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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

REVISITING THE RELATIONSHIP BETWEEN CARBON EMISSIONS, MEDIUM AND HIGH-TECH INDUSTRIES AND ECONOMIC GROWTH: U-SHAPED EVIDENCE FROM DEVELOPING EUROPEAN COUNTRIES

KARBON EMİSYONLARI, ORTA VE YÜKSEK TEKNOLOJİLİ SEKTÖRLER VE EKONOMİK BÜYÜME ARASINDAKİ İLİŞKİLERİN YENİDEN DEĞERLENDİRİLMESİ: GELİŞMEKTE OLAN AVRUPA ÜLKELERİ İÇİN U-ŞEKLİNDE BULGULAR

Büşra ŞİMŞEK[*]
Halil TUNALI[**]

Abstract

Environmental pollution is one of the biggest problems faced by the developing countries while sustaining their growth rates. The relationship between economic growth and environmental pollution is dealt with within the context of Environmental Kuznets Curve in literature. Most of the studies conducted within the context of Environmental Kuznets Curve have established that there is an inverted U-shaped relationship between economic growth and CO_2 emissions. This study has been designed to analyse the relationship between the income per capita and CO_2 emissions in 8 developing European countries between 2001 and 2018. Unlike the previous studies, in this study the effect of the added value of the medium and high-tech products on CO_2 emissions has been analysed and the analysed time period has been made to represent the more updated state of CO_2 emissions. In this study conducted by using the panel data analysis method, unlike in most of the studies in literature, it has been found out that Environmental Kuznets Curve is U-shaped. Besides, the added value of the medium and high-tech products has a statistically significant effect on CO_2 emissions, and the increase in the added value of the medium and high-tech products reduces CO_2 emissions.

Keywords: Environmental Kuznets Curve (EKC), CO2 emissions, Economic Growth, Medium and High-Tech Industries, U-shaped relationship

Jel Codes: C33, P28, N7

* Doktora Öğrencisi, İstanbul Üniversitesi, Sosyal Bilimler Enstitüsü, İktisat Anabilim Dalı, busrasimsek02@gmail.com, ORCID: 0000-0001-5295-375X

** Prof. Dr., İstanbul Üniversitesi, İktisat Fakültesi, htunali@istanbul.edu.tr, ORCID: 0000-0002-7065-4080

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Öz

Gelişmekte olan ülkelerin yüksek büyüme oranlarını sürdürürken karşı karşıya kaldıkları en büyük problemlerden biri çevre kirliğidir. Ekonomik büyüme, çevre kirliliği arasındaki ilişki literatürde Çevresel Kuznets Eğrisi kapsamında ele alınmaktadır. Çevresel Kuznets Eğrisi bağlamında yapılan çalışmaların büyük bir kısmı ekonomik büyüme ile CO_2 emisyonları arasında ters-U şeklinde bir ilişki olduğunu tespit etmiştir. Bu çalışmada 2001-2018 yılları arasında gelişmekte olan 8 Avrupa ülkesinde kişi başına düşen gelir ile CO_2 emisyonları arasındaki ilişki analiz edilmiştir. Daha önce yapılmış çalışmalardan farklı olarak bu çalışmada orta ve yüksek teknoloji ürünlerinin katma değerinin CO_2 emisyonları üzerindeki etkisi incelenmiş ve analiz edilen zaman periyodunun CO2 emisyonlarının daha güncel halini temsil etmesi sağlanmıştır. Panel veri analizi yöntemi kullanılarak yapılan çalışmada gelişmekte olan Avrupa ülkelerinde Çevresel Kuznets Eğrisi'nin literatürdeki çalışmaların çoğundan farklı olarak U – biçiminde olduğu sonucu elde edilmiştir. Bu sonuca ek olarak orta ve yüksek teknolojili endüstrilerin katma değeri CO_2 emisyonları üzerinde istatistiki olarak anlamlı bir etkiye sahiptir ve orta ve yüksek teknolojili endüstrilerin katma değerindeki artış CO_2 emisyonlarını azaltmaktadır.

Anahtar Kelimeler: Çevresel Kuznets Eğrisi (ÇKE), CO2 emisyonları, Ekonomik Büyüme, Orta ve Yüksek Teknolojili Sektörler, U – şeklinde ilişki

Jel Kodları: C33, P28, N7

Introduction

The use of fossil fuels such as oil, coal, natural gas, etc. known as non-renewable energy sources and of the energy from these sources in the industrial activities leads to the release of greenhouse gases to the nature. Gas emissions, affecting the air quality negatively, also bring about various problems like global warming, climate displacement and other environmental problems. Not only do these issues have big repercussions in the international circles but they also cause the environmental concepts to draw a lot of attention in field of economic growth and lead the researchers to seek to eliminate or overcome the environmental problems in time. The basic motivation of the studies regarding Environmental Kuznets Curve (EKC) is the search for some evidence into any relationship between environmental pollution and income per capita in order to investigate whether the economic growth has an effect on overcoming the issue of environmental pollution (Kijima et al., 2010: 1187). From the early 1990s on, it has been concluded in most of the empirical studies conducted to test the EKC hypothesis that there is an inverted U-shaped relationship between economic growth and environmental pollution. This relationship shows that environmental recovery moves in conformity with the economic growth. Even though there has been an inverted U-shaped relationship in most of the empirical studies conducted so far, literature offers us varying empirical results such as N-shaped, inverted U-shaped and U-shaped relationship. This case reveals that the shape of the curve varies, depending on the scaling factors to be used in regression models, namely the sample of the selected country the time period considered (Borghesi, 2001: 201).

Hypothesis of Environmental Kuznets Curve (EKC)

Kuznets (1955) stated that as the economies of the countries develop, firstly income inequality increases and then reaches a maximum level at a given income level, and after that level it begins to decrease. This relationship is represented with the inverted U – shape and recorded in literature as Kuznets curve. Kuznets (1995) hypothesizes that this result resulted from the transition from the agricultural sector to industrial sector in the period in question. In the 1990s, however, Kuznets Curve gained a new interpretation based on the account of the relationship between economic growth and environmental pollution. According to this approach, environmental pollution increases parallel to the income at the early stages of economic growth, and at a certain level of income the environmental pollution reaches the maximum level, but after this point the pollution decreases with the increase in income. In other words, economic growth leads to an increase in the environmental quality when it exceeds a given level (Dinda, 2004: 432). This systematic relationship came into existence with the study by Grossman and Krueger (1991) on the effects of North American Free Trade Agreement (NAFTA); the study by Shafik and Bandyopadhyay (1992) on the effects of the World Bank's World Development Report of 1992; and the study by Panayotou (1993) on environmental degeneration, development, employment, and technology policies. These studies showed that there is an inverted U-shaped relationship between income per capita and environmental degeneration, as in the Kuznets Curve. Panayotou (1993) named this as "Environmental Kuznets Curve" on the grounds of its similarity to Kuznets' hypothesis (1955), and this approach has come to be an important concept describing the relationship between environmental quality and income per capita.

Grossman and Krueger (1991) argued that the effect of economic growth on environmental quality would be realized through three different mechanisms, such as trade and foreign investment policies. Scale effect, the first of these three mechanisms, means that the increase in production with the liberalization in trade and investment activities supports the economic growth on one hand and increases the amount of income and energy, finally causing environmental pollution. According to the structural effect, the second of them, the countries will specialize in the sectors, in which they are advantageous in competition and rivalry, with the liberalization of trade, thereby leaving the industries in which the cost of reducing the pollution is high. In other words, the structural effect indicates that with the increased economic growth, the economic structure will also change and less polluting inputs will be used in production (Bo, 2011: 1323). Finally, technical effect implies that with the increased income level, the individuals will demand a cleaner environment as a token of the increased national income and this will be followed by more strict policies and regulations regarding the environment (Cherniwchan et al., 2017: 13-14). In this way, environment-friendly advanced technologies will replace the old ones damaging the environment and environmental pollution will thus be prevented (Grossman and Krueger, 1991).

Because the initiatives to increase the production and income had been prioritized with the changed structure of production in the first stage of industrialization, both the environment and the regulations concerning it were ignored to a large extent (Dasgupta et al., 2002: 147). The pollution was however reduced in the following years, a fact which is explicable by the economic developments concomitant with the transition to the information-based industries as a result of the structural and technical transformation, by the creation of environmental consciousness and by the increased share of environment in the total expenses and environmental regulations. This transformation is a description of the transition from an agricultural economy to the one overwhelmingly based on environment-polluting industry and finally to the service economy based largely on technology (Arrow et al., 1996; Dinda, 2004: 435).

The purpose of this study is to test the validity of EKC hypothesis in the European countries between 2001 and 2018. Panel regression method has been used as the analysis method. To represent the environmental quality, carbon dioxide (CO_2) emission per capita has been used as the dependent variable in the study, and income per capita and the added value of medium and high-tech industries have been used as the explanatory variables. In this sense, following the introduction and the first part devoted to the theoretical framework, empirical literature on the EKC hypothesis will be reviewed and in the next part data set, model, analysis method and findings will be presented. The last part of the study will be concerned with the interpretation of the results obtained.

Empirical Literature

In recent years, the damages of CO_2 emissions on the environment have led the researchers to study the economic growth and environmental pollution so as to test the EKC hypothesis. Most of the studies done in this context have found the EKC as inverted U-shaped, while a number of other empirical results have been observed in empirical literature with the development of analyses and samples, such as N-shaped, inverted N-shaped and U-shaped. Viewing the studies in literature in general, the shape of EKC varies, depending on the countries, time, economic factors and other explanatory variables in the data set analysed.

In their study, Jalil and Mahmud (2009) analysed the long-term relationship between CO_2 emissions and energy consumption, income and foreign trade between 1975 and 2005 in China. It was found out in the study that income and energy consumption affect CO_2 emissions in the long run, and that there is an inverted U-shaped relationship between income and CO_2 emissions. As for the foreign trade, it was found out to have positive but statistically insignificant effect on CO_2 emissions. In their study, Pao and Tsai (2010) analysed dynamic causative relationships between economic growth, environmental pollution and energy consumption in BRICT countries between 1971 and 2005. In the study, they found an inverted U-shaped relationship between CO_2 emissions and growth. In another study, Arouri et al. (2012) analysed the relationship between CO_2 emissions, energy consumption and real GDP for 12 Middle-East and North African Countries between 1981 and 2005. Their study came up with result that in the long term energy consumption has a positive effect on CO_2 emissions, and they also found an inverted U-shaped parabolic relationship between real GDP and CO_2 emissions. Saboori et al. (2012) analysed the relationship between CO_2 emission and economic growth in Malaysia. The relationship between CO_2 emission and economic growth was found as inverted U-shaped in this study.

In their study Shahbaz et al. (2013) analysed the relationship between CO_2 emission and economic growth, energy consumption, financial development and commercial liberalization. According to the findings, it was concluded that economic growth and energy consumption increased CO_2 emission, while financial development and commercial liberalization decreased CO_2 emission. On the other hand Jebli et al. (2016) analysed the relationship between CO_2 emission per capita and gross domestic product, renewable and non-renewable energy consumption and trade in the context of OECD countries. It was seen that inverted U-shaped EKC hypothesis was confirmed. Besides, it was concluded that the increase in the consumption of non-renewable energy increases the CO_2 emissions and renewable energy and foreign trade were found to decrease the CO_2 emissions. Chen et al. (2016) analysed the relationship between CO_2 emissions and growth and energy consumption by using the model of panel co-integration and vector error correction by using the data between 1993 and 2010 for 188 countries. It was found out in the study that the variables were in long-term relationships with one another for all the countries analysed, that energy consumption affected the growth in developing countries in a negative way and that there was a one-way causality from the energy consumption to the CO_2 emissions both in the developing and developed countries. An inverted U-shaped relationship was found between the income and CO_2 emissions. Sinha and Shahbaz (2018) tested the relationship between the CO_2 emissions and income per capita for India between 1971 and 2015 by using ARDL and unit root test with multiple structural breaks and obtained an inverted U-shaped relationship between the variables. They also arrived at the conclusion that renewable energy had a negative effect on the CO_2 emissions. Demissew Beyene and Kotosz (2020) tested the relationship between the CO_2 emissions and income per capita by using the data for 12 East African countries between 1990 and 2013 and through the pooled mean group estimator. It was determined in the study that there was an inverted U-shaped relationship between the CO_2 emissions and income per capita.

Some studies in literature arrived at the conclusion that CO_2 emissions increase until a given level of income and tend to decrease after that level (inverted U shape) and that if the income level goes on increasing there is an N-shaped EKC, meaning that the CO_2 emissions will increase again. In the study by Zhang and Zhao (2014), the effect of national and regional growth and income inequality on the CO_2 emissions was analysed by using the data in China between 1995 and 2010 through the panel regression method. It was found out in the study that the equality in income distribution could help decrease the CO_2 emissions and also an N-shaped relationship was found between the income per capita and CO_2 emissions. Similarly, Kang et al. (2016) tested the relationship between CO_2 emissions and economic growth for China. In the study, an N-shaped relationship was found between CO_2 emissions and economic growth. It was also found that coal energy consumption and urbanization were among the basic factors of the increase in CO_2 emission. Lorente and Alvarez-Herranz (2016) formed a model with the data of Re-De expenditure, income per capita and CO_2 emission for 25 OECD countries between 1992 and 2010. It was concluded in the study that there was an N-shaped relationship between income and CO_2 emissions, and that Re-De expenditure had a significant effect on the reduction in carbon emission. Allard et al. (2018) analysed the relationship between income per capita and CO_2 emission for 74 countries between 1994 and 2012. As a result of the study in which additional explanatory variables such as energy consumption, technologic development, trade and institutional quality, it was found that an N-shaped EKC was obtained for all income groups, except for income countries with high-middle income.

In few of the studies, EKC was found as U-shaped as a result of the empirical analysis. Kaufmann et al. (1998) analysed the effect of income per capita and spatial density of the economic activity on the density of SO_2, one of the pollutants of the environment, by using the data for 23 countries between 1974 and 1989. It was concluded that there was a U-shaped relationship between income and SO_2, and an inverted U-shaped relationship between the spatial density of the economic activity and SO_2. Wang et al. (2011) analysed the relationship between income per capita, CO_2 emissions and energy consumption for 28 cities in China between 1995 and 2007 by using panel co-integration and panel vector error correction models. It was found out in their study that CO_2 emission, energy consumption and economic growth were co-integrated in the long term and that there was a U-shaped relationship between economic growth and CO_2 emissions.

Methodology

In this study, the relationship between CO_2 emissions, economic growth and medium and high-tech industries' added value between 2001 and 2018 was examined within the context of EKC for the developing European countries. The countries making up the cross-sectional dimension of the study are chosen as Turkey, Belarus, Bulgaria, Hungary, Poland, Romania, Russia and Ukraine. These countries were determined on the basis of the grouping in the IMF (2020) economic report. Table 1 includes the information on the data.

Table 1. Information on the Variables Used in the Study

Variable	Abbreviation	Unit
CO_2 emission per capita (logarithmic)	$\ln(CO_2)$	metric ton per capita
GDP per capita (logarithmic)	ln(gdp)	constant 2010 US$
GDP per capita square (logarithmic)	$\ln(gdp)^2$	constant 2010 US$
Medium and high-tech industry's value added	techva	% of manufacturing value added

To represent the dependent variable, CO_2 emission per capita was used as it has the highest rate of emission of all the greenhouse gases. As the explanatory variables, however, GDP per capita, GDP per capita square and the added value of the middle and high-tech industries were used. All the variables in the model were included in the analysis with their logarithms taken. The data used in the research were obtained from the data base of World Bank (2020) and British Petrol (2020).

The research model to be estimated is as follows:

$$ln(CO_2)_{it}= \beta_0+ \beta_1 ln(gdp)_{it} + \beta_2 ln(gdp)^2{}_{it} + \alpha_1 (techva)_{it} + u_{it}$$

After the parameters were estimated, the following probable result were obtained between the environmental pollution and economic growth. The obtained parameter signs play a determinative role in the determination of the shape of EKC (Dinda, 2004). As the cubic GDP per capita is not in the model, ı β_3 0 is accepted.

- In case of $\beta_1 = \beta_2 = \beta_3 = 0$, there is not a relationship between CO_2 emissions and economic growth.
- In case of $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$, there is a linear relationship between CO_2 emissions and economic growth.

- In case of $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$, there is a monotonously decreasing relationship between CO_2 emissions and economic growth.
- In case of $\beta_1 > 0$ and $\beta_2 < 0$ and $\beta_3 = 0$, there is an inverted U-shaped relationship between CO_2 emissions and economic growth.
- In case of $\beta_1 < 0$ and $\beta_2 > 0$ and $\beta_3 = 0$, there is a U-shaped relationship between CO_2 emissions and economic growth.
- In case of $\beta_1 > 0$ and $\beta_2 < 0$ and $\beta_3 > 0$, there is an N-shaped relationship between CO_2 emissions and economic growth.
- In case of $\beta_1 < 0$ and $\beta_2 > 0$ and $\beta_3 < 0$, there is an inverted N-shaped relationship between CO_2 emissions and economic growth.

In the study, panel data analysis was used as a research method. Panel data method makes it possible to analyse the time sequence and cross-sectional data at the same time. Thus, the number of observations and the degree of liberty increase, which increases the reliability of the estimations obtained as a result of the analysis by decreasing the multicollinearity problem (Tatoğlu, 2013: 9).

The model developed for the developing European countries was first tested with unit and time effects LR test for the estimation and it was found that two-way model was valid. Then time effect was tested with F and LR tests, and unit effect was tested with F, LR, respectively; the results of the tests are summarized in Table 2 and Table 3.

According to the results of F test, the hypothesis H_0: l_t= 0 cannot be denied and it is concluded that time effect does not exist in the model. According to the results of LR test (H_0:s_l=0), H_0 hypotheses that standard errors of time effects are equal to zero cannot be denied. It was found as a result that time effect is absent. After the time effect was found to be absent, the F test was the first one to be applied that enabled the hypothesis (H_0: μ_i=0) that unit effects are zero to be tested. According to the results of the F test, H_0 hypothesis was refused. The presence of unit effect was confirmed. In the probability value (LR) test, the hypothesis (H_0: σ_i=0) that standard errors of unit effects are accepted as zero is tested. According to the test results, H_0 hypothesis was refused. There is unit effect in the model.

Table 2. Test Results of Time Effect

	Statistics	Probability value	Result
F test	F(17,123)= 0.33	0.984	No time effect
LR test	Chibar2(01)= 0.00	1.000	No time effect

Table 3. Test Results of Unit Effect

	Statistics	Probability value	Result
F test	F(7,133)= 728.84	0.000	Unit effect exists
LR test	Chibar2(01)= 211.66	0.000	Unit effect exists

In the one-way model in which time effect is absent but unit effect is present, Hausman test was used to make a choice between fixed effects and random effects estimator. In this test, H_0 (H_0:

Random effects model is suitable) hypothesis was tested. As a result of the test, H_0 hypothesis was refused, and it was concluded that fixed effects model was valid. Test results are given in Table 4.

Table 4. Hausman Test Results

Independent Variables	Coefficients (Fixed effects)	Coefficients (Random effects)	Probability value
ln(gdp)	-3.5372	-3.6403	
$\ln(gdp)^2$	0.2085	0.2147	0.036
techva	-0.0113	-0.0119	

After it was decided as a result of Hausman test that fixed effects model was valid, tests of deviation from the hypothesis were conducted. In this sense, first of all heteroscedasticity was tested with the Modified Wald Test according to the units in fixed effect model. According to the test results, H_0 hypothesis was refused. The presence of heteroscedasticity according to the units was identified. Then to measure the auto-correlation Durbin Watson-Baltagi Wu LBI test was applied. Considering the test results, there is autocorrelation in the model as both values are lower than 2, which is the critical value. To determine the deviations from the hypothesis fully, it should be tested whether there is a cross-sectional dependence in the model. In this context, Pesaran (2004), Friedman (1937) and Frees (1995) tests were conducted, respectively, as the tests that measure the cross-sectional dependence. According to the test results, there is a cross-sectional dependence in the model. Test results are given in Table 5.

Table 5. Deviations from Hypothesis

	Probability value	Result
Modified Wald	0.000 < 0.05	Heteroscedasticity exists
Durbin-Watson	0.291 < 2	Autocorrelation exists
Baltagi – Wu LBI	0.517 < 2	Autocorrelation exists
Pesaran	0.000 < 0.05	Cross-sectional dependence exits
Friedman	0.000 < 0.05	Cross-sectional dependence exits
Frees	1.814 > 0.188	Cross-sectional dependence exits

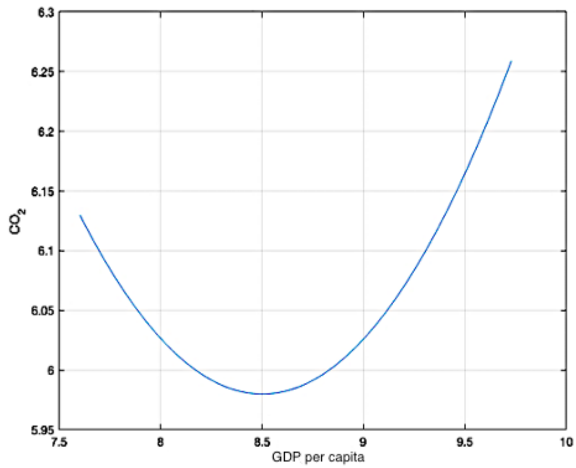
Heteroskedasticity, autocorrelation and cross-sectional dependence was found in the model, a test was made with Driscoll – Kraay standard errors to correct these deviations. Within the framework of the research model, estimated values of β_1, β_2 and α_1 parameters of the gross domestic product per capita, gross domestic product per capita square and medium and high-tech industries' added value respectively, are given in Table 6.

Table 6. Driscoll-Kraay Standard Errors Results

Independent Variables	Coefficients	Standard Error	Probability value
ln(gdp) (β_1)	– 3.5372	0.9908	0.009
$\ln(gdp)^2(\beta_2)$	0.2085	0.5531	0.007
techva (α_1)	– 0.0113	0.0027	0.005
constant (β_0)	20.355	4.4593	0.003

As a result of the analyses done, the parameters of gross domestic product per capita (β_1), gross domestic product per capita square (β_2) and medium and high-tech industries' added value (α_1) in the developing European countries were found as statistically significant. EKC was found as U-shaped according to $\beta_1 < 0$ and $\beta_2 > 0$ parameter results between CO_2 emissions and economic growth. EKC in the developing European countries is given in Graphic 1*.

Graphic 1. Shape of the Environmental Kuznets Curve Obtained from the Analysis



Findings

As a result of Driscoll-Kraay standard errors test, all the variables were found to be statistically significant. According to the results obtained, EKC was found to be U-shaped in the developing European countries when the signs of the parameters were taken into consideration. The minimum point of the functional equation was calculated by taking first derivative. Another important issue is that the turning point, or minimum point, of EKC in the developing European countries was calculated as 4.935$. For these countries, CO_2 emissions decreased until income per capita reached about 4.935$; CO_2 emissions were reduced to the minimum level at this level of income; CO_2 emissions increased with the increase in income level. Another important result is the finding that added value of the medium and high-tech industries has a statistically significant effect on CO_2 emissions. 1 unit increase in the added value of the medium and high-tech industries leads to 1,13% decrease in CO_2 emissions.

Conclusion

Considering the conditions and dynamics of the globalized world, it is obvious that environmental pollution is the common problem of all the countries. In this study, the relationship between

* The graphic was prepared by us in Matlab-2020b program by using the parameters obtained as a result of the test.

CO_2 emissions, economic growth and medium and high-tech industries' added value rate was tested with the panel regression method by using the data for the 8 developing European countries between 2001 and 2018. According to the findings, EKC hypothesis was not confirmed but there was found a U-shaped relationship between the variables. According to this relationship, CO_2 emissions decrease until the income per capita rise to 4.935$ in the developing European countries; CO_2 emissions are reduced to the minimum at this level of income; and CO_2 emissions start to increase with the increase in the income level. Besides, the increase in the added value of the medium and high-tech industries has a significant and negative effect on the CO_2 emissions. In other words, environmental pollution decreases with the development of medium and high-tech industries.

The reason for the U-shaped relationship between CO_2 emissions and income per capita can be that environmental consciousness is not adequately grown and legal regulations concerning the environment are not sufficient in the developing countries. It could also be said that the fact that most industrial activities causing intensive environmental pollution are moved from the developed countries to the developing ones is one of the reasons why the CO_2 emissions are increasing in these countries. For the solution to this problem, environmental policies and measures should be arranged and practiced both in such a way as to cover all the countries in minimum and in such a way that they need to be put into force separately in every country, depending on the current pollution level, income level, energy structure, and use of technology in production. In this sense, long-term environmental conservation programs should be formed, and technologies should be developed towards the reduction of energy consumption and environment-friendly technologies should be integrated into the production process.

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