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INVESTIGATION OF PLASTIC WASTE WITH ENVIRONMENTAL KUZNETS HYPOTHESIS: AN EMPIRICAL STUDY ON EUROPEAN UNION COUNTRIES*

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Abstract

Plastics have become an indispensable part of modern life. Although plastics, which become waste after use, are recycled for the economy, they have become a critical problem because many cause environmental pollution and threaten life. It is known that the use of plastics has increased rapidly in parallel with the increase in income that has emerged from the increasing industrialization since the 1950s. According to the Environmental Kuznets Curve (EKC) hypothesis, there is an inverted U-shaped relationship between environmental pollution and economic growth. Considering the critical importance of the plastic waste problem, plastic waste should also be evaluated with the EKC approach. For this purpose, panel data analysis was applied to the plastic waste data of the European Union (EU) countries. Research findings show that the EKC validates plastic waste in EU countries from 2004 to 2019. This shows that environmental policies should be planned around the Plastic Waste EKC.

Keywords: *Plastic waste, Environmental kuznets Hypothesis, Environmental kuznets curve, Panel data analysis, European union.*

JEL Codes: *Q50, Q51, Q56*

PLASTİK ATIKLARIN ÇEVRESEL KUZNETS EĞRİSİ HİPOTEZİ İLE İNCELENMESİ: AVRUPA BİRLİĞİ ÜLKELERİ ÜZERİNE AMPİRİK BİR ÇALIŞMA

Öz

Plastikler modern yaşamın vazgeçilmez bir parçasıdır. Kullanıldıktan sonra atığa dönüşen plastikler ekonomi için geri dönüştürülse de önemli bir kısmı çevre kirliliğine neden olduğu ve yaşamı tehdit ettiği için kritik bir sorun haline gelmektedir. 1950'li yıllardan itibaren artan sanayileşme ile ortaya çıkan gelir artışına paralel olarak plastik kullanımının hızla arttığı bilinmektedir. Çevresel Kuznets Eğrisi'ne göre çevre kirliliği ile ekonomik büyüme arasında ters U şeklinde bir ilişki vardır. Plastik atık sorununun kritik önemi göz önüne alındığında, plastik atıkların da Çevresel Kuznets Eğrisi yaklaşımıyla değerlendirilmesi gerekmektedir. Bu amaçla Avrupa Birliği (AB) ülkelerine ilişkin plastik atık verilerine panel veri analizi uygulanmıştır. Araştırma bulguları Çevresel Kuznets Eğrisinin 2004-2019 döneminde AB ülkelerindeki plastik atıklar için geçerli olduğunu gösteriyor. Bu da çevre politikalarının Plastik Atık Çevresel Kuznets Eğrisi etrafında planlanması gerektiğini göstermektedir.

Anahtar kelimeler: *Plastik atık, Çevresel kuznets hipotezi, Çevresel kuznets eğrisi, Panel veri analizi, Avrupa birliği.*

JEL Kodları: *Q50, Q51, Q56*

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1. INTRODUCTION

Plastics have become an indispensable part of modern life today. Plastics have many areas of use, ranging from packaging to durable industrial applications (Hopewell et al., 2009). However, as it is known, most plastics are produced for a limited period of use and become waste after use (Chawla et al., 2022). As plastics become waste after use, they become a critical problem due to causing environmental pollution and threatening life, even though some are recycled for the economy.

The global plastics industry, which did not show significant growth in the half-century following the production of the first synthetic plastic in 1907, has developed rapidly since the 1950s. According to the OECD's Global Plastics Outlook (2022) report, global plastic production has reached 460 million tons. On the other hand, it is known that most of the plastics produced are crude or primary plastics made from crude oil or gas. The amount of plastic obtained from recycled or secondary plastics corresponds to only 6% of the total plastic production. Although secondary plastic production increases rapidly, this rate is expected to reach only 12% by 2060 (OECD, 2022). The more critical estimate in the OECD report is that the leakage of plastic waste into the environment may double and reach 44 million tons per year. In addition, the amount of plastic waste accumulating in aquatic environments is expected to triple. According to this scenario, it can be said that the adverse effects of plastics on the environment and health will reach excellent dimensions beyond the current situation.

It is known that the use of plastic has increased rapidly in parallel with the increase in income due to increasing industrialization since the 1950s. Studies conducted within the framework of environmental pollution relevant to economic growth argue that pollution, which increases rapidly in the early stages of development, reaches a peak at a certain income level and then slows down (Grossman & Krueger, 1991; Cole et al., 1997; Schmalensee et al., 1998; Agras & Chapman, 1999; Galeotti & Lanza, 1999; Neumayer, 2002; Cole & Elliott, 2003; Dijkgraaf & Vollebergh, 2005; Apergis & Payne, 2010; Bento & Moutinho, 2016). In these studies, carbon emissions are generally discussed as the center of environmental pollution. However, plastic waste is thought to be directly proportional to income, considering the periods of high consumption patterns.

The amount of plastic waste generated annually in the EU is approximately 26 million tons. Moreover, less than 30% of the plastic waste generated is recycled. While some plastic waste is exported to non-EU countries for recycling, the remaining waste is collected in landfills, incinerated, or released to waterways. The Plastics Strategy, included in the Circular Economy Action Plan of the EU Commission, aims to make all plastic packaging recyclable by 2030. On the other hand, this strategy consists of a plan to reduce the consumption of single-use plastics. Considering these targets, it is thought that more research and guiding recommendations for policies are needed for EU countries, especially regarding plastic waste.

The primary aim of this study is to address the increasing production of plastics and the plastic waste problem. The concern over the depletion of limited resources arises from the leakage of plastics into the aquatic environment after use, which causes environmental pollution due to their insoluble nature for extended periods (World Economic Forum, 2016). On the other hand, considering the findings in the literature regarding the effects of economic growth on pollution, plastic waste pollution may also be associated with economic growth. Using the EKC, this study examines the relationship between plastic waste and economic development in EU countries. On the other hand, no analysis was found in the literature in which the relationship between plastic waste and economic growth was evaluated within the framework of the EKC. The main constraints of this study are that it only covers countries in the European Union and that the plastic waste was analyzed without being included in any classification. If the lack of data is eliminated in future studies, plastics can be classified according to their areas of use and analyzed using different models covering all countries.

The remaining parts of this study are designed as follows. Section 2 introduces the theoretical framework and literature findings. Section 3 describes the data and methodology. Then, Section 4 shows empirical findings. Finally, Section 5 discusses results in the context of empirical and theoretical approaches in the literature.

2. THEORETICAL FRAMEWORK AND LITERATURE FINDINGS

The Kuznets curve is a hypothesis that examines GDP per capita and income inequality in its original version and states that the relationship between these variables has an inverted U-shape. Accordingly, while per capita income increases, income inequality will first increase and reach its peak, and then it will begin to decrease (Kuznets, 1955). This hypothesis was later used in studies focused on the pollution problem to examine the linkage between economic growth and environmental quality. It has begun to be called the EKC (Grossman & Krugman, 1991).

The EKC (EKC) hypothesis expresses an inverted U-shaped relationship between pollution and economic growth. Expressing the relationship between pollution and economic development as an inverted U-shape began with the hypothesis proposed by Grossman and Krueger (1991). Grossman and Krueger (1991), in their study, which was one of the initial works in the literature investigating the relationship between environmental pollutants and economic activities, modeled a cubic function of per capita income and trade intensity of some pollutants such as smoke, SO_2, and SPM to examine whether the trade liberalization under NAFTA affects the environment or not. In their study, Grossman and Krueger determined that as the income level increases in Mexico, various pollutants reach their maximum levels and decrease the environmental quality in the subsequent periods. This relationship was named the "EKC" (EKC) hypothesis in the literature by Panayotou (1993) due to its similarity with Kuznets's (1955) hypothesis. The EKC hypothesis argues that environmental destruction and degradation occur at a particular stage of economic development. Moreover, economic growth increases environmental quality after passing a certain income level (Dinda, 2004).

Following Grossman and Krueger's (1991) testing of EKC for ten different environmental indicators through linear, quadratic, and cubic functional forms, Shafik (1994) found that environmental indicators related to water and sanitation were positively correlated with income. It was determined that indicators related to the quality of life negatively correlated with income. With the publication of the findings of Shafik and Bandyopadhyay's (1992) work in the World Development Report 1992, the EKC hypothesis had a broad repercussion in the literature on environmental economics. Many studies examined the EKC hypothesis for different countries, regions, periods, and methodologies (Lieb, 2003; Purcel, 2020). In some studies, variables such as CO2, SO2, and SPM were considered as air pollution criteria (Al-Mulali et al., 2015; Shahbaz & Sinha, 2019; Narayan & Narayan, 2010), while in some others, wastewater and seawater qualities were considered as water pollution criteria (Wang et al., 2020; Diao et al., 2009; Zhang et al., 2017; Sebri, 2015), and their relationship with economic growth was investigated.

Apart from issues such as air pollution, water pollution, and environmental quality, the problem of waste is an essential aspect of ecological problems. Poor waste management can release various toxic gases during the waste disposal process or cause the accumulation of multiple wastes, especially plastics, in the oceans and waterways. Fossil-based plastics, which contain chemicals considered carcinogenic and are released into the ocean and waterways, can be ingested by sea creatures and enter the human food chain (OECD, 2011; Geyer et al., 2017; Chaerul et al., 2013; Azapagic et al., 2003). Accordingly, due to waste's adverse effects, waste management has become the focus of much research.

Boubellouta and Kusch-Brandt (2020), who examined e-waste for the European Union countries with the EKC, found that e-waste increased with economic growth, reached a peak at a certain level, and then decreased with the increase in growth. On the other hand, they stated that the turning point of the EKC for e-waste was at a very high GDP level. Studying municipal solid waste in the USA, Tsiamis et al. (2018) determined that while solid waste generation increased by approximately %2.8 during the 1960-2013 period, plastic production increased by 84 times. Przydatek (2020), examining the changes in municipal waste accumulations in Poland, found that the amount of waste generated and the GDP indicated a specific convergence. Barnes (2019) examined the relationship between plastic waste and economic development in 151 countries with cross-sectional data and determined that the EKC was valid for 2010 for mismanaged plastic waste per person. Examining the relationship of household plastic waste with economic growth, lack of education and corruption in 122 countries, Cordier et al. (2021) found that improving corruption control policies could reduce plastic waste by 28% and that there was a negative relationship between economic growth and plastic waste. Testing the EKC hypothesis in the context of garbage using the provincial data in China, Song et al. (2008) determined that there was an inverted U-shaped relationship between waste gas, wastewater, solid wastes, and GDP.

In the empirical literature, there are studies on municipal solid waste, e-waste, packaging waste, medical waste, and industrial waste addressed by the EKC (Boubellouta & Kusch-Brandt, 2020; Mazzanti & Zoboli, 2008; Managi & Kaneko, 2009; Cheng et al., 2020; Su & Chen, 2018; Arbulú et al., 2015; Ichinose et al., 2015; Kim et al., 2018; Gui et al., 2019). The study by Barnes (2019), which examined plastic waste, was based on cross-sectional data, and the information he gave was limited to the year of analysis. On the other hand, Cornier discussed the relationship of plastics with economic growth, lack of education, and corruption in different income-level countries. Accordingly, no study investigating plastic waste in EU countries within the framework of the EKC hypothesis was found. As far as is known, this study is the first to examine plastic waste in the framework of testing the EKC for 2004-2019 on panel data for EU countries.

3. DATA AND METHODOLOGY

This study discusses the countries of the European Union[1] and examines the relationship between plastic waste generation and economic growth within the framework of the EKC hypothesis. The analysis did not cover three EU countries[2] due to a lack of data. GDP per capita[3] in US dollars represents economic growth, and plastic waste generation per capita in kilograms represents plastic waste. The recovery rate of plastic waste was considered a percentage, and energy recovery from plastic waste was included in the analysis in kilograms per capita. Considering the data availability, 2004-2019 was included in the study.

This study hypothesizes that "the EKC is valid for plastic waste in the countries of the European Union". This hypothesis was tested using the panel data analysis method. In this context, the equation of the model that was created with the panel data is expressed as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \ldots + \beta_k X_{it} + v_{it} \tag{1}$$

$$v_{it} = u_{it} + e_{it} \tag{2}$$

$$i = 1, 2, \ldots, N \tag{3}$$

$$t = 1, 2, \ldots, T \tag{4}$$

Accordingly, the model of the EKC is expressed as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{1it}^2 + v_{it} \tag{5}$$

According to equation (5), if the EKC is valid, the turning point or threshold value calculation is expressed as follows (Dinda, 2004):

$$\frac{-\beta_2}{2.\beta_1} \tag{6}$$

Accordingly, the models of the empirical analysis are expressed as follows:

$$\textbf{Model – 1: } RP_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + u_{it} \tag{7}$$

$$\textbf{Model – 2: } PW_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + u_{it} \tag{8}$$

$$\textbf{Model – 3: } RT_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + u_{it} \tag{9}$$

The variables in the model are defined as follows:

PW: Plastic Waste Generation per Capita in Kilograms

RT: Recovery of Plastics Waste (%)

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1 Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, United Kingdom, Iceland, and Norway.

2 Croatia, Liechtenstein, and Northern Ireland

3 World Bank Database, Date of Access: 01.08.2022

RP: Energy Recovery from Plastic Waste per Capita in Kilograms

GDP: GDP (per Capita) in USD at Fixed Prices

GDP²: GDP (per Capita) in USD Squared at Fixed Prices

Figure 1 shows the average values of plastic waste generation per capita and GDP per capita for the referred countries.

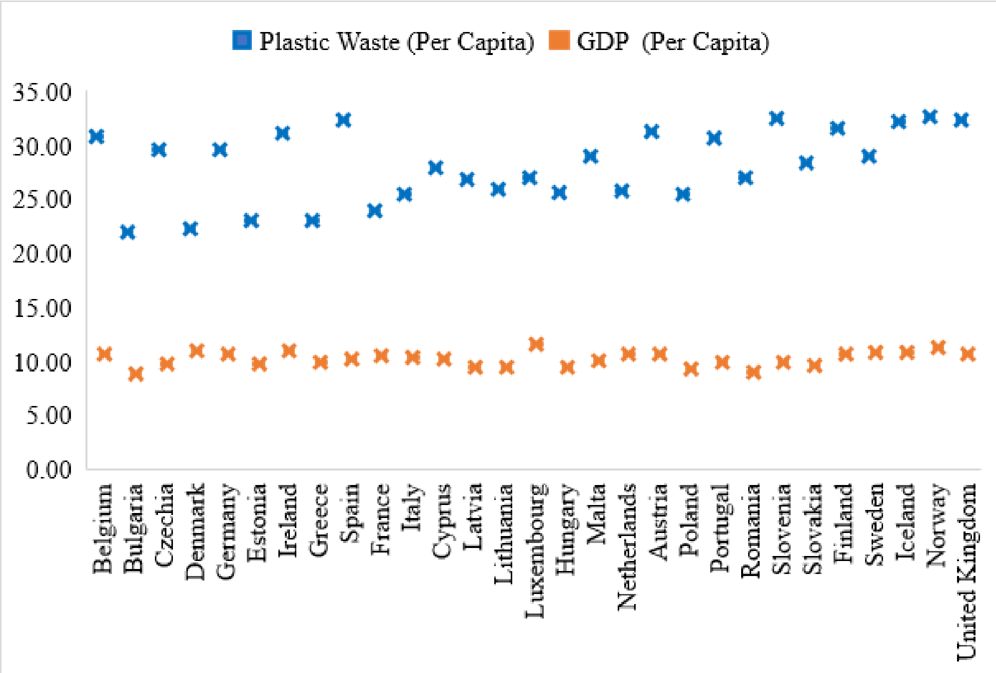

Figure 1: Average Values of Variables by Country

Six out of ten countries with the highest average income per capita in the European Union during 2004-2019 also have the highest average plastic waste generation per capita. This indicates that there may be a relationship between income level and plastic waste generation.

Since the variables show a geometric increase, all except RP were included in the analysis logarithmically to eliminate the scale difference. Descriptive statistics are shown in Table 1.

Table 1: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
PW	444	3.27	0.36	2.23	4.16
RT	453	3.94	0.58	1.09	4.85
RP	442	7.98	8.86	0	44.79
GDP	464	10.19	0.67	8.48	11.62
GDP²	464	104.36	13.77	72.02	135.25

Diagnostic test statistics are shown in Table 2.

Table 2: Diagnostic Test Statistics

	Model – 1	Model – 2	Model – 3
VIF	687.00	678.49	692.44
LR Time Effect	$1.8e^{-12}$	$4.0e^{-13}$	48.35*
LR Unit Effect	319.02*	0.66	235.41*
Cluster-Robust Hausman Test	39.91*	76.79*	21.65*
Modified Bhargava et al. Durbin-Watson Test	0.32	1.97	0.35
Modified Wald Test	20626.00*	32.66	$8.8e^{5}$*
Pesaran's Test of Cross-Sectional Independence	1.71*	-2.17*	20.2*

Findings related to diagnostic tests indicated autocorrelation, heteroscedasticity, and cross-sectional dependence in all three models. Therefore, in the analysis of the models, the problems of autocorrelation, heteroscedasticity, and inter-unit correlation were solved by estimating with the Driscoll-Kraay resistant standard errors.

According to the results of the Hausman test applied to choose between the fixed effects and the random effects of the models, the models were analyzed with the fixed effects.

4. EMPIRICAL FINDINGS

Model statistics are shown in Table 3.

Table 3: Model Statistics

	Model – 1	Model – 2	Model – 3
GDP	-237.01*	5.05*	7.65**
GDP²	12.88*	-0.26*	-0.31***
Constant	1079.31*	-21.09*	-40.67**
R^2	0.2559	0.0047	0.149
F	29.91*	7.83*	13.91*
Obs.	442	444	453

Note: *, ** and *** are significant at the levels of 1%, 5%, and 10%, respectively

Accordingly, Model 1 showed that the energy recovery from plastic waste first decreases with an increase in income and then increases after reaching the minimum point. Model 2, on the other hand, indicated that the plastic waste generation per capita rises with income and decreases after reaching the maximum threshold. Similarly, Model 3 showed that plastic waste recovery increases with increasing revenue and decreases after reaching the maximum point. The findings of Models 2 and 3 are consistent with studies of Song (2008), Barnes (2019), and Boubellouta & Kusch-Brandt (2020).

It can be said that the energy recovery from plastic waste follows a decreasing course with the increase in income and that the economies with an income per capita level below a certain level do not attach enough importance to energy recovery from waste in the beginning. However, creating income and energy recovery from plastic waste increases. This shows that high-income groups may compensate for some energy loss due to plastic production. On the other hand, the total plastic waste recovery rate initially follows an increasing trend along with income. Accordingly, recycling plastics is essential in economies with an income below a certain per capita. However, after a certain income level, the total plastic recovery rate begins to decrease in the face of an income increase. This may be because the plastics are not available in forms suitable for recycling. For example, plastics mixed with garbage must be separated from the other waste before recycling. This can often lead to high costs. On the other hand, more research is needed on plastics recovery. Finally, plastic waste generation, which is the main focus of this study, initially shows an increasing trend with the increase in income. This means a society with an expanding income consumes more plastic-containing or packaged products. However, it is observed that plastic waste production decreases after a certain income level. This may be related to the high-income groups' environmental awareness, consumption habits, and environmental regulations that restrict the use of plastics.

When the turning points of all three models for the EKC were calculated according to the formula in equation (6), it was observed that they were 1.027, 1.026, and 1.021, respectively. Since these values express low-income levels well below the income levels in the data set, we can say that the relationship in Model 1 is negative. In contrast, the relationships in Models 2 and 3 are positive.

5. CONCLUSION

Although plastics have become an indispensable part of our lives, the problem of waste caused by plastics is essential. Plastic waste characterizes life and the environment as being threatened in many ways. Considering that the cause of waste is related to production and consumption activities, it becomes essential to examine how waste management changes with the development of economies.

Many researchers examined the relationship between environmental pollution and income per capita, believing that there may be a similar relationship between environmental pollution and revenue through various variables. In the literature, studies confirm the relationship between income and environmental factors such as air quality, water pollution, carbon emissions, greenhouse gases, and ecological footprint in the context of the EKC. On the other hand, various wastes were also examined within the framework of the EKC. Solid waste, household waste, e-waste, and municipal waste are the types of waste for which there is evidence of the EKC. In this study, plastic waste and income per capita were examined for EU countries in the context of the EKC.

Recycling methods are used to recycle the wastes generated by the increasing use of plastics, industrialization, and the production cycle. It is known that most of the plastics we use in our daily lives are produced from petroleum derivatives. Although it is known that plastics cause energy loss during the production phase, energy recovery is attempted through the recycling process. This circumstance can be expressed as the primary motivation for us to focus on the variables such as plastic waste amount, amount of energy recovery from plastic waste, and recovery rate of plastics in the empirical analysis of this study.

The EKC argues for an inverted U-shaped relationship between environmental pollution and income level. Many studies on various ecological pollutants have confirmed this hypothesis. However, studies examining the EKC within the framework of waste are limited. On the other hand, as far as we know, there is no study on plastic waste in European Union countries. For this reason, this study investigated whether the EKC hypothesis is valid by considering plastic waste generation per capita, total plastic waste recovery, and energy recovery from plastic waste per capita in European Union countries. Empirical findings show that the EKC hypothesis is valid for plastic waste generation per capita, total plastic waste recovery, and energy recovery from plastic waste per capita in European Union countries.

The findings show a U-shaped curve for the relationship between energy recovery from plastic waste and income per capita (Model 1). It has been determined that the relationship between income per capita with variables of plastic waste generation per capita (Model 2) and total plastic waste recovery (Model 3) is inverted U-shaped. On the other hand, as far as we know, there is no study on plastic waste in European Union countries. For this reason, this study investigated whether the EKC hypothesis is valid by considering plastic waste generation per capita, total plastic waste recovery, and energy recovery from plastic waste per capita in European Union countries.

When the turning points of the EKC were calculated, they indicated low-income levels according to the dataset values. This shows a negative relationship between energy recovery from plastic waste and income per capita. On the other hand, a positive relationship exists between plastic production per capita and total plastic recovery rate as a function of income level. Based on these results, several policies are suggested for the EU countries as follows:

- More emphasis should be placed on energy recovery from waste,
- Plastic waste recycling campaigns should be organized separately for consumers and producers,
- Interventions should be arranged to keep the rate of increase in plastic waste production lower than the rate of recovery of plastic waste,
- Awareness studies should be carried out to increase the environmental responsibility of high-income groups for plastic waste consumption,
- Another way to increase the recovery rate of plastic waste is the taxation policy. Accordingly, a policy should be designed so that a tax rate will be determined according to the amount of plastic waste they use in production, especially for businesses that contribute high amounts of plastic waste production.

Conflicts of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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