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Testing the Waste Kuznets Curve on the Example of Bulgaria

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Abstract

Waste generation is inevitably a part of any economic activity. It is widely accepted among scientists and policymakers that economic development leads to an increase in the volume of waste. However, the latter has a harmful impact on the environment. In the context of a transition to a circular economy, institutional efforts are aimed at decoupling economic growth from waste generation. One instrument for analysing the relationship between gross domestic product and waste is the inverted-U curve, known as the Waste Kuznets Curve. In this study, we present the theoretical framework of this curve and the mixed results obtained from its application in empirical studies. Our aim is to investigate the validity of the hypothesis of the inverted-U curve for Bulgaria in the period 2000 - 2020 in terms of gross domestic product and municipal waste. Considering the non-stationarity of the analysed time series, we fail to find evidence in support of the Waste Kuznets Curve for the studied period in Bulgaria.

Keywords: Waste Kuznets Curve, municipal waste, gross domestic product, ordinary least squares, Bulgaria
Jel codes: C10, Q50

1. Introduction

Addressing the climate and environmental challenges within the European Union is the focus of The European Green Deal (2019). Its main objectives are decoupling economic growth from resource use, reducing consumption and increasing the circular use of materials. Waste generation is inevitably a part of any economic activity. Intense urbanisation, population growth, prosperity and consumption are complementary factors that increase waste generation worldwide. As defined in the current Waste Framework Directive (Directive 2008/98/EC, 22.11.2008), waste is any substance or object from which the holder disposes, intends to dispose of, or is obliged to dispose of. Waste generation and accumulation are becoming an environmental problem due to the occupation of large areas, the pollution of soil and water and the release of hazardous emissions into the atmosphere.

It is widely accepted among scientists and policymakers that economic development leads to an increase in the volume of waste. In the context of a transition to a circular economy, institutional efforts are aimed at decoupling economic growth from waste generation. Delinking resource consumption from economic growth entails increasing resource productivity, leading to waste reduction and efficiency of the waste management process.

According to Eurostat data, since 2016, the total amount of waste generated in the EU-27 has decreased from 2.26 billion tonnes per year to 2.15 billion tonnes in 2020 (Generation of waste by waste category, hazardousness and NACE Rev. 2 activity, n.d.). It can be assumed that this is the result of the implementation of the policy measures introduced with the adoption of the first Circular Economy Plan by the European Commission (Closing the loop - An EU action plan for the Circular Economy, 2.12.2015) and its update (A new Circular Economy Action Plan "For a cleaner and more competitive Europe", 2020). At the same time, GDP in the EU has increased from €12.55 million to €14.53 million between 2016 and 2021 (GDP and main components (output, expenditure and income), n.d.). This suggests that GDP growth is associated with less waste generation. One instrument for analysing the relationship between economic growth and waste generation is the inverted-U curve, known as the Waste Kuznets Curve.

This research aims to investigate the validity of the hypothesis of the Waste Kuznets Curve for Bulgaria in the period 2000 - 2020. GDP at constant 2015 prices is used to represent economic growth. The waste generated is described by the amount of municipal waste. The paper consists of an introduction, three sections and a conclusion. In **Section 2**, we review the theoretical framework of the Waste Kuznets Curve and the mixed results obtained with its application in empirical studies. In **Section 3**, we present the data used and the methodology applied in the study. In **Section 4**, we provide the results of our empirical analysis. In **Conclusion**, we summarise the main results and suggest directions for further research on the problem.

2. Literature Review

In economic theory, the classical Kuznets curve depicts the long-run impact of economic growth on income inequality (Kuznets, 1955). The hypothesis is that in the process of economic growth, inequality initially increases, reaches a "turning point", and then decreases. Analytically, the model is described by a quadratic function. Its graphical representation is an inverted-U curve. The hypothesis is confirmed or not depending on the presence of additional factors such as technological progress, economic and political measures, etc.

The Ecological Kuznets Curve (EKC) is a model of the environmental impact of economic growth. The indicators by which environmental pollution is measured can be related to air pollution (e.g. from greenhouse gas emissions), water pollution (e.g. from sewage) or soil pollution (from solid waste). In the case that solid waste pollution is studied, some authors use the term Waste Kuznets Curve for the Kuznets hypothesis. Due to its graphical representation, it is also known as the inverted-U curve. Without using the environmental Kuznets curve as a concept, Grossman & Krueger (1995) were the first to examine the relationship between per capita income and four sets of environmental indicators related to urban and river basin air pollution. They find evidence for the hypothesis of an initial deterioration and subsequent improvement of the studied indicators due to economic growth.

Empirical studies cover various periods, territories, countries or groups of countries with different economic development. The obtained results are diverse, and no pattern can be derived for cases in which the Environmental Kuznets Curve is confirmed and in which it is not. Sarac & Yaglikara (2017) supported the EKC hypothesis for BSEC countries from 1992-2012. Pata (2018) examined the short-run and long-run dynamic relationship between GDP per capita and environmental indicators for Turkey from 1974 to 2014. The EKC hypothesis was supported because an inverted-U relationship was found between economic growth and carbon dioxide emissions. The turning points of GDP per capita obtained from long-run regressions were found to be outside the study period. The results showed that Turkey had not reached the level of GDP per capita that can reduce environmental pollution and renewable energy consumption was not a solution to reduce carbon dioxide emissions. Magazzino et al. (2020) investigated the relationship between municipal waste generation and GDP in Switzerland from 1990 to 2017. They found a bidirectional causal relationship, which validated the Environmental Kuznets Curve hypothesis for Switzerland. Mohammed et al. (2021) showed the existence of an EKC for GHG emissions and economic growth in Hungary, where they will increase at a decreasing rate relative to economic growth. The only study we are aware of for Bulgaria was conducted by Kalchev (2016), who tested the Environmental Kuznets Curve for several pollution indicators. The author confirmed the hypothesis for most of the pollutants under study (nitrous oxide, ammonia, carbon dioxide). Moreover, the turning point was obtained at a high GDP per capita.

Zhai et al. (2020) identified an inverted-U curve for the relationship between industrial solid waste and economic growth in China through a vector autoregression model of the impact of GDP per capita on industrial waste emissions. However, the EKC hypothesis is invalid for industrial wastewater and industrial waste gases.

When the hypothesis of an inverted-U Environmental Kuznets Curve is not confirmed, the authors usually continue their studies by determining the relationship between the studied indicators. For 33 OECD countries, Baalbaki & Marrouch (2020) found a decreasing relationship between per capita income and municipal solid waste between 1995 and 2012. The EKC hypothesis for Croatia over the period 2004-2017 was not confirmed by Zmajlovic et al. (2019) because the turning point was obtained for a much higher level of GDP compared to the study period, but a linear relationship was found between GDP per capita and total municipal waste. In an investigation of the relationship between GDP per capita and carbon dioxide emissions per capita in 7 Gulf countries from 1980 to 2014, Tsujimoto (2018) proposed a positive linear relationship between the indicators. Jaligot & Chenal (2018) failed to confirm the existence of an EKC for the canton of Vaud in Switzerland, as waste generation tended to stabilise as income increased. Ari & Senturk (2020) described the relationship between GDP per capita and methane emissions from solid waste disposal in G7 countries between 1960 and 2016 with an inverted-N curve.

Some authors use additional factor variables to model economic growth's environmental impact. In including population, urbanization, industrialization, and access to electricity as factor variables, Boubellouta & Kusch-Brandt (2021) improve the adequacy of the EKC model based on e-waste generation as an indicator of environmental degradation. A specific result of the study is that the estimated turning points are at very high levels of GDP. Ciegis et al. (2007) reviewed the results of empirical studies of Environmental Kuznets Curves and identified the economic implications of the findings. They note that despite considering income as the main explanatory factor of the EKC, other factors, such as technological and structural changes, and trade patterns, are also included in the studies. They note that globalization favours more sustainable development, which affects the realization of the EKC model - the decreasing part of the curve describes the world economy. However, this may only be a temporary phenomenon, a result in the short term. Some studies show that over a long period, the condition of a non-increasing level of emissions is violated, i.e. Environmental Kuznets Curves become N-shaped. It is concluded that to reduce environmental degradation in developed countries, strict environmental policies such as those applied in the EU are needed apart from economic growth.

3. Data & Methodology

3.1. Data

According to economic theory, economic growth characterises the productivity of factors of production and is one of the drivers of economic development. The primary indicator for measuring economic growth is "gross domestic product". It accounts for the actual quantity of goods produced in the economy over a given period. Sources of data for the indicator are various statistical surveys, annual accounts of economic units and administrative data. They are collected comprehensively for all statistical units (enterprises, households, government institutions) that comprise the statistical population.

The indicator "Municipal waste generated" represents the quantities of household waste or similar waste of administrative or other public places, which is collected through waste collection systems. Statistical estimates of the quantities of waste generated by the population not covered by the waste collection systems are also included in the indicator. Data for the indicator are compiled through two main streams - a comprehensive specialised statistical survey of municipal administrations and administrative data from the executive environmental agency.

We use official data from the National Statistical Institute of Bulgaria in the empirical analysis. Since the indicators "Gross Domestic Product" and "Municipal Waste Generated" belong to the list of standard statistical indicators published by the institution, open access data for them have been available through the Information System INFOSTAT (Information System INFOSTAT, 9.11.2022) since 2000. The level of GDP is measured in millions of BGN - the national currency of Bulgaria. In order to eliminate the impact of inflation, we use the indicator "Gross Domestic Product" at constant 2015 prices (Real GDP). "Municipal waste generated" (MWG) is a natural indicator. The unit of measurement is thousands of tonnes. As data up to 2020 are available for the indicator "Municipal waste generated", the study is carried out for the period 2000-2020, which includes periods before and after Bulgaria's accession to the EU in 2007.

3.2. Methodology

The Waste Kuznets Curve models the relationship between GDP as the independent variable and municipal waste generation as the dependent variable through an inverted-U curve. A quadratic function model can describe this relationship:

$$y = b_0 + b_1 x + b_2 x^2 + \varepsilon, \quad (1)$$

where: y is municipal waste generated, x is real GDP, b_0, b_1, b_2 are the model parameters, ε is the error term.

The parameter b_1 characterises the change in the dependent variable when the independent variable changes by unity, and the parameter b_2 indicates that the second successive differences of the dependent variable are constant.

In terms of the interpretation of the parameters of this model, the following cases are possible:

- there is no relationship between GDP and municipal waste generated, if $b_1 = b_2 = 0$;
- the relationship between the two indicators is positive, i.e. the amount of municipal waste generated increases as GDP increases if $b_2 = 0$ but $b_1 > 0$ or if $b_2 > 0$ and $b_1 > 0$. Moreover, in the first case, the increase is directly proportional (with constant increment b_1) and can therefore be described by a straight line, while in the second case, the increase is with constant increments of the increments and is described by the part of the parabola located to the right of it;
- the relationship between GDP and municipal waste generated is inverse, i.e. as GDP increases, the amount of waste decreases if $b_2 = 0$ but $b_1 < 0$ or if $b_2 < 0$ and $b_1 < 0$. In the first case the decrease is of constant magnitude b_1 and is therefore represented by a straight line, while in the second case the decrease is of constant increments of the increments and is described by the part of the parabola to the right of its peak;
- there is a U-shaped relationship between GDP and municipal waste generated when $b_2 > 0$ and $b_1 < 0$;

- there is an inverted U-shaped relationship between GDP and municipal waste generated when $b_2 < 0$ and $b_1 > 0$. Precisely this case represents the presence of Waste Kuznets Curve.

Model (1) belongs to the class of intrinsically linear nonlinear models, and its parameters can be estimated using the ordinary least squares estimator. However, to obtain unbiased, consistent and efficient estimates, it is necessary to comply with the method's constraints (Gujarati, 2004).

When using regression analysis based on time series (in principle, as in this case), the question of their stationarity is crucial. By definition, in a broad sense, stationarity means that the time series is characterised by constant, time-invariant, mathematical expectation, variance and autocovariance. Stationary series are integrated of order zero. A time series integrated of order d is a nonstationary series that is rendered stationary by filtering by successive differences of d times (Maddala, 1998).

One form of nonstationarity common to many economic time series is the presence of a trend. For time series containing a trend, it is essential to identify its nature - deterministic or stochastic. A time series with a deterministic trend is known in the literature as trend stationary and is rendered stationary by detrending.

In case a stochastic trend is present, i.e. the time series is integrated of non-zero order, the parameter estimates of the regression model are compromised, and the inferences about the presence of a relationship between the examined indicators may be highly misleading. This problem is known in the scientific literature as the spurious regression phenomenon (Granger & Newbold, 1974). As noted by Phillips (1986), the problem lies in the non-existence of correct critical values of Fisher's *F*-test and Stewart's *t*-test. Moreover, the estimates of the regression parameters are inconsistent, and their distributions are nonstandard. There are two general solutions to avoid the spurious regression problem – cointegration and differencing. In this study, we utilise the latter.

The identification of a trend of stochastic nature is achieved by various statistical methods for determining the order of integration, which have gained recognition in the literature as unit root tests. In this study, we apply the augmented Dickey-Fuller test, whose theoretical foundations were laid by Dickey & Fuller (1979; 1981) and Said & Dickey (1984). They studied the problem of testing the null hypothesis of nonstationarity against the alternative of trend stationarity based on a particular specification of an auxiliary regression model whose general form is:

$$\Delta z_t = \mu + \delta t + \gamma z_{t-1} + \sum_{i=1}^{p} \beta_i \Delta z_{t-i} + \varepsilon_t, \quad (2)$$

where: z_t is the time series under study; Δ is the first difference operator; t is time trend; p is the number of lags included in the model; μ, δ, γ, β_i are the model parameters; ε_t is the error term.

Concerning the specification of model (2), three choices are possible - a model with constant and trend ($\mu \neq 0$ and $\delta \neq 0$), with constant ($\mu \neq 0$ and δ =0) and without constant and trend ($\mu = 0$ and $\delta = 0$). Dickey & Fuller (1979) formulated a class of test statistics based on the t and *F*-criteria. Since their distributions do not follow the standard Student and Fisher distributions, the authors tabulate the corresponding critical values obtained by Monte Carlo simulations. The test statistics τ_τ, τ_μ and τ are used to test the hypothesis of nonstationarity H_0: $\gamma = 0$ for the models: with constant and trend, with constant, and without constant and trend, respectively.

In the current study, we use Akaike's information criterion to select the number of lags included in model (2) and apply a procedure proposed by Dolado et al. (1990) to select the particular auxiliary regression model from which to infer the order of integration of the time series.

4. Results

The dynamics of municipal waste generated and GDP in Bulgaria for the period 2000-2020 is presented in Figure 1. The graphical representation demonstrates a trend for both indicators, with an upward trend for GDP and a downward one for waste. The autocorrelation functions of both indicators also confirm the initial assumption of a trend. The first-order coefficient has a significantly high positive value for both indicators, $r_1 = 0.8506$ and $r_1 = 0.8702$, for GDP and household waste, respectively. The coefficients decrease slowly with the increase of the lag order and are significant up to lag 4 for waste and lag 3 for GDP.

We apply the augmented Dickey-Fuller test to determine whether municipal waste, GDP and the squared GDP are nonstationary. The number of lags included in the auxiliary regression, determined by the Akaike information criterion, is one. We use the procedure of Dolado et al. (1990), which consists of several stages, to choose the auxiliary equation specification. All tests are conducted with significance level $\alpha = 0.05$. The results are reported in Table 1.

In the first stage, we test the hypothesis that the series is nonstationary, $H_0: \gamma = 0$, in a model with a constant and trend with the test statistic τ_τ. Its empirical values for all three considered series are smaller in absolute value than the critical value. This does not allow us to reject the hypothesis of integration of the series.

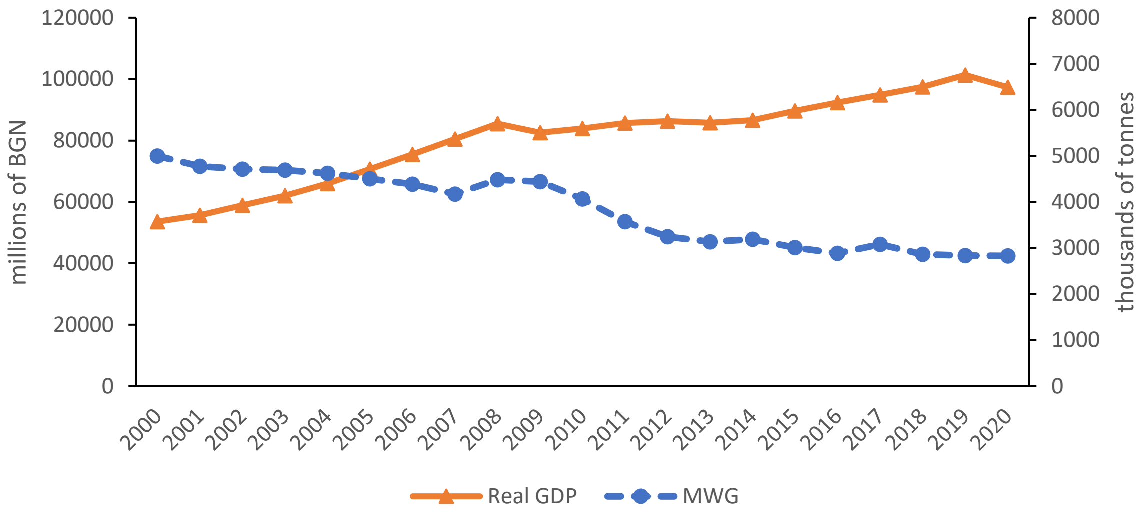

Figure 1. Municipal waste and GDP in Bulgaria in 2000-2020

Source: Information System INFOSTAT

Then we test the validity of the inclusion of trend components in the auxiliary regressions. For this purpose, we use the null hypothesis $H_0: \gamma = \delta = 0$. Since the test statistic Φ_3 for none of the indicators exceeds the critical value, we perform an additional test for the presence of trend using the model $\Delta z_t = \mu + \delta t + \varepsilon_t$. As this model does not contain unit root components, we can use the standard t-statistic. Its empirical values are not greater in absolute terms than the critical values, which confirms that we do not include the trend in the auxiliary equation.

Table 1. Results from unit root testing for MWG (y), real GDP (x) and x^2

Model	Hypothesis	Test statistic				Critical value $\alpha = 0.05$
		type	MWG y	Real GDP x	x^2	
$\Delta z_t = \mu + \delta t + \gamma z_{t-1} + \sum_{i=1}^{p} \beta_i \Delta z_{t-i} + \varepsilon_t$	$\gamma = 0$	τ_τ	-2.4848	-1.6041	-1.8188	-3.60
	$\gamma = \delta = 0$	Φ_3	3.0921	2.9604	2.4098	5.68
$\Delta z_t = \mu + \delta t + \varepsilon_t$	$\delta = 0$	t	0.3460	-1.7900	-1.0120	2.10
$\Delta z_t = \mu + \delta t + \gamma z_{t-1} + \sum_{i=1}^{p} \beta_i \Delta z_{t-i} + \varepsilon_t$	$\gamma = 0$	τ_μ	-0.6634	-2.2083	-1.5630	-3.00
	$\gamma = \mu = 0$	Φ_2	1.5139	4.1792	3.5209	5.18
$\Delta z_t = \mu + \varepsilon_t$	$\mu = 0$	t	**-2.6380**	**3.9850**	**3.5750**	2.10

Note: significant values are in bold

Source: authors' calculations

Moving to the next stage of the procedure, we test the hypothesis that the time series are nonstationary - $H_0: \gamma = 0$ in a model with constant through τ_μ. Its empirical values are not greater in absolute terms than the critical values, and thus we fail to reject the nonstationarity hypothesis. The joint hypothesis $H_0: \gamma = \mu = 0$ cannot be rejected since the empirical values of Φ_2 are smaller than the critical values. However, by further checking the significance of the constant in the auxiliary equation, we find that its inclusion is appropriate. The empirical t-statistic values based on the model $\Delta z_t = \mu + \varepsilon_t$ are greater in absolute terms than the critical values.

The overall conclusion of the applied procedure is that to test the nonstationarity of municipal waste, GDP and the squared GDP, it is most appropriate to use a model with constant included. The results confirm that all of the examined time series contain a deterministic trend and a unit root.

The transformation of the time series into first successive differences is necessary to eliminate model estimation problems caused by the unit root in the independent and dependent variables. The presence of the deterministic trend is a justification for a constant to be included in the model. Estimating model (3) with the available data yields the results shown in Table 2.

$$\Delta y = a_0 + b_1 \Delta x + b_2 \Delta x^2 + \varepsilon, \quad (3)$$

Table 2. Results from estimation and diagnostics of model (3)

Parameter	Estimate	Standard error	R^2	Diagnostic analysis	
a_0	-123.8270	60.7092	0.01	Durbin-Watson	1.6536
b_1	0.0102	0.0880		White	6.4212
b_2	-2.1275	5.2282		Jarque-Bera	0.1201

Source: authors' calculations

The Diagnostic analysis of the residuals reveals no statistically significant autocorrelation as the Durbin-Watson statistic is 1.65 and the Box-Ljung statistics are not significant to order 12. There is no significant autocorrelation in the squares of the residuals, and the White test statistic (6.42) is less than the critical value at 5% risk of error (11.07), supporting the assumption of no heteroscedasticity and conditional autoregressive heteroscedasticity. The Jarque-Bera test statistic (0.12) is not significant at 5% risk of error as it is smaller than at the critical value (5.99). The distribution of the residuals can be defined as normal. The overall conclusion from the diagnostics is that the residuals can be treated as independent, identical and normally distributed random variables. The model explains less than 1% of the variance of the outcome variable, and none of the regression coefficients of the factor variables is statistically significant at either 5% or 10% risk of error. The constant is the only significant coefficient at 10% risk of error.

5. Conclusion

To test the validity of the hypothesis of the presence of the Waste Kuznets Curve for Bulgaria in 2000-2020, we modelled the relationship between municipal waste generated and gross domestic product. As a result, we found that the model does not support a statistically significant relationship between gross domestic product and the amount of waste generated. The only significant coefficient at 10% risk of error is the constant in the regression equation, which reflects the presence of a deterministic trend in the two variables. A reasonable conclusion can be drawn that trends exist in both indicators. However, the data do not support the assumption of a relationship between the trends, as there is no relationship between the indicators, at least as far as the time between 2000 and 2020 is concerned. The available data do not support the Waste Kuznets Curve hypothesis.

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