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URBANIZATION AND CLIMATE CHANGE: ENVIRONMENTAL KUZNETS CURVE (EKC) AND STIRPAT ANALYSIS FOR TURKEY

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ABSTRACT. Urbanization and CO_2 emissions have become major environmental concerns that are closely related to climate change and sustainable economic growth. The goal of this paper is to investigate the long-run relationship between CO_2 emissions, urbanization, and achieving sustainable development in Turkey from 1990 to 2020. The STIRPAT hypothesis and the Environmental Kuznets curve (EKC) hypothesis are employed in the article. The findings indicate that there is a long-run relationship between the variables of the STIRPAT model: the coefficient of economic activities and urbanization affects CO_2 emission positively. This means that urbanization and the expansion of economic activity have a significant impact on environmental degradation. These results are also confirmed by the N-shaped Environmental Kuznets curve (EKC) that is detected for Turkey.

Keywords: STIRPAT, ImPACT, CO2 emissions, energy, Environmental Kuznets curve

Introduction

As a developing country, Turkey has a rapid urbanization. People living in rural areas have been moving to the cities. One of the consequences of urbanization is increasing energy consumption and, by way of it, environmental degradation. In Turkey, in 1935, 17% of the population lived in urban areas; in 1950, it was 19%; in 1960, 26% and 45% in 1975 (Levine, 1980). There is a connection between environmental degradation, global warming and climate change (Uğurlu, 2019b, 2019a, 2022). Growing urban population leads to expectations of increased output, which requires higher energy consumption, altogether affecting climate change. Energy consumption is, in fact, one of the crucial reasons for climate change. The relationship between development and the planet's atmosphere has been a highly controversial issue since the 1990s. The Rio 1992 and Kyoto 1997 UN conferences outlined concerns about the environmental effects of unsustainable development, especially for developing countries. 165 nations voted on the carbon market of the United Nations Kyoto

Protocol in Kyoto (Chichilnisky, 2010). The 1997 Kyoto Protocol's objective was to reduce greenhouse gases (GHG) to the 1990 level from 2008 to 2012.

The increasing relationship between energy usage and CO_2 emissions is a well-known and frequently researched problem. Furthermore, there is substantial literature on the relationships between economic expansion and the environment, and between urbanization and climate change.

Two leading theories are used to analyze the impact of urbanization, population, and economic growth on the environment. The first is STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology), developed by (Dietz & Rosa, 1997); the other one is the EKC (Environmental Kuznets Curve) hypothesis, named after the study of (Kuznets, 1955) who suggested that income inequality first increases economic activities and after a certain threshold point decreases economic activities. Similar to the Kuznets curve, the EKC suggests that income inequality initially increases environmental degradation but after a specific threshold decreases environmental degradation (Wang et al., 2021).

The STIRPAT model is an extension of the IPAT model, which is proposed by (Ehrlich & Holdren, 1971). IPAT model aims to explain factors that affect the environment. The model was extended by some researchers: an IPBAT (Schulze, 2002), STIRPAT (Dietz & Rosa, 1994) and ImPACT (York et al., 2003). The other model is EKC and it was developed by (Panayotou, 1993), transforming the Kuznets Curve (Kuznets, 1955), which asserts that the inverted U-shaped GDP per capita and income. Our aim is to test the STIRPAT and EKC for Turkey.

The rest of the paper is organized as follows: Section 1 presents the theory. Section 2 presents the previous literature. Section 3 reveals the model and data, and the econometric methodology is presented.

1. Theoretical model

There are two main hypotheses to analyse environmental deregulation. One of them is the STIRPAT hypothesis which is a formula for analyzing the effects of human activities on the environment. It explains the idea that environmental impact is dependent on three factors: population, affluence and technology. The other one is the Environmental Kuznets Curve (EKC) hypothesis which focuses on how environmental pollution related to economic growth.

1.1. STIRPAT hypothesis

One of the most popular theories used to analyze the interaction between the impact of population and economic growth on the environment is STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model, developed by (Dietz & Rosa, 1994) and (Dietz & Rosa, 1997). The model is hypothesis testing by proposing a stochastic version of the study of the "*impact of population growth*" (Ehrlich & Holdren, 1971). The model of (Ehrlich & Holdren, 1971) can be written as follows:

$$I = P \times A \times T \tag{1}$$

where I denotes environmental impact, P is population, A is affluence or consumption per capita, and T is technology or impact per unit of consumption. The STIRPAT model of (Dietz & Rosa, 1997) can be written as follows:

$$I = \alpha P_i^{\beta} \times A_{\mathrm{i}}^{\gamma} \times T_i^{\delta} e_i \tag{2}$$

where α, β, δ are estimated terms of I and, e_i is the error term.

Suppose eq (2) is transformed to log form. It will take liner form as follows:

$lnI_{it} = \alpha + \beta lnP_{it} + \gamma lnA_{it} + \delta \ln A_{it} + u_{it}$

Consequently, if we rewrite eq (2):

$$lnCE_{it} = \alpha + \beta ln\, U_{it} + \gamma lnY_{it} + \delta \ln EC_{it} + u_{it} \quad (3)$$

where CE is a proxy for CO_2 emissions, U is urbanization, Y is per capita GDP, EC is energy consumption, and finally, u is the error term. Following (Pata, 2018), (Zmami & Ben-Salha, 2020) and (Destek et al., 2018), we add international trade as a proxy for the degree of openness and foreign direct investment (FDI) to the model. Therefore, eq(3) will be extended to eq(4) as follows:

$$logCE_{it} = \alpha + \beta\, \mathrm{Ln}U_{it} + \gamma \mathrm{Ln}Y_{it} + \delta\, \mathrm{Ln}\, EC_{it} + \theta \mathrm{Ln}FDI_{it} + \vartheta\, \mathrm{Ln}\, Trade_{it} + e_{it} \quad (4)$$

1.2. The environmental Kuznets curve (EKC)

EKC is a hypothesis that explains an inverted U-shaped relationship between environmental quality and economic development which proposes that environmental degradation increases until a country reaches a certain economic development level, and decreases after the turning point. The two leading papers on EKC are (Grossman & Krueger, 1991, 1995). In these papers, authors focus on the relationship between per capita income and various environmental indicators and investigate the turning points for the different pollutants in an inverted U-shaped relationship. Numerous empirical investigations have since been conducted to confirm the inverted U-shaped relationship, but many papers found a U-shape and N-shape relationship and some found no relationship between economic development and environmental degradation(Chu, 2021). EKC can be written as follows:

$$lnCE_{it} = \alpha_0 + \alpha_1 ln\, y_{it} + \alpha_2 lnY_{it}{}^2 + \alpha_3 lnY_{it}{}^3 + \alpha_4 \ln FDI_{it} + \alpha_5 \ln Trade_{it} + \alpha_6 \ln U_{it} + e_{it} \quad (5)$$

where, CE is CO_2 emissions, U is urbanization, Y is per capita GDP, Trade is proxy for the degree of openness, FDI is a foreign direct investment and squared and cubic term of real GDP per capita are $Y_{it}{}^2$ and $Y_{it}{}^3$ respectively, and finally, e is the error term.

2. Literature review

The hanges in output are linked with changes in energy consumption and CO_2 emission (e.g. (Al-mulali & Binti Che Sab, 2012), (Fallahi, 2011), (Yuan et al., 2010), (Bilgili et al., 2016,) is widely investigated. Moreover, there is considerable literature about these relationships; economic growth and environment (such as (Apergis & Payne, 2009); (Bilgili et al., 2016); (Cai et al., 2018); (Cole et al., 1997); (Nyasha et al., 2018); (Orubu & Omotor, 2011); (Saboori et al., 2012); (Shafik & Bandyopadhyay, 1992), and urbanization and environment/climate change such as (Uğurlu, 2015); (Crawley, 2008); (Gu et al., 2011); (Henderson et al., 2017); (Lin et al., 2019); (Zheng et al., 2020)

(Akbostancı et al., 2009) investigates the EKC hypothesis and finds an N-shaped pattern for Turkey. (Ozatac et al., 2017) take into consideration urbanization and financial development while they are investigating the EKC hypothesis for Turkey and confirm it for the 1960-2013 period. Moreover, the authors find that trade and urbanization have inelastic and impacts on CO_2 emissions is positive. (Pata, 2018) adds renewable energy consumption to the EKC model and finds that EKC is valid for Turkey for the 1974-2014 period. (Bölük &

Mert, 2015) aim to test the EKC hypothesis by adding one more variable to the main model, which is electricity production -from renewable sources per capita excluding hydroelectric-, and results show the validity of the EKC hypothesis for Tukey for the 1961-2010 period. (Bölük & Mert, 2015) state that; (Gürlük & Karaer, 2004) is the first paper which investigates the EKC hypothesis for Turkey, and the paper finds an inverted U-shaped curve. Moreover (Bölük & Mert, 2015) summarize previous literature on Turkey: (Başar & Temurlenk, 2010) and (Omay, 2013) find an N-shaped relationship, (Acaravci & Ozturk, 2010) find that the EKC relationship is not valid for Turkey. (Özcan et al., 2018) use instead of carbon emissions, the ecological footprin as a proxy for environmental degradation and confirms the EKC hypothesis for Turkey for the period of 1961-2013. (Gökmenoğlu & Taspinar, 2016) find that the EKC hypothesis is valid in Turkey for the period 1974–2010. (Koyuncu et al., 2021) use the STIRPAT model for Turkey from 1990 to 2015 and find that environmental degradation has reached a reduced level of prosperity in Turkey. Another paper that estimates the STIRPAT model for Turkey is (Saraç & Yağlıkara, 2019) which focus on the impact of globalization and financial development on the environment. The authors find that there is a cointegrated relationship among the variables in the STIRPAT model.

One of the contributions of our paper to the literature, is that we investigate both STIRPAT and EKC hypothesis for Turkey. Another contribution is that we take into consideration both growth and urbanization on climate change.

3. Empirical analysis

The empirical investigation is the World Bank database and Github[1] . The variables used are: CO_2 emission (emissions, kt), which is denoted by CE, CO_2 Per Capital which is denoted by CEPC, GDP per capita (in constant 2010 US$) which is denoted by by Y , % population living in urban areas which is denoted by U, the sum of exports and imports as a %GDP which is denoted by Trade and finally consumption carbon intensity of industry energy consumption which is denoted by EC. The data are annual and cover a period between 1990 and 2020, and all series are transformed to natural logarithm.

Table 1 shows descriptive statistics of the series.

Table 1. Descriptive Statistics

	LnEC	LnCEPC	LnCE	LnFDI	LnY	LnTrade	LnU
Mean	4.081	1.36	12.37	-0.082	8.928	3.84	4.206
Median	4.17	1.35	12.32	0.157	8.881	3.87	4.208
Maximum	4.28	1.65	12.93	1.287	9.393	4.13	4.319
Minimum	3.81	1.03	11.84	-1.186	8.576	3.41	4.080
Std. Dev.	0.16	0.19	0.33	0.762	0.260	0.19	0.072
Skewness	-0.48	-0.13	0.035	0.129	0.344	-0.80	-0.068
Kurtosis	1.58	1.63	1.83	1.609	1.823	3.10	1.75
Sum Sq. Dev.	0.73	4.37	3.04	16.27	1.903	1.108	0.148

Source: own compilation

3.1. 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 differencing d times, that variable is I(d) degree integrated. In our study, we use the two most popular unit root tests; the Augmented

[1] https://github.com/owid/co2-data

Dickey-Fuller test (ADF) developed by (Dickey & Fuller, 1979) and (Dickey & Fuller, 1981) and Phillips and Perron (PP) developed by (Phillips & Perron, 1988). The results of the unit root tests are summarized in *Table 2*.

Table 2. Unit Root Test[2]

	ADF[3]		PP[4]	
Variables	Intercept	Intercept and trend	Intercept	Intercept and trend
CE	-0.25(0)	-3.43(0)**	0.26(10)	-3.49(3)**
ΔCE	-6.16(0)***	-6.03(0)***	-8.09(7)***	-7.86(7)***
CEPC	-1.44 (6)	-1.29(6)	-1.46(6)	-1.51(6)
ΔCEPC	-4.46 (5)***	-4.63(5)***	-2.56(12)*	-3.59(8)**
U	-2.45(1)*	3.30(1)	-3.97(3)***	0.023(3)
ΔU	0.98(1)	-5.36(0)***	-4.06(4)***	-4.94(4)***
Y	-0.014(0)	-2.55(0)	0.13(4)	-2.60(3)
ΔY	-5.48(0)***	-5.37(0)***	-6.02(6)***	-5.94(6)***
Trade	-0.64(6)	-3.94(1)**	-1.89(18)	-2.71(18)
ΔTrade	-4.81(1)***	-3.83(2)**	-5.71(15)***	-6.22(19)***
EC	-1.16(0)	-1.83(0)	-1.10(2)	-1.86(2)
ΔEC	-5.91(0)***	-5.86(0)***	-5.91(2)***	-5.87 (2)***
FDI	-1.96(0)	-2.69(0)	-1.84(5)	-2.65(3)
ΔFDI	-6.13 (0)***	-6.01(0)***	-10.49(27)***	-10.65(27)***
Y^2	0.06(0)	-2.48(0)	0.21(4)	-2.52(3)
ΔY^2	-5.41(0)***	-5.31(0)***	-5.86(6)***	-5.82(6)***
Y^3	0.13(0)	-2.41(0)	0.29(4)	-2.45(3)
ΔY^3	-5.34(0)***	-5.25(0)***	-5.49(5)***	-5.71(6)***

Note: The signs *, ** and *** represent; 10%, 5%, and 1% significance levels, respectively and the parenthesis shows the optimum number of lags. Source: *own compilation*

According to *Table 2*, selected variables are integrated in a different order. The findings show that CE is stationary at level I(0) in the intercept and trend (5% significant level), U is stationary at level I(0) in the intercept, and all other variables are non-stationary and have a unit root. The null hypothesis is that no unit root is rejected after the first differences of the series are taken $I\ (1)$. These findings led to the conclusion that our series are stationary in combinations of $I\ (0)$ and $I\ (1)$, and none of them is stationary at $I\ (2)$. Therefore, ARDL bound test developed by (Pesaran et al., 2001) is considered for testing the long-run relationship of the series.

3.1. Model and the results

The ARDL bound test is a test for co-integration among/between variables which integrated of 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).

The ARDL model of Eq(4) for the STIRPAT model can be written as follows:

[2] All series are seasonally adjusted
[3] Based on Schwartz Info Criterion
[4] Based on Bartlett Kernel

$$\Delta lnCE_i = \alpha_0 + \sum_{q=1}^{p1} \alpha_{1q} \Delta lnCE_{i,t-q} + \sum_{q=0}^{p2} \alpha_{2q} \Delta lnU_{i,t-q} + \sum_{q=0}^{p3} \alpha_{3q} \Delta lnY_{i,t-q} + \sum_{q=0}^{p4} \alpha_{4q} \Delta lnEC_{i,t-q} + \sum_{q=0}^{p5} \alpha_{5q} \Delta lnFDI_{i,t-q} + \sum_{q=0}^{p6} \alpha_{6q} \Delta lnTrade_{i,t-q} + \beta_1 lnCE_{i,t-1}$$

$$+\beta_2 LnU_{i,t-1} + \beta_3 LnY_{i,t-1} + \beta_4 LnEC_{i,t-1} + +\beta_5 LnFDI_{i,t-1} + \beta_6 Trade_{i,t-1} + \varepsilon_t \text{ Eq(5)}$$

According to related literature, we estimate two models with dependent variable CO_2 emissions and with dependent variable used CO_2 emission per capita. Some studies use CO_2 emission as (Khoshnevis Yazdi & Dariani, 2019), (Diartho & Fardian, 2022), (Aziz & Chowdhury, 2022) etc, , and some studies use CO_2 emission per capita such as (Anser, 2019), (Montero et al., 2021), (Haug & Ucal, 2019) . Hence, to cover a wide range of relevant literature, we set Model 1 (in which CO_2 emission (CE) is the dependent variable) and Model 2 (in which CO_2 emission per capita (CEPC) is the dependent variable)in *Table 3*. *Table 3* shows the long-run coefficient of Eq(5) or the STIRPAT model.

Table 3. Long Run Coefficient of STIRPAT model (eq (4))

Variables	MODEL 1 ARDL(3,2,2,2,2,2)	MODEL 2 ARDL(2,3,0,2,0,0)
	Long Run Coefficients Depended Variable: lnCO2(CE)	Long Run Coefficients Depended Variable: lnCO2 per capital (CEPC)
α_0	-2.92(-1.33)	-6.20 (-3.55)***
LnEC	0.18 (1.37)	-0.04(-0.43)
LnFDI	0.032(1.4)*	0.025(1.40)
LnY	0.52(2.27)**	0.24(1.79)**
lnTrade	0.21(2.6)**	0.01(0.23)
LnU	2.19(2.6)***	1.29(2.39)***
EC_{t-1}	-0.03 (-3.36)***5	-0.04(-4.38)***6
$F-$ Bounds	3.17 Lower bound of 5% :2.39	3.57 Upper bound of %5: 3.38
$\chi^2_{RESET,ARCH}$	1.86 F. Prob: 0.17	1.28 f prob: 0.25
CUSUM	Stable in full period	Stable in full period
CUSUMQ	Not stable (between 2002 and 2011)	Not stable (between 2000 and 2004)

Note: The signs *, ** and *** represent; 10%, 5%, and 1% significance level, respectively and the parenthesis shows the optimum number of lags. Source: *own compilation*

Since the variables are in natural logarithms, the estimated coefficients are considered as long-run elasticities. In Model 1, the coefficient of FDI, Y, Trade and URB are statistically significant, but EC is not statistically significant, and the results show that all coefficients are positive. The EC_{t-1} term is in the acceptable range, which is -1 to 0. In the second model(in which CO_2 per capita is considered the dependent variable) the coefficients of Y and URB are

[5] $ECT_{-1} = LnCE - (0.188.LnEC + 0.032.LnFDI + 0.52.LnY + 0.2159.LnTrade + 2.19LnU - 2.9201)$

[6] $ECT_{-1} = LnCEPC - (-0.0490.LnEC + 0.0255LnFDI + 0.24.LnY + 0.01 \times LnTrade + 1.29LnU - 6.20)$

positive and statistically significant. The other variables are not significant in this model. 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. Although CUSUM of Squares is unstable in some periods, the CUSUM test is stable in the full period for both models. Therefore, there is a long-run relationship between variables, and the coefficient of the Y, which is used as a proxy for economic activities and urbanization , affects CO_2 emission positively, which means that urbanization and the expansion of economic activity significantly affect environmental degradation.

The coefficients of urbanization in model 1 and model 2 are 2.19 and 1.29, respectively. Those coefficients have the largest impact on environmental degradation, among other coefficients. The increase in urbanization is associated with a rise in per capita CO_2 emissions by 2.19 (in the first model) and 1.29 (in the second model), which is relatively high.

In the next step EKC model helps us to understand the tradeoff between economic growth and environmental quality. Table 4 shows the long-run coefficient of the Environmental Kuznets Curve (EKC) model. Simalar to STIRPAT model, we use two dependent variables to present for CO_2 emission. In Eq (5), CE is the logarithmic transformation of CO_2 emissions in Model 3, and CEPC is CO_2 emissions per capita in Model 4. ${Y_{it}}^2$ and ${Y_{it}}^3$ are the squared and cubic terms for real GDP per capita. For recognizing the shape of the EKC, the signs of the Y_{it}, ${Y_{it}}^2$, ${Y_{it}}^3$ should be examined. If coefficient of y_{it} (α_1) > 0, and the coefficient of ${Y_{it}}^2$ (α_2) < 0, and the coefficient of ${Y_{it}}^3$ $(\alpha_3) > 0$, and 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 can be proof of the existence of the Revised EKC scenario (Taguchi, 2013). In the case N-shaped hypothesis, $\alpha_1 > 0$, $\alpha_2 < 0$ and $\alpha_3 > 0$ need to be justified and if $\alpha_1 > 0$, $\alpha_2 < 0$ and $\alpha_3 > 0$ is insignificant, then the conventional EKC is confirmed while the N-shaped hypothesis fails to be supported and also 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 and each of them can be either positive or negative (Zhang, 2021). The ARDL model of Eq (4) for the EKC model can be written as follows:

$$\Delta lnCE_i = \alpha_0 + \sum_{q=1}^{p1} \alpha_{1q}\Delta lnCE_{i,t-q} + \sum_{q=0}^{p2} \alpha_{2q}\Delta lnY_{i,t-q} + \sum_{q=0}^{p3} \alpha_{3q}\Delta lnY^2{}_{i,t-q} + \sum_{q=0}^{p4} \alpha_{4q}\Delta lnY^3{}_{i,t-q} + \sum_{q=0}^{p5} \alpha_{5q}\Delta lnFDI_{i,t-q} + \sum_{q=0}^{p6} \alpha_{6q}\Delta lnTrade_{i,t-q} + \sum_{q=0}^{p7} \alpha_{7q}\Delta lnU_{i,t-q} + \beta_1 lnCE_{i,t-1} + \beta_2 LnY_{i,t-1} + \beta_3 L n{Y_{it}}^2{}_{,t-1} + \beta_4 Ln{Y_{it}}^3{}_{i,t-1} + +\beta_5 LnFDI_{i,t-1} + \beta_6 Trade_{i,t-1} + \beta_6 U_{i,t-1} + \varepsilon_t \tag{6}$$

Similar to the previous section (*Table 3*), in this section, we also set two models, Model 3 (in which CO_2 emission (CE) is the dependent variable) and Model 4 (in which CO_2 emission per capital (CEPC) is the dependent variable) in *Table 4*. *Table 4* shows the long-run coefficient of Eq (6) or the EKC model.

Table 4. Long Run Coefficient of Kuznets curve (EKC) model (eq (5))

Variables	MODEL 3 ARDL(2,0, 2,2,2,2,2)	MODEL 4 ARDL(2,3,0,2,0,0)
	Long Run Coefficients Dependent Variable: LnCO2(CE)	Long Run Coefficients Dependent Variable: LnCO2 per capital (CEPC)
α_0	-2291.02 (-5.21)***	-1388.8(-4.48)***
LnY	758.4(5.17)***	454.13(4.62)***
$\ln Y_{it}{}^2$	-83.81(-5.13)***	-49.68(-4.62)***
$LnY_{it}{}^3$	3.08(5.10)***	1.80(4.45)***
LnTrade	-0.10(-2.00)*	-0.11(-2.822)**
LnU	4.48(7.55)***	2.188(4.77)***
LnFDI	0.06(2.51)**	0.05(3.36)***
EC_{t-1}	-1.39(-6.62)***7	-1.57(-7.91)***8
F-Bounds	10.43 Upper bound of 1% :3.99	2.98 Lower bound of 5% : 2.27
$\chi^2_{RESET,ARCH}$	1.86 F. Prob: 0.17	0.84 f prob: 0.36
CUSUM	Stable	Stable
CUSUMQ	Stable	Stable

Notes: The signs *** represent less than a 1% significance level. Source: *own compilation*

Table 4 shows the long-run coefficient of the Eq (6) EKC hypothesis. The error terms are -1.39 and -1.579 , and both of them are statistically significant; and according to CUSUM and CUSUMQ tests, both of the models are stable. In both models, all variables are statistically significant and $\alpha_1 > 0$, $\alpha_2 < 0$, and $\alpha_3 > 0$. Therefore, the N-shaped EKC hypothesis is confirmed. Same to the STIRPAT model, the coefficient of urbanization is positive and statistically significant, which means urbanization is the most important factor which has a significant effect on environmental degradation in Turkey.

Conclusion

Urbanization and climate change are two conserving issues that are closely related to sustainable economic growth. In this paper, the contribution of the driving forces of urbanization and CO_2 emissions were tested for Turkey by employing the STIRPAT and Environmental Kuznets Curve (EKC) models.

In this context, we investigate the long-run relationship among/between CO2 emissions, urbanization and sustainable development. We estimated two models for each hypothesis and the difference between the models is their dependent variable. We tested both CO2 emissions and CO2 emissions per capita by using them as a dependent variable. To estimate models we use ARDL bounds methodology for the period of 1990 to 2020 annual data. Firstly, we detect the N-shaped curve. According to EKC estimation, there is a long-run relationship among variables, and urbanization and economic activities affect CO2 emission, leading to environmental degradation in Turkey. Also, there is a long-run relationship among

[7] $ECT_{-1} = Ln(CE - (758 \times LnY - 83.81.LnY_{it}{}^2 + 3.08.Y_{it}{}^3 - 0.1049.LnTrade + 4.48.LnU + 0.062.LnFDI - 2291.0199)$

[8] $ECT_{-1} = LnECPC - \left(454.1372.ECPC - 49.68.Y_{it}{}^2 + 1.80.Y_{it}{}^3 - 0.1146.LnTrade + 2.18.LnU + 0.054.LnFDI - 1388.8399\right)$

[9] The condition of equation (21.168) in the Microfit 5 manual Witten by Bahram Pesaran and M. Hashem Pesaran.

variables of the STIRPAT model that confirmed the results of EKC that the coefficient of GDP which used as a proxy for economic activities and urbanization are, affected CO2 emissions positively, which means that urbanization and the expansion of economic activity have a significant effect on environmental degradation in Turkey.

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