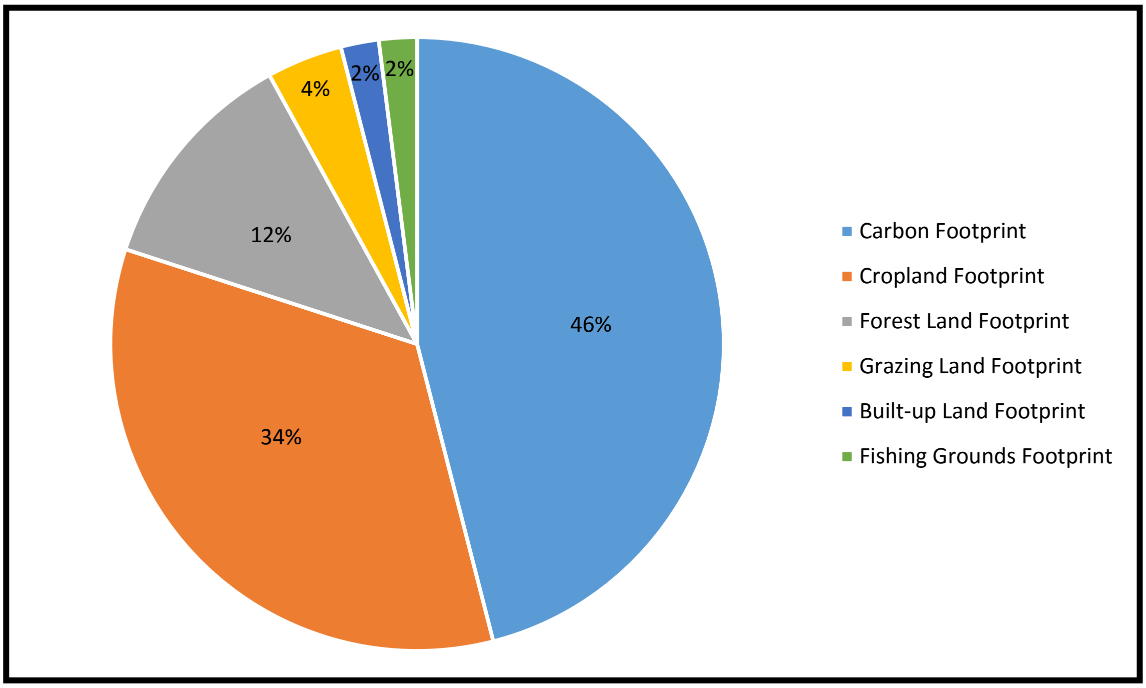


Sources: [11]

Between 1961 and 1988 Turkey was a net biocapacity exporter even though the amount was rather small in the last years, but after 1988 it has become a net biocapacity importer. Accordingly, the Global Ecological Footprint report, Turkey's ecological product and service demand are met by import and the value is about 20% of the footprint of consumption [10]. Population growth of Turkey is the major reason why they turned from a country which has biocapacity reserve into a country which has biocapacity deficiency [12]. The population of Turkey has gone up from 28 million to 82 million from 1961 and 2019.

One of the ways to make a calculation of ecological footprint and biocapacity is to deal with the different natural resources used by humankind (e.g. farm products, fish) individually with respect to the land categories (farmland, fishing areas, etc.) which supply these resources [12]. In this context, Turkey's ecological footprint of consumption components can be grouped under six categories of land types. The ratios of these categories in ecological footprint are as follow [13]:

Graph 2: Turkey's Ecological Footprint by Land Type



Source: [13]

As seen in Graph 2, carbon footprint emission which has the largest share in ecological footprint of Turkey. Although footprint of Turkey has expanded for all types of land between 1961 and 2014, the topmost increase appeared in carbon footprint [12]. CO_2 emission per capita is measured as 4.33t in 2016, with an increase of 85% from 2.34t in 1990 [14]. The cropland footprint takes the second place in the footprint pie chart of Turkey and the rate is about 34%. The food gets the biggest cut of the cropland footprint which is 83% [12].

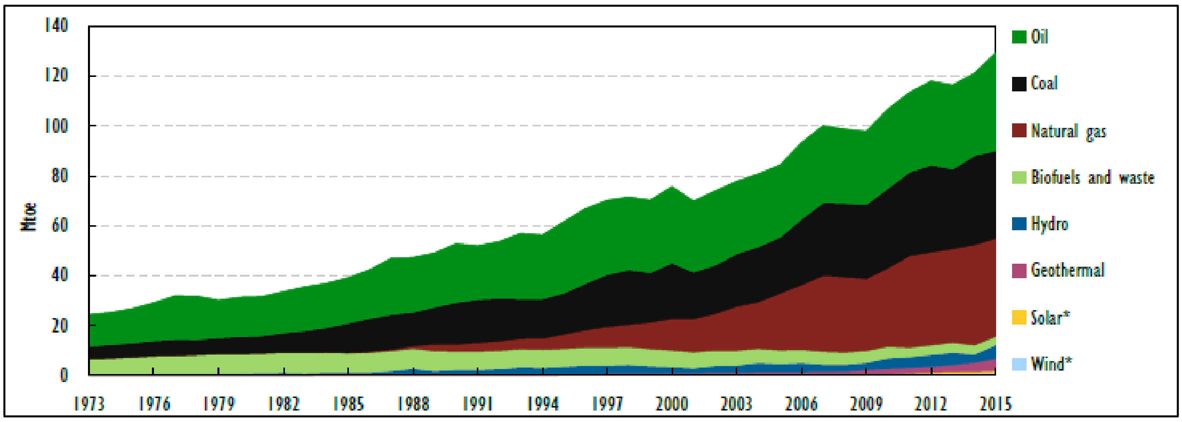
Considering Turkey’s ecological footprint with the income level, it is seen that, ecological footprint disperses unevenly among the various income levels. The highest income group’s ecological footprint is 4.4 gha per person and this is almost three times greater than the lowest income group's footprint (1.5 gha per person) [12].

2.2. Renewable and Non-Renewable Energy Sources in Turkey

It is possible to define renewable energy as an energy which is produced by using natural resources that are continuously replenished. The major renewable energy types are solar, hydropower, wind, geothermal, bioenergy, and ocean energy. On the contrary to renewable energy, non-renewable energy is an energy source which will eventually run out. Most commonly used non-renewable energy sources are fossil fuels; such as coal, oil, and gas. Nuclear energy as a most debated issue in the world also counts in non-renewable energy sources.

Turkey's energy supply has a tendency to rise in response to the rapidly increasing energy demand due to the fast growing economy for 40 years [15]. Total Primary Energy Supply (TPES) of Turkey is 129.7 million tons of oil equivalent (Mtoe) in 2015, while it was 84.2 Mtoe in 2005. Since only about one fourth of energy demand is met via domestic production, Turkey highly depends on oil and natural gas imports [15]. Turkey’s TPES by the source is shown in Graph 3.

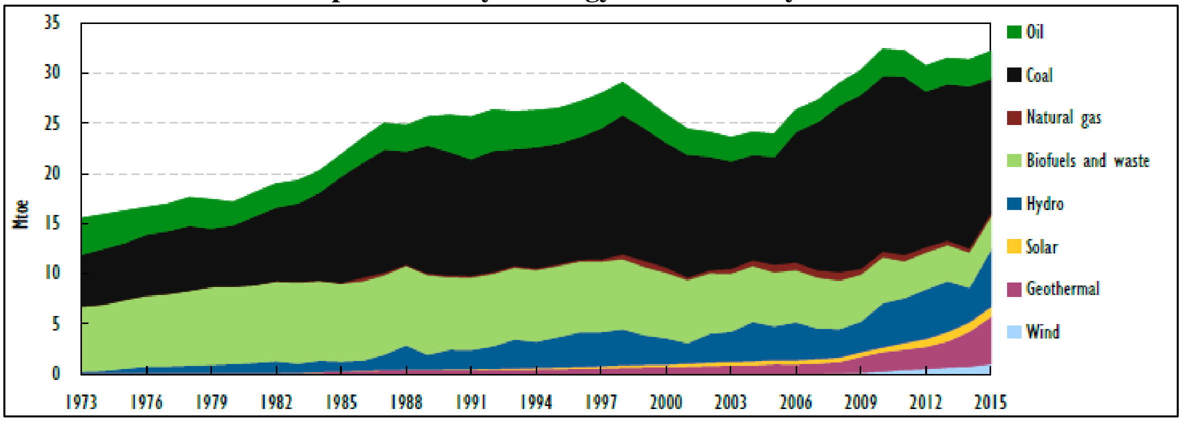
Graph 3: Turkey's Total Primary Energy Supply by Source



Source: [15]
* Negligible.

Approximately 88% of Turkey's TPES in 2015 is a composition of fossil fuels (natural gas 30.2%, oil 30.1%, and coal 27.3%). However, the energy obtained from renewable resources is only about 12% of TPES and met from hydro (4.4%), biofuels and waste (2.5%), geothermal (3.7%), wind (0.8%) and solar (0.7%) [15]. When it comes to Turkey's domestic energy production, only 24.8% of TPES in 2015 is covered by domestic sources. Most of the domestic energy was procured from non-renewable resources such as coal (41.8%) especially lignite, oil (8.3%) and natural gas (1%) as seen from Graph 4 [15]. On the other hand, 48.9% of domestic energy was produced from renewable sources and 17.9% of total production came from hydro, 14.8% from geothermal, 10.1% from biomass, 3.1% from wind, and 3% from solar energy [15]. It is important to state that Turkey has no nuclear energy production and consumption.

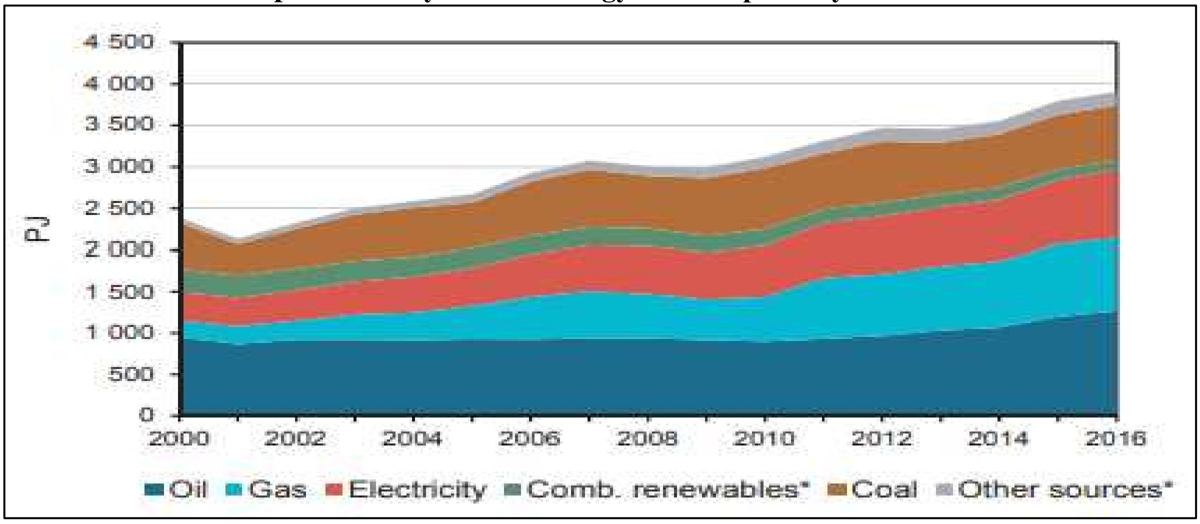
Graph 4: Turkey's Energy Production by Source



Source: [15]

In Graph 5, Turkey's final energy consumption by sources is shown. As shown, while Turkey's energy consumption was about 2500 petajoules (PJ) in 2000, it experiences an increase to approx. 4000 PJ in 2016. Between 2000 and 2016, two sources that have the highest share in consumption are natural gas and electricity respectively. On the other hand, the share of renewable energy in consumption declined over the years.

Graph 5: Turkey's Final Energy Consumption by Sources



Source: [16]

Even though Turkey has a fairly good geographical position in terms of renewable energy potential, the level of renewable energy production is quite low. After 2009, Turkey has shown a remarkable improvement in capacity of renewable energy. While Turkey's total installed power capacity of renewable energy production was 15.5 GW in 2009, with a significant improvement, this number has been risen to 31.7 GW as of 2015 [15]. Moreover, about 67% of Turkey's total electricity production was obtained from non-renewable resources, only 31.5% of the electricity production was procured from renewable resources in 2018. In 1018, as the primary fossil fuel in Turkey the share of coal is 37.3% while only 6.6% and 2.6% of Turkey's electricity generation came from renewable sources such as wind and solar respectively [17].

Due to the higher costs of renewable energy plants, fossil energy remains at the top of the list in energy production of Turkey. Thus, since the domestic fossil energy sources are limited and insufficient, energy imports take the higher share in total imports of Turkey. Turkey meets almost 75% of its total energy requirement from other countries [16]. This dependence on external sources causes the country's economy to continuously generate high current account deficits.

The amount of CO_2 emission is also increasing together with the higher energy demand. The energy sector in Turkey, as well as all over the world, should be decarburized sustainable manner in the economic, environmental and social senses. For this reason, the renewables that has abundant potential should replace fossil fuels currently used for electricity production in Turkey. Preferring sustainable energy sources should decrease energy dependence and lead to greater energy security and price stability.

3. LITERATURE REVIEW

It is possible to find several articles on the relation among energy consumption, environmental degradation and economic growth. These studies can be categorized by three main groups. The first group studies are the ones that focus on the connection between energy (electricity) consumption and economic growth. There are also plenty of papers related to energy utilization and economic growth nexus in the literature. Especially after [18], several studies have emerged in the static and dynamic econometric analyses framework for different countries. For instance; [19, 20, 21, 22, 23, 24] are some of these studies. However, findings from the empirical analysis show that the direction of causality differs from country to country. For example, [25] have surveyed the causality between the GDP and energy consumption using Hsiao's Granger causality test over the period of 1950-2000 for Turkey. They have not found any causality between the related variables. On the other hand, [26] have investigated the short-term relationship between energy consumption and economic growth of Algeria's economy for 1971-2010. According to the results of VECM, there is bidirectional causality between the variables. In another study, [27] have employed panel regression method and found that fossil energy consumption, particularly coal energy affects positively and significantly on the economic growth in BRICS economies between 1995 and 2014.

The second group tested the link between economic growth and carbon dioxide emissions as a proxy of environmental degradation. It is linked to the Environmental Kuznets Curve (EKC) which suggests that the nexus between economic growth and CO_2 is inverted U-shaped. According to the EKC hypothesis in the early stage of economic growth, degradation and pollution increases, but when the high-income level is reached the trend reverses. Thus, economic growth causes positive impact on environment when higher income levels are reached. That is to say, there is an inverted-U relation between environmental pollution indicators and economic growth [28]. The EKC concept is introduced by Grossman and Krueger [29]. After that, many other studies emerged in the EKC framework. [30, 31, 32, 33] are among these studies. The findings of the empirical studies on the EKC hypothesis conflict even for the same countries and regions. For example, while [34, 35] confirmed the EKC hypothesis for Turkey, [36, 37] reached no evidence that the hypothesis of EKC is valid for the same country.

Finally, the third category merges the first two groups into the survey of the relation among economic growth, environmental degradation (and ecological footprint) and energy use by source namely renewable and non-renewable. In recent years, the effects of trade and financial development, as well as economic growth and energy consumption on ecological footprint have been widely examined. [38] investigates the impact of energy consumption, urbanization and economic growth on emerging economies' ecological footprints over the period from 1971 to 2014. The results show that urbanization increases the ecological footprint, but the moderating effects of economic growth and urbanization reduce the ecological footprint, reducing environmental degradation in Next-11 countries. [39] seeks to test the convergence of per capita ecological footprint and its six components which include the footprints of built up, carbon, crop land, fishing ground, forest land, and grazing land in 92 countries for the period 1961–2014. The results demonstrate 10 convergence clubs for ecological footprint and four convergence clubs for built-up footprint. There are five convergence clubs for carbon footprint, while there are seven convergence clubs for cropland footprint and two convergence clubs for fishing ground footprint. They discover whole panel convergence for forest land footprint and two convergence clubs for grazing land footprint. The post merging analysis suggests two convergence clubs for ecological footprint, while there are six convergence clubs for cropland footprint.

[40] have analyzed the influence of green and fossil energy use on environment. They used fully modified ordinary least squares (FM-OLS) and panel causality techniques taking by the data between 1990 and 2015 for 74 economies. The evidence of their results shows that usage of fossil energy has increasing effect on environmental degradation while green energy consumption's coefficient is negative and significant. Financial system development also has a negative effect on pollution according to the authors. They also affirmed the existence of the EKC hypothesis for the countries. In other respect, [41] have examined the association between renewables consumption, GDP and foreign trade for the period between 1996 and 2012 of 25 emerging economies. As a result of dynamic ordinary least square (DOLS) and FMOLS, they found that upsizing the share of renewable energy utilization leads a comparatively bigger decrease on carbon emissions while increasing the magnitude of green energy use causes to a raise in the long-term CO_2 emissions. Export and import have a beneficial impact on ecological footprint. Besides, their empirical results proved that the EKC hypothesis is verified. For Qatar, [42] has employed the Markov Switching Equilibrium Correction Model (MS-ECM) in order to analyze the relationship between ecological footprint, development of financial sector, yield, and trade openness. He revealed the long-run equilibrium relationship for all of these variables for the period of 1970-2015. In addition, he detected two-way causal relation between ecological footprint and yield as well as unilateral causality from usage of electricity and total foreign trade to ecological footprint. The final one-way causality he established is between ecological footprint and financial advancement.

[43] have investigated whether the EKC hypothesis is valid for 116 countries using data from 2004-2008. They found that the EKC hypothesis was valid in the study in which the import and production components of the ecological footprint is used. In addition, panel regression analysis showed that high per capita energy consumption decreased production footprint and increased imported footprint. Similarly, [44] have tested the EKC hypothesis for 15 MENA countries and determined that it was valid for oil exporting countries for the period 1975-2017, while they found a U-shaped relationship for non-oil exporting countries. In addition, they observed from the results of the panel FMOLS and DOLS analyses that energy use increased the ecological footprint, whereas urbanization reduced the footprint. [45] have investigated the effects of hydroelectric energy use on the environment in Malaysia for 1971-2016. For this, they have set up 4 different models using ecological footprint, carbon footprint, water footprint and carbon dioxide emission variables. As a result of ARDL boundary test, they found that the use of Hydroelectric energy reduced environmental degradation, and urbanization increased environmental degradation. They also confirmed the validity of the EKC hypothesis for Malaysia.

[46] have explored the influence of income and livestock on carbon footprint in addition to energy sources for 6 Arabic countries. They have employed Panel FMOLS and DOLS Models for 1980-2014 data. The empirical analyses have confirmed the existence of the EKC hypothesis in Arab countries. In addition, a 1% increase in renewable energy mitigates the carbon footprint by 0.14%. However, the same increase in non-renewable energy consumption and livestock increases the carbon footprint by 0.35% and 0.42% respectively. Another panel study investigating the effects of renewable energy on ecological footprint by using FMOLS and DOLS techniques belongs to [47]. The data set of the study covers the period 1992-2016 for BRICS countries. As a result of the econometric analyses, the validity of the EKC hypothesis was confirmed for all countries. They have also found that urbanization, renewable energy, and natural resources reduce the ecological footprint. [48] have observed that trade and income increase pollution in 22 Central and South American countries in the long run, whereas renewable energy, the number of tourists and foreign direct investments contribute to environmental quality.

[49] have examined the relationship between per capita energy consumption, income and ecological footprint for South Africa. They have performed the bound test and Toda-Yamamoto causality approaches for the study covering the period 1973-2014 and determined that income contributes to the increase of environmental degradation in the long run. However, energy consumption and ecological footprint are negatively related in the long term, and also there is a unidirectional causality from energy consumption to the ecological footprint. Finally, [50] have examined the relationship between energy consumption and ecological footprint for 11 new industrialized countries in the years 1977-2013. Augmented Mean Group (AMG) analysis results supports the EKC hypothesis for Mexico, the Philippines, Singapore, and South Africa, while it reveals a U-shaped relationship for China, India, South Korea, Thailand, and Turkey. In addition, panel causality analysis has shown that energy use is the cause of the ecological footprint.

By far, we have reviewed the literature on the EKC analysis for ecological footprint. Apart from the lack of consensus regarding the shape or range of turnaround points of the EKCs, most of the studies were carried out without considering the sustainable development aspects of Turkey. While devising a robust policy for internalizing the negative externalities caused by the economic growth trajectory, the analysis should be carried out by segregating the entire dataset at various levels, and the policy parameters might have diverse impacts at dissimilar levels. Therefore, in methodological front, none of the studies have considered to analyze the EKC for ecological footprint in Turkey at quantile levels. Given the recent developments in sustainable development scenario in Turkey, there remains a gap in terms of a comprehensive policy-level approach, which can address the sustainable development issues in a comprehensive manner, by considering the various quantiles of the policy variables. There lies the focus of the present study.

4. METHDOLOGY

It is observed in empirical studies that unit root is generally encountered in time series analyzes using macroeconomic variables. In these analyses, the levels at which the variables are stationary are often used because the relationship between the non-stationary series is likely to be spurious. However, this situation causes loss of information in the long-term. Facing such problems led to the development of cointegration tests. According to the two-stage cointegration test, developed by Engle and Granger [51], series that contain unit roots at their levels and become stationary at first difference can be regressed at their levels and thus loss of information can be prevented. However, Engle-Granger cointegration test is valid only if there is one cointegrated vector, it is insufficient to determine more than one cointegration relationship. On the other hand, the multiple cointegration analysis developed by Johansen [52] based on the VAR model provides the opportunity to determine whether there is more than one cointegration among the variables. In Engle-Granger [51], Johansen [52] and Johansen and Juselius [53] cointegration tests, all variables that are modeled should not be stationary at their levels and should be stationary in their first difference, that is, I (1).

The boundary test approach developed by Pesaran et al [54] does not require all series to be I (1) to determine whether there is a long-term relationship between variables. Variables can be a combination of I (0) and I (1), but none of the variables must have a degree of integration I (2). In addition, Xiao [55] extends the cointegration methodology to quantile regressions. According to that approach, leads and lags of the integrated regressors are considered for endogeneity. “The quantile cointegration model allows for additional volatility of dependent variables in addition to regressors and provides an interesting class of cointegration models with conditional heteroskedasticity” [55]. In other Words, quantile cointegration regression both provides a robust method and expands modeling options for economic time series. Later, Cho et al [6] developed the quantile ARDL further.

4.1 Quantile Autoregressive Distributed Lagged (QARDL Method)

In the present study, to determine the nonlinear link between ecological footprint, renewable energy, non-renewable consumption and economic growth, we apply the novel QARDL method newly proposed by Cho et al [6]. Particularly, the QARDL method permits checking the long-term quantile equilibrium effect of renewable energy, non-renewable energy consumption and economic growth on ecological footprint in the Turkey. The dependability parameters measures in each quantile are further checked applying Wald test for both short and long term equilibrium.

In the beginning, the traditional linear ARDL model is inscribed as follows:

$$\mathrm{EFP}_t = \alpha + \sum_i^p \beta_1 \mathrm{EFP}_{t-i} + \sum_i^q \beta_2 \mathrm{Y}_{t-i} + \sum_i^m \beta_3 \mathrm{Y}_{t-i}^2 + \sum_i^n \beta_4 \mathrm{REC}_{t-i} + \sum_i^r \beta_5 \mathrm{NEC}_{t-i} + \epsilon_t \qquad \text{Equation (1)}$$

where ϵ_t is the white noise error explained by the lowest field created by $\{EFP_t, Y_t, REC_t, NEC_t, EFP_{t-1}, Y_{t-1}, \ldots\}$, and *p, q, m, n* and *r* are the lag orders designated by the Schwarz Info Criterion (SIC). Moreover, EFP_t, Y_t, REC_t and NEC_t mention to the natural log series of ecological footprint, economic growth, renewable and non-reneable energy consumption respectively.

Next, the revision of equation-1 to a context of quantile finally suggests to the below framework of the QARDL method:

$$Q_{\mathrm{EFP}_t} = \alpha(\tau) + \sum_i^p \beta_1(\tau)\mathrm{EFP}_{t-i} + \sum_i^q \beta_2(\tau)\mathrm{Y}_{t-i} + \sum_i^m \beta_3(\tau)\mathrm{Y}_{t-i}^2 + \sum_i^n \beta_4(\tau)\mathrm{REC}_{t-i} + \sum_i^r \beta_5(\tau)\mathrm{NEC}_{t-i} + \epsilon_t(\tau) \qquad \text{Equation (2)}$$

where $\epsilon_t(\tau) = EFP_t - Q_{EFP_t}(\tau/\epsilon_{t-1})$ [56] and $0 < \tau < 1$ is the quantile. In order to perform data analysis, we use the subsequent pair of quantiles τ belongs to {0.05, 0.10, 0.20, 0.30... 0.90 and 0.95}. Moreover, because of probability of sequential correlation in the white noise error, the QARDL framework in equation-2 is comprehensive as below:

$$Q_{\Delta EFP_t} = \alpha(\tau) + \rho EFP_{t-i} + \varphi_1 Y_{t-i} + \varphi_2 Y_{t-i}^2 + \varphi_3 REC_{t-i} + \varphi_4 NEC_{t-i} + \sum_i^p \beta_1(\tau) EFP_{t-i} + \sum_i^q \beta_2(\tau) Y_{t-i} + \sum_i^m \beta_3(\tau) Y_{t-i}^2 + \sum_i^n \beta_4(\tau) REC_{t-i} + \sum_i^r \beta_5(\tau) NEC_{t-i} + \epsilon_t(\tau) \qquad \text{Equation (3)}$$

Moreover, the above equation-3 can be revised [6] to provide the below Error correction model remeasurement of the QARDL framework:

$$Q_{\Delta EFP_t} = \alpha(\tau) + \rho(\tau)\big(EFP_{t-i} - \omega_1(\tau)Y_{t-i} - \omega_2(\tau)Y_{t-i}^2 - \omega_3(\tau)REC_{t-i} - \omega_4(\tau)NEC_{t-i}\big) + \sum_{i=1}^{p-1} \beta_1(\tau)\Delta EFP_{t-i} + \sum_{i=0}^{q-1} \beta_2(\tau)\Delta Y_{t-i} + \sum_{i=0}^{m-1} \beta_3(\tau)\Delta Y_{t-1}^2 + \sum_{i=0}^{n-1} \beta_4(\tau)\Delta REC_{t-i} + \sum_{i=0}^{r-1} \beta_5(\tau)\Delta NEC_{t-i} + \epsilon_t(\tau) \qquad \text{Equation (4)}$$

Utilizing the Δ technique, collective short-term effect of the previous ecological footprints on the current ecological footprint is calculated by $\beta_* = \sum_{i=1}^{p-1} \beta_1$, however the collective short-term effect of contemporary and previous Y on the present stage of ecological footprint is captured as $\beta_* = \sum_{i=1}^{q-1} \beta_2$. The remaining cumulative short-term impact of previous and current renewable and non-renewable energy utilization on the current level of ecological footprint is estimated with the same method. Finally, the speed of adjustment coefficient ρ in equation-4 should be negative and significant [6].

Finally, in order to examine the long and short term asymmetric effect of economic growth, renewable and non-renewable energy consumption on ecological footprint, we apply the Wald test to check the below particular null and alternative hypotheses for the long and short term parameters. Following [6], few motivating facts appear from the earlier equations. Initially, the long and short term coefficients could be quantile-based, which indicates that QARDL procedure coefficient could be dissimilar on each quantile, representing that these coefficients could be impacted at every period. Also, the boundaries on the long and short term coefficient with and between the quantiles could be checked utilizing the Wald test [6].

4.2. Granger-Causality in Quantiles Test

In the economic literature, whether a variable is a precursor to another variable or not has been examined within the framework of causality analysis developed by Granger [57]. More generally, the Granger causality test assumes that the current value of the dependent variable is determined by itself and the lagged values of the independent variable. After Granger [57], many new causality tests were developed with various methods. In the current study, to examine the quantile-causal of ecological footprint with economic growth, renewable and non-renewable energy consumption, we apply Granger-causality in quantiles method recently introduced by Troster [56]. According to Granger [57], a variable X_i does not Granger-cause other variable Y_i if previous X_i does not support to estimate Y_i, giving the previous Y_i. We suppose that there is a explain vector $(N_i = N_i^y, N_i^x)' \in \mathbb{R}^e, s = o + q$, where N_i^x is the past indication group of $X_i N_i^x :=$

$(X_{i-1}, \dots, X_{i-q})' \in \mathbb{R}^q$. Moreover, the current study describes the null of Granger non-causality from X_i to Y_i as below:

$$H_o^{X \nrightarrow Y}: F_Y(y|N_i^Y, N_i^x) = F_Y\,(y|N_i^Y), \text{for all } y \in \mathbb{R}, \qquad \text{Equation (5)}$$

where $F_y(.|N_i^Y, N_i^X)$ is the provisional distribution purpose of Y_i providing (N_i^Y, N_i^X). Below the null from equation-5. According to [57], the we apply the D_T check by classifying the QAR method $m(\cdot)$ for complete $\pi \in \Gamma \subset [0,1]$, based on the null of non-Granger causal association as below:

$$QAR(1): m^1\left(N_i^Y, \partial(\pi)\right) = \lambda_1(\pi) + \lambda_2(\pi)\, X_{i-1} + \mu_t \Omega_Y^{-1}(\pi), \qquad \text{Equation (6)}$$

where the coefficient $\partial(\pi) = \lambda_1(\pi), \lambda_2(\pi)$ and μ_t are estimated by highest likelihood in an equal point of quantiles, and $\Omega_Y^{-1}(.)$ is the opposite of a conventional basic distribution function. To confirm the indication of causality between the factors, the current study estimates the QAR method in equation-6 with lagged factor to alternative factor. Lastly, the equation of QAR(1) model with the help of equation-6 is below:

$$Q_\pi^Y(Y_i|N_i^Y, N_i^X) = \lambda_1(\pi) + \lambda_2(\pi)\, Y_{i-1} + \eta(\pi) X_{i-1} + \mu_t \Omega_Y^{-1}(\pi). \qquad \text{Equation (7)}$$

5. DATA AND EMPIRICAL RESULTS

5.1. Data and Descriptive Statistics

In this current study, we empirically examine the role of renewable and non-renewable energy consumption on ecological footprint in EKC framework from 1965Q1 to 2017Q4 for Turkey. To this end, we use Gross Domestic Product (GDP), Renewable electricity consumption (RENC), Non-renewable electricity consumption (NENC) and Ecological footprint (EFP). Electricity consumption from renewable sources is used as a proxy of renewable electricity consumption while non-renewable electricity consumption is used as a proxy of non-renewable energy consumption. The RENC, NENC and GDP data are taken from the World Development Indicators (WDI). On the other hand, ecological footprint indicator is used as a proxy of environmental degradation. Economic footprint is often measured in global hectares and also serves as an economic indicator for environment. It shows the rate at which area of biological productive water, land, individual, activity and/or population needed to create entire resources consume by the environment and also to mop up waste produced, via prevailing resource management practices and technology. The EFP is a broader measure for environmental degradation relative to CO_2 which previous studies employed. The EFP indicator is procured from the Global Footprint Network. The aforementioned variables are converted into quarterly frequency from annual frequency by using quadratic match sum method and finally convert in natural log form. Also, all the variables are considered in per capita form.

<Insert Table-1 here>

Table 1 presents the results of the descriptive statistics and the correlation relationship of EFP with other selected variables (REC, NEC and GDP). The results show that the average of non-renewable energy utilization is more than renewables consumption in Turkey. Also, non-renewable energy shows the more variability than renewable energy while GDP has the highest variability among the selected variables. The positive correlation is found between EFP and other variables. The Jarque-Bera test rejects the null hypothesis of normal distribution for each variable under consideration at 1% significance level. Hence, the use of quantile techniques is suitable and necessary for this study.

5.2. Empirical Results and Interpretation

This section focuses on empirical result interpretation and discussion. Before performing the QARDL model, it is crucial to investigate the stationarity properties of the series. Since the distribution of the series is different from normal distribution. This present study follows the quantile unit root test techniques rather than to apply standard unit root test methods (such as Augmented Dickey Fuller (ADF), Phillips and Perron (PP) unit root test, etc.) to eliminate possible biased results and obtain robust inference [58]. Table 2 reports the quantile unit root test results of the variables under consideration for the study at different quantiles. As can be seen from the results, t-statistic value of each coefficient is numerically greater than the critical value. It means that the null hypothesis of $\alpha(\tau) = 1$ cannot be rejected at 5 % significance level for each quantile.

<Insert Table-2 here>

The QARDL model estimation results are presented in Table 3. The results show that the estimated speed of adjustment coefficient, ρ_*, is significantly negative at each quantile. This confirms the existence of reversion to the long-run equilibrium among ecological footprint, renewable energy consumption, non-renewable energy consumption, gross domestic product and the square of gross domestic product for Turkey. Specifically, the speed of adjustment (-0.337) is at the highest rate in the last quantile. The cointegration parameter of GDP is positive which means there is an upward trend long-run relationship between EFP and GDP at entire quantiles. However, the cointegration coefficient of GDP^2 is found statistically negative at all quantiles. In another ways, this result indicates an inverted U-shaped long-run relationship between GDP and GDP^2 to EFP establishing the EKC hypothesis in Turkey. While saying this, it also needs to be seen that the significance level of GDP^2 is gradually falling with rise in the quantiles. It signifies that the ecological sustainability started facing difficulty at the higher levels of economic growth. Moreover, the turnaround points of the EKCs start rising between 0.05-0.80 quantiles, and thereby, demonstrating the inefficiency of the existing energy and environmental policies in controlling the environmental degradation issues persisting in Turkey. This finding demonstrates the quantile-level desegregation of EKCs, and this aspect has never been analyzed in the literature of EKC hypothesis in Turkey. This finding extends the previous studies in this domain [59, 60, 61, 62, 63], and thereby, contributes to the literature. Although the long-run relationship between REC and EFP is not statistically significant in the lower quantiles, the results support that REC has a negative impact on EFP after the second quantile. In another way, increasing renewable energy consumption will help to decrease ecological footprint in the long-run. This result confirms that consumption of renewable energy as a veritable tool to reduce environmental degradation and the threat of climate change in Turkey. Conversely, the empirical results show that the coefficient of non-renewable energy consumption has positive impact on ecological footprint at all quantiles. Also, results reveal that the magnitude of the impact of non-renewable energy consumption on ecological footprint is greater than the impact of renewable energy consumption. The results are consistent with the studies of [64, 65, 66, 67, 68, 69, 70]. However, the significance levels and magnitude of impact of renewable energy consumption provide us with certain significant insights. At the quantiles of 0.05-0.10, the impact of renewable energy consumption is not significant, whereas at the quantiles of 0.20-0.40, the significance levels of the impact are low. Beyond quantile 0.40, the significance level has increased, along with the magnitude of impact. This shows that low penetration of renewable energy might have no or very low impact on ecological footprint and with the rise in penetration level, the impact starts to increase. This finding about the decomposed impact of renewable energy consumption on the ecological footprint of Turkey can be considered as a contribution to the literature, as according to our knowledge, no study has divulged this aspect earlier.

According to the short-run dynamics, the results indicate that past values of ecological footprint has significant and positive effect on the current ecological footprint at each quantile. The contemporaneous changes in GDP have positive impact on the current ecological footprint only at the lower quantiles. On the other hand, past changes of GDP and current changes of GDP^2 do not have any impact on the current ecological footprint at all quantiles. The empirical piece of evidence supports the study of [71] for the case of Turkey. Moreover, the results reveal current ecological footprint changes are significantly and negatively affected by current renewable and nonrenewable energy consumption in the lower quantiles. Contrarily, past changes of both renewable and non-renewable energy consumption do not have significant impact on the current changes in ecological footprint.

<Insert Table-3 here>

This study used Wald test to examine the parameter constancy (i.e. linearity) of the estimated parameters as reported in Table 4. Regarding to the results, the null hypothesis of parameter constancy of the speed of adjustment parameter is rejected at 1% significance level. Also, the null of linearity across the different tails of each quantiles for the long-run parameters of the variables under review are rejected. Thus, we infer that the long-run parameters between ecological footprint and gross domestic product, the square of gross domestic product, renewable, non-renewable energy consumption are dynamic in various quantiles for Turkey. This outcome might be as results of structural changes in macroeconomic indicators in Turkey over the sample period. For instance, the early 2000s macroeconomic changes in the architecture of the Turkish economy like 2002 liberalization which was far from last 2 to 3 decades [72]. Correspondingly, the Wald test rejects the null hypothesis of linearity of the short-run cumulative influence of the past levels of ecological footprint over the examined quantiles. Furthermore, the results show that GDP, REC and NENC have nonlinear contemporaneous effect on ecological footprint as the Wald test reject the null hypothesis of parameter linearity across the quantiles. In contrast, GDP, REC and NENC have linear past impact on ecological footprint for Turkey. In addition, the findings reveal the cumulative short-run effect of GDP, REC and NENC on ecological footprint is non-linear (asymmetric) at the 1% level of significance across the quantiles.

<Insert Table-4 here>

<Insert Table-5 here>

Table 5 provides the p-values of the Granger-causality in Quantile test results. Considering the overall quantiles i.e. [0.05-0.95], we found a bi-directional causal relationship among the consider variables in Turkey. The findings indicate that contemporaneous and past realizations of economic growth (GDP) are better predictor of ecological footprint and vice versa. This implies that Turkey is still at the scale stage of its growth trajectory, where emphasis is on economic growth relative to environmental degradation [73]. In addition, the empirical piece of evidence from the Quantile causality test result shows that there exists two-way causality between nonrenewable energy consumption and ecological footprint across all the tails of quantiles. These results are consistent with the studies of [74, 75, 50]. However, we observed a one-way causality running from renewable energy consumption to ecological footprint at the all quantiles while also one-way causal link from ecological footprint to renewables use at the upper quantiles. This finding complements the finding of the QARDL test, as at the lower quantiles, the impact of renewable energy consumption is yet to be realized, and this is reflected in terms of the non-causality from ecological footprint to renewable energy consumption. The notional demand of renewable energy consumption arising out of the rise in ecological footprint is visible beyond the quantile of 0.50, and this divulges the policy-level ineffectiveness in terms of creating the demand of renewable energy consumption at the low penetrated areas.

6. CONCLUSION AND POLICY IMPLICATIONS

The current study re-investigates the impact of renewable and non-renewable energy consumption in testing EKC in Turkey by taking quarterly data from 1965 to 2017. This study applies Quantile Autoregressive Lagged (QARDL) approach introduced by Cho et al [6]. This analysis is used because it checks that how a variety of quantiles of renewable energy, non-renewable energy and economic growth affect ecological footprint, thus giving a more detailed explanation of the general dependence of renewable energy, non-renewable energy and EKC matched to traditional techniques such as OLS or quantile regression. We also have investigated causality in Quantiles proposed by Troster [56] to determine the causal link among the renewable energy, non-renewable energy, economic growth and ecological footprint and the vice versa.

The results of QARDL show that error correction parameter is statistically significant with the expected negative sign for all quantiles. This indicates that there is a presence of significant reversion to the long-term connection between the related variables and ecological footprint in Turkey. In particular, the outcomes suggested that renewable energy decrease ecological footprint in long-term on each quantile. However, the results of economic growth and non-renewable energy impact positively to ecological footprint at lower quantiles to upper quantiles. This implies that in long-term, economies at different level of growth carry greater damage to the environment. As for energy consumption, the results imply that increase in power utilization brings positive influence on ecological footprint in long-term. In addition to this, the results of short-term dynamics confirmed an asymmetric short-run influence of renewables and economic growth on ecological footprint. Finally, we tested the EKC hypothesis and the results of QARDL confirmed that economic growth shows positive impact, and square of economic growth shows negative impact on ecological footprint which supports the EKC hypothesis. Therefore, the inverted U-shaped connection between economic growth and ecological footprint is verified. Furthermore, the findings of causal investigation from *Granger*-causality in quantiles demonstrate the presence of a bi-directional causality between renewable energy usage, energy usage and economic growth with ecological footprint in Turkey.

If the empirical outcomes are carefully scrutinized, then a number of policy implications for sustainable development come to pass. As the environmental quality is prone towards deterioration at the higher levels of income, then it can be assumed that the growth trajectory being attained by Turkey is not sustainable. One of the major reasons behind this is the consumption of fossil fuel-based energy, and this is evident from the empirical outcome. On the other hand, low penetration of renewable energy solutions is having low or no significant impact on the ecological footprint, and this shows the policy level ineffectiveness in diffusing the renewable energy solutions. One straightforward solution can be replacement of fossil fuel based solutions with renewable energy solutions, but this solution might not be practicable, as this solution can have a negative impact on the economic growth pattern itself. Therefore, the policy level solution can be devised based on the different levels of quantiles, and therefore, the solution can be designed in a phase-wise manner. We will now discuss those phases.

Let us begin with the low quantiles of income. At these levels, the turnaround points of EKCs are comparatively lower than that of the higher quantiles. Therefore, at this level, the policy level probing might be effective, as lower turnaround points of EKCs might help to internalize the negative externalities caused by the growth trajectory. This can be achieved by helping renewable energy consumption to reach its desired potential, by enhancing the level of its acceptance among the industry and households. This can be achieved through people-public-private participation for enhancing the level of environmental awareness among the citizens. While doing this, the government can provide the renewable energy solutions to the households at a pro-rata rate with certain period of interest rate holiday. This decision might gradually enhance the acceptability of renewable energy solutions among the households. In order to complement this policy, the government might amend the educational curriculums for providing more stress on the ecological benefits of renewable energy solutions. This combination of two policies might help the government to attract more people towards scientific development of alternate energy solutions, and possibly, Turkey might experience a rise in the renewable energy generation firms. This might help Turkey in moving towards attaining the objective of SGD 4, by gradually enhancing the academic outcome in science. However, in the first phase, there will be certain economic losses, which might be reflected in the fiscal deficit. The losses might be recovered in the second phase, where higher quantiles of income can be targeted. At this phase, economic growth trajectory is more prone towards environmental degradation, and therefore, at this phase, the industries will be targeted. Industries might be provided with two options: (a) avail the renewable energy solutions from the government, at a higher rate interest than that of the households, and (b) provide higher rate of interest on the loans and advances for the projects, which are driven by fossil fuel-based energy solutions. In this way, the industries will be gradually discouraged to use the fossil fuel-based solutions, and they will gradually move towards using the renewable energy solutions. Now, the existing renewable energy generation infrastructure might not be sufficient enough to cater to the rise in the demand of renewable energy solutions. In such a scenario, the industries will have to rely on the renewable energy generation firms, which were created during the first phase of this policy implementation. It will enhance the domestic competition in the renewable energy generation market, which might result in rise in the R&D and patents in this pursuit, and thereby, moving towards attaining the objective of SDG 9. Lastly, in the third phase, the government should bring forth proper rules and legislations to have a control over the competition in this market, progressively taxing the fossil fuel solutions, gradually improving the educational curriculums for institutionalizing the ecological awareness through scientific innovations, and encouraging new firms to enter the renewable energy generation segment. Once these policy level measures are in place, the contamination of land and water will gradually come down, ambient air pollution will come down, and eventually the objectives of SDG 13, SDG 14, and SDG 15 will be achieved. In this way, Turkey will be progressing towards attaining the sustainable development objectives, where they are presently falling behind.

Table 1: Results of Descriptive Statistics

Variables	Mean	Min.	Max.	Std. Dev.	J-B Stats	Correlation
EFP	2.450	1.588	3.360	0.518	13.683***	-
RENC	6.487	0.524	17.823	4.804	13.398***	0.945***
NENC	307.090	34.805	715.383	224.213	20.608***	0.967***
GDP	1864.178	848.617	3842.456	743.013	26.614***	0.965***

Note: The asterisk *** shows the level of significance at 1%

Source: Authors Estimations

Table 2: Results of Quantile Unit Root test

Quantile	EFP			RENC			NENC			GDP			GDP2		
	α(τ)	t-stats	C.V	α(τ)	t-stats	C.V	α(τ)	t-stats	C.V	α(τ)	t-stats	C.V	α(τ)	t-stats	C.V
0.05	0.862	-2.456	-3.027	0.812	-2.145	-2.377	0.803	-1.872	-2.705	0.963	-0.775	-2.489	0.953	-0.767	-2.462
0.10	0.896	-1.758	-2.839	0.707	-1.136	-2.377	0.810	-2.507	-2.745	0.929	-0.984	-2.769	0.919	-0.973	-2.739
0.15	0.868	-2.322	-2.996	0.739	-0.607	-2.377	0.817	-2.514	-2.755	0.971	-0.570	-2.911	0.961	-0.564	-2.880
0.20	0.876	-2.113	-2.949	0.842	-0.466	-2.379	0.824	-2.626	-2.942	0.920	-1.280	-2.966	0.910	-1.266	-2.934
0.25	0.836	-2.715	-2.774	0.881	-0.302	-2.377	0.847	-2.274	-3.085	0.860	-1.841	-3.094	0.850	-1.821	-3.060
0.30	0.856	-2.555	-2.843	0.881	-0.025	-2.377	0.859	-2.339	-3.032	0.909	-1.245	-3.064	0.899	-1.231	-3.031
0.35	0.860	-2.476	-2.855	0.942	1.137	-2.377	0.826	-1.597	-3.093	0.868	-1.656	-3.081	0.858	-1.638	-3.048
0.40	0.887	-2.001	-2.851	0.953	1.368	-2.377	0.872	-1.674	-3.143	0.855	-1.714	-3.087	0.846	-1.695	-3.054
0.45	0.890	-1.962	-2.552	0.963	1.423	-2.430	0.963	-1.588	-3.228	0.793	-2.292	-3.189	0.785	-2.267	-3.155
0.50	0.895	-1.885	-2.700	0.975	1.279	-2.623	0.944	-1.335	-3.144	0.815	-2.016	-3.125	0.806	-1.994	-3.091
0.55	0.915	-1.585	-2.593	0.995	1.475	-2.726	0.903	-0.828	-3.015	0.793	-2.045	-2.964	0.785	-2.023	-2.932
0.60	0.927	-1.522	-2.377	1.021	2.731	-2.650	0.843	-0.200	-3.124	0.825	-1.782	-2.961	0.816	-1.762	-2.929
0.65	0.910	-1.612	-2.377	1.003	2.431	-2.562	0.861	-0.707	-3.043	0.835	-1.796	-2.900	0.826	-1.777	-2.868
0.70	0.938	-1.510	-2.436	0.977	1.891	-2.528	0.860	-1.366	-2.972	0.800	-1.901	-2.867	0.791	-1.880	-2.836
0.75	0.898	-1.715	-2.454	1.030	1.630	-2.377	0.857	0.017	-2.832	0.786	-2.362	-2.929	0.778	-2.336	-2.897
0.80	0.893	-1.839	-2.491	1.056	1.968	-2.472	0.920	0.612	-2.765	0.770	-2.678	-2.840	0.762	-2.649	-2.809
0.85	0.921	-1.656	-2.425	1.103	2.908	-2.455	1.031	1.855	-2.683	0.777	-2.471	-2.706	0.769	-2.444	-2.677
0.90	0.927	-1.443	-2.377	1.055	2.905	-2.377	1.068	0.434	-2.456	0.737	-2.111	-2.533	0.729	-2.088	-2.505
0.95	0.942	-1.252	-2.377	1.100	5.525	-2.377	0.928	0.985	-2.641	0.766	-2.260	-2.377	0.757	-2.235	-2.351

Source: Authors Estimations

Table 3: Results of Quantile Autoregressive Distributed Lag (QARDL) for Turkey

Quantiles (τ)	$\alpha_*(\tau)$	$\rho_*(\tau)$	$\beta_{GDP}(\tau)$	$\beta_{GDP2}(\tau)$	$\beta_{REC}(\tau)$	$\beta_{NEC}(\tau)$	$\varphi_1(\tau)$	$\omega_0(\tau)$	$\omega_1(\tau)$	$\lambda_0(\tau)$	$\theta_0(\tau)$	$\theta_1(\tau)$	$\delta_0(\tau)$	$\delta_1(\tau)$
0.05	0.302***	-0.284***	0.416***	-0.247***	-0.004	0.402***	0.274***	0.201***	0.004	-0.048	-0.384***	-0.150	0.218***	0.005
	(3.398)	(-4.284)	(6.486)	(-3.785)	(-1.362)	(7.485)	(3.495)	(3.475)	(0.486)	(-0.597)	(-4.395)	(-1.457)	(4.583)	(0.473)
0.10	0.307***	-0.289***	0.411***	-0.235***	-0.089	0.416***	0.280***	0.194***	0.004	-0.043	-0.332***	-0.099	0.194***	0.005
	(3.403)	(-4.485)	(6.295)	(-3.635)	(-1.495)	(6.894)	(3.572)	(3.138)	(0.443)	(-0.603)	(-4.024)	(-0.898)	(3.968)	(0.576)
0.20	0.312***	-0.292***	0.409***	-0.214***	-0.138*	0.412***	0.283***	0.005	0.003	-0.041	-0.283***	-0.085	0.184**	0.018
	(3.483)	(-4.593)	(6.129)	(-3.084)	(-1.748)	(6.968)	(3.596)	(0.384)	(0.395)	(-0.683)	(-3.894)	(-0.784)	(2.394)	(0.895)
0.30	0.319***	-0.295***	0.395***	-0.208***	-0.174*	0.428***	0.289***	0.004	0.007	-0.038	-0.219**	-0.078	0.085	0.029
	(3.416)	(-4.674)	(6.009)	(-2.975)	(-1.885)	(6.586)	(3.554)	(0.321)	(0.386)	(-0.725)	(-2.274)	(-1.294)	(1.379)	(0.994)
0.40	0.322***	-0.298***	0.387***	-0.201***	-0.239**	0.434***	0.291***	0.010	0.009	-0.028	-0.020	-0.059	0.077	0.048
	(3.543)	(-4.429)	(5.994)	(-2.884)	(-2.263)	(6.685)	(3.694)	(0.584)	(0.367)	(0.738)	(-1.483)	(-1.049)	(1.245)	(1.038)
0.50	0.329***	-0.307***	0.368***	-0.197***	-0.274***	0.439***	0.297***	0.013	0.013	-0.020	-0.018	-0.007	0.045	0.078
	(3.459)	(-4.184)	(5.753)	(-2.586)	(-2.774)	(6.699)	(3.654)	(0.448)	(0.375)	(-0.784)	(-1.183)	(-0.984)	(1.004)	(1.185)
0.60	0.337***	-0.305***	0.362***	-0.176**	-0.294***	0.441***	0.304***	-0.006	0.015	-0.020	-0.012	-0.021	0.032	0.098
	(3.280)	(-4.098)	(5.226)	(-2.194)	(-2.894)	(6.894)	(3.783)	(-0.896)	(0.473)	(-0.832)	(-1.083)	(-0.894)	(1.238)	(1.286)
0.70	0.338***	-0.313***	0.358***	-0.155**	-0.302***	0.456***	0.312***	-0.005	0.011	-0.018	-0.010	-0.032	0.089	0.135
	(3.254)	(-3.974)	(5.053)	(-2.119)	(-3.374)	(7.095)	(3.802)	(-0.876)	(0.498)	(-0.857)	(-0.898)	(-0.854)	(1.485)	(1.364)
0.80	0.340***	-0.318***	0.351***	-0.174*	-0.374***	0.459***	0.319***	0.007	0.018	-0.015	-0.008	-0.043	0.153	0.179*
	(3.205)	(-3.945)	(4.732)	(-1.883)	(-3.884)	(7.119)	(3.884)	(0.473)	(0.549)	(-0.873)	(-0.837)	(-0.790)	(1.532)	(1.843)
0.90	0.341***	-0.321***	0.342***	-0.186*	-0.394***	0.462***	0.319***	0.032	0.014	-0.011	-0.005	-0.069	0.194**	0.187*
	(3.200)	(-3.856)	(4.119)	(-1.824)	(-4.184)	(7.194)	(3.475)	(0.334)	(0.596)	(-0.895)	(-0.813)	(-1.003)	(1.994)	(1.886)
0.95	0.347***	-0.337***	0.339***	-0.204*	-0.402***	0.462***	0.320***	0.039	0.012	-0.006	-0.003	-0.104	0.249**	0.201**
	(3.196)	(-3.774)	(3.989)	(-1.803)	(-4.083)	(7.039)	(3.412)	(0.475)	(0.632)	(-0.935)	(-0.783)	(-1.195)	(2.483)	(2.028)

Note: The t-statistics are between parentheses. ***, ** and * specify significance at the 1%, 5% and 10% levels, respectively.
Source: Authors Estimations

Table 4: Results of the Wald Test for the constancy of parameters

Variables	Wald-statistics
ρ	7.377*** (0.000)
β_{GDP}	5.273*** (0.000)
β_{GDP}^2	1.891** (0.050)
β_{REC}	4.823*** (0.000)
β_{NEC}	4.260*** (0.000)
φ_1	2.142** (0.024)
ω_0	2.789*** (0.002)
ω_1	1.361 (0.201)
λ_0	0.510 (0.883)
θ_0	3.974*** (0.000)
θ_1	0.952 (0.491)
δ_0	4.478*** (0.000)
δ_1	1.300 (0.232)
Cumulative short-term effect:	
ω*	8.385*** (0.000)
θ*	6.496*** (0.000)
δ*	7.382*** (0.000)

Note: The p-values are between parentheses. ***, ** and * specify significance at the 1%, 5% and 10% levels, respectively.
Source: Authors Estimations

Table 5: Results of Granger-Causality in Quantile Test

Quantiles	ΔGDP_t ↓ ΔEFP_t	ΔEFP_t ↓ ΔGDP_t	ΔREC_t ↓ ΔEFP_t	ΔEFP_t ↓ ΔREC_t	ΔNEC_t ↓ ΔEFP_t	ΔEFP_t ↓ ΔNEC_t
[0.05-0.95]	0.000	0.000	0.000	0.000	0.000	0.000
0.05	0.000	0.000	0.000	0.134	0.000	0.000
0.10	0.000	0.000	0.000	0.121	0.000	0.000
0.20	0.000	0.000	0.000	0.110	0.000	0.000
0.30	0.000	0.000	0.000	0.142	0.000	0.000
0.40	0.000	0.000	0.000	0.109	0.000	0.000
0.50	0.000	0.000	0.000	0.140	0.000	0.000
0.60	0.000	0.000	0.000	0.026	0.000	0.000
0.70	0.000	0.000	0.000	0.013	0.000	0.000
0.80	0.000	0.000	0.000	0.008	0.000	0.000
0.90	0.000	0.000	0.000	0.006	0.000	0.000
0.95	0.000	0.000	0.000	0.003	0.000	0.000

Source: Authors Estimations

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