The Impact of Environmental Taxes on Renewable Energy Consumption in Türkiye: A Fourier-Based Approach

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ABSTRACT

One of the most important measures to mitigate global climate change, a major problem of our time, is to transform the energy mix into an environmentally friendly one. This means reducing reliance on fossil fuels, which account for a large share of countries' energy mixes, and replacing them with renewable energy sources. Such a transition will also contribute to reducing harmful emissions that pollute the environment and thereby threaten environmental sustainability. Therefore, the role of fiscal instruments implemented by countries to increase the energy obtained from renewable sources is becoming increasingly important. The primary focus of this study is to examine the influence of environmental taxes on renewable energy consumption in Türkiye using annual data from 1994 to 2023. Thus, it is determined whether environmental taxes, which are punitive or incentive-based, are effective in influencing renewable energy consumption. In addition to environmental taxes, the analysis also examines the role of economic growth, green innovation, and financial development, which are important determinants of renewable energy. Methodologically, a Fourier-based econometric approach that accounts for smooth structural breaks is employed. According to the results, environmental taxes, financial development, and green innovation positively affect renewable energy consumption. However, no statistically significant relationship was found between economic growth and renewable energy consumption. Overall, the results suggest that environmental taxes implemented in Türkiye are useful tools for shifting the energy mix toward a more environmentally friendly composition.

Key Words: *Environmental Taxes, Renewable Energy Consumption, Economic Growth, Financial Development*

JEL Classification: *H23, Q28, Q58, C32*

Türkiye'de Çevre Vergilerinin Yenilenebilir Enerji Tüketimi Üzerindeki Etkisi: Fourier Temelli Bir Yaklaşım

ÖZ

Günümüzün en önemli sorunlarından biri olan küresel iklim değişikliyle mücadele etmenin en önemli yollarından biri enerji bileşimini çevre dostu yapıya dönüştürmektir. Bunun anlamı ülkelerin enerji kompozisyonu içerisinde yüksek paya sahip olan fosil yakıtların azaltılarak yenilenebilir enerjiyle ikame edilmesidir. Böylesi bir geçiş, çevresel kirliliğe yol açan ve dolayısıyla çevresel sürdürebilirliği tehdit eden zararlı emisyonların azaltımına da katkı sağlayacaktır. Dolayısıyla ülkelerin yenilenebilir kaynaklardan elde edeceği enerjinin arttırılması için uyguladıkları mali enstrümanların rolü önem kazanmaktadır. Bu kapsamda, bu araştırmanın ana odak noktası Türkiye'de 1994-2023 dönemi yıllık verilerini kullanarak çevre vergilerinin yenilenebilir enerji tüketimi üzerindeki etkisini ortaya koymaktır. Böylelikle cezalandırıcı veya teşvik edici doğaya sahip olan çevre vergilerinin yenilenebilir enerji tüketimini etkilemede etkili olup olmadığı açığa

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çıkarılmaktadır. Ayrıca analiz sürecinde çevre vergilerinin yanı sıra yenilenebilir enerjinin önemli belirleyicilerinden ekonomik büyüme, finansal gelişme ve yeşil inovasyonun rolü de incelenmektedir. Metodolojik olarak yumuşak yapısal kırılmaları dikkate alan Fourier temelli ekonometrik yaklaşım takip edilmektedir. Elde edilen sonuçlara göre, çevre vergileri, finansal gelişme ve yeşil inovasyon yenilenebilir enerji tüketimini arttırıcı bir etkiye sahiptir. Bununla birlikte ekonomik büyüme ile yenilenebilir enerji tüketimi arasında istatistiksel olarak anlamlı bir ilişkinin olmadığı tespit edilmiştir. Genel olarak sonuçlar, Türkiye'de uygulanan çevre vergilerinin enerji bileşiminin çevre dostu olacak bir şekilde değiştirilmesi sürecinde faydalı bir araç olduğunu ima etmektedir.

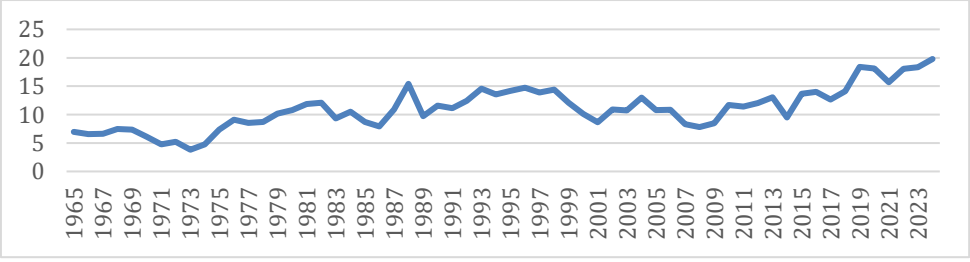
Anahtar Kelimeler: *Çevre Vergileri, Yenilenebilir Enerji Tüketimi, Ekonomik Büyüme, Finansal Gelişme*

JEL Sınıflandırması: *H23, Q28, Q58, C32*

INTRODUCTION

One of the most critical aspects of combating global climate change is the high dependence on fossil fuels within countries' energy systems. Although this dependence is decreasing gradually, it still remains high. According to Our World in Data (2025a), the share of fossil fuels in total energy consumption is projected to be 81.26% in 2024. This rate was 93.75% in 1965, by 2024, more than half a century later, it had decreased by only 13.32%. Therefore, focusing on policy designs that both reduce environmental pollution from fossil fuels (e.g., CO_2 and other GHGs) and promote renewable energy (REN) to encourage environmental sustainability is vitally important. In policy design, the role of environmental taxes (ETAX) is prominent. Historically, ETAX, whose theoretical foundations are based on Pigou's (1920) groundbreaking work, are also referred to as "Pigouvian taxation" in the literature of public finance. ETAX, a public economics tool for internalizing negative externalities (such as environmental pollution), are based on the "polluter pays" principle. Furthermore, ETAX's role is not limited to this. Indirectly, as Porter and Van der Linde (1995) suggest, they encourage firms to develop new technologies. Based on this theoretical background, ETAX both discourages the use of conventional fossil-based fuels and technologies and encourages the adoption of environmentally friendly energy technologies. ETAX makes REN sources more attractive than fossil fuels by incorporating the external costs of pollution through the price mechanism. This creates an incentive for economic units to transit from dirty energy to clean energy. Furthermore, the adoption of REN has been increasing because of innovation-driven cost reductions. Thus, ETAX is expected to play an important role in increasing the share of REN in the total energy mix over the long term (Aydin and Bozatli, 2023; Fang et al., 2022).

Figure 1. REN sources in Türkiye (% equivalent primary energy)



Source: Our World in Data (2025b)

As a developing country, Türkiye has experienced a significant increase in energy demand, driven by rapid industrialization and population growth. Increasing the share of REN in Türkiye's energy mix is crucial for reducing its dependence on foreign energy and ensuring energy security. Furthermore, given Türkiye's 2053 net-zero emissions target, its harmonization with the European Union's Green Deal, and its status as a party to the Paris Agreement, Türkiye must more effectively utilize environmental policy tools for REN investment, production, and consumption. As shown in Figure 1, the share of REN in Türkiye's primary energy consumption reached 19.79% by 2024. The recent upward trend in the proportion of REN represents a step toward these stated goals. In this context, determining the degree to which ETAX, as applied in Türkiye, supports the established goals and the green energy transition is crucial for policy design.

While previous literature has examined the effects of ETAX on renewable energy consumption (REC) at the country or panel level using various methods, no studies that conduct time-series analyses for Türkiye have been identified. Studies on REN in Türkiye (Çelikkaya, 2017; Yurdadoğ and Tosunoğlu, 2017; Çelikkaya, 2018; Ulusoy and Daştan, 2018; Kaya and Bayraktar, 2021; Akdoğan and Kovancılar, 2022; Çelebi and Cura, 2023; Pala, 2024; Demir, 2025) have examined the effects of tax incentives and subsidies. Therefore, whether the ETAX policies pursued in Türkiye have an impact on REN remains unclear. This situation motivates the present study and suggests that it will contribute to the existing literature in the areas as follows: (I) To the best of our knowledge, this article is the first in the literature to analyze the ETAX-REC nexus in Türkiye. While the main objective is to fill the gap in the literature, this study is expected to provide policymakers and researchers with insights for policy design and to lay the groundwork for future research. (II) When investigating the impact of ETAX, key determinants of REN are also tested based on empirical and theoretical literature. Accordingly, the econometric model is designed to take into account the role of green innovation, economic growth (EG), and financial development. Thus, the influence of the relevant policy set is considered in its entirety. (III) Methodologically, a Fourier-based framework is employed. This choice is made because the relevant methods allow consideration of shocks or structural changes occurring within the period under consideration and enable more reliable estimation. Ignoring the impact of frequently occurring crises or policy changes, especially in countries such as Türkiye, can lead to misleading results and incorrect policy recommendations.

The following sections of the study consist of a literature review, a model and methodology, empirical findings, and conclusion and policy implications.

I. LITERATURE REVIEW

This section of the study presents, discusses, and evaluates empirical research on REC. Table 1 summarizes the relevant empirical literature.

Table 1. Empirical Literature Review

Author(s)	Sample	Method	Findings
Sadorsky (2009a)	G-7 (1980-2005)	PD	EG (+) CO_2 (+)
Sadorsky (2009b)	18 Emerging Countries (1994-2013)	PD	EG (+)
Omri and Nguyen (2014)	64 Countries (1990-2011)	PD	EG (x) CO_2 (+) TOP (+) OIL (-)
Balcilar et al. (2018)	G-7 (1960-2015)	Bootstrap Historical Decomposition	EG (+)
Eren et al. (2019)	India (1971-2015)	Time Series Techniques	EG (+) FD (+)
Ankrah and Lin (2020)	Ghana (1980-2015)	Time Series Techniques	EG (x) FD (-)
Anton and Afloarei Nucu (2020)	EU (1990-2015)	PD	EG (x) FD (+)
Khan et al. (2021)	Belt and Road Countries (2000-2014)	PD	EG (-) FD (+) GI (-)
Shahbaz et al. (2021)	Upper-middle-income countries (1994-2015)	PD	EG (-) FD (+)
Shahzad et al. (2021)	Developed Countries (1994-2018)	PD	ETAX (+) GI (+) EG (+) ER (+)
Usman et al. (2022)	EU (2005-2018)	PD	GI (+)
Shang et al. (2022)	USA (2000-2021)	ARDL	EG (+)
Somoye et al. (2022)	Nigeria (1960-2019)	ARDL	EG (+) FD (+)
Fang et al. (2022)	Belt and Road Countries 1998-2019	PD	ETAX (+) GI (+) EG (+) FD (+)
Bashir et al. (2022)	OECD 1996-2018	PD	ETAX (-) GI (+) EG (+) ER (-) FD (+)
Abbas et al. (2023)	China (2012-2021)	Time Series Techniques	ETAX (+) GF (+) GR (-)
Usman et al. (2023)	EU (2005-2018)	PD	GI (+) FDI (+)
Aydin and Bozatli (2023)	OECD (1994-2019)	PD	ETAX (+) GI (+) EG (+) FD (+)
Dogan et al. (2023)	EU (1995-2019)	PD	ETAX (-) CO_2 (-) OIL (+) EG (+)
Ameer et al. (2024)	E-7 (1990-2020)	PD	ETAX (-) GI (-) EG (+) CO_2 (+)
Degirmenci and Yavuz (2024)	EU (1995-2019)	PD	ETAX (x) GI (x) EG (x)
Alam et al. (2024)	India (1980-2023)	Augmented ARDL	URB (x) GI (+) EG (x) CO_2 (x)
Yin and Qamruzzaman (2024)	BIMSTEC (1965-2021)	PD	URB (+) FD (+)
Degirmenci et al. (2024)	OECD (1990-2018)	PD	GI (x) ER (+)
Can et al. (2024)	China (1990-2019)	Bootstrap ARDL	EG (-) GI (+)
Adem and Çetin (2024)	African Countries (1980-2018)	PDA	EG (+) FD(-) FDI(+) TOP(+)
Wang and Pang (2025)	OECD (2000-2020)	PD	ETAX (+) GI (+) EG (+)
Purohit and Baxi (2025)	G-20 (2001-2020)	PD	ETAX (+)
Aydin et al. (2025)	EU (1994-2019)	PD	ETAX (x) GI (x) EG (x)
Fodol et al. (2025)	Nigeria (1990-2022)	ARDL	EG (+) CO_2 (+)
Eyuboglu and Uzar (2025)	Italy (1970-2022)	Fourier Augmented ARDL	EG (+) CO_2 (-)
Gerni et al. (2025)	Newly Industrialized Countries (1998-2021)	PD	ETAX (+) EG (-) EFP (-) FD (x)

Notes: *The symbols (+), (–), and (x) imply positive, negative, and statistically insignificant relationships, respectively. PD: Panel Data, EG: Economic Growth, CO_2: Carbon Emissions, TOP: Trade Openness, OIL: Oil Prices, FD: Financial Development, ETAX: Environmental Taxes, GI: Green Innovation, ER: Environmental Regulations, GF: Green Finance, GR: Geopolitical Risk, FDI: Foreign Direct Investment, URB: Urbanization, EFP: Ecological Footprint*.

First, based on the empirical findings in Table 1, the following inferences can be drawn regarding ETAX. ETAX, one of the fiscal instruments that, in theory, help reduce environmental pollution to an optimal level by internalizing negative externalities (Pigou, 1920), is also frequently emphasized as an incentive for the transition to environmentally friendly clean energy sources (Degirmenci et al., 2025). Porter and Van der Linde (1995) predict that well-designed environmental regulations will stimulate firms to innovate, increase energy efficiency, and accelerate the transition to REN (Bozatli and Akca, 2024). Therefore, these theoretically expected positive effects of ETAX are closely related to its optimal design. To date, the empirical literature remains divided on the impact of ETAX on REC. Some researchers (Shahzad et al., 2021; Aydin and Bozatli, 2023; Wang and Pang, 2025; Fang et al., 2022; Purohit and Baxi, 2025; Gerni et al., 2025) find that ETAX have a positive impact, which confirms their role as a driving force in the transition to REN. In contrast, other researchers (Bashir et al., 2022; Ameer et al., 2024; Dogan et al., 2023; Degirmenci and Yavuz, 2024; Aydin et al., 2025) find that ETAX do not always have the theoretically expected impact, suggesting that they are not effective policies on their own and may reflect problems in policy design. Therefore, the impact of ETAX and REC remains unclear in the empirical literature, and no study has specifically examined Türkiye using time-series techniques. Only Gerni et al. (2025) included country-specific results for Türkiye in their study of newly industrializing countries. Accordingly, ETAX and EG in Türkiye positively affect REC, whereas financial development negatively affects it.

The relationship between EG and REC is one of the most frequently discussed topics in the literature. The expansion of economic activity is closely linked to energy demand. Accordingly, given the theoretical origins of the "Environmental Kuznets" hypothesis of Grossman and Krueger (1991), energy demand—and therefore pollution— increases in the early stages of EG. However, as income exceeds a certain threshold, this negative impact is reversed as public environmental awareness and demand for environmentally friendly technologies and energy increase. Therefore, based on this hypothesis, EG is expected to have a positive indirect effect on REC. However, the large share of fossil fuels in countries' energy mix and their high dependence on them (Bozatli et al., 2025) may lead to a negative, or even null, effect of income growth. Consequently, increases in income or EG raise energy demand, but their effect on energy efficiency and REN use remains uncertain. At this point, the empirical literature, unlike the ETAX literature, is closer to a consensus on the effect of EG on REC. Numerous researchers have demonstrated that an increase in EG encourages REC. However, some researchers emphasize that the effect in question may be negative (Gerni et al., 2025; Shahbaz et al., 2021) or statistically insignificant (Omri and Nguyen,

2014; Ankrah and Lin, 2020; Degirmenci and Yavuz, 2024; Alam et al., 2024; Aydin et al., 2025).

It is argued that financial development is critical for supporting REN production and consumption (Aydin and Bozatli, 2023). Due to the high initial costs and technology-intensive nature of REN investments, financing them — and, therefore, the development of a country's financial structure — is crucial. Accordingly, in nations with advanced financial systems, the effectiveness, accessibility, and institutional structure of funds can encourage REN investment and use. Conversely, in countries with insufficient financial development, the incentive mechanism may not work. In this context, the empirical literature overwhelmingly confirms the stimulating effect of financial development on REC. Only Ankrah and Lin (2020) (for Ghana) and Gerni et al. (2025) (for newly industrializing countries) report that this relationship is, respectively, negative and statistically insignificant.

Finally, green innovation, or environmental patent, is an important determinant of REN investments, production, and consumption because of its technology-intensive nature. Accordingly, green innovation can accelerate the transition to and adoption of REN by reducing costs, promoting energy efficiency, and developing new technologies. The relative majority of researchers empirically examining the impact of green innovation on REC report a positive relationship. Other researchers (Aydin et al., 2025; Ameer et al., 2024; Degirmenci and Yavuz 2024) note that the effect of green innovation may be harmful or statistically insignificant.

Findings in the empirical literature allow for the following general and specific conclusions: Firstly, it is difficult to identify a clear relationship or effect between ETAX and REC. A significant number of researchers have concluded that ETAX is ineffective. There may be many reasons for such a conclusion. For example, the flawed design of ETAX may neither deter the use of conventional, highly polluting fossil fuels nor encourage the widespread adoption of REN. Therefore, factors affecting REN may not produce the predicted policy effects depending on the country's conditions and the period under consideration. Similar conclusions apply to EG, financial development, and green innovation. Another noteworthy point in empirical research is the lack of previously presented evidence, based on time-series techniques, regarding the impact of ETAX in Türkiye. In this context, analyzing the ETAX-REC nexus, considering the effects of EG, financial development, and green innovation, will fill an important gap in the literature. Furthermore, given Türkiye’s obligations as a party to the Paris Agreement and its goals to reduce external dependence related to its energy composition, investigating such a relationship will provide guidance for researchers and policymakers.

II. MODEL AND METHODOLOGY

This study examines the influence of ETAX, economic growth, green innovation, and financial development on REC, using data for Türkiye for the period 1994-2023. Since ETAX data were available for the period under consideration, the analysis was conducted for this period. Information on the units

and data sources used in the analysis is presented in Table 2, and the econometric model is specified in Equation (1).

Table 2. Definition of Variables

Variables	Abbreviation	Unit	Source
Renewable Energy Consumption	REC	Per Capita	Our World in Data
Economic Growth	GDP	Constant 2015 Prices (USD) Per Capita	WDI
Environmental Taxes	ETAX	% of GDP	OECD
Financial Development	FD	Domestic Credit to Private Sector by Banks (% of GDP)	WDI
Green Innovation	GI	Environmental Patents (% of Total Patents)	OECD

$$\ln REC_t = \beta_0 + \beta_1 \ln ETAX_t + \beta_2 \ln GDP_t + \beta_3 \ln FD_t + \beta_4 \ln GI_t + \varepsilon_t \quad (1)$$

The dependent variable in equation (1) is REC. The coefficient β_1, whose effect is investigated, represents ETAX. Furthermore, while investigating the impact of ETAX, several determinants of REC were also included in the model. In this context, β_2, β_3 and β_4 represent EG, financial development, and green innovation, respectively. A priori, all variables are expected to have a statistically significant and positive effect on REC. The notations ε_t and β_0 in the relevant equation symbolize the error and constant term, respectively. The 'ln' prefix on the variables indicates that a logarithmic transformation has been applied.

Given that ignoring the impact of structural changes on economic relationships can lead to biased results, this study employs a Fourier-based econometric approach. Accordingly, we first examine the stationarity properties of the series and then determine, using an appropriate method, whether cointegration holds. Based on this, if the cointegration relationship is valid, the analysis will conclude by calculating the long-run coefficients.

First, stationarity of the study variables is investigated using the Fourier KPSS test of Becker et al. (2006), which accounts for smooth structural breaks. They extended the traditional KPSS stationarity test (Kwiatkowski et al., 1992) by incorporating deterministic terms. This method does not require prior knowledge of the shape and number of structural breaks and can model smooth structural breaks. This method is preferred because ignoring specific shocks (such as political volatility and economic and financial crises) to which the time series are exposed during a particular period can lead to biased results (Bozatli et al., 2024). In the second stage, the validity of the cointegration relationship in the specified model is investigated using the Fourier-Shin method. Extending the traditional Shin (1994) cointegration methodology with Fourier terms, Tsong et al. (2016) propose a cointegration test that considers smooth structural breaks. In this method, the null hypothesis (NH), which implies cointegration, is tested against the alternative hypothesis, which implies no cointegration. Tsong et al. (2016), who examine the significance of Fourier terms using the F-test, emphasize that if the Fourier terms

are significant, the Fourier-Shin cointegration results can be trusted; otherwise, the traditional Shin (1994) cointegration test should be used.

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

If the NH, that a valid cointegration relationship exists cannot be rejected, long-term estimates are calculated using the dynamic least squares (DOLS) method of Stock and Watson (1993), as suggested by Tsong et al. (2016). To do this, the deterministic terms presented in equation (2) are incorporated into the model in equation (1) and subsequently estimated using the DOLS method.

III. EMPIRICAL RESULTS

In the initial phase of the investigation, the stationarity of the analyzed series was examined using the Fourier KPSS method, and the findings are reported in Table 3.

Table 3. Stationarity Results

Variables	I(0)	Optimal Frequency Number	5% C.V.	I(1)	Optimal Frequency Number	5% C.V.
REC	0.644*	1	0.172	0.184	4	0.459
ETAX	0.398*	1	0.172	0.044	1	0.172
GDP	1.010*	1	0.172	0.055	3	0.448
FD	0.510*	1	0.172	0.151	1	0.172
GI	0.220*	1	0.172	0.207	3	0.448

Note: * *notation implies that the NH is rejected (5%).*

Regarding the stationarity test results presented Table 3, the NH is rejected for all series. However, when the Fourier KPSS test is applied to the first differences of the series, the NH cannot be rejected. Accordingly, the series exhibits stationarity properties at its first differences. Since all variables share I(1) properties, the Fourier-Shin cointegration method was used to investigate whether they move together in the long run. The findings are reported in Table 4.

Table 4. Fourier-Shin Cointegration Test Results

Test	Value	k	1% Critical Value	F-statistic
Fourier-Shin	0.103*	2	0.171	27.981[a]

Note: * *indicates that the NH cannot be rejected at the 1% significance level. The superscript a denotes that the Fourier terms are statistically significant at the 1% level. The parameter k represents the number of frequencies*.

The Fourier-Shin cointegration test results presented in Table 3 indicate that a cointegration relationship exists. Since the Fourier-Shin test statistic is less than the critical value at the 1% significance level, the NH, which implies that the cointegration relationship is valid, cannot be rejected. Since the calculated F-statistic is greater than the critical values, the deterministic terms are statistically significant. Accordingly, there is no obstacle for using the Fourier-Shin cointegration test findings to calculate the long-run coefficients. In this context, the DOLS estimation results, extended with Fourier terms, are presented in Table 5.

Table 5. Fourier-DOLS Estimation Results

Variables	Coef.	t-stat.	p-value
ETAX	0.570	4.004	0.001*
GDP	-0.036	-0.169	0.868
FD	0.879	2.875	0.013**
GI	0.324	3.976	0.001*
COS	0.440	6.277	0.000*
SIN	0.494	3.443	0.004*

Note: **p<0.01, **p<0.05. The frequency number is 1. The lag and lead structure in the DOLS estimate is 1 according to the Schwarz criterion.*

Based on the long-term estimation findings, the following inferences can be made: (I) ETAX have a statistically significant and positive effect on REC. Accordingly, ETAX is an effective fiscal instrument for increasing the consumption of REN. This result confirms the incentive role of ETAX reported in the empirical literature (Gerni et al., 2025; Wang and Pang, 2025; Aydin and Bozatli, 2023; Abbas et al., 2023). (II) EG has no statistically significant effect on REC. While in theory an increase in welfare is thought to encourage a more environmentally friendly society and economy, this may not be the case in practice. On the other hand, policymakers may prioritize increasing income levels, independently of other factors, rather than pursuing an environmentally friendly economic structure. The lack of a statistically significant effect of EG is consistent with the findings of several studies (Aydin et al., 2025; Alam et al., 2024; Degirmenci and Yavuz, 2024; Anton and Afloarei Nucu, 2020; Ankrah and Lin, 2020; Omri and Nguyen, 2014). (III) Financial development has a positive and statistically significant effect on REC. Such a finding supports the view that the development of the financial sector or the increased accessibility to financial markets may play an important role in providing the necessary capital for REN projects (Yin and Qamruzzaman, 2024; Aydin and Bozatli, 2023; Bashir et al., 2022). (IV) The green innovation-REC nexus is significant and positive. Accordingly, developments in environmental patents promote the use of more environmentally friendly REN through spillover effects. Therefore, as theoretically predicted, technological advances in general and environmental patents in particular are significant drivers of the transition from traditional fuels to REN. This finding is consistent with the empirical research (Wang and Pang, 2025; Alam et al., 2024; Usman et al., 2023).

CONCLUSION AND POLICY RECOMMENDATIONS

This paper analyzes the influence of ETAX on REC in Türkiye, using annual data from 1994 to 2023, focusing on EG, financial development, and green innovation policies. Empirical results verify a long-term relationship despite the presence of structural breaks. The results indicate that ETAX, financial development, and green innovation policies increase REC. Specifically, this theoretically expected positive effect of ETAX measures reinforces not only their role in reducing environmental pollution but also their effect on accelerating the transition to environmentally friendly REN. Similarly, considering the influence of green innovation (or environmental patents/technologies) and financial development in fueling REC, as well as factors such as the high initial costs and

technology-intensive nature of REN investments, the importance of funding efficiency, access, and institutional structure in REN investments and utilization is confirmed in terms of financial development. Green innovation activities, in addition to reducing costs, contribute to energy efficiency and the development of new green energy technologies. In contrast to these findings, which are consistent with theoretical expectations, the result for EG was not statistically significant. Such a result implies that the dynamics of EG have not yet been fully integrated into environmentally friendly processes within the Turkish economy. As Türkiye's per capita income increases, particularly given its status as a developing country, energy demand and pollution rise due to scale effects, while technological development and demand for clean energy also increase through technical effects. Since it is unclear which of these two effects will dominate, the impact of EG is likely to be uncertain. Furthermore, the persistently high share of fossil fuels in the aggregate energy composition and the high dependence on them may cause income increases to have a negative or statistically insignificant effect.

The following policy implications can be drawn from the findings. Given the positive impact of ETAX, expanding the scope of existing ETAX and removing exemptions can strengthen the policy's deterrent and incentive effects. In particular, the structure of environmental taxes in Türkiye could be reconsidered to prioritize environmental sustainability over the generation of public revenue. For example, the tax amounts listed in the excise duty list (1) are fixed. This leads to environmental costs not being fully accounted for. Accordingly, shifting from a fixed taxation regime to a carbon-based tax structure based on the unit emission values of fuels would be more appropriate for the purpose of the relevant tax. Similarly, changing the structure of the motor vehicle tax to one based on CO_2 emissions could increase demand for low-emission and electric vehicles, thereby promote renewable energy. In this way, environmental taxes would become not only a revenue tool but also an incentive mechanism that makes the green transition mandatory. As a party to the Paris Agreement, Türkiye's role in achieving its 2053 net-zero emissions target is critical. Furthermore, the European Union's Carbon Border Adjustment Mechanism and the Green Deal harmonization processes reinforce ETAX's crucial role. In this context, implementing options such as national emissions trading systems and carbon taxes is an issue policymakers should consider. Furthermore, to enhance the effectiveness of ETAX, other policies should be designed to support and complement one another. For example, low-interest green loans for both the production and consumption in REN projects should be incentivized, and green bond issuances should be supported through tax advantages in capital markets. Regarding green innovation, special incentive mechanisms should be implemented to expand clean energy technologies and university-industry collaborations. Furthermore, to strengthen the diffusion of green innovation, the government should allocate more resources to R&D. Finally, economic policies should focus on the following dilemma: growth at the expense of the environment versus environmentally friendly growth. In this context, an environmentally sensitive (green growth) paradigm should be adopted by setting

development targets that reduce both the share of fossil fuels in the energy mix and dependence on them.

Finally, this study has several limitations. While further research on Türkiye will enrich the empirical literature, it is important to address several issues. This study assumes that the impact of ETAX policies implemented in Türkiye on REC is linear and symmetric. Future researchers addressing this effect using nonlinear or asymmetric models would provide significant insights. Furthermore, since the total impact of ETAX is accounted for in the analyses, future studies using disaggregated ETAX data or considering their compositional effects would deepen the policy perspective.

Statement of Research and Publication Ethics

In all processes of the article, the principles of research and publication ethics of the Journal of Management and Economics have been followed.

Contribution Rates of Authors to the Article

The entire article was written by Assist. Prof. Dr. Oğuzhan BOZATLI.

Declaration of Interest

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