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Economic Activities and Management Issues for the Environment: An Environmental Kuznets Curve (EKC) and STIRPAT Analysis in Turkey

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Abstract: The emission of air pollutants from energy production and consumption is a major cause of environmental problems. In addition, urbanisation and CO_2 emissions have become major environmental concerns that are closely related to climate change and sustainable economic growth. The purpose of this paper is to investigate the long-run relationship among CO_2 emissions, energy consumption, economic activities, and management issues for Turkey for the period between 1980 and 2021. The STIRPAT hypothesis and the environmental Kuznets curve (EKC) hypothesis were employed by using dynamic conditional correlation (DCC) and ARDL bound methodologies for these goals. The findings indicate that there is a long-run relationship between variables of the STIRPAT model. The coefficient of economic expansion and energy consumption affected CO_2 emissions positively, which means that energy consumption and the expansion of economic activity have significant effects on environmental degradation. Those results are also confirmed by the environmental Kuznets curve (EKC) model. In addition, the N-shaped environmental Kuznets curve (EKC) is developed for Turkey. The DCC model also shows that economic growth increases CO_2 emissions significantly, and energy productivity can be considered for decreasing CO_2 emissions.

Keywords: CO_2 emissions; energy; economics; management; environmental Kuznets curve; STIRPAT; ImPACT

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1. Introduction

Environmental degradation and climate change have been a vital concern for the world since the 1990s after the Rio 1992 and Kyoto 1997 UN conferences. The conference is the starting point for policies about the environmental effects of sustainable development. The Kyoto Protocol's goal was to bring greenhouse gas (GHG) emissions down to 1990 levels between 2008 and 2012. Environmental deterioration, global warming, and climate change are interconnected [1–3].

According to [4], two direct reasons for environmental degradation are energy consumption and energy production. These two factors are closely related to economic activities and urbanisation, as well as their management sphere. One of the consequences of urbanisation is increasing energy consumption and, further, environmental degradation. Turkey is one of the countries which has a long urbanisation history. Population in urban areas was 15% in 1937, then reached 45% in 1975 [5], and in 2021, it was 93.2% [6]. These data are the main evidence of urbanisation in Turkey. It is well-known that urbanisation increases industrial output and energy consumption. It has occurred the same in Turkey, and the increasing energy consumption caused environmental degradation in big cities.

In this paper, we investigate two models using two different theories on the relationship between climate change and urbanisation. The two theories are STIRPAT (stochastic impacts by regression on population, affluence, and technology) and the EKC (environmental Kuznets curve). STIRPAT was developed by [7], and the EKC was developed by [8]. In the literature, various models are developed on the variables affecting CO_2 emissions, such as the Laspeyres method [9] and the LMDI method [10].

The paper is organised as follows. Section 2 presents the literature review. The theoretical model is introduced in Section 3. Section 4 reveals the empirical analysis, data, and unit test. Section 5 presents the results and the discussion of the results, while Section 6 provides the conclusions, limitations, and policy recommendations.

2. Literature Review

There is much literature on these connections between environmental degradation, economic growth, and management, such as [11–18], and urbanisation and environment/climate change, such as [11,19–23].

The STIRPAT model is the extended model of the proposed IPAT model [9]; Ref. [10] extended it and reached the IPBAT model after the IPBAT model and [11] extended it and reached the STIRPAT model. The IPAT, IPBAT, and STIRPAT models aim to explain factors that affect the environment, capture behavioural choices' effects, and estimate causal effects between the driving forces, respectively. The IPAT model is a straightforward conceptual representation that links various drivers to environmental impact and is inappropriate for direct use to determine the individual factors [12]. Ref. [11] aims to solve the lack of individual determining features of the IPAT model and developed STRIPAT, which is a stochastic version of IPAT. Different techniques have been used to estimate the STIRPAT model, e.g., the common correlated effects mean group estimator (CCEMG) of [24], the augmented mean group (AMG) estimator of [25], and the kernel-based regularised lease squares estimator [24,25].

The EKC hypothesis [13] assumes that the dependent variable CO_2 in its model is affected by the independent variable GDP and other control variables, which explains an inverted U-shaped relationship between environmental quality and economic development. The researchers investigate this relationship, whether it is U-shaped, N-shaped, or V-shaped.

The EKC has enormously wide literature, and the STIRPAT model has less fame compared to the EKC. That is why there are many articles on the EKC for Turkey but few on the STIRPAT model. At first, considering the EKC literature of Turkey, we split the papers into two categories: papers showing that the EKC is valid in Turkey and papers showing that the EKC is not valid in Turkey. The papers which find that the EKC is valid in Turkey are [14–23,26]. The papers which find EKC is not valid in Turkey are [24,25,27–32].

Similar to our paper, there are two papers [33,34] that investigate both STIRPAT analysis and the EKC for Turkey. Additionally, ref. [34] states that this paper is the first paper on these topics for Turkey, but based on our literature survey, the first is [33]. However, these two pieces of research are similar to our paper based on the theories they used. They combine two theories and estimate one model, but in our paper, we estimate the model for each theory. Ref. [33] uses ecologic footprint (EF) as the dependent variable in the EKC model and finds that GDP has a positive and its square has a negative impact on EF; therefore, the relation is in an inverted U-shape in the long-run and short-run relationship. (Çağlar, 2022) uses CO_2 emissions per capita and finds an inverted-U shape for Turkey, which is consistent with [33].

Ref. [35] estimated the VEC model and used the Johansen cointegration method for STIRPAT analysis of Turkey for the 1970–2013 period. They find a long-run relationship between CO_2 emissions and affluence, population, technology, urbanization, financial development, and globalization. Except for financial development, all the variables have an increasing effect on CO_2 emissions in the long run, and short-run dynamics are valid in the model. Another paper that investigates the validity of the STIRPAT model for Turkey is [36], which uses panel data methodology for ten newly industrialized countries (NICs), one of which is Turkey. The empirical analysis consists of a dynamic common correlated effects estimator (DCCE), fully modified ordinary least square (FMOLS), and dynamic ordinary least square (DOLS). DCCE shows that all the independent variables (population, affluence, technology, energy intensity, urban employment, and energy mix) have a significant impact on CO_2 emissions. The general results show that for the NIC's population, GDP per capita is the main reason for CO_2 emissions. Ref. [37] conducted the quantile regression methodology implemented within the STIRPAT model structure for 154 countries' data, one of the countries being Turkey. They used ecological footprint per capita as a dependent variable and found that GDP per capita and the financial development index have a positive impact on population, and services negatively impact ecological footprint. Ref. [36] presents a literature review on the extended STIRPAT model, with CO_2 as the dependent variable, and summarizes the direction of the variables, which are P (population), A (affluence), and T (technology). Refs. [38–41] find positive P (population) and A (affluence), and positive T (technology); Refs. [42–45] find positive P (population) and A (affluence), and negative T (technology), and [46] finds negative P (population) and A (affluence), and positive T (technology) in their STIRPAT model.

In this paper, we aim to use the ARDL and DCC models to investigate the validity of the STIRPAT model and the EKC hypothesis in Turkey. The EKC model is a widely investigated topic in economics and management, especially in the energy economics area. Ref. [47] is the first paper to examine the EKC theory for Turkey and discover an inverted U-shaped curve. Additionally, there are broad literature sources on Turkey on the EKC [32–38,42,43]. The literature has contradictory results; while [48,49] find an N-shaped relationship, Ref. [50] finds an invalid EKC relationship for Turkey. Ref. [30] uses instead of carbon emissions, the ecological footprint as a proxy for environmental degradation, and confirmed the EKC hypothesis for Turkey from 1961 to 2013. STIRPAT does not have as many literature achievements compared to the EKC results. Ref. [51] finds that emissions have achieved a reduced level of prosperity in Turkey during 1990–2015 using the STIRPAT model. Ref. [35] finds that there is a cointegration among the variables in the STIRPAT model in Turkey.

This paper has some contributions to the literature. First, we use both the EKC and STIRPAT model, which are the theories of environmental degradation, by including the urbanization variable. Second, to estimate the relationship, we use two different kinds of models: The ARDL bound approach and the DCC-GARCH approach.

3. Theoretical Model

We mentioned the development steps of the STIRPAT model in the previous section. The model starts with the following Equation (1), which is developed by [52]:

$$I = P \times A \times T \quad (1)$$

where I presents the environmental impact, P presents population, A presents affluence or consumption per capita, and T presents technology or impact per unit of consumption. Ref. [7] extends the IPAT model to the STIRPAT model and indicates the model in exponential form as follows:

$$I = \alpha P_i^{\beta} \times A_i^{\gamma} \times T_i^{\delta} e_i \quad (2)$$

where β, γ, and δ are exponent terms of P, A, and T, respectively, and e_i is the error term. If we take the logarithm of both sides of Equation (2), we will reach Equation (3):

$$\log I_{it} = \alpha_0 + \beta \log P_{it} + \gamma \log A_{it} + \delta \log T_{it} + e_{it} \quad (3)$$

At last, if we change the variables I to COE (carbon dioxide emission), P to URB, A to Y, and T to E, we will have Equation (4):

$$\log COE_{it} = \alpha_0 + \alpha_1 \log URB_{it} + \alpha_2 \log Y_{it} + \alpha_3 \log E_{it} + e_{it} \quad (4)$$

where COE is a proxy for CO_2 emissions, URB is urbanisation, E is energy components, Y is per capita GDP, and finally, e is the residual error term. Following [16,53,54], we add international trade (TR) as a proxy for the degree of openness, foreign direct investment (FDI), and for energy components, total energy supply (ES), total final consumption (FEC), and environmental and resource productivity (energy productivity)(EP). Therefore, (4) will take (5), as follows, by showing the logarithm by L:

$$LCOE_{it} = \alpha_0 + \alpha_1 LY_{it} + \alpha_2 LFDI_{it} + \alpha_3 LFEC_{it} + \alpha_4 LEP_{it} + \alpha_5 LTR_{it} + \alpha_6 LURB_{it} + e_{it} \quad (5)$$

Another hypothesis is the environmental Kuznets curve (EKC). The EKC is a hypothesis that explains an inverted U-shaped relationship between environmental quality and economic development. It means that per capita income increases, and the degree of environmental degradation also increases until the turning point. After the turning point, environmental degradation begins to decline. The EKC investigates the relation between the relative levels of environmental damage and the GDP per capita [53]. By using the variables we select, the EKC can be written as follows (L shows the logarithm of the variables):

$$LCO_{2it} = \alpha_0 + \alpha_1 LY_{it} + \alpha_2 LY_{it}{}^2 + \alpha_3 LY_{it}{}^3 + \alpha_4 LFEC_{it} + \alpha_5 LTR_{it} + \alpha_6 g_{it} + \alpha_7 LES_{it} + e_{it} \quad (6)$$

We aim to test the three forms (level, quadratic, and cubic) of per capita GDP in the model. The coefficients of the three forms of GDP per capita determine the relationship between environmental quality and economic growth. If $\alpha_1 \geq 0$, $\alpha_2 < 0$, and $\alpha_3 = 0$, it is described as an inverted U-shaped curve.

4. Empirical Analysis

4.1. Data

The main variables of the STIRPAT model are P (population), A (affluence), and T (technology), but in previous empirical studies, such as [36,42–44] and many more, it was extended. Therefore, we aim to use more variables that have an effect on environmental degradation. When we are selecting independent variables to extend the model, we take into consideration the World Bank [55], International Energy Agency [56,57] and EU [58] reports, which focus on the factors of energy consumption. Therefore, we extended the STIRPAT model, including new environmental degradation factors such as energy productivity (EP), total energy supply (ES), and total final consumption (FEC).

To investigate the theories on Turkey, we collected annual data for 1980–2021. The data sources were the OECD, World Energy Statistics, World Bank databases, and GitHub. The variables are annual total production-based emissions of carbon dioxide (CO_2), environmental and resource productivity as energy productivity (EP), GDP (growth)(g), GDP per capita in Turkish Lira (Y), the sum of imports and exports (TR), total energy supply (ES), total final consumption (FEC), and urban population (% of the total population) (URB). The description and source of the data are summarised in Table 1.

Table 1. Description of the data.

Variable	Definition	Unit	Data Source
CO_2	Annual total production-based emissions of carbon dioxide (CO_2)	Million tonnes	(GitHub) [1]
EP	Environmental and resource productivity (energy productivity)	%	OECD
g	GDP (growth)	%	World Bank
Y	GDP per capita	Constant (TRL)	World Bank
TR	The sum of imports and exports	% of GDP	World Bank
FDI	Foreign direct investment, net inflows	% of GDP	World Bank
ES	Total energy supply	Petajoule (PJ.)	World Energy Statistics
FEC	Total final consumption	Petajoule (PJ.)	World Energy Statistics
URB	Urban population (% of the total population)	(% of the total population)	World Bank

Notes: [1]: Our World in Data based on the Global Carbon Project (2022), https://github.com/owid/co2-data (accessed on 12 November 2022). Source: own study.

All these data are up-to-date, and the latest available data have been used. Data related to 2022 was not available in most of the databases. Therefore, our data are set from 1980 to 2021. Descriptive statistics of our series are summarized in Table 2.

Table 2. Descriptive statistics of level data.

	LCO_2	LEP	LES	LFDI	LFEC	LTR	LURB	LY
Mean	5.57	3.40	8.20	−0.06	7.93	3.25	4.21	9.52
Median	5.57	3.40	8.16	0.15	7.91	3.29	4.21	9.51
Maximum	6.06	3.83	8.72	1.28	8.43	3.66	4.33	9.97
Minimum	5.02	2.85	7.65	−1.18	7.43	2.81	4.08	9.14
Std. Dev.	0.33	0.27	0.34	0.73	0.30	0.22	0.07	0.27
Skewness	−0.09	−0.24	0.01	0.07	0.001	−0.32	−0.09	0.26
Kurtosis	1.69	2.00	1.79	1.69	1.77	2.42	1.75	1.69

Notes: Logarithmic values are shown using L. Source: own study.

4.2. Unit Root Test

In order to apply for the cointegration test, the integration of each variable must be examined. If a variable becomes stationary after differing d times, that variable is I(d) degree integrated. In our study, we use the two most popular unit root tests of the augmented Dickey–Fuller test (ADF), developed by [59,60] and Phillips and Perron (PP), developed by [61]. The results of the unit root test are presented in Table 3.

Table 3. Unit root test results.

	ADF		PP	
Variables	Intercept	Intercept and Trend	Intercept	Intercept and Trend
LCO_2	−2.62 (0) *	−2.13 (0)	−5.68 (20) ***	−1.87 (8)
ΔLCO_2	−6.20 (0) ***	−5.47 (1) ***	−6.20 (0) ***	−8.48 (15) ***
CO_2	0.56 (0)	−2.61 (0)	3.19 (40)	−2.46 (7)
ΔCO_2	−5.64 (1) ***	−5.68 (1) ***	−7.12 (39) ***	−11.97 (39) ***
LFEC	−1.04 (1)	−3.89 (0) **	−1.50 (35)	−3.85 (2) **
ΔLFEC	−8.39 (0) ***	−8.38 (0) ***	−2.01 (16) ***	−18.12 (23) ***
LFDI	−1.97 (0)	−2.71 (0)	−1.84 (5)	−2.66 (3)
ΔFDI	−6.14 (0) ***	−6.02 (0) ***	−10.5 (27) ***	−10.66 (27) ***
ULRB	−4.30 (9) ***	−2.69 (9)	−6.78 (5) ***	−6.85 (4) ***
LY_{Per_cap}	0.07 (9)	−4.58 (7) ***	−0.56 (7)	−2.63 (0)
ΔLY_{Per_cap}	−3.50 (8) ***	−3.44 (8) **	−6.98 (4) ***	−6.87 (4) ***
LEP	−1.82 (0)	−1.46 (0)	−1.78 (1)	−1.35 (2)
ΔLEP	−6.25 (0) ***	−4.37 (7) ***	−6.29 (3) ***	−7.57 (7) ***
LES	−1.04 (0)	−3.08 (0)	−1.90 (9)	−2.88 (4)
ΔES	−6.77 (0) ***	−6.85 (0) ***	−7.30 (6) ***	−8.56 (8) ***
LFDI	−2.97 (0) **	−4.02 (0) ***	−3.03 (5) **	−4.04 (1) ***
LY	0.41 (0)	−2.26 (0)	1.20 (6)	−2.26 (0)
ΔLY	−6.61 (0) ***	−4.09 (5) ***	−6.96 (5) ***	−7.61 (6) ***
LY^2	0.59 (0)	−2.02 (0)	1.67 (7)	−2.02 (0)
ΔLY^2	−6.48 (0) ***	−4.10 (5) ***	−6.72 (5) ***	−7.77 (7) ***
LY^3	0.78 (0)	−1.79 (0)	2.05 (7)	−1.78 (1)
ΔLY^3	−6.34 (0) ***	−4.09 (5) ***	−6.47 (5) ***	−7.61 (7) ***

Notes: ADF test lags are determined based on Schwartz Information Criterion, PP test lags are determined based on Bartlett Kernel. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively. The parentheses show the optimum number of lags. L shows the logarithm of the series. Source: own study.

According to Table 3, all selected variables are integrated in a different order (CO_2 emission, foreign direct investment, and urbanization can be considered as at I(0)), and none of the variables are stationary at I(2). Therefore, the ARDL bound test developed by [62] is considered for testing the long-run relationship of the series.

One of the most widely used dynamic unrestricted models in the literature on econometrics is the autoregressive distributed lag (ARDL) model. Since ARDL methodology employs a general to a specific approach, it may be possible to address numerous econometric issues, including misspecification and autocorrelation, and produce an interpretable model that is most suitable.

In a long-term relationship, variances do not change over time and are constant. However, the majority of empirical studies have demonstrated that time series analysis does not satisfy the constancy of means and variances. The autoregressive distributed lag (ARDL) bound cointegration technique is one of the powerful techniques that help us analyze the long-run relationship of variables. Additionally, ARDL was used to estimate the cointegrated relationship based on selected variables and their respective I(0) and I(1) integration levels. Hence, most of the articles that have been written about STIRPAT and the EKC have been analyzed using ARDL's method, for instance [63–68]. In the case of Turkey [17,33,69] used the ARDL bound model for the EKC and STIRPAT models. Looking at these articles, it can be seen that a limited range of variables has been selected to estimate STIRPAT and the EKC, especially the articles based in Turkey. Therefore, we used all the variables that were used in the relevant literature in our modelling.

In addition, there is an important issue with using traditional regressions and cointegration models. They cannot investigate different responses of variables to each other when a covariate changes over time during the follow-up period. Recently, to solve this problem, some researchers, such as [36,70,71], used dynamic conditional correlation (DCC-GARCH). Dynamic correlation models are tools for examining the relationships between a set of variables and determining if those relationships are stable over time. In this perspective, we employed two main methodologies (ARDL and DCC-GARCH) to capture the abovementioned points.

5. Results and Discussion

The ARDL bound test is a test for cointegration between variables that integrates different orders less than I(2), and the bounds test can be employed for all the cases, provided none of the series is beyond I(1). We tried many different lags for the ARDL model, and the results show that the ARDL (1,0,0,0,2,0,1) is the best-fit model.

Table 4 shows the long-run coefficient of (4) or the STIRPAT model. The ARDL (1,0,0,0,2,0,1) is the best-fit model for our model. Using CO_2 emissions as a dependent variable, the coefficient of GDP per capita, EP, FEC, and URB are statistically significant, but FDI and TR are not significant. The $EC_{t\text{-}1}$ term is in the acceptable range, which is -2 to 0, and F-bound is 39.60, which is the upper bound of 1% of 3.99, indicating that the variables are cointegrated and there is a long-run relationship among the variables. The coefficient of Y is positive, which indicates that economic activities are caused by CO_2 emissions and environmental degradation in Turkey. The total final energy consumption coefficient is 1.17 and positive, the largest coefficient among the factors which have caused environmental degradation. Urbanisation has a negative impact.

Residual diagnostics of the ARCH test show that the null hypothesis of homoscedasticity cannot be rejected; therefore, we do not have heteroscedasticity in the two models. The serial correlation (LM) test shows there is no problem regarding the autocorrelation problem. The CUSUM and CUSUMSQ tests are stable in the full period for both models (see Appendix A). Therefore, the estimated model is stable and has a long-run relationship between variables. In the next step, the EKC model helps us to understand the functional form of this GDP on emissions. Therefore, we rewrite our EKC model (7):

$$LCO_{2it} = \alpha_0 + \alpha_1 LY_{it} + \alpha_2 {LY_{it}}^2 + \alpha_3 {LY_{it}}^3 + \alpha_4 LFEC_{it} + \alpha_5 LTR_{it} + \alpha_6 g_{it} + \alpha_7 LES_{it} + e_{it} \quad (7)$$

Table 4. Long-run coefficient of the STIRPAT model.

MODEL 1 ARDL (1,0,0,0,2,0,1)	
Coefficient	**Long-Run Coefficient Dependent Variable: Log CO_2**
α_0	0.26 (1.73)
LY	0.23 (1.85) **
LFDI	−0.009 (−0.89)
LFEC	1.17 (5.57) ***
LEP	−0.14 (−4.72) ***
LTR	−0.017 (−0.39)
LURB	−1.34 (−1.82) *
EC_{t-1} [a]	−0.73 (−9.11) ***
F-bounds	39.60 upper bound of 1%: 3.99
$\chi^2_{RESID,LM,SER}$	1.44 prob: 0.25
$\chi^2_{RESID,ARCH}$	0.40 prob: 0.52
CUSUM	Stable in full period
CUSUMQ	Stable in full period

Notes: [a]: $EC_{t-1} = LCO_2 - (-0.01.LTR + 0.23.LY - 0.009.LFDI - 1.34.LURB + 1.17.LFEC - 0.14.LEP + 0.2635)$. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively. Source: own study. Source: own study.

In the model, ${Y_{it}}^2$ and ${Y_{it}}^3$ are the squared and cubic terms for real GDP per capita. For recognising the shape of the EKC, the signs of the Y_{it}, ${Y_{it}}^2$, and ${Y_{it}}^3$ should be examined. Based on the revised EKC scenario [72,73], the coefficients are significant, and the result will be $\alpha_1 > 0$, $\alpha_2 < 0$, and $\alpha_3 > 0$. Thus, the turning point of $\frac{-\alpha_1}{2\alpha_2}$ means there is a linkage between the later development of the economy with lower pollution. In the N-shaped hypothesis, the significant coefficients $\alpha_1 > 0$, $\alpha_2 < 0$, and $\alpha_3 > 0$ need to be justified. $\alpha_1 > 0$, $\alpha_2 < 0$, and α_3 are insignificant and the N-shaped hypothesis fails to be supported, but the conventional EKC is confirmed. In case both α_1 and α_2 are insignificant, then the validity of the EKC cannot be confirmed. The coefficient of energy consumption (α_4) is expected to be $\alpha_4 > 0$. The signs of α_5 and α_6 are unclear due to their mixed effects on the environment. Each of them can be either positive or negative [73].

We find a significant relationship between GDP, URB, and FDI, which is consistent with [35–37]. Although the direction of the coefficients of urbanization is generally positive in previous articles, we found that urbanization has a negative effect in our research, which is similar to [35]. Consistent with [33–37], GDP increases the values of the variable and it is different in each paper, which shows environmental degradation in the models. In our STIRPAT model, P (urban population) is negative and A (affluence) is positive, which is consistent with [46], and T (technology) (EP is used as a proxy of technology in this paper) is negative, which is consistent with [42,45].

The results of the ARDL bound test of (6) are summarized in Table 5.

Table 5 shows the long-run coefficient of the (6) EKC hypothesis. The error terms are −1.27 and they are statistically significant. According to the CUSUM and CUSUMQ tests (Appendix B), the model is stable, and the important variables, such as Y components, are statistically significant, and in the model $\alpha_1 > 0$, $\alpha_2 < 0$, and $\alpha_3 > 0$. Therefore, the N-shaped environmental Kuznets curve (EKC) hypothesis is confirmed. Similarly, in the STIRPAT model, the coefficients of energy consumption and economic activities are positive and statistically significant, which means both have a significant effect on environmental degradation. Our results are consistent with previous studies, such as [28,74–77], which fund an N-shaped Kuznets curve as well.

In this section, we analyse the relationship between economic activities and the environment of Turkey's indicators. Based on [30,35,51], resources, and availability of data, we select emissions of carbon dioxide (CO_2), economic growth, and environmental and resource productivity (energy productivity) in Turkey using dynamic conditional correlation multivariate GARCH (DCC-EGARCH(1,1)) [52] for the period between 1990 and 2021, which reflects investing levels of renewable energy and the impact of economic activities on emissions of carbon dioxide in Turkey. According to the theoretical framework, the testable model is taken as follows:

$$CO_{2t} = f(g_t, EP_t) \tag{8}$$

Table 5. Long-run coefficient of the Kuznets curve (EKC).

	MODEL 1 ARDL (4,2,2,2,1,1,2,2)
Coefficient	**Long-Run Coefficient Dependent Variable: Log CO_2**
α_0	−33.95 (−2.53) **
LY	117.75 (2.36) **
${LY_{it}}^2$	−11.49 (−2.18) **
${LY_{it}}^3$	0.35 (2.02) **
LTR	0.01 (0.30)
LFEC	0.76 (2.13) **
g	−0.04 (−1.99) *
LES	−0.30 (−1.1)
${EC_{-1}}^a$	−1.27 (−4.67) ***
F-bounds	3.33 upper bound of 5%: 3.21
χ^2_{RESID,LM_SER}	F = 3.09 (prob = 0.09)
$\chi^2_{RESET,ARCH}$	F = 0.02 (prob: 0.86)
CUSUM	Stable
CUSUMSQ	Stable

Notes: [a]: $EC_{t-1} = LCO_2 - \left(117.75LY - 11.49{LY_{it}}^2, +0.37{LY_{it}}^3 + 0.76LFEC + 0.01LTR - 0.04g - 0.30LES - 399.95\right)$. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively. Source: own study. Source: own study.

The dynamic conditional correlation multivariate GARCH (DCC_GARCH) model is defined by [78]. Conditional correlation between two random variables is shown with $\rho_{12,t}$ as follows:

$$\rho_{12,t} = \frac{E_{t-1}(r_{1,t}r_{2,t})}{\sqrt{E_{t-1}\left(r^2_{1,t}\right)E_{t-1}\left(r^2_{2,t}\right)}} \tag{9}$$

where r_1 and r_2 show two random variables. Conditional correlation lies between −1 and +1, the same condition of a correlation coefficient. Following [55,79], we set a multivariate GARCH model allowing for time-varying correlation as follows:

$$A(L)y_t = \epsilon_t \quad t = 1, \ldots, T \tag{10}$$

where $y_t = [y_{1t}, y_{2t}]'$ and A(L) is a matrix in the lag operator L, $\epsilon_t = [\epsilon_{1t}, \epsilon_{2t}]'$ is the vector of innovation, which follows the conditional variance–covariance matrix, and $\epsilon_t \sim N(0, H_t)$. At last, H is defined as follows:

$$H_t = D_t \times R_t \times D_t \tag{11}$$

where $R_t = \left[\rho_{ij}\right]_t$ for I, and j = 1, 2 is a symmetric positive definite matrix with $\rho_{ij} = 1, \forall i$, i is the correlation matrix containing conditional correlation coefficients, and $D_t =$ diag $\left(\sqrt{h_{11t}} \ldots \sqrt{h_{NNt}}\right)$, which contains the time-varying standard deviational from univariate GARCH models. The univariate GARCH (p, q) process is as follows:

$$h^2_t = \omega + \sum_{i=1}^{q} \alpha_i \in^2_{t-i} + \sum_{j=1}^{p} \beta_i h^2_{t-j} \tag{12}$$

Table 6 presents the dynamic conditional correlation model estimation results.

Table 6. DCC model estimation results.

Parameters		Coefficient (t-Value)		
DCC (1,1)	alfa	0.259 *** (2.81)		
	beta	0.67 *** (5.48)		
	ρ_{21}	0.51 ** (2.40)		
	ρ_{31}	−0.55 * (−1.77)		
	ρ_{32}	0.09 (0.34)		
Autocorrelation and heteroskedasticity test				
Parameters	Q	*p*-values	Q^2	*p*-values
Hosing (5)	53.40	0.13	57.23	0.79
Hosking (10)	107.1	0.08	82.03	0.51
Li-McLeod (5)	54.07	0.126	59.61	0.097
Li-McLeod (10)	108.32	0.081	88.21	0.61

Notes: *, **, and *** represent 10%, 5%, and 1% significance levels, respectively. Source: own study. Source: own study.

Based on the results of the estimation of the DCC model in Table 3, α and β of the DCC model are non-negative, and their sum $(0.25 + 0.67 = 0.92)$ is less than one $(\alpha + \beta < 1)$. β in the DCC model shows the effect of the conditional correlation of the previous period on the conditional correlation of the current period, which in our case is 0.67. A larger β indicates that conditional correlations of the current period will be close to the conditional correlations of the previous period.

Since the probability value related to the Hosking, Li, and McLeod test on the standardised residuals is greater than 0.05, there are no autocorrelation and heteroskedasticity problems in the estimated models, and the models are relevant.

Figure 1 shows the dynamic condition correlation between CO_2 emissions, economic growth, and environmental and resource productivity in Turkey.

Figure 1 illustrates that by the improvement of investments in environmental and resource productivity to energy productivity, the CO_2 emissions have shown a negative response. These results are consistent with the findings of [16,33,53,55,70].

As seen in Figure 1, there is a distinct dynamic conditional correlation to alter in response to a time change and a positive DCC between economic growth and CO_2 emissions in the whole selected period, except for the short term in late 1997, and only one dot is negative in 2010. In the case of CO_2 emissions and environmental and resource productivity, there is a full and strong negative DCC between CO_2 and environmental resource productivity. There is a positive DCC between environmental and resource productivity and growth in 1997–1999, 2002–2004, and 2009–2011. In contrast, the relationship is mainly negative, showing that increased growth was affected negatively when inverting environmental and resource productivity. Nevertheless, at the end of 1997 and from 2009 to 2011, when carbon dioxide had a negative relationship with economic growth, economic growth and environmental and resource productivity had a positive relationship. We find that final energy consumption is the most important factor that has caused environmental degradation in Turkey. This result is consistent with related theories that the European Environmental Agency emphasizes. Additionally, we find that economic activities have an important role in environmental deregulation in Turkey, which is consistent with the EKC hypothesis.

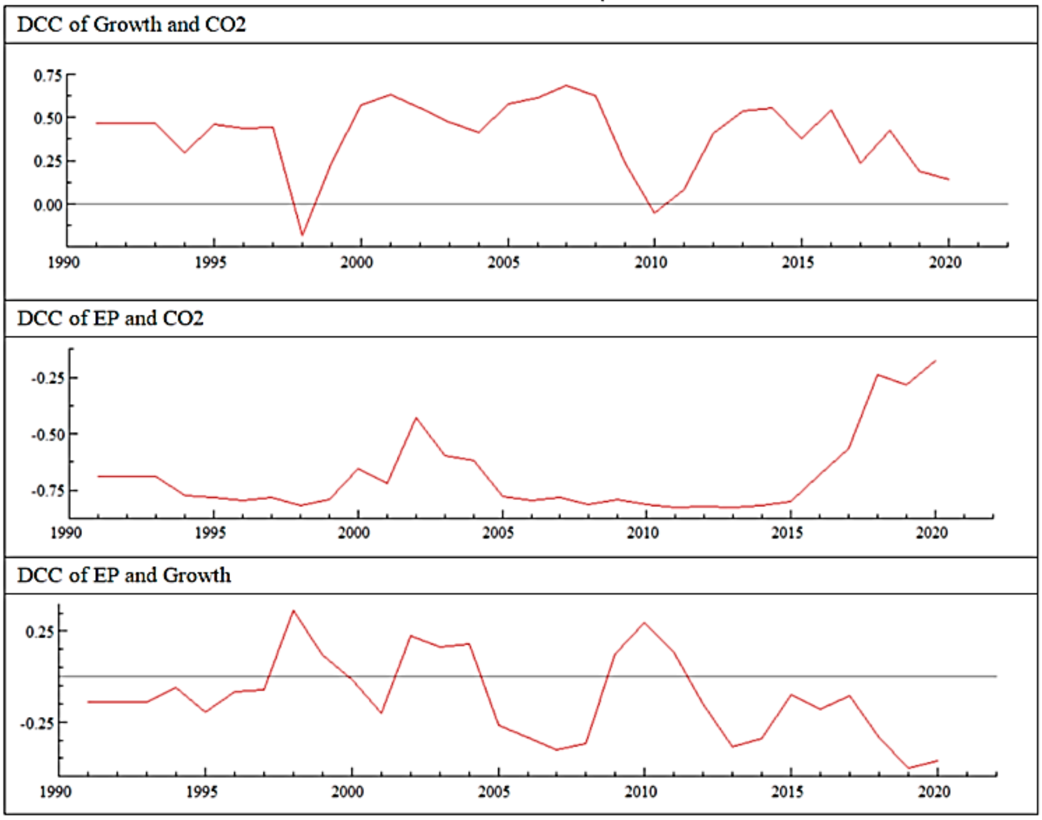

Figure 1. Dynamic condition correlation between CO_2 emissions, economic growth, and environmental and resource productivity. Source: own study.

6. Conclusions

In this paper, the contribution of the driving forces to economic activities and CO_2 emissions was tested for Turkey by employing the STIRPAT and EKC models.

In this context, we investigated the long-run relationship between CO_2 emissions, economic activities and management, energy consumption components, urbanization, and sustainable development. We estimated three hypotheses and methodology using the ARDL bound test and the DCC model over the period between 1980 and 2021.

In the STIRPAT case of the analysis, there is a long-run relationship among variables of the STIRPAT model that confirmed the results of the EKC. The coefficient of income and energy consumption affected CO_2 emissions positively, which means that energy consumption and the expansion of economic activity have a significant effect on environmental degradation, which is consistent with [42]. According to the EKC estimation, there is a long-run relationship between variables and energy consumption. Economic activities and management have the main effect on CO_2 emissions, which leads to environmental degradation in Turkey. Additionally, in the EKC analysis, we find the N-shaped curve.

After obtaining these results, we aimed to understand clearly the impact of energy production and economic activities and the management of CO_2 emissions. Therefore, we applied the DCC model. The results of the DCC model indicate that there is a distinct dynamic conditional correlation to alter in response to a time change. Additionally, we find a positive DCC between economic growth and CO_2 emissions in the whole selected period, except for the short term in late 1997; it became negative in 1997 and then reached positive values again in 2010. In the case of CO_2 emissions and environmental and resource productivity, there is a full and strong negative DCC between CO_2 and environmental resource productivity. Hence, if the government invests in energy productivity, it can prevent environmental degradation by reducing economic activities that cause carbon dioxide emissions and manage the economy based on environmental concerns.

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Appendix A. Stability Diagnostics of the STIRPAT Model

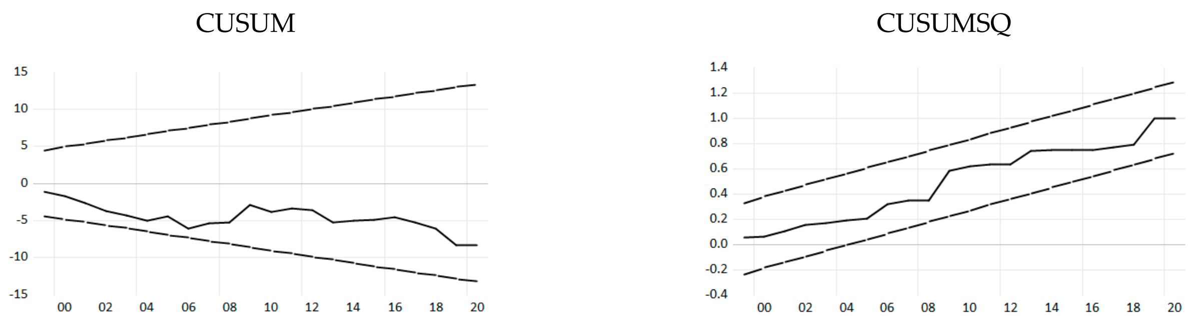

Figure A1. Graphs shows the stability results of stability test from the cumulative sum (CUSUM test) and cumulative summed squared (CUSUMSQ). The test curves perfectly between and along the lower and upper bounds at 5% significance level and stable around the mean. Source: own study.

Appendix B. Stability Diagnostics of the EKC Model

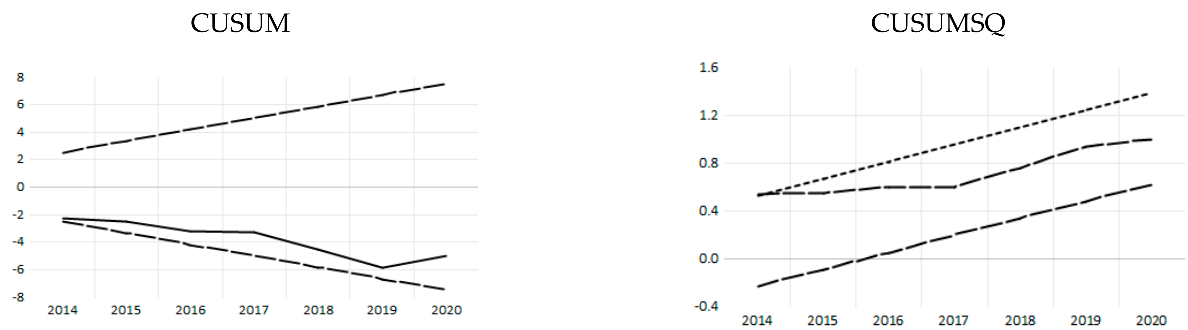

Figure A2. Graphs shows the stability results of stability test from the cumulative sum (CUSUM test) and cumulative summed squared (CUSUMSQ). The test curves perfectly between and along the lower and upper bounds at 5% significance level and stable around the mean. Source: own study.

References

1. Uğurlu, E. Greenhouse Gases Emissions and Alternative Energy in the Middle East. In *Climate Change and Energy Dynamics in the Middle East: Modeling and Simulation-Based Solutions*; Qudrat-Ullah, H., Kayal, A.A., Eds.; Understanding Complex Systems; Springer International Publishing: Cham, Switzerland, 2019; pp. 259–291. [CrossRef]
2. Uğurlu, E. Renewable Energy Strategies for Sustainable Development in the European Union. In *Renewable Energy: International Perspectives on Sustainability*; Kurochkin, D., Shabliy, E.V., Shittu, E., Eds.; Springer International Publishing: Cham, Switzerland, 2019; pp. 63–87. [CrossRef]
3. Uğurlu, E. Renewale Energy Sources and Climate Change Mitigation. In *Energy Policy Advancement: Climate Change Mitigation and International Environmental Justice*; Kurochkin, D., Crawford, M.J., Shabliy, E.V., Eds.; Springer International Publishing: Cham, Switzerland, 2022; pp. 69–92. [CrossRef]
4. IPCC. Summary for Policymakers—Global Warming of 1.5 °C. 2022. Available online: https://www.ipcc.ch/sr15/chapter/spm/ (accessed on 14 January 2023).

5. Levine, N. Antiurbanization: An Implicit Development Policy in Turkey. *J. Dev. Areas* **1980**, *14*, 513–538.
6. TURKSTAT. Adrese Dayalı Nüfus Kayıt Sistemi Sonuçları. 2022. Available online: https://data.tuik.gov.tr/Bulten/Index?p=Adrese-Dayali-Nufus-Kayit-Sistemi-Sonuclari-2021-45500 (accessed on 22 November 2022).
7. Dietz, T.; Rosa, E.A. Effects of population and affluence on CO_2 emissions. *Proc. Natl. Acad. Sci. USA* **1997**, *94*, 175–179. [CrossRef] [PubMed]
8. Panayotou, T. Demystifying the environmental Kuznets curve: Turning a black box into a policy tool. *Environ. Dev. Econ.* **1997**, *2*, 465–484. [CrossRef]
9. Apergis, N.; Payne, J.E. CO_2 emissions, energy usage, and output in Central America. *Energy Policy* **2009**, *37*, 3282–3286. [CrossRef]
10. Schulze, P.C. I=PBAT. *Ecol. Econ.* **2002**, *40*, 149–150. [CrossRef]
11. Dietz, T.; Rosa, E.A. Rethinking the Environmental Impacts of Population, Affluence and Technology. *Hum. Ecol. Rev.* **1994**, *1*, 277–300.
12. Haseeb, M.; Hassan, S.; Azam, M. Rural–urban transformation, energy consumption, economic growth, and CO_2 emissions using STRIPAT model for BRICS countries. *Environ. Prog. Sustain. Energy* **2017**, *36*, 523–531. [CrossRef]
13. Stern, D.I. Environmental Kuznets Curve. In *Encyclopedia of Energy*; Cleveland, C.J., Ed.; Elsevier: New York, NY, USA, 2004; pp. 517–525. [CrossRef]
14. Bulut, M. Analysis of The COVID-19 Impact on Electricity Consumption and Production. *Sak. Univ. J. Comput. Inf. Sci.* **2020**, *3*, 283–295. [CrossRef]
15. Pata, U.K. Renewable energy consumption, urbanization, financial development, income and CO_2 emissions in Turkey: Testing EKC hypothesis with structural breaks. *J. Clean. Prod.* **2018**, *187*, 770–779. [CrossRef]
16. Pata, U.K. The influence of coal and noncarbohydrate energy consumption on CO_2 emissions: Revisiting the environmental Kuznets curve hypothesis for Turkey. *Energy* **2018**, *160*, 1115–1123. [CrossRef]
17. Bölük, G.; Mert, M. The renewable energy, growth and environmental Kuznets curve in Turkey: An ARDL approach. *Renew. Sustain. Energy Rev.* **2015**, *52*, 587–595. [CrossRef]
18. Gozgor, G.; Can, M. Export product diversification and the environmental Kuznets curve: Evidence from Turkey. *Environ. Sci. Pollut. Res.* **2016**, *23*, 21594–21603. [CrossRef] [PubMed]
19. Elgin, C.; Öztunalı, O. Environmental Kuznets Curve for the Informal Sector of Turkey (1950–2009). *Panoeconomicus* **2014**, *61*, 4. [CrossRef]
20. Yavuz, N.Ç. CO_2 Emission, Energy Consumption, and Economic Growth for Turkey: Evidence from a Cointegration Test with a Structural Break. *Energy Sources Part B Econ. Plan. Policy* **2014**, *9*, 229–235. [CrossRef]
21. Bilgili, F.; Koçak, E.; Bulut, Ü. The dynamic impact of renewable energy consumption on CO_2 emissions: A revisited Environmental Kuznets Curve approach. *Renew. Sustain. Energy Rev.* **2016**, *54*, 838–845. [CrossRef]
22. Koçak, E.; Şarkgüneşi, A. The impact of foreign direct investment on CO_2 emissions in Turkey: New evidence from cointegration and bootstrap causality analysis. *Environ. Sci. Pollut. Res. Int.* **2018**, *25*, 790–804. [CrossRef]
23. Genç, M.C.; Ekinci, A.; Sakarya, B. The impact of output volatility on CO_2 emissions in Turkey: Testing EKC hypothesis with Fourier stationarity test. *Environ. Sci. Pollut. Res.* **2022**, *29*, 3008–3021. [CrossRef]
24. Akbostancı, E.; Türüt-Aşık, S.; Tunç, G.İ. The relationship between income and environment in Turkey: Is there an environmental Kuznets curve? *Energy Policy* **2009**, *37*, 861–867. [CrossRef]
25. Katircioğlu, S.; Katircioğlu, S. Testing the role of urban development in the conventional Environmental Kuznets Curve: Evidence from Turkey. *Appl. Econ. Lett.* **2018**, *25*, 741–746. [CrossRef]
26. Eren, B.M.; Katircioglu, S.; Gokmenoglu, K.K. The moderating role of informal economy on financial development induced ekc hypothesis in turkey. *Energy Environ.* **2022**, *33*, 1203–1226. [CrossRef]
27. Alola, A.A.; Donve, U.T. Environmental implication of coal and oil energy utilization in Turkey: Is the EKC hypothesis related to energy? *Manag. Environ. Qual. Int. J.* **2021**, *32*, 543–559. [CrossRef]
28. Awan, A.M.; Azam, M. Evaluating the impact of GDP per capita on environmental degradation for G-20 economies: Does N-shaped environmental Kuznets curve exist? *Environ. Dev. Sustain.* **2022**, *24*, 11103–11126. [CrossRef]
29. Katircioğlu, S.T.; Taşpinar, N. Testing the moderating role of financial development in an environmental Kuznets curve: Empirical evidence from Turkey. *Renew. Sustain. Energy Rev.* **2017**, *68*, 572–586. [CrossRef]
30. Ozcan, B.; Apergis, N.; Shahbaz, M. A revisit of the environmental Kuznets curve hypothesis for Turkey: New evidence from bootstrap rolling window causality. *Environ. Sci. Pollut. Res.* **2018**, *25*, 32381–32394. [CrossRef]
31. Özokcu, S.; Özdemir, Ö. Economic growth, energy, and environmental Kuznets curve. *Renew. Sustain. Energy Rev.* **2017**, *72*, 639–647. [CrossRef]
32. Ozturk, I.; Acaravci, A. CO_2 emissions, energy consumption and economic growth in Turkey. *Renew. Sustain. Energy Rev.* **2010**, *14*, 3220–3225. [CrossRef]
33. Destek, M.A. Çevresel Kuznets Eğrisi Hipotezinin Türkiye İçin İncelenmesi: Stirpat Modelinden Bulgular. *Cumhur. Üniversitesi İktisadi Ve İdari Bilim. Derg.* **2018**, *19*, 268–283.
34. Çağlar, A.E. Türkiye'de çevresel Kuznets Eğrisi hipotezinin araştırılmasında çevresel patentlerin rolü: Genişletilmiş ARDL ile kanıtlar. *Ömer Halisdemir Üniversitesi İktisadi Ve İdari Bilim. Fakültesi Derg.* **2022**, *15*, 913–929. [CrossRef]
35. Saraç, Ş.; Yağlikara, A. The Impact of Globalization and Financial Development on Environment within the Context of STIRPAT Model: The Case of Turkey. *Anadolu Üniversitesi Sos. Bilim. Derg.* **2019**, *19*, 55–64. [CrossRef]

36. Ghazali, A.; Ali, G. Investigation of key contributors of CO_2 emissions in extended STIRPAT model for newly industrialized countries: A dynamic common correlated estimator (DCCE) approach. *Energy Rep.* **2019**, *5*, 242–252. [CrossRef]
37. Topdağ, D.; Acar, T.; Çeli, İ.E. Estimation of the Global-Scale Ecological Footprint within the Framework of STIRPAT Models: The Quantile Regression Approach. *İstanbul İktisat Derg.* **2020**, *70*, 339–358.
38. Lin, S.; Wang, S.; Marinova, D.; Zhao, D.; Hong, J. Impacts of urbanization and real economic development on CO_2 emissions in non-high income countries: Empirical research based on the extended STIRPAT model. *J. Clean. Prod.* **2017**, *166*, 952–966. [CrossRef]
39. Ma, M.; Yan, R.; Cai, W. An extended STIRPAT model-based methodology for evaluating the driving forces affecting carbon emissions in existing public building sector: Evidence from China in 2000–2015. *Nat Hazards.* **2017**, *89*, 741–756. [CrossRef]
40. Sadorsky, P. Trade and energy consumption in the Middle East. *Energy Econ.* **2011**, *33*, 739–749. [CrossRef]
41. Liddle, B. What are the carbon emissions elasticities for income and population? Bridging STIRPAT and EKC via robust heterogeneous panel estimates. *Glob. Environ. Change* **2015**, *31*, 62–73. [CrossRef]
42. Yang, L.; Xia, H.; Zhang, X.; Yuan, S. What matters for carbon emissions in regional sectors? A China study of extended STIRPAT model. *J. Clean. Prod.* **2018**, *180*, 595–602. [CrossRef]
43. Roy, M.; Basu, S.; Pal, P. Examining the driving forces in moving toward a low carbon society: An extended STIRPAT analysis for a fast growing vast economy. *Clean Technol. Environ. Policy* **2017**, *19*, 2265–2276. [CrossRef]
44. Wang, F.; Shackman, J.; Liu, X. Carbon emission flow in the power industry and provincial CO_2 emissions: Evidence from cross-provincial secondary energy trading in China. *J. Clean. Prod.* **2017**, *159*, 397–409. [CrossRef]
45. Martínez-Zarzoso, I.; Maruotti, A. The impact of urbanization on CO_2 emissions: Evidence from developing countries. *Ecol. Econ.* **2011**, *70*, 1344–1353. [CrossRef]
46. Rafiq, S.; Salim, R.; Apergis, N. Agriculture, trade openness and emissions: An empirical analysis and policy options. *Aust. J. Agric. Resour. Econ.* **2016**, *60*, 348–365. [CrossRef]
47. Gürlük, S.; Karaer, F. Türkiye'de Ekonomik Büyüme ile Çevre Kirliliği İlişkisinin İncelenmesi. *Tarım Ekon. Derg.* **2004**, *10*, 43–54.
48. Başar, S.; Temurlenk, M.S. Çevreye Uyarlanmiş Kuznets Eğrisi: Türkiye Üzerine Bir Uygulama. *Atatürk Üniversitesi İktisadi Ve İdari Bilim. Derg.* **2010**, *21*.
49. Omay, R.E. The Relationship between Environment and Income: Regression Spline Approach. *Int. J. Energy Econ. Policy* **2013**, *3*, 52–61.
50. Acaravci, A.; Ozturk, I. On the relationship between energy consumption, CO_2 emissions and economic growth in Europe. *Energy* **2010**, *35*, 5412–5420. [CrossRef]
51. Koyuncu, T.; Beşer, M.K.; Alola, A.A. Environmental sustainability statement of economic regimes with energy intensity and urbanization in Turkey: A threshold regression approach. *Environ. Sci. Pollut. Res.* **2021**, *28*, 42533–42546. [CrossRef] [PubMed]
52. Ehrlich, P.R.; Holdren, J.P. Impact of population growth. *Obstet. Gynecol. Surv.* **1971**, *26*, 769–771. [CrossRef]
53. Zmami, M.; Ben-Salha, O. An empirical analysis of the determinants of CO_2 emissions in GCC countries. *Int. J. Sustain. Dev. World Ecol.* **2020**, *27*, 469–480. [CrossRef]
54. Destek, M.A.; Ulucak, R.; Dogan, E. Analyzing the environmental Kuznets curve for the EU countries: The role of ecological footprint. *Environ. Sci. Pollut. Res. Int.* **2018**, *25*, 29387–29396. [CrossRef]
55. World Bank Group. *Türkiye Country Climate and Development Report*; World Bank: Washington, DC, USA, 2022; Available online: https://openknowledge.worldbank.org/handle/10986/37521 (accessed on 8 February 2023).
56. IEA. Global Energy Review: CO2 Emissions in 2021—Analysis. 2021. Available online: https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2 (accessed on 8 February 2023).
57. IEA. *Global Energy Review 2021 Assessing the Effects of Economic Recoveries on Global Energy Demand and CO2 Emissions in 2021*; IEA: Paris, France, 2021; Available online: https://www.iea.org/reports/global-energy-review-2021/co2-emissions (accessed on 8 February 2023).
58. Eurostat. CO2 Emissions from Energy Use Up by More Than 6% in 2021. 2021. Available online: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220624-1 (accessed on 8 February 2023).
59. Dickey, D.A.; Fuller, W.A. Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *J. Am. Stat. Assoc.* **1979**, *74*, 427–431. [CrossRef]
60. Dickey, D.A.; Fuller, W.A. Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. *Econometrica* **1981**, *49*, 1057–1072. [CrossRef]
61. Phillips, P.C.B.; Perron, P. Testing for a Unit Root in Time Series Regression. *Biometrika* **1988**, *75*, 335–346. [CrossRef]
62. Pesaran, M.H.; Shin, Y.; Smith, R.J. Bounds testing approaches to the analysis of level relationships. *J. Appl. Econom.* **2001**, *16*, 289–326. [CrossRef]
63. Voumik, L.C.; Ridwan, M. Impact of FDI, industrialization, and education on the environment in Argentina: ARDL approach. *Heliyon* **2023**, *9*, e12872. [CrossRef]
64. Voumik, L.C.; Rahman, M.H.; Hossain, M.S. Investigating the subsistence of Environmental Kuznets Curve in the midst of economic development, population, and energy consumption in Bangladesh: Imminent of ARDL model. *Heliyon* **2022**, *8*, e10357. [CrossRef] [PubMed]
65. Ali, W.; Abdullah, A.; Azam, M. Re-visiting the environmental Kuznets curve hypothesis for Malaysia: Fresh evidence from ARDL bounds testing approach. *Renew. Sustain. Energy Rev.* **2017**, *77*, 990–1000. [CrossRef]

66. Sesma-Martín, D.; Puente-Ajovín, M. The Environmental Kuznets Curve at the thermoelectricity-water nexus: Empirical evidence from Spain. *Water Resour. Econ.* **2022**, *39*, 100202. [CrossRef]
67. Frodyma, K.; Papież, M.; Śmiech, S. Revisiting the Environmental Kuznets Curve in the European Union countries. *Energy* **2022**, *241*, 122899. [CrossRef]
68. Vo, D.H.; Nhan, T.N.; Ho, C.M.; Nguyen, T.C. Does the Kuznets curve apply for financial development and environmental degradation in the Asia-Pacific region? *Heliyon* **2021**, *7*, e06708. [CrossRef]
69. Ibrahim, S.S.; Celebi, A.; Ozdeser, H.; Sancar, N. Modelling the impact of energy consumption and environmental sanity in Turkey: A STIRPAT framework. *Procedia Comput. Sci.* **2017**, *120*, 229–236. [CrossRef]
70. Hao, Y.; Cho, H.C. Research on the relationship between urban public infrastructure, CO_2 emission and economic growth in China. *Environ. Dev. Sustain.* **2022**, *24*, 7361–7376. [CrossRef]
71. Gargallo, P.; Lample, L.; Miguel, J.A.; Salvador, M. Co-Movements between Eu Ets and the Energy Markets: A Var-Dcc-Garch Approach. *Mathematics* **2021**, *9*, 1787. [CrossRef]
72. Taguchi, H. The environmental Kuznets curve in Asia: The case of Sulphur and carbon emissions. *Asia Pac. Dev. J.* **2013**, *19*, 77–92. [CrossRef]
73. Zhang, J. Environmental Kuznets Curve Hypothesis on CO_2 Emissions: Evidence for China. *J. Risk Financ. Manag.* **2021**, *14*, 93. [CrossRef]
74. Allard, A.; Takman, J.; Uddin, G.S.; Ahmed, A. The N-shaped environmental Kuznets curve: An empirical evaluation using a panel quantile regression approach. *Environ. Sci. Pollut. Res.* **2018**, *25*, 5848–5861. [CrossRef]
75. Aljadani, A.; Toumi, H.; Toumi, S.; Hsini, M.; Jallali, B. Investigation of the N-shaped environmental Kuznets curve for COVID-19 mitigation in the KSA. *Env. Sci. Pollut. Res. Int.* **2021**, *28*, 29681–29700. [CrossRef] [PubMed]
76. Shehzad, K.; Zeraibi, A.; Zaman, U. Testing the N-shaped environmental Kuznets Curve in Algeria: An imperious role of natural resources and economic globalization. *Resour. Policy* **2022**, *77*, 102700. [CrossRef]
77. Mahmood, H.; Tanveer, M.; Furqan, M. Investigating the N-Shaped Energy-Environmental Kuznets Curve Hypothesis in Saudi Arabia. *Int. J. Energy Econ. Policy.* **2021**, *11*, 499–503. [CrossRef]
78. Engle, R. Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models. *J. Bus. Econ. Stat.* **2002**, *20*, 339–350. [CrossRef]
79. Hamilton, J.D. *Macroeconomics and ARCH*; Working Paper Series; National Bureau of Economic Research: Cambridge, MA, USA, 2008. [CrossRef]

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