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WASTE SECTOR IN SOUTH AFRICA IN TERMS OF PUBLIC EXPENSES AND ANALYSIS ON THE FACTORS THAT DEFINE WASTE GENERATION

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Abstract

The main purpose of this study is to address the waste problem that exists, especially in underdeveloped, and developing countries, and has the potential to grow day by day. For this, analyzes of waste types and public waste management activities in South Africa in terms of public expenditures were made. In addition, the stages of the waste process were systematically revealed by approaching the subject in a more holistic manner. For this purpose, the waste management hierarchy was emphasized. From this hierarchy, it was concluded that the most important stage for long-term waste management policies is the waste generation stage. Then, the economic and demographic factors that triggered the waste production were investigated, and parallel to this, analyzes were made on the South African sample at the end of the study. It is aimed that the results of the research will set an example for other countries with similar economic and sociological structures. In the empirical analysis part, ARDL cointegration analysis was carried out using the 2001-2020 period data of South Africa. While the gross domestic product (GDP) was determined as the economic factor determining the waste production of the country, population variables were used as the demographic factor. According to the results, long-term and statistically significant effects were found between waste production, GDP, and population. Accordingly, it was concluded that a 1-unit increase in GDP will affect waste production by 3.35 units in the same direction, while the population will affect waste production by 10.9 units in the same direction. In addition, it was determined that the effect of a deviation from a short-term balance on wastes will decrease after 1.57 periods (years) and return to balance, and this is statistically significant.

Keywords: Waste generation, Integrated waste management, ARDL cointegration analysis.

Jel Kodları: C22, H54, H59, H72, Q53

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KAMU GİDERLERİ AÇISINDAN GÜNEY AFRİKA'DA ATIK SETÖRÜ VE ATIK ÜRETİMİNİ BELİRLEYEN FAKTÖRLERİN ANALİZİ

Öz

Bu çalışmanın temel amacı, özellikle geri kalmış ve gelişmekte olan ülkelerde var olan ve gün geçtikçe de büyüme potansiyeline sahip atık sorununa değinmektir. Bunun için Güney Afrika'daki atık türleri ve kamu atık yönetim faaliyetlerinin kamu giderleri açısından analizleri yapılmıştır. Ayrıca konuya daha bütüncül yaklaşarak atık sürecinin aşamaları sistemli olarak ortaya koyulmuştur. Bu amaçla atık yönetim hiyerarşisine vurgu yapıldı. Ardından bu hiyerarşinin de işaret ettiği atık sorununun kaynağına odaklanıldı ve atık üretimini tetikleyen ekonomik ve demografik faktörler araştırıldı. Buna paralel olarak çalışmanın sonunda Güney Afrika örneği üzerinde analizler yapıldı. Araştırma sonuçlarının ekonomik ve sosyolojik yapıları benzer diğer ülkelere de örnek oluşturması amaçlanmıştır. Uygulama kısmında Güney Afrika'ya ait 2001-2020 dönemi verileri kullanılarak ARDL eşbütünleşme analizi yapılmıştır. Ülkenin atık üretimini belirleyen ekonomik faktör olarak gayri safi yurtiçi hâsıla(GSYH) belirlenirken, demografik faktör olarak nüfus değişkenleri kullanıldı. Çıkan sonuçlara göre, atık üretimi ile GSYH ve nüfus arasında uzun dönemli ve istatistiksel olarak anlamlı etkilere rastlanmıştır. Buna göre GSYH'deki 1 birimlik artış atık üretimini aynı yönde 3,35 birim etkileyeceği, nüfusun ise atık üretimini gene aynı yönde 10,9 birim etkileyeceği sonucuna ulaşıldı. Ayrıca kısa dönemdeki bir dengeden sapmanın atıklar üzerindeki etkisi 1,57 dönem (yıl) sonra azalıp tekrar dengeye geleceği ve bunun istatiksel olarak anlamlı olduğu tespit edildi.

Anahtar Kelime: Atık üretimi, Entegre atık yönetimi, ARDL eşbütünleşme analizi.

Jel Codes: C22, H54, H59, H72, Q53

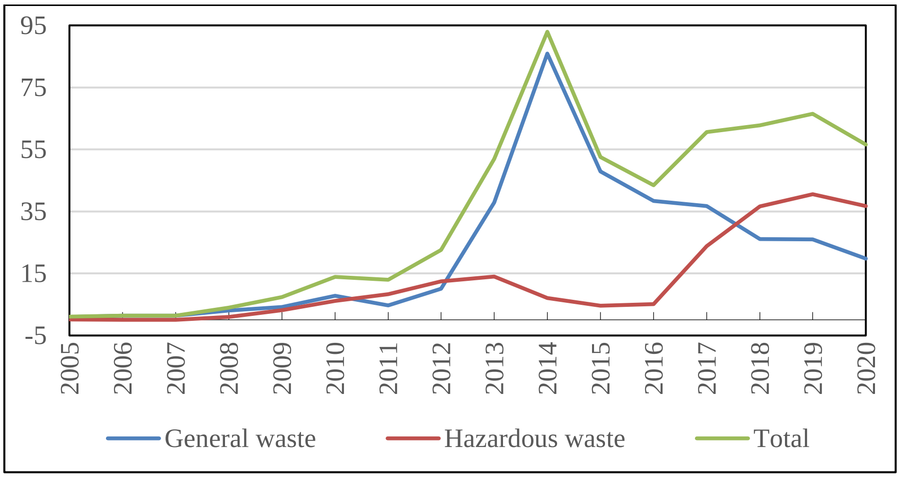
INTRODUCTION

The issue of waste is on the agenda of the world more and more due to its increasing importance in terms of both the environment and waste financing. It is becoming an important problem faced by some nation-states in particular. Today, the global annual amount of waste is 2.24 billion tons. It is estimated that this amount will increase by 73% to 3.88 billion tons by 2050 (World Bank, 2021, p.4). Although the total amount of waste is like this, waste generation is not evenly distributed throughout the world.That is, different regions produce different levels of waste for various reasons. Looking at the total amount of waste between regions in the world in 2020, East Asia and the Pacific region comes first, Europe and Central Asia comes second. According to current figures, although the Sub-Saharan Africa region, which includes the Republic of South Africa, ranks sixth in total waste generation, it is expected to rise to third place in 2040 and the second in 2050. In parallel with this, it is expected that South Africa's importance in world waste production will increase (World Bank, 2021, pp.7-8). Africa is preparing to undergo a major social and economic transformation in the next century, with the population explosion and the change in urbanization and consumer purchasing habits due to the increase in income. This situation is expected to lead to significant growth in waste generation, putting significant pressure on the already limited public and private waste services and waste infrastructure (UNEP, 2018, p.3).

In terms of waste, the sub-Saharan African region has some important characteristics. One of them is that it has the highest poverty level in the world. Although poverty rates have decreased in recent years, this process has occurred at a much slower pace compared to other parts of the world. The poverty rate in sub-Saharan Africa, which was about 57% in 1990 (with less than $1.90 per day income), decreased to 43% in 2012 (IMF, 2015, pp.56-57). However, within the region, the Republic of South Africa is the second richest country. With the effect of these economic conditions, the issue of waste in South Africa is already a striking point. The country's daily waste amount per capita is 0.98 kg, which is above the world and regional average. It is also the third country in the region in terms of waste per capita. The SAA region has an important waste potential in terms of population growth as well as income growth in the future (World Bank, 2018, p.78). The fact that the Republic of South Africa is among the five main African countries that cause plastic waste in the seas indicates that the country's waste management issue will increase in the future with this country's increasing purchasing power and changing population structure (Jambeck et al., 2015).

Before addressing the current situation of the waste problem in the Republic of South Africa, it is useful to explain the foundations of the waste concept in this country. Waste in South Africa is divided into “general” and “hazardous” wastes as a result of the combination of the South Africa Waste Information System (SAWIS) and the National Waste Information Regulation (RSA, 2012). With the regulations made in the following years, this distinction was further clarified, and wastes were defined. Accordingly, general wastes are those that do not cause direct harm or pose a threat to health or the environment. These are; household waste, building construction and demolition residues, commercial wastes and waste that do not react chemically. Alternatively, wastes that do not contain hazardous materials, objects, or objects, and those that do not fall under the classification of hazardous wastes are considered general waste. If it is hazardous waste; It is any type of waste that may have harmful effects on health and the environment due to the physical, chemical or toxic properties of organic or inorganic elements and compounds in it, and any type of waste that contains dangerous substances, materials or objects (RSA, 2014).

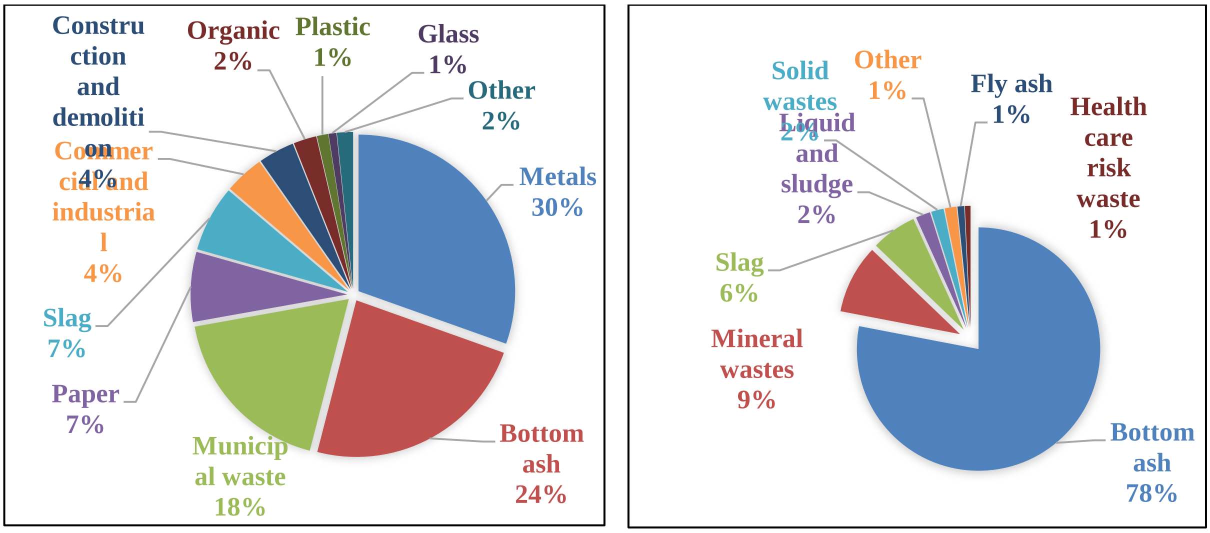
In the light of available data, waste generation in the Republic of South Africa has showns a general upward trend in the last fifteen years (Figure 1). In 2021, the country produced a total of 53.27 million tons of waste, of which 26.75 million tons of general waste and 26.52 million tons of hazardous waste (SAWIC). According to the data of the South African Waste Information Center, when we further detail the measurements, we can see the distribution of waste types as in Figure 2. According to the general waste data of 2021, metals with 8.14 million tons (mt) are 30%, the ash accumulated at the bottom in coal burning processes (bottom ash) with 6.3 million tons is 24%, and municipal wastes with 4.86 million tons are 18% constitutes more than 70% of the general waste. The remaining wastes are respectively were paper (7%) with 2 million tons, slag (7%) with 1.8 million tons, commercial and industrial wastes (%4) with 1 million tons, building construction and demolition wastes (4%) with 1 million tons, organic wastes (2%) with 0.6 million tons, plastic wastes (1%) with 0.3 million tons and glass wastes (1%) with 0.2 million tons. Apart from these, there are mineral wastes, fly ash and dust from miscellaneous filter sources, sludge, waste of electric and electronic equipment, and tyres collected under the other waste heading.



Source: It was generated with the information obtained from the Waste Information System website of the Ministry of Environment, Forestry and Fisheries of South Africa (SAWIC).

Figure 1. South Africa Waste Generation 2005-2020, (Millions Tons)

In the case of hazardous wastes, the bottom ash formed in coal burning processes with 20.7 million tons alone causes 78% of hazardous wastes. Mineral wastes are in the second place, constituting 9% with 2.4 mt. 2021, the rest of the total hazardous waste consists of slag (6%), liquid and sludge wastes (2%), solid wastes (2%), fly ash, and dust from miscellaneous filter sources (1%), health care risk waste (1%). Other hazardous wastes include waste oil, sludge, batteries, asbestos waste, solvents, tarry waste, bituminous waste, brine, waste of electric and electronic equipment, permanent organic pollutants[*], gases, mercury containing waste (SAWIC).



Source: It was generated with the information obtained from the Waste Information System website of the Ministry of Environment, Forestry and Fisheries of South Africa (SAWIC).

a) General Wastes b) Hazardous Wastes

Figure 2. Distribution of Waste Types in South Africa, 2021

As it can be seen that in Figure 2a, metals are the type of waste that the largest share in general waste in South Africa today. In addition, from 2015 to 2021, metal waste increased 2.5 times with from 2.3 mt to 8.1 mt (SAWIC). Since the South African economy has more scrap metal[3] than domestic demand, it is a net exporter of scrap metals by selling the surplus to the foreign market. China, India, Korea, Brazil, Germany, Pakistan, and Turkey are the leading countries in which scrap metal is exported (TUTWA, 2017). In addition, South Africa is one of the world leaders in metal packaging recycling, where more than 75% of metal packaging is recycled. (Research and Markets, 2021).

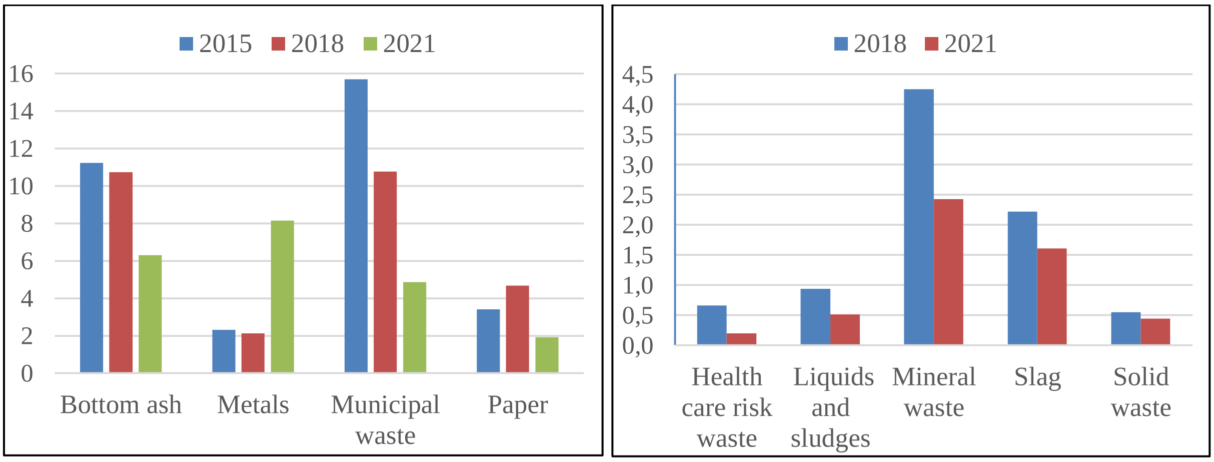
In the last four years, about three-quarters of South Africa's hazardous waste problem has been caused by ashes from coal combustion. As it can be seen in Figure 2b, in 2021, the ashes accumulated at the combustion floor has exceeded 78% of the total hazardous waste (SAWIC). The most important factor in producing such wastes is the coal-fired power plants

[*] Persistent organic polluting wastes (POPs): These are the wastes that accumulate biologically in the environment permanently through the food web and pose a risk to human health and the environment.

[3] Metal waste or metal scrap can be divided into two basic categories: Production scrap and used scrap. Production scrap metals refers to the scraps and splinters formed during the production of metal products (turning, cutting, shaving, pressing). Used scrap metals are metal products that have completed their life or failed to provide the expected benefits when first produced.

operating in the country. In practice, approximately 3.5 tons of coal used for electricity generation results in 1 tonne of ash. This problem is expected to increase further as new ones of this type of energy plant are planned to be operational too in the future (Reynolds and Singh, 2019, p.10). While a decrease of up to 70% was observed in mining wastes, which closely follow the ash problem, in the period of 2011-2017 (DEA, 2018, p.43), there is a general decrease in other hazardous wastes in the period of 2018-2021 (Figure 3b).

General wastes have undergone significant changes since 2015, as shown in Figure 3a below. Accordingly, while bottom ash has decreased from 11.2 mt to 6.3 mt in the last six years, municipal waste also has decreased from 15.7 mt to 4.9 mt. on the other hand, paper waste is still the fourth largest general waste type today, with a decrease of 44% compared to 2015 and 59% compared to 2018 (SAWIC).



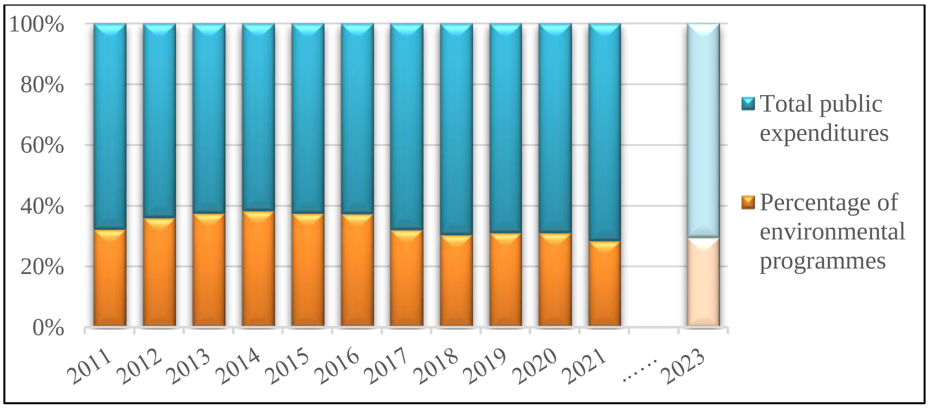
Source: It was generated with the information obtained from the Waste Information System website of the Ministry of Environment, Forestry and Fisheries of South Africa (SAWIC).

a) General Wastes b) Hazardous Wastes

Figure 3: Changes in Waste Types in South Africa (billion tons)

Although a decrease is observed in some of the variables mentioned above, as can be seen from Figure 1, a fluctuating upward trend is observed in total waste. The fact that hazardous wastes have been over the general wastes since 2018 reveals the current seriousness of the issue. In addition, no waste service is provided for approximately 30% of household waste (Rodseth et al., 2020, p.1) Adequate budgeting and strict financial management policies are needed to improve waste services (South Africa National Development Programme, 2020, p.60). Therefore, a heavier financial burden on the government and local administration emerges each passing day. Especially in African countries with high public debt, the situation is of particular importance. At this point, it is useful to closely examine the waste management policies and waste production mechanisms developed over time in order to cope with the waste problem. With this study, it is primarily aimed to be beneficial for administrators and policy makers who are responsible for providing waste services. If those concerned can correctly identify the factors and stages that cause waste production in society, they will have the opportunity to take measures against developing problems.

Depending on the type of waste, they can pollute the air, water, soil and even groundwater. In order to prevent such risks of waste, governments have developed environmental programs, environmental protection measures, and waste management activities. For this reason, it would be useful to investigate the reflections of these waste-related expenditure items on public finances. Because environmental and waste programs have an important share in the budgets of underdeveloped and developing countries. The graph in Figure 4 was created in order to determine the weight of *environmental programs* on the budget according to the information compiled from the South African budget national expenditure estimates. Accordingly, the share of environmental programs developed in the 2011-2021 period in total public expenditures is an average of 53.4%. Although this rate started to decrease after 2014, it is still seen to be above a high rate of 40% today. In addition, this rate is expected to be 42.1% according to 2023 forecasts (National Treasury, Republic of South Africa, 2021, p.578).

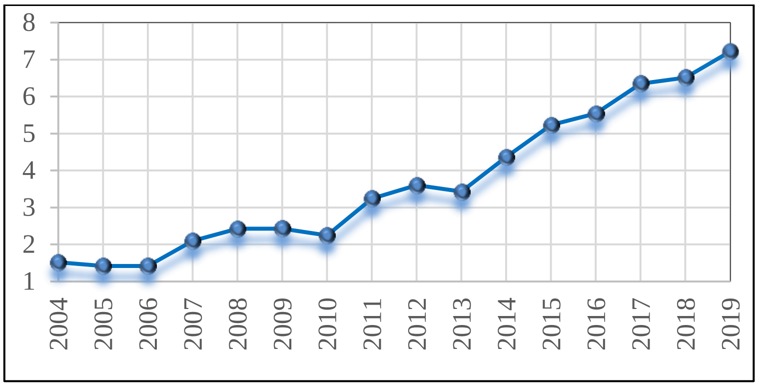


***Source**:* It was generated by compiling from the South African budget documents between 2011/2012 and 2021/2022 (National Treasury, Republic of South Africa, *Estimates of National Expenditures 2011/2012-2021/2022).*

Figure 4.: Environmental Programmes in Total Public Expenditures (%)

Another important subprogram of environmental programs in South Africa in terms of waste is *environmental protection and infrastructure expenditures*. They make up, on average, more than 40% of environmental programs (National Treasury, Republic of South Africa, 2012-

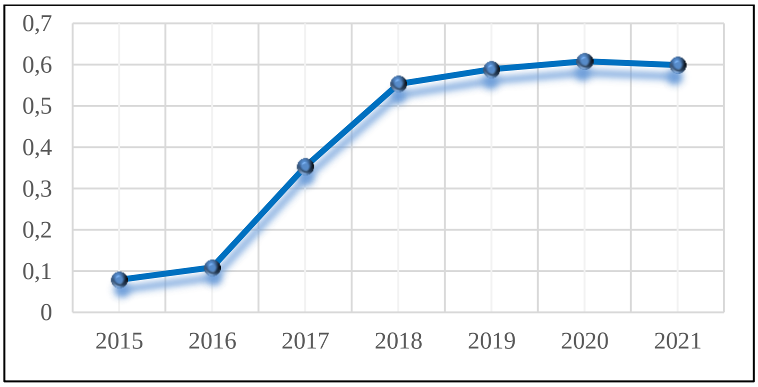
2022). The budget realization amounts of environmental protection expenditures by years are shown in Figure 5. According to the graph, there is a clear upward trend in the environmental protection expenditures item of the national budget. In particular, a large part of the 19% increase in 2019 was only due to environmental protection expenditures (Statistics South Africa, 2019/2020, p.10). Environmental protection activities are; waste management, wastewater management, pollution abatement, protection of biodiversity and landscape, R & D environmental protection and environmental protection not elsewhere classified (Statistics South Africa, 2019/2020, p.27).



Source*:* It was generated by compiling from the South African budget documents between 2004/2005 and 2019/2020. (National Treasury, Republic of South Africa, *Estimates of National Expenditures 2004/2005 - 2019/2020).*

Figure 5. Environmental Protection Expenditures, *Millions Rant*

Another sub-program that concerns waste in the South African budget system is the Chemicals and Waste Management classification. Among the objectives of this program are to manage the waste process and reduce waste generation with the technical and legal tools to be provided by the public sector. The national expenditures made in South Africa in recent years to achieve these targets are shown in Figure 6 in local currency. In the light of this information, it can be said that the country's *chemicals and waste management expenditures* grew approximately 7.5 times in the 2015-2021 period (National Treasury, Republic of South Africa, 2015/2016, p.23).



Source: It was generated by compiling from the South African budget documents between 2011/2012 and 2021/2022 (National Treasury, Republic of South Africa, *Estimates of National Expenditures 2011/2012-2021/2022).*

Figure 6. Chemicals and Waste Management Expenditures, 2015-2021, (Millions Rant)

In this study, it is aimed to be beneficial for policymakers related to the waste sector in South Africa and such countries, whose population and economic indicators are predicted to increase. For this purpose, systematic waste management policies and the factors that determine waste generation will be mentioned in the following.

1. FACTORS DETERMINING WASTE PRODUCTION IN SOUTH AFRICA AND RELATED LITERATURE

As mentioned before, the amount of waste production varies from country to country. The underlying reasons for this situation stem from the difference in waste generation dynamics. However, many studies have shown that as per capita gross domestic product (GDP) increases, the production of local solid waste (Municipal Solid Waste-MSW) and other types of waste increases per capita (El-Haggar, 2007, p.1). Nigeria and South Africa, which have high waste amounts per capita in Sub-Saharan Africa, are also the countries with the highest income in the region supports this situation (Balı, 2016, p.689; World Bank & OECD). An indication of this is that high-income groups in South Africa have 74% more household waste than middle-income groups and 3 times more than low-income groups. In addition, the waste generation of middle and high income groups in 2016 is 71% of total waste (Rodseth et al., 2020, p.5). These waste causes, which are briefly mentioned here, will be discussed in two classes as economic and demographic factors in the continuation of the study.

1.1.Economic Factors

The economy is one of the most important factors affecting waste production. The amount of waste may be directly related to manufacturing and industry and indirectly related to increasing consumption due to higher incomes (EEA, 1999, p.12). Therefore, waste generation is generally considered to be linked to national GDP. That is, the higher the GDP, the larger the waste generation. As in this study, other studies in the literature reached similar results (Cole et. al., 1997; DEFRA, 2003, p.1; Dlamini, et al., 2018; Godfrey et. al., 2020, p.1418; Johnstone & Labonne, 2004; Karousakis, 2006; Kowalski & Amann 2001; Mazzanti & Zoboli, 2008; Nkosi, 2014; Seppala et al., 2001; World Bank, 2021). However, there are some studies that show that economic developments and waste are unequivocally unrelated. (Berrens et al., 1998; Leigh, 2004; Mazzanti et al., 2008). It is useful to mention these studies which are in both poles briefly.

One of the first studies on this subject was by Cole et al. (1997, p.414) analyzed municipal waste data for 13 OECD countries for the period 1975–1990. Research findings revealed that municipal waste production increased in the same course as income. In other words, he found no evidence of an inverted U shape between municipal waste and economic indicators. That is, environmental damage is constantly increasing due to economic developments. Similarly, Seppala et al. (2001), a study on five industrialized countries, including Japan, the United States, and Germany, covering nearly the same period (1970–1994), found no evidence of a relationship between direct material flows from economic activities and waste. However, Kowalski and Amann (2001, p.23) analyzed the wealthier OECD countries and found that material input intensity was correlated with all countries' 1975-1995 growth data. However, they stated that, unlike total waste, only solid wastes are independent of economic indicators.

In a later study by Johnstone and Labonne (2004, p.536); In the framework of OECD countries, a panel data analysis was applied to solid wastes to determine the economic reasons for domestic solid waste generation rates. Accordingly, the positive elasticity of waste against income was found as 0.15. Karousakis (2006) in his study, dealt with policy assessment and focused on the determinants of waste generation. According to the panel data analysis for 30 OECD countries with data between 1980 and 2000, domestic solid wastes increase monotonously with income. This study also provides information about the driving forces behind the recycling rates of paper and glass waste and the rate of waste going to the landfill.

Mazzanti and Zoboli (2008, p.1233) state that there is a relationship between waste and economic reasons in their study in which they analyzed the years 1995-2005 among European Union countries (EU25). However, they point out that this relationship has decreased in recent years. In addition, in the analysis, show that Western Europe and Eastern European countries diverge and have different dynamics.

World Bank (2021, p.22, 27) stated that living standards and income level are closely related to the consumption of goods and services and waste production. Accordingly, while the total amount of waste is expected to increase by about 200% in low-income countries by 2050, it is likely to increase by 110% in low-middle-income countries, 53% in upper-middle-income countries, and only 29% in high-income countries. Dlamini et al. (2018, p.255) found that the increase in income per capita in countries resulted in an increase in household waste production. Therefore, it increases the pressure on municipalities in terms of service delivery and infrastructure related to waste management, including landfills.

There is also some evidence that there is no definite relationship between economic developments and wastes. Berrens et al. (1998, p.439) and Wang et al., (1998, p.46) found evidence for negative resilience, focusing on US hazardous waste stocks as an indicator of environmental impact and utilizing a county-based cross-sectional dataset. In addition, Leigh (2004) provides similar evidence for a waste indicator derived from environmental sustainability indices (ESI). Mazzanti et al. (2008, p.57) concluded that a decreasing trend of economic indicators with waste (negative flexibility) is only in industrialized countries where waste management and waste policies are more developed (Mazzanti et al., 2008, p.57).

1.2.Demographic Reasons

The population factor has economic and environmental reflections beyond just showing human characteristics. For example, from the point of view of our subject, waste generation may be higher in areas with population density. (DEA, 2018, p.7). Therefore, the structure of the population is accepted as a determining factor in the amount of waste production. As in this study, Johnstone and Labonne (2004), Mazzantini and Zoboli (2008), Hoornweg et al. (2013), Nkosi (2014), DEA (2018), Polasi et al. (2020) concluded that there is a positive relationship between population and waste. Albeit a little, Begum et al. (2015) show that the population growth rate does not have a significant effect on the waste produced per capita.

In a study by Johnstone and Labonne (2004), they applied a panel data analysis on solid waste in OECD countries to gain insight into the demographic determinants of domestic solid waste generation rates. Accordingly, the positive elasticity of the wastes in the face of population density was found to be in the range of 0.69, but lower than 1.

Mazzantini and Zoboli (2008, p.1224) focused on variables that positively affect the amount of waste, such as the number of households in EU countries, in their study examining various factors as potential drivers of future trends in waste generation. The results are that population density emerged ~~as~~ positively related to waste generation per capita. Another study examined the issue of household waste generation and concluded that population size would increase household waste generation (Nkosi, 2014, p.3).

From the perspective of municipal services in urban areas, population growth increases the amount of waste, causing inadequacies in waste management infrastructure, including waste collection-disposal services and landfills, above local governments (Polasi et al., 2020, p.5).

It has been mentioned before that the environmental effects of waste can take various forms. Collecting all these environmental damages and expressing them in terms of CO2 equivalent is an approach accepted in the literature. From this point of view, the study of Begum et al (2015: 600) in which investigates the dynamic effects of GDP growth, energy consumption, and population growth on CO2 emissions using econometric approaches for Malaysia is important. Because CO2 emissions can be accepted as an indicator of waste, and the effect of population growth rate on per capita CO2 emissions can be evaluated accordingly. Empirical results from the ARDL bound test for the period 1970-1980 in Malaysia show that the population growth rate does not have a significant impact on CO2 emissions per capita.

2. EMPIRICAL ANALYSIS

Although wastes are a problem in all countries of the world, some special situations in underdeveloped and developing countries take this problem to a higher level. The special conditions of these countries are the inadequacies in the technical knowledge and finance necessary to overcome the waste problem. In this direction, the continuation of research aims to make an analysis within the framework of the Republic of South Africa, which is a developing country. This analysis has been preferred to reveal the economic and demographic effects on the dependent variable of waste generation.

2.1. Data and Methodology

At this stage of the study, it is aimed to conduct an empirical analysis using the data of the South African country for the years 2001-2020. Details of the series used in the research are given in Table 1. Also, to put it briefly here, Amount of Waste *(WASTE, tons)* represents the overall amount of waste produced by the country in a year, in tons according to the calculations of the South African Waste Information System (SAWIS). Population *(POP, people)* is the number of people living in the country according to the calculations of the World Bank. And the GDP per Capita *(GDP, dollar)* variable represents the income in dollars according to the 2015 fixed prices according to the calculations of the World Bank. In the application part, the "EViews 12" package program was used to perform the analysis.

Table 1: Variable Definitions and Sources

Variable	*Defination*	*Source*
$WASTE_t$	It is the annual general waste amount in tons according to the waste classification accepted in the Republic of South Africa.	SAWIS
POP_t	The total population based on mid-year actual population estimates, which take into account all residents of the country, regardless of legal status or citizenship.	World Bank
GDP_t	GDP per capita is calculated as gross domestic product divided by mid-year population. GDP is arrived at by adding all product taxes to the gross value added by all incumbent producers in the economy and subtracting subsidies not included in the value of the products. GDP is calculated without depreciating assets produced or deductions for depletion and degradation of natural resources. Data are in US dollars at constant 2015 prices.	World Bank

2.2.Empirical Analysis

Although wastes are a problem in all countries of the world, some special situations in underdeveloped and developing countries take this problem to a higher level. The special conditions of these countries are the inadequacies in the technical knowledge and finance necessary to overcome the waste problem. In this direction, an analysis will be made in the context of the Republic of South Africa, a developing country, in the continuation of the research. In this analysis, it is preferred to reveal the economic and demographic effects on the dependent variable of waste generation.

After giving detailed information about the variables used in the model, information about the model structure is given below:

$$WASTE = f(POP, GDP)$$

The regression model in which WASTE is the dependent variable and POP and GDP is the independent variable is given below.

$$WASTE_t = \alpha_0 + \alpha_1 POP_t + \alpha_2 GDP_t$$

The bounds test developed by Pesaran et al. (2001) first estimates an unconstrained error correction model adapted to the dependent variable in order to investigate the existence of a long-term relationship between the variables. In this context, the above regression equation is restated in ARDL(p,q,r) model format.

$$\Delta WASTE_t = \alpha_0 + \alpha_1 t + \alpha_2 WASTE_{t-1} + \alpha_3 POP_{t-1} + \alpha_4 GDP_{t-1} + \sum_{i=1}^{p} \beta_{1,i} \Delta WASTE_{t-i} + \sum_{i=0}^{q} \beta_{2,i} \Delta POP_{t-i} + \sum_{i=0}^{r} \beta_{3,i} \Delta GDP_{t-i} + \varepsilon_t$$

α_0 constant term, α_1 deterministic trend coefficient, $\alpha_2, \alpha_3, \alpha_4$ parameters represent long-term coefficients and $\beta_1, \beta_2, \beta_3$ parameters represent short-run coefficients, (p, q, r) optimal lag length, Δ difference operator, εt error term. According to the ARDL bounds test results, if a cointegration relationship between the variables is detected, the long and short run coefficients can be estimated. Pesaran et al. (2001) proposed two tests to test the cointegration relationship between variables. The first of is the standard F-test (limit test) with lower and upper critical values. In this method, the critical values obtained by Pesaran et al. (2001) are compared with the calculated test statistics; If the calculated test statistic is greater than the upper critical value, the null hypothesis, which shows no cointegration between the variables, is rejected. In other words, it means that there is a long-run relationship between the variables. In another test which is called the Error Corection Model the variables are expected to converge to their long-term equilibrium values. For this, the following error correction model is estimated, and the error correction coefficient (λ) must be negative and statistically significant (Pesaran, Shin and Smith, 2001).

$$\Delta WASTE_t = \alpha_0 + \alpha_1 t + \alpha_2 WASTE_{t-1} + \alpha_3 POP_{t-1} + \alpha_4 GDP_{t-1} + \sum_{i=1}^{p} \beta_{1,i} \Delta WASTE_{t-i} + \sum_{i=0}^{q} \beta_{2,i} \Delta POP_{t-i} + \sum_{i=0}^{r} \beta_{3,i} \Delta GDP_{t-i} + \lambda ECM + \varepsilon_t$$

2.3. Results

In this part of the analysis, the impact of economic growth and population changes on the amount of waste is analyzed. For this purpose, firstly, unit root tests and then ARDL cointegration analysis is performed.

Before proceeding to the cointegration analysis, it is necessary to determine the stationarity levels of the variables. For this purpose, unit root tests have been applied to the variables used in the study. However, before moving on to the unit root test results, it is useful to give information about each series's model and lag lengths. Whether there are deterministic components (constant and/or trend) or not in the model to be used in unit root testing has been determined by a hierarchical process. According to this process, it has been determined that the most suitable model according to all three variables is the constant model. Secondly, the number of lags that should add to the model in order to determine whether the residuals are clean-sequences or not is selected by Schwartz Information Criteria (SIC). Accordingly, unit root test results are presented in Table 2.

Table 2. Unit Root Test Results

Variables	ADF	PP
WASTE	-4.474938* (0.0026)	-4.763282* (0.0014)
POP	0.6387 (0.9856)	1.1572 (0.996)
GDP	-3.555512** (0.0176)	-3.534865** (0.0184)
ΔPOP_t	-3.7473* (0.014)	-2.3033** (0.0404)

Note: * and ** indicate significant at 1% and 5% significance level, respectively, Δ: difference operator.

When Table 2 is examined, it is seen that the POP variable is non-stationary at level according to both ADF and PP unit root tests, but when the first difference of the series is taken, it becomes stationary according to both ADF and PP unit root tests. That is, the population variable is stationary at the first difference (I(1)). In addition, it has been determined that the WASTE and GDP variables are stationary at level. According to the unit root test results, the ARDL model structure is preferred in the study because all the variables in the model are stationary at different degrees, and the number of observations is small.

After it is determined that none of the variables used in the analysis is I(2) according to the unit root test result, the ARDL cointegration relationship between the variables can be conducted. According to Schwartz Information Criteria, it was determined that the most suitable model was the ARDL (1,0,1) model. Accordingly, one lag of the WASTE variable and one lag of the POP variable is included in the model. While selecting the appropriate model, the constant model with the lowest SIC value is selected by using the general-to-specific approach.

Table 3. ARDL(1, 0, 1) Model Pre-Tests

Model tests	***Calculated value***	***Inference***
Autocorrelation (Breusch-Godfrey)	F-statistics:1.478418 Prob. F: 0.2667	Since the p-value of the calculated F-statistic is greater than the critical value, it shows that there is no autocorrelation problem.
Varying Variance / heteroscedasticity (Breusch-Pagan-Godfrey)	F-statistics: 0.655644 Prob. F: 0.6326	It shows that there is no problem with varying variance since the p-value of the calculated F-statistic is greater than the critical value.
Ramsey RESET Test	F-statistics: 0.355819 Prob. F: 0.5611	It shows that there is no specification error because the p-value of the calculated F-statistic is greater than the critical value.
Normality	Jarque-Bera: 1.276409 Prob: 0.528240	Since the p-value of the calculated statistic is greater than the critical value, the residues are normally distributed.

Apart from these tests, two more test show the stability condition. Their results are given in the graphs below. According to the results, parameter estimates in both tests provide the stability condition at the 5% confidence level.

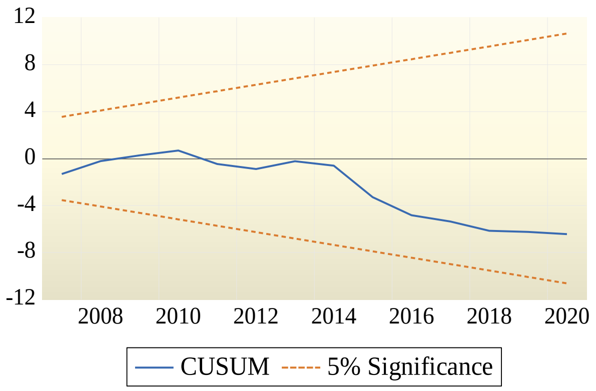


Figure 8. CUSUM Test

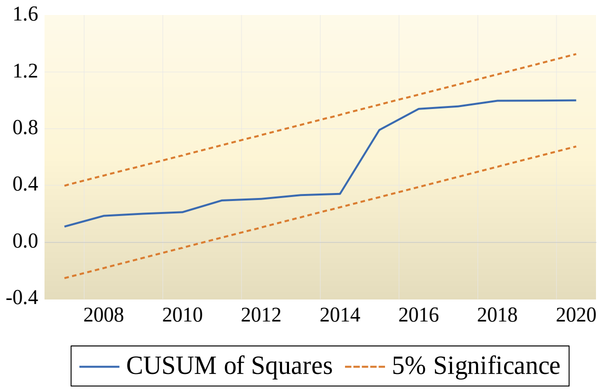


Figure 9. CUSUM Squares Test

When Table 3 and Figures 8 and 9 are examined, it is seen that the tests are at the desired values, and there is no obstacle to the long-term predictions of the model.

It can be decided whether there is a cointegration relationship between the variables or not by looking at the F-statistic in Panel C. The calculated F-statistic is above the upper critical value at the 1% significance level. Therefore, the null hypothesis claiming that there is no cointegration relationship between the variables is rejected. In other words, it is seen that there is a long-term relationship between the amount of waste, population, and GDP in the period under analysis.

Table 4. ARDL(1, 0, 1) Model Results

Panel A: Long-Term Forecasts				
Dependent variable: ΔWASTE	Coefficient	Standard error	t-statistics	P value
GDP	3.352096	3.685450	0.909549	0.3785
POP	10.98810	4.363080	2.518428	0.0246
Panel B: Short-Term Forecasts				
Dependent variable: ΔWASTE	Coefficient	Standard error	t-statistics	P value
C	-139.5407	19.81051	-7.043768	0.000
ΔPOP	359.3342	100.46492	3.570164	0.0031
EC_{t-1}	-0.637746	0.098157	-7.153054	0.000
$\bar{R}^2 = 0.73, DW = 1.87$				
t-Boundary Test		α	I(0)	I(1)
t=-7.153		%10	-2.57	-3.21
		%5	-2.86	-3.53

		%2.5	-3.13	-3.8
		%1	-3.43	-4.1
Panel C: Limit Test Results				
H_0: There is no cointegration.				
		A	I(0)*	I(1)*
F=14.92		%10	3.437	4.47
K=2		%5	4.267	5.473
		%1	6.183	7.873
*: These are the critical values produced by Narayan (2005) for n=75				
Panel D: Diagnostic Test Results				
$\bar{R}^2 = 0.95$				
$DW = 1.87$				
Autocorrelation (Breush-Godfrey): F=1.47 (p=0.26)				
Normality (Jarque-Bera): JB=1.27 (p=0.52)				
Varying Variance (Breush-Pagan-Godfrey): F=0,65 (p=0.63)				

After revealing the existence of a long-term relationship between the variables, the ARDL long-term model is estimated (Table 4). The findings in Panel A give the long-term coefficients. Accordingly, in the long run, the coefficient of the GDP variable is positive (3,352) as expected and statistically significant at the 10% level. In other words, a 1% increase in GDP leades to a 3.352% increase in the amount of waste. In addition, the coefficient of the population variable is positive (10.988) as expected and statistically significant at the 5% level. Accordingly, a 1% increase in population leades to a 10.988% increase in the amount of waste.

It is seen that the error correction coefficient in Panel B and obtained from the error correction model is negative (-0.637) and statistically significant at the 1% level. It shows that these coefficients converge to the equilibrium values in the long run.

CONCLUSİON

According to the economic theory, a positive relationship exists both between the amount of waste and GDP and the amount of waste and population (Andersen et al., 2007; GreenCape, 2020; Johnstone and Labonne, 2004; Nkosi, 2014; Zaman, 2013). In this study, the effects of GDP and population on waste amount for South African countries have been examined. In this context, the ARDL approach has been used with the annual data for 2001-2020. Findings show that in the long run, GDP and population have a positive effect on the amount of waste.

The segment that produces the most household waste per capita in South African society is high-income groups. Then comes the middle-income level and the low-income level, respectively. This difference between the lowest and highest incomes is more than 3 times. Therefore, the improvement of the income distribution, on the one hand, discourages those who produce high waste from these tendencies. On the other hand, it serves to raise the living standards of the poor.

Based on the results obtained in the study, the first solution to be put forward for the waste problem in South Africa should be ensured so that the waste sector can be compatible with green growth. In other words, the link between economic growth and waste production needs to be broken. For this, economic activities that do not produce waste can be preferred, or they should adopt clean production mechanisms can be adopted by transforming economic activities. In order to be successful in this process, integrated waste management planning should be done. Policies of reducing waste generation, promoting waste reuse, recycling and recovery can be used in integrated waste management. Secondly, in order to reduce the negative impact of population growth, the public should be aware of the effects of waste on health, welfare, and the environment.

Since the waste issue is affected by many variables, the above recommendations should not be expected to provide a definitive solution. Other supportive policies should also be included to minimize the waste problem. One of these policies is waste services, and the country's waste services are not at an adequate level. 30% of household waste in South Africa is not provided with any waste services, including waste collection and treatment. For this reason, the public administration should expand waste services and ensure that existing services are provided effectively and efficiently. Because most of the domestic waste services are in the form of waste collection to be collected in landfills. Continuation of this situation will require greater measures to rehabilitate contaminated land in waste policy reform. Since increasing waste services in terms of quality and quantity and cleaning the lands polluted due to waste will cause high costs, the prerequisite for realizing these policies is to provide adequate financing. In other words, a sufficient share of the budget should be allocated to waste services.

Another responsibility of the public sector in solving the waste problem is the regulation of the waste sector. At the beginning of 2020, the waste management environment in South Africa has some legislation, such as the Waste Act, but it still requires a lot of regulation and publication of important documents. With these regulations, waste management should ensure that the obstacles in front of especially plastic, organic, electronic, construction, and demolition wastes are removed.

Later studies can analyze the effects of population, economic growth, and waste generation variables individually or collectively on public environmental protection expenditures or local government environmental protection expenditures in detail. In addition, it is useful to evaluate variables such as urbanization, consumption habits, and income groups in the society, which are not included in detail in this study, in the waste production process.

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