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Araştırma Makalesi ● Research Article

Circular Economy, Solid Waste Recovery, and Growth: An Empirical Analysis for Sustainable Development in the 100th Anniversary of the Republic

Döngüsel Ekonomi, Katı Atık Geri Dönüşümü ve Büyüme: Cumhuriyet'in 100. Yılında Sürdürülebilir Kalkınma için Ampirik Bir Analiz

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Döngüsel ekonomi,
Sürdürülebilir kalkınma,
ARDL Metodolojisi.

Ö Z

Bu makale, Türkiye ekonomisinin döngüsel ekonomi perspektifinde katı atık geri dönüşümü ile ekonomik büyüme arasındaki ilişkiyi incelemeyi amaçlamaktadır. Türkiye'nin Cumhuriyet'in 100. yılını yaklaşırken karşıladığı bu önemli dönemde, sürdürülebilir ve kapsayıcı bir ekonomik büyüme hedefi hem ekonomik hem de çevresel açıdan büyük öneme sahiptir. Katı atık geri dönüşümü, günümüzde sadece atıkları azaltmakla kalmayıp aynı zamanda doğal kaynakların korunmasına ve ekonomik büyümeye olumlu bir katkı sağlayan bir süreç olarak kabul edilmektedir. Bu bağlamda, çalışma 1994Q1 ile 2020Q4 arasındaki çeyrek verileri kullanarak, katı atık geri dönüşümünün Türkiye ekonomisi üzerindeki etkilerini ayrıntılı bir şekilde analiz etmektedir. Yapılan analizler, Bootstrap Otoregresif Dağıtılmış Gecikme (BARDL) metodolojisi kullanılarak gerçekleştirilmiştir ve sonuçlar hem kısa vadeli hem de uzun vadeli dönemlerde katı atık geri dönüşümünün ekonomik büyümeyi olumlu bir şekilde etkilediğini göstermektedir. Bu, katı atık geri dönüşümünün döngüsel ekonominin temel bir bileşeni olduğunu ve Türkiye'nin sürdürülebilir büyüme hedeflerine ulaşmasına katkı sağlayabileceğini vurgulamaktadır. Çalışma ayrıca, bu sonuçlara dayanarak politika önerileri sunmaktadır. Öneriler arasında, döngüsel ekonomiye daha hızlı bir geçişin teşvik edilmesi, teknolojik yeniliklere ve altyapı geliştirmelere yatırım yapılması, farkındalık ve eğitim programlarının düzenlenmesi, kamu ve özel sektör iş birliğinin desteklenmesi, yenilikçi finansman yaklaşımlarının benimsenmesi ve kapsamlı yasal düzenlemelerin yapılması yer almaktadır. Sonuç olarak, bu çalışmanın bulguları ve önerileri, Türkiye'nin sürdürülebilir ekonomik büyüme ve kalkınma hedeflerine ulaşmasına yardımcı olabilir ve Türkiye'nin Cumhuriyet'in 100. yılını karşıladığı bu dönemde gelecek nesillere daha iyi bir yaşam ve çevre bırakma vizyonunu desteklemektedir.

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A B S T R A C T

This article aims to examine the relationship between solid waste recycling and economic growth within the framework of the circular economy perspective in Turkiye. As Turkiye approaches its 100th anniversary of the Republic, achieving a sustainable and inclusive economic growth goal is of paramount importance. Solid waste recycling is now recognized as a process that not only reduces waste but also contributes positively to both economic growth and environmental preservation. In this context, the study utilizes quarterly data from 1994Q1 to 2020Q4 to comprehensively analyze the impact of solid waste recycling on the Turkish economy. The analyses were conducted using the Bootstrap Autoregressive Distributed Lag (BARDL) methodology. The results confirm that solid waste recycling has a positive influence on economic growth in both the short and long terms. This underscores the essential role of solid waste recycling as a fundamental component of the circular economy, emphasizing its potential to contribute to Turkiye's sustainable growth goals. Additionally, the study offers policy recommendations based on these findings. These recommendations include accelerating the transition to a circular economy, investing in technological innovations and infrastructure enhancements, organizing awareness and education programs, fostering collaboration between the public and private sectors, adopting innovative financing approaches, and establishing comprehensive legal regulations. In conclusion, the findings and recommendations of this study can contribute to Turkiye's achievement of sustainable economic growth and development goals, particularly as it approaches the 100th anniversary of the Republic. Prioritizing solid waste recycling as part of the circular economy vision can help create a better living environment and a sustainable future for the upcoming generations.

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Introduction

Global challenges such as overpopulation, industrial progression, metropolitan growth, and climate change require the immediate creation of sustainable and pragmatic remedies. These factors, resulting in elevated consumption patterns and the subsequent growth in abnormal waste creation, exert pressure on natural resources and environmental sustainability (Philippidis et al., 2019; IPCC, 2021; IPBES, 2019). Simultaneously, the detrimental influence of waste on living organisms, coupled with aspects like socio-economic dynamics and climate change, muddles the process of waste management (Gardiner and Hajek, 2020; Uddin et al., 2017). One of the central causes of human-induced (anthropogenic) environmental and climate alterations is the linear production and consumption system (Aksay et al., 2015; UNIDO, 2017; Huang et al., 2020; Kuvvetli Yavaş, 2023). The global economic system predominantly possesses a linear structure in terms of the transfers of commodities and energy (Korhonen et al., 2018). The linear economy fundamentally adheres to a "take-make-use-dispose" approach and integrates the procurement of natural resources, production, consumption, and waste management (McDowall et al., 2017; Korhonen et al., 2018; De Jesus et al., 2021; Morseletto, 2023). This approach requires the processing of considerable quantities of natural resources and ultimately produces waste (Kuvvetli Yavaş, 2023).

Figure 1: Linear Economy
Source: Kuvvetli Yavaş (2023)

In the wake of the linear economy perspective and growing concerns, waste management has emerged as a global necessity, and circular economy (CE) principles have been suggested as a remedy for sustainable progression. A circular economy is an approach that seeks to minimize the production, consumption, and dumping of commodities while concurrently enhancing well-being (World Bank, 2022). The essence of this approach is centered on recycling. Over time, the strategies of reduction and reuse were integrated into recycling, establishing the 3R strategy. Later on, with the 2008 Solid Waste Framework Directive of the European Union, the 4R (reduce, reuse, recycle, recover) emerged on the scene. In 2017, the most comprehensive strategy of circularity was articulated: A circular design based on the 10R principles, being Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacturing, Repurpose, Recycling, and Recover (Potting et al. 2017; Ekins, 2019; Moraga et al., 2019). In this sense vein, the circular economy is an approach drawing inspiration from natural ecosystems and strives to distance itself from the linear economy principle, exceeding the singular cycle of manufacture, distribution, consumption, and discarding, aiming for a shift towards a regenerative economic model that reconsiders products from origin to culmination (De Jesus et al., 2018).

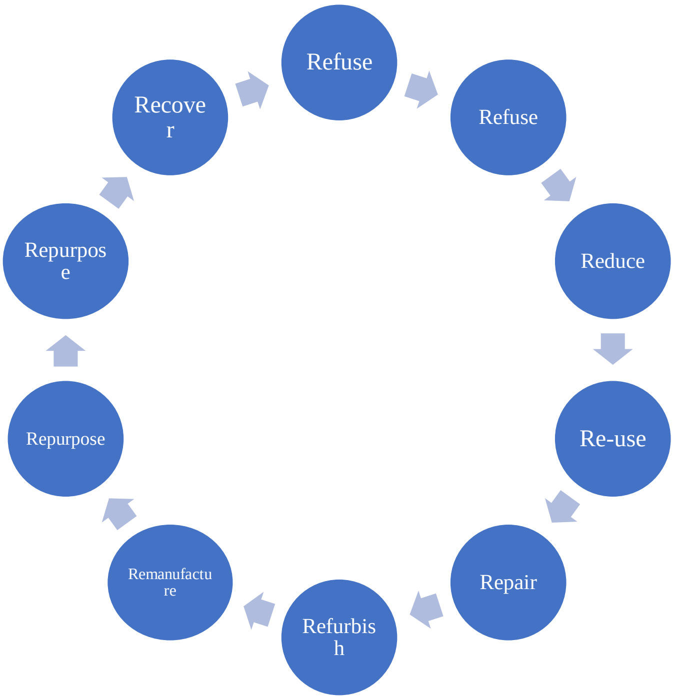

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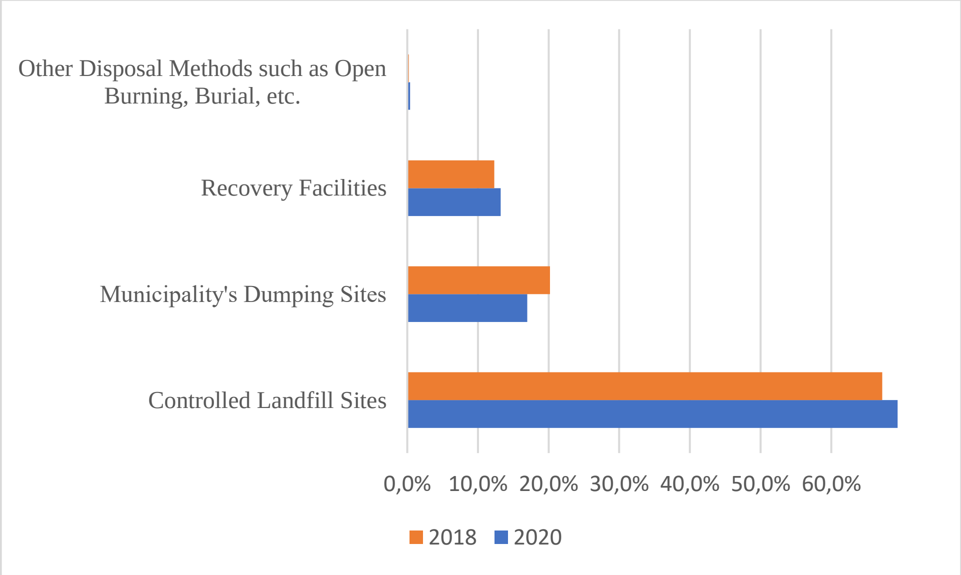
Figure 2: Circular Economy Based on the 10R Principle
Source: Kuvvetli Yavaş, 2023

While the theoretical strides cited above are observed in the circular economy, disappointingly, there's no marked betterment in solid waste management. For instance, following the "What a Waste 2.0" report by the World Bank (World Bank, 2019), the volume of global household solid waste is persistently rising, forecasting it to hit 3.4 billion tons by the year 2050. This increment is anticipated to be notably 40% in nations with low and middle incomes and 19% or more in high-income countries (Kaza et al., 2018). Yet, this expansion occurs via traditional and unsustainable waste management methods, resulting in 1.6 billion tons of carbon emissions. Furthermore, the costs of handling domestic solid waste are anticipated to escalate from 205 billion USD to 376 billion USD by 2025 (Hoornweg and Bhada-Tata, 2012).

When considering Türkiye's waste handling and recycling relative to this global predicament, the 2020 waste figures from the Turkish Statistical Institute (TÜİK) afford a crucial perspective. In this scope, Türkiye's waste creation was calculated as 104.8 million tons in 2020 (TÜİK, 2020). Waste statistics for 2020 offer an extensive dataset about Türkiye's management of waste. These data have been compiled by the Turkish Statistical Institute and sourced from diverse entities like city councils, manufacturing entities employing 50 or more individuals, active thermal energy centers with a minimum of 100 MW capacity, organized industrial sectors with completed infrastructure, mining operations, and plants focusing on waste recycling and disposal. Plus, regardless of hazardous conditions, controlled landfill sites, combustion facilities, and composting centers run by municipalities or those acting on their behalf. In 2020, a total of 104.8 million tons of waste was generated, with 30.9 million tons being deemed as hazardous waste. These statistics lay bare the vital role of waste management and sustainable waste strategies. Relative to 2018, the total amount of waste witnessed a rise of 10.5%. The manufacturing industries produced 23.9 million tons of waste, 4.6 million tons of it are deemed hazardous. 56.3% of the total waste has been either marketed or routed to sanctioned waste processing facilities. 24.2% were dispatched to waste disposal grounds, and the remaining 7.1% were stored within the facility. 7% has been treated in recycling units, 3.2% was handled within the facility, and 1.7% was taken care of by municipalities or industrial districts. Merely 0.1% of these wastes were treated using alternative techniques. Organized industrial zones have generated 279 thousand tons of waste from actions such as services encompassing infrastructure and handling wastewater. 59.4% of these wastes were transferred to controlled disposal grounds, while 40.6% were dispatched to waste disposal sites managed by municipalities or organized industrial territories. While these statistics indicate where Türkiye is in the domain of waste management, they highlight the imperative nature of effective waste control and recycling for sustainable futures.

Figure 1: Distribution of collected municipal wastes as per disposal and recycling tactics



Source: Authors’ calculations based on TÜİK.

To sum up, driving forces like the burgeoning global citizenry, industrial advancement, urban expansion, and climate change necessitates the prompt crafting of sustainable and feasible resolutions. These challenges lead to environmental assets being strained by heightened consumption patterns and increasing waste production. Circular economy principles seek to create a nexus between waste administration and sustainable development, by lessening the production, consumption, and discard of commodities while increasing well-being. However, globally, waste management still contains profound concerns. Türkiye's waste statistics underline the significance of adeptly managing and recycling waste to ensure sustainability. From this perspective, embracing circular economy principles by focusing on waste management may be a vital leap in reinforcing environmental sustainability and also in promoting economic growth.

Drawing from the theoretical frameworks previously conveyed, this research seeks to recognize the dynamic correlations between waste management and the pursuit of sustainable growth. The potential additions of this research to the existing literature can be summarized as i. Given our current knowledge, this is the pioneering empirical investigation probing the bond between solid waste recycling and economic progression in the Turkish economy from a circular economy perspective. ii. Unlike preceding analyses, this study adopts the bootstrap Autoregressive Distributed Lag (BARDL) methodology, a robust technique to explore short-term and long-term dynamic ties among variables. In the subsequent sections of this study, the second section offers an overview of the empirical literature. The third section explicates the methodology. Empirical discoveries are presented in the fourth section. In the fifth and final section, conclusions and policy suggestions are relayed.

Review of Literature

Macro-level aggregate research investigating the nexus between municipal solid waste (MSW) recycling and both environmental and economic indicators is notably scarce in the current literature. A few existing studies in this domain seek to understand the impacts of MSW recycling on environmental quality and economic expansion. At this juncture, the study's segment is dedicated to encapsulating studies that focus on the nexus between MSW recycling and environmental and economic metrics, marking notable augmentations to the scholarly domain.

One of the pivotal works that delves deeply ties between solid waste recycling and environmental and economic measures is the study by Razzaq et al. (2021). This research offers insights into appraising the repercussions of MSW recycling on the environmental milieu and economic progression in the U.S. This study employs the Autoregressive Distributed Lag (ARDL) methodology, and explores the cointegration dynamics of MSW recycling, economic growth, carbon emissions, and energy productivity, grounded on data covers 1990-2017. The results indicate that a 1% uptick in MSW recycling, in the long run, results in economic growth, while slashing carbon emissions by 0.317% in the long run and 0.157% in the short run. In the same vein, a 1% surge in energy efficiency augments economic growth rates by 0.489% (long term) and 0.281% (short term), and cuts down carbon emissions by 0.285% (long term) and 0.197% (short term). Moreover, the investigation points out a one-way causality from MSW recycling towards economic growth, carbon emissions, and energy efficiency. These findings present an enlightening view on policy endeavors that can efficiently lower carbon releases by recyclable waste governance, and concurrently yield considerable economic value.

Eralp and Gökmen (2023) delve into the nexus between environmental pollutants and income, contextualized by the Environmental Kuznets Curve (EKC). Using biennial data for Türkiye's 81 provinces from 2002 to 2020, a panel data set was constructed. The study utilized municipal solid waste to signify environmental pollutants. The main finding of the study is that the nexus between environmental contaminants and income doesn't adhere to the Environmental Kuznets Curve (EKC) but rather takes on an N-shaped curve.

Caiyi et al. (2022) delve into the mien of the growth of the e-commerce industry on solid waste production in China. The analysis period of the investigation which opted for second-generation panel unit root and cointegration assessments has been determined as 2010-2015. The results demonstrate the manifestation of a quadratic Environmental Kuznets curve in the Whole, Eastern, Central, and Western regions of China, and it's observed that heightened foreign direct investments in these zones lead to higher solid waste emissions. In Central China, the increase in market size leads to heightened solid waste emissions, whereas enhanced trade visibility curtails these emissions.

Rahman et al. (2020) examined the nexus between the rising population, urbanization, and industrial growth with solid waste production in the Kingdom of Saudi Arabia, and it further scrutinized the greenhouse gas (GHG) emission steered by these interlinked dynamics. According to the causality analysis conclusions, methane (CH4) emissions stemming from municipal solid waste (MSW) ascend in tandem with escalations in per capita GDP, swelling of the city-bound populace, and an upsurge in foreign direct investments (FDI). On the flip side, advancing literacy levels and the influx of FDI tend to diminish CH4 discharges from MSW.

Lee et al. (2016) applied the Granger causality test to U.S. yearly data from the period 1990-2012. The results reveal no evident nexus between GDP and waste production; however, the overall waste and its recycling do have a marked effect on greenhouse gas emissions in the waste sector. This means that a rise in GDP doesn’t lessen with an increase in GDP. Moreover, if there's a drop in waste produced or an increment in recycling, then greenhouse gas emissions will diminish. Therefore, the main proposition is to enhance the rate of recycling. The subsequent recommendation is to disrupt the causative nexus between BKA and greenhouse gas emissions originating from the waste sector. As a third point, the proposal is for the U.S. government to set a benchmark with a successful waste management case. Based on the research conclusions, there's a belief that the production of waste and the related carbon dioxide emissions from the waste sector can be tackled more effectively.

Shah et al. (2023) assess the effects of economic growth, industrialization, and foreign direct investment (FDI) on municipal solid waste (MSW) production in OECD nations from 2000 to 2020. Additionally, the influence of technology on waste management practices has been investigated. It discerns that evolving economic development and industrialization have over the years transformed waste production in economies of the OECD. The research indicates that the entry of FDI is detrimental and heightens waste output. But its impact is milder than the implications of economic development and industrialization. Technological advancement (R&D) are vital in curbing waste generation. The OECD must concentrate on technological solutions for better waste handling.

In general, the literature has tackled how solid waste management and recycling impact economic growth, environmental wellness, and emissions of greenhouse gases. Studies done across various nations and territories have been carried out to discern the impact of solid waste management on the aims of sustainable growth. Research indicates that recycling of solid waste might bolster economic development and simultaneously serve as pivotal component in cutting back on carbon emissions. Concurrently, it's evident that the role of technological strides and the process of industrialization seem to have a marked effect on shaping solid waste production and its environmental ramifications. The findings emphasize that solid waste management and recycling could be a potent approach to amplifying environmental and economic sustainable practices.

Methodology

Model and data set

The primary objective of this study is to delve into the consequences of municipal solid waste (BKA) recycling on the Turkish economy's growth, probing the tie between recycling practices and the ascent of the Turkish economy from a circular economy perspective. To fulfill these objectives, a model has been established with quarterly data covering the period 1994Q1 to 2020Q4, illustrated in Equation (Razzaq et al. 2021):

$$lnGDP_t = \beta_0 + \beta_1 lnCPT_t + \beta_2 lnLBR_t + \beta_3 lnRCY_t + \beta_4 \ln EF_t + \varepsilon_t \quad (1)$$

In Equation 1, GDP denotes the gross domestic product variable, gauged by per capita GDP (using constant 2015 US Dollars); CPT is indicative of the capital element, depicted by Gross fixed capital aggregation (consistent 2015 US$); LBR indicates the labor component, represented by the labor force participation rate (as a percentage of the population aged 15 and above); RCY serves as the recycling marker, characterized by the quantum of municipal solid waste collected and reprocessed (annually in kilotons); and finally, EF stands for energy efficiency, shown through per-capita energy consumption. GDP and LBR are sourced from the World Bank-World Development Indicators (WDI); RCY from the TÜİK-Municipal Waste Statistics database; and EF from the Our World in Data database. These variables are each displayed using distinct units of measurement. Hence, to tackle the challenge of distributional peculiarities it is essential to establish a homogeneous unit of measurement. In line with the previous literature, all variables have been log-transformed to streamline the interpretation process, paving the way for elasticity-based explanations (Shahbaz et al., 2020).

Unit root and cointegration tests

Unit roots represent one of the major challenges in time series analysis. This situation can hinder the accurate comprehension of fluctuations and stationarity properties in the series. Nonetheless, various unit root tests have been formulated to tackle these difficulties. For instance, the Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are essential in this context. Unit root tests are significant statistical methods for identifying the stationary characteristics of time series datasets. The ADF test is one of these tests and seeks to handle autocorrelation challenges by including lagged values of the dependent variable among the independent ones. This approach enables a more precise evaluation of the stationarity property of the series. Concurrently, the PP unit root test stands as an extension to the ADF test. The PP test tackles scenarios in which error terms demonstrate weak interdependence and show a non-uniform distribution. This aids in assessing the stationarity property of the series with a more expansive viewpoint. Still, both tests overlook structural breaks. Thus, their capacity to identify structural shifts at particular junctures in the series is not optimal. This could potentially make the test results misleading. Especially in instances of structural breaks, the test results may not portray the actual scenario. As a result, though unit root tests are vital in analyzing time series data's stationarity, they exhibit shortcomings in identifying structural breaks. Therefore, in this study, the Zivot-Andrews (ZA) unit root test, proposed by Zivot and Andrews (2002) which caters to one intrinsic structural break has been utilized. In this test, the null hypothesis posits the presence of a unit root in a variable, whereas the alternative hypothesis signifies the stationary status of the variable in question.

For this research, the choice has been made to employ the recently developed bootstrap autoregressive distributed lags (ARDL) boundary test approach to delve into the long-term cointegration nexus between variables (McNown et al., 2018). This approach builds upon the conventional ARDL boundary test approach developed by Pesaran and Shin (1999) and Pesaran et al. (2001), embedding a new cointegration examination to heighten the efficacy of t and F tests. The traditional cointegration test adheres to two distinct prerequisites when probing into cointegration dynamics (Pesaran et al., 2001). The primary rule mandates that error correction terms (ECT) need to be statistically relevant. Concomitantly, the lagged independent variables should also hold significant coefficients. Pesaran et al. (2001) have posited that while the secondary condition evaluates both lower and upper bounds (critical boundaries), the same doesn't hold for the primary criterion. It has been indicated that if the model comprises solely first-order integrated I(1) variables, then this testing mechanism is apt for scrutinizing the first condition, which is that the ECTs hold statistical significance. Consequently, the traditional ARDL method's capacity to elucidate remains limited (Goh et al., 2017; McNown et al., 2018). By applying an additional F test to the coefficients of lagged independent variables, these difficulties have been remedied, courtesy of the bootstrap ARDL boundary test approach (Goh et al., 2017). The bootstrap ARDL approach, by permitting mixed integration stages for the variables, offers a more apt choice for dynamic models that have various independent variables, addressing the problem of uncertain evidence from the conventional ARDL boundary test method (McNown et al., 2018).

Findings and Discussion

Results of the Zivot-Andrews Unit Root Tests

In the research, the Zivot-Andrews (Z-A) unit root test has been applied to identify structural breaks within the series and avert inaccurate projections.

Table 1: Zivot-Andrews Unit Root Test Results

Variables	Level		First Difference		Decision
	C Model: Constant and Trend		C Model: Constant and Trend		
	t-statis.(Prop.)	Break Period	t-statis. (Prop.)	Break Period	
lnGDP	-4.451 (0.112)	2000Q2	-6.344 (<0.01)	2001Q2	I(1)
lnCPT	-4.189 (0.209)	2003Q4	-8.552 (<0.01)	2011Q2	I(1)
lnLBR	-1.930 (0.103)	1999Q2	-5.599 (<0.01)	2016Q4	I(1)
lnRCY	-6.904 (<0.01)	2014Q2	-8.116 (<0.01)	2019Q3	I(0)
lnEF	-2.221 (0.322)	2011Q1	-6.441 (<0.01)	2017Q1	I(1)

Note: I(0) represents stationarity at the level, while I(1) represents stationarity at the first difference.

The Z-A Unit Root Test Results in Table 1 showcase the conclusions from an analysis that probes the stationarity attributes of the variables and potential structural break points embedded in these aspects. Evaluating the findings of the test in which the null hypothesis "has a unit root with a structural break in both constant and trend (Model C)" for every variable, the null hypothesis for the lnLBR variable has been rejected at the level, implying that this variable exhibits stationarity at the level, I(0). Concerning the remaining variables (lnGDP, lnCPT, lnLBTR, and lnEF), when considering their first differences, the null hypothesis faces rejection when their first differences are taken, suggesting they're stationary at the first difference, I(1). Once the series' stationarity characteristics are determined, the cointegration of the series can be deduced

Bootstrap ARDL long-term and short-term estimates

Table 2 showcases the outcomes of the Bootstrap ARDL analysis. The results have shown that there's a cointegration link among variables that exhibit structural breaks, evident at the 5% significance criterion for the Model. After identifying the cointegration between the variables with the F-test, $F_{independent}$, and $t_{dependent}$ statistics, the existence of a long-term coefficient in the model was spotted.

Table 2: Bootstrap ARDL Cointegration Results

Model	Statistic	Value	Bootstrap Values		Critical
			%1	%5	%10
$\mathbf{lnGDP_t = f(lnCPT_t, lnLBR_t, lnRCY_t, ln\ EF_t)}$	**F-test**	3.78*	4.439	3.591	2.101
ARDL(3,4,6,3,6)	***t*-dependent**	-3.11***	-3.023	-2.49	-2.07
	F-independent	4.37**	4.801	3.543	2.845

Note: ***, **, and * respectively indicate the significance levels of 1%, 5%, and 10%.

It's necessary to evaluate the outcomes of the Diagnostic tests before delving into the short and long-term coefficients presented in Table 3. Based on the result of the Jarque-Bera normality test, the calculated F statistic is 1.762, and the probability value is 0.766. Since the probability value is substantial, we can presume the error terms have a normal distribution. This denotes that the model satisfies the statistical criteria. Based on the Serial Correlation LM test outcomes, the obtained F statistic is 4.722 with a probability rating of 0.232. This indicates that the model lacks serial correlation, ensuring the independence of error terms through subsequent periods. Based on the heteroskedasticity test's outcomes, the F statistic is 2.111 and the probability value is 0.455. Given the pronounced probability value, it indicates that the model doesn't display notable heteroskedasticity concern. Based on the Ramsey-Reset Test conclusions, the F statistic is 3.981 and the probability value sits at 0.651. Since the probability value is high, the model demonstrates stability, with its parameters unchanged across time. As mirrored by the CUSUM and CUSUM graph (Figure 3), the model is "Stable". This denotes that the model remains stable over a defined span. Wrapping up, the diagnostic test outcomes uphold the general statistical reliability of the model. The results indicate that the error terms follow a normal distribution, with no serial dependency, no signs of heteroskedasticity, and the model stands stable, collectively indicate the model is well-suited for the dataset under scrutiny.

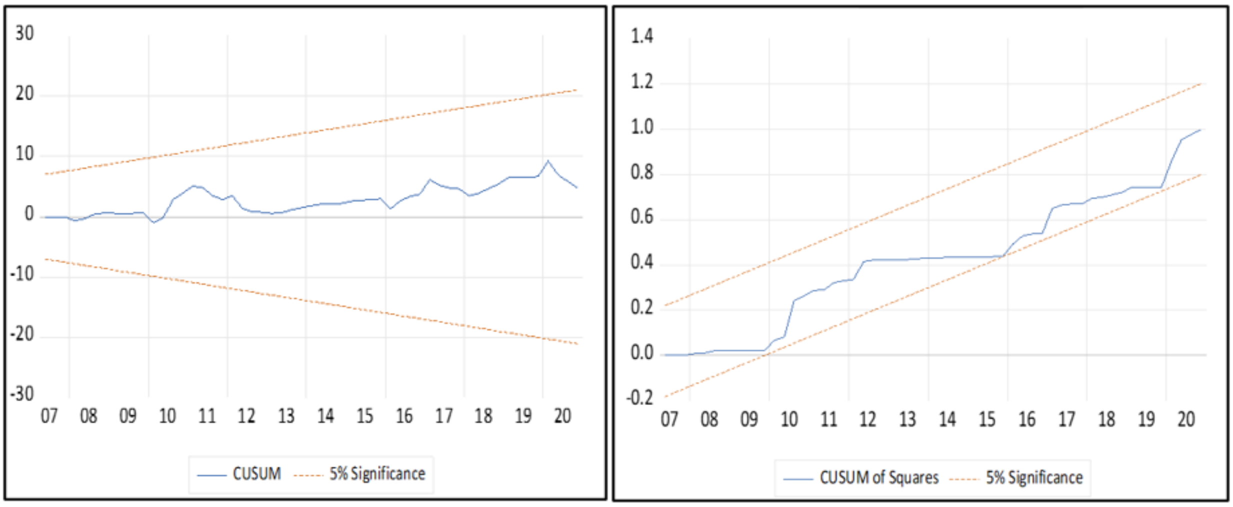


Figure 3: CUSUM and CUSUMsq Results

Discovering the cointegration link between variables enables to interpret the predicted long-term and short-term elasticities.

Table 3: Long-Term and Short-Term Bootstrap ARDL Cointegration Results

Dependent Variable: GDP			
Model: ARDL (3, 4,6,3,6)			
Long Run			
Variable	**Coefficient**	**t-statistics**	**Prop.**
CAP	0.349***	0.039	0.000
LBR	0.365**	0.142	0.013
RCY	0.004*	0.005	0.078
EF	0.153*	0.111	0.074
Trend	0.003***	0.001	0.000
Short Run			
Constant	-0.078***	-3.713	0.001
ΔGDP(-1)	0.676***	7.734	0.000
ΔCPT	0.311***	38.398	0.000
ΔLBR	0.290***	5.376	0.000
ΔRCY	0.002*	-1.441	0.055
ΔEF	0.030**	2.555	0.013
ECM(-1)	-0.070***	-3.732	0.000
Diagnostic Tests			
	F-Statistics	**Prop.**	
χ^2_{NORMAL}	**1.762**	**0.766**	
χ^2_{SERIAL}	**4.722**	**0.232**	
χ^2_{ARCH}	**1.554**	**0.309**	
χ^2_{HETERO}	**2.111**	**0.455**	
χ^2_{RESET}	**3.981**	**0.651**	
CUSUM	**Stable**		
CUSUMsq	**Stable**		

Note: ***, **, and * respectively indicate the significance levels of 1%, 5%, and 10%.

Table 3 displays the long-term and short-term predictions derived from the model. When considering economic growth as the dependent variable, long-term increments of 1% in capital, labor, municipal solid waste recycling, and energy efficiency correspond to upswings in economic growth rates of 0.349%, 0.365%, 0.004%, and 0.153% respectively. In the short term, a rise of 1% in capital, labor force, municipal solid waste recycling, and energy efficiency translates into upticks in economic growth of 0.311%, 0.290%, 0.002%, and 0.130% in order. The signs of the coefficients of independent variables, whether looking at the long or short term, match theoretical predictions, and a significant slice of the empirical documentation corroborates these results (Razzaq, 2021; Caiyi et al., 2022; George et al., 2015). Moreover, the ECM (Error Correction Model) coefficient being significant and negative signifies an amending process in the long-term nexus between economic growth and solid waste recycling. The negative sign points out that there's an adverse deviation while the association between economic growth and solid waste recycling balances out in the long term. Hence, if an upswing in economic growth or a decrease in solid waste recycling occurs, then the system will undergo a correction to attain balance in the long run (Banerjee et al., 1998).

Conclusions and Remarks

This study has addressed the influence of solid waste recycling on economic growth under the circular economy perspective of the Turkish economy. In pursuit of this goal, the Bootstrap Autoregressive Distributed Lag (BARDL) methodology was applied on quarterly data from 1994Q1 to 2020Q4. Upon analyzing the results, a positive and significant nexus between solid waste recycling and economic growth has been discerned. Both the long-term and short-term BARDL cointegration results demonstrate a positive impact of solid waste recycling on economic progression. The insights derived from the results affirm that solid waste recycling is an indispensable component of the circular economy and serves as an important key for sustainable growth.

Moreover, the contribution of waste recycling to economic development resonates with the foundational principles of the circular economy. Separating wastes at their inception, reprocessing, and recycling is a method to safeguard natural resources and and reducing the amount of waste. Thus, as a component of the circular economy, solid waste recycling presents an essential means to augment the sustainability of economic advancement.

Given these outcomes, this study puts forth the following key policy recommendations: i. Hastening the Shift to a Circular Economy: Solid waste recycling must be central to the circular economy. Waste management procedures should be aligned with the principles of the circular economy. Initiatives like source-based waste segregation, fostering recycling, and amplifying product longevity will align with the core goals of the circular economy. ii. Technological Innovation and Infrastructure Enhancement: Solid waste recycling requires technological innovations and contemporary infrastructure. Funding should be directed towards technologies that refine recycling processes and bolstering the infrastructure for waste management. iii. Awareness and Education Programs: Activities focused on education should be organized to increase the community's consciousness about the circular economy and the practice of waste recycling. In schools, workplaces, and public spaces, awareness events should be conducted to foster community engagement. iv. Cooperation and Initiatives: The government should launch strategic endeavors in the circular economy by establishing cooperative avenues with the business sector, academia, and non-governmental entities. Such platforms might aid in deriving enhanced results By enabling diverse actors to impart their experience and knowledge. v. To encourage the circular economy, novel financing approaches need to be crafted. For the private sector and investors keen on waste management and recycling projects, incentives and assistance can be provided. vi. Comprehensive Legal Regulations: There should be legal provisions underscoring the importance of the circular economy.

Standards for waste management and recycling should be set and their application should be confirmed.

Ultimately, the findings and recommendations of this research are an important guide that can contribute to Türkiye's transition to a circular economy and achieving its sustainable development goals in the 100th year of the Republic. Solid waste recycling should be prioritized as a strategic tool to support the sustainability vision of the circular economy and create a healthy living space for future generations. In this context, the findings and recommendations of the study aim to guide the steps to be taken towards Türkiye's sustainable development goals on the occasion of the 100th anniversary of the Republic.

References

Aksay, C. S., Ketenoğlu, O., & Latif, K. U. R. T. (2005). Küresel ısınma ve iklim değişikliği. *Selçuk Üniversitesi Fen Fakültesi Fen Dergisi*, 1(25), 29-42.

Banerjee, A., Dolado, J., & Mestre, R. (1998). Error‐correction mechanism tests for cointegration in a single‐equation framework. *Journal of Time Series Analysis*, 19(3), 267-283.

Caiyi, L., Xiaoyong, L., & Zhenyu, L. (2022). The nexus between e-commerce growth and solid-waste emissions in china: Open the pathway of green development of e-commerce. *Frontiers in Environmental Science*, 10, 963264.

De Jesus, A., Antunes, P., Santos, R. And Mendonça, S. (2018). Eco-innovation in the transition to a circular economy: An analytical literature review. *Journal of Cleaner Production*, 172, 2999-3018. https://doi.org/10.1016/j.jclepro.2017.11.111.

De Jesus, A., Lammi, M., Domenech, T., Vanhuyse, F., Mendonça, S. (2021). Eco-ınnovation diversity in a circular economy: Towards circular ınnovation studies. *Sustainability*, 13, 10974. https://doi.org/10.3390/su131910974

Ekins, P., Domenech Aparisi, T., Drummond, P., Bleischwitz, R., Hughes, N., & Lotti, L. (2020). The circular economy: What, why, how and where, managing environmental and energy transitions for regions and cities. *Manag. Environ. energy transitions Reg. cities, 1-89.*

Eralp, A., ve Gökmen, Ş. (2023). Çevresel Kuznets eğrisi hipotezinin geçerliliğinin Türkiye'nin kentsel atığı için test edilmesi. *Sosyal Bilimlerde Toplumsal Sorunlara Bakış*, 67.

Gardiner, R., & Hajek, P. (2020). Municipal waste generation, R&D intensity, and economic growth nexus–A case of EU regions. *Waste Management*, 114, 124-135.

George, D. A., Lin, B. C. A., & Chen, Y. (2015). A circular economy model of economic growth. *Environmental Modelling & Software*, 73, 60-63.

Goh, S. K., Yong, J. Y., Lau, C. C., & Tang, T. C. (2017). Bootstrap ARDL on energy-growth relationship for 22 OECD countries. *Applied Economics Letters*, 24(20), 1464-1467.

Hoornweg, D., Bhada-Tata, P., 2012. What a waste: A global review of solid waste management. Urban Development Series; *Knowledge Papers* no. 15. World Bank. https://openknowledge.worldbank.org/handle/10986/17388

Huang, J., Tang, Z., Liu, D., & He, J. (2020). Ecological response to urban development in a changing socio-economic and climate context: Policy implications for balancing regional development and habitat conservation. *Land Use Policy*, 97, 104772.

Intergovernmental Panel on Climate Change (IPCC). (2021). Climate change 2021 the physical science basis: Summary for policymakers. ISBN 978-92-9169-158-6.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (2019): Global assessment report on biodiversity and ecosystem services of the. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (ed.). IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.3831673.

Kaza, S., Yao, L., Bhada-Tata, P., Van Woerden, F., 2018. What a waste 2.0: A global snapshot of solid waste management to 2050. *The World Bank*.

Korhonen, J., Honkasalo, A. And Seppälä, J. (2018). Circular economy: The concept and its limitations. *Ecological Economics*, 143, 37–46. http://dx.doi.org/10.1016/j.ecolecon.2017.06.041.

Kuvvetli Yavaş, H. (2023). *Ekonomide bir paradigma değişimi olarak döngüsel ekonomi*. Ülger Bulut Karaca (Ed.) *Türkiye'de sıfır atık: Tespitler, beklentiler ve fırsatlar* (6-34) İstanbul: Arel Üniversitesi Yayınları.

Lee, S., Kim, J., & Chong, W. K. (2016). The causes of the municipal solid waste and the greenhouse gas emissions from the waste sector in the United States. *Waste Management*, 56, 593-599.

McDowall, W., Geng, Y., Huang, B., Bartekova, E., Bleischwitz, R., Turkeli, S., Kemp, R. & Domenech, T. (2017). Circular economy policies in China and Europe. *Journal of Industrial Ecology*, 21 (3), https://doi.org/10.1111/jiec.12597.

McNown, R., Sam, C. Y., & Goh, S. K. (2018). Bootstrapping the autoregressive distributed lag test for cointegration. *Applied Economics*, 50(13), 1509-1521.

Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., & Dewulf, J. (2019). Circular economy indicators: What do they measure? *Resources, Conservation and Recycling*, 146, 452-461.

Morseletto, P. (2023). Sometimes linear, sometimes circular: States of the economy and transitions to the future. *Journal of Cleaner Production*, 390, 136138 https://doi.org/10.1016/j.jclepro.2023.136138.

Pesaran, M. H., & Shin, Y. (1999). An autoregressive distributed lag modelling approach to cointegration analysis (Vol. 9514). *Cambridge, UK: Department of Applied Economics, University of Cambridge.*

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289-326.

Philippidis, G., Sartori, M., Ferrari, E., & M'Barek, R. (2019). Waste not, want not: A bio-economic impact assessment of household food waste reductions in the EU. *Resources, Conservation and Recycling*, 146, 514-522.

Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). Circular economy: Measuring innovation in the product chain. *Planbureau voor de Leefomgeving*, (2544).

Rahman, M. M., Rahman, S. M., Rahman, M. S., Hasan, M. A., Shoaib, S. A., & Rushd, S. (2021). Greenhouse gas emissions from solid waste management in Saudi Arabia—Analysis of growth dynamics and mitigation opportunities. *Applied Sciences*, 11(4), 1737.

Razzaq, A., Sharif, A., Najmi, A., Tseng, M. L., & Lim, M. K. (2021). Dynamic and causality interrelationships from municipal solid waste recycling to economic growth, carbon emissions and energy efficiency using a novel bootstrapping autoregressive distributed lag. *Resources, Conservation and Recycling*, 166, 105372.

Shah, W. U. H., Yasmeen, R., Sarfraz, M., & Ivascu, L. (2023). The repercussions of economic growth, industrialization, foreign direct investment, and technology on municipal solid waste: Evidence from OECD economies. *Sustainability*, 15(1), 836.

Shahbaz, M., Raghutla, C., Song, M., Zameer, H., & Jiao, Z. (2020). Public-private partnerships investment in energy as new determinant of CO2 emissions: The role of technological innovations in China. *Energy Economics*, 86, 104664.

Shahbaz, M., Shafiullah, M., Papavassiliou, V. G., & Hammoudeh, S. (2017). The CO2–growth nexus revisited: A nonparametric analysis for the G7 economies over nearly two centuries. *Energy Economics*, 65, 183-193.

Sharif, A., Afshan, S., & Qureshi, M. A. (2019). Idolization and ramification between globalization and ecological footprints: Evidence from quantile-on-quantile approach. *Environmental Science and Pollution Research*, 26, 11191-11211.

TÜİK (2020) Waste Statistics https://data.tuik.gov.tr/Bulten/Index?p=Atik-Istatistikleri-2020-37198 Erişim Tarihi: 10 Haziran 2023.

Uddin, G. A., Salahuddin, M., Alam, K., & Gow, J. (2017). Ecological footprint and real income: Panel data evidence from the 27 highest emitting countries. *Ecological Indicators*, 77, 166-175.

United Nations Industrial Development Organization. (2017). *Circular Economy*. https://www.unido.org/sites/default/files/2017-07/Circular_Economy_UNIDO_0.pdf

World Bank (2019): Available at: https://datatopics.worldbank.org/what-awaste/trends_in_solid_waste_management.html. Access date: June 07, 2023.

World Bank (2022). Global economic prospects. ISBN (electronic): 978-1-4648-1844-8. DOI: 10.1596/978-1-4648-1843-1.

Zivot, E., & Andrews, D. W. K. (2002). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business & Economic Statistics,* 20(1), 25-44.