
| RESEARCH ARTICLE

The Impact of Solid Waste Management to the Economic Growth in selected OECD Countries and Philippines

Danielle Marie-Louise Ella¹, Dennise Marie Lim², Bosyong Lu³ ✉ and Ronaldo Cabauatan⁴

¹²³*College of Commerce of Business Administration, University of Santo Tomas, Manila, Philippines*

⁴*College of Commerce of Business Administration, University of Santo Tomas, Manila, Philippines; College of Commerce of Business Administration, University of Santo Tomas, Manila, Philippines; The Graduate School, University of Santo Tomas, Manila, Philippines; Research Center for Social Sciences and Education, University of Santo Tomas, Manila, Philippines*

Corresponding Author: Bosyong Lu, **E-mail:** bosyong.lu.comm@ust.edu.ph

| ABSTRACT

Solid waste was an unavoidable by-product of most human activities. Solid waste management played a significant role in reducing waste and increasing recycling in the MSW sector. The purpose of this study was to discuss the effects of environmental factors on variables such as municipal solid waste (MSW), MSW per capita, and recycling rate to socioeconomic factors such as population and economic performance from selected countries or economies. The study used selected OECD countries, namely, South Korea, the USA, Spain, Switzerland, and the Philippines utilizing their annual data from 1990 to 2018. This study employed panel regression analysis to examine the effect of environmental factors on the individual economy and Granger Causality test with the basis of the Environmental Kuznets Curve (EKC) to conduct empirical verification of the theoretical basis. The result indicated that municipal solid waste (MSW) has a significant positive effect on a country's economic growth (GDP per capita). However, for material recycling, Spain was the only country that has shown a positive relationship between material recycling (Recycling Rate) and economic growth (GDP per capita). While the rest of the selected countries have shown no significant effect on the country's economic growth. The results of the granger causality test are confirmed bidirectionally between municipal solid waste per capita (MSW), GDP per capita growth in %(EG), and Recycling Rate(RR). The research strongly recommended that solid waste management policies/practices of the selected OECD Countries should be considered and applied in the Philippines to decrease the amount of waste and increase the recycling in the MSW.

| KEYWORDS

Recycling, Municipal Solid Waste, Environmental Degradation, Disposal, Economic Growth

| ARTICLE DOI: [10.32996/jefas.2022.4.1.20](https://doi.org/10.32996/jefas.2022.4.1.20)

1. Introduction

Waste management was one of many categories that can be delved into to be able to generate a sustainable economy and environment. Certain manufacturer-producing products consist of rare materials such as Rare Earth Elements (REEs) or some materials which are hard to be absorbed into the environment, such as polyethylene terephthalate (PET). Effective waste management is an essential element (Zhou et al., 2021). Several studies that venture on well-developed waste management allow economic benefits that, when taken at a broader scale, include benefits for job creation and lower environmental costs caused by improper waste management (Razzaq et al., 2021).

As recycling is a subject ignored by many countries and causing substantially harmful repercussions to the environment and human beings, this study would have an impact on the perception of municipal solid waste recycling, transforming the idea of recycling into a more mercenary attraction towards the public as the incentive to achieve the goal of creating a sustainable environment and economy. Besides, the significance of the study will also enable us to know the different effects of waste management on the

economic growth of different nations. It would be essential to understand the impact of recycling policy to make more economically informed decisions in the long run (Chen & Liu, 2014).

According to the World Bank Urban Development department report, the estimated amount of municipal solid waste (MSW) will rise from the current 1.3 billion tons per year to 2.2 billion tons per year by 2025. Much of the increase will come in rapidly growing cities in developing countries. Continuous rapid urbanization, population growth, and economic development will push global waste generation to increase by 70% over the next 30 years. Plastics are a profoundly complex and challenging problem. Even when plastic waste is collected, many countries can't process the waste, leading to dumping or mismanagement. Uncollected waste and poorly disposed waste have significant health and environmental impacts. The cost of addressing these impacts is often higher than developing and operating simple, adequate waste management systems. The global waste statistics disclose that the US is the most significant contributor of municipal solid waste globally, producing 12% of global municipal waste and representing only 4% of the worldwide population.

In contrast, India and China generate 27% of global waste and carry 36% of the worldwide population (World Bank, 2019). For these reasons, the US's waste management framework is firmly legitimized by the "Resource Conservation and Recovery Act" passed in 1976, which aims to manage waste collection and disposal sustainably. Encouraging businesses, industries, and communities to reduce and recycle waste is imperative, leading to sustainable consumption patterns by 2030.

Since the world is facing issues caused by insufficient natural resources and externalities of extracting new supplies of raw materials, recycling can be one of the most effective ways to tackle such problems; however, sustainable waste management methods are usually coming with higher front costs and low financial incentives, therefore, in this research, there are methods employed to identify the economic benefits and costs in larger scale in terms of recycling (Chen & Liu, 2014; Razzaq et al., 2021), and mostly on a regional basis as the aim that this study would provide a clearer picture of the relationship between waste management and overall economic growth of a country, and the financial incentives in the market for the manufacturing industry. The purpose of this study is to identify if municipal waste and material recycling affect a country's economic growth. Moreover, knowing the impact of waste management on the economic growth of different nations would be essential to understand the effect of recycling policy for a more sustainable economy in the long run (Daskalopoulos et al., 1998) (Chen & Liu, 2014).

The study would proceed to be further studies on waste recycling systems, and it would provide a better understanding of its impact on the economy and the overall economic benefits for the nation. To achieve this, the researchers will provide an overview of comprehensive waste management scenarios across different countries. To be anchored on the research data of municipal solid waste per capita, recycling rate, and economic growth by growth of GDP per capita in % will be presented identify the direct and indirect cause and effect relationship from recycling rate to municipal solid waste, and integrated environmental quality factor (recycling rate and municipal solid waste) to economic growth. All these will help to come up with an accurate estimate of the economic benefits of recycling and create a foundation of new ways of producing materials wherein additional studies can take over.

The findings of this study will help distinguish the importance of waste management in material recycling to a country's economic growth by ensuring that recycling and waste management practices will serve as a solution to the increasing amount of waste that could further harm the environment. Data produced from this study can also be used to determine the relationship between recycling waste management and economic growth. In addition, it is hoped that the results of this study about solid waste recycling will identify if municipal solid waste and recycling are factors that affect economic growth. The knowledge which will be produced from this review can further be used as the basis to increase solid waste recycling in the country moving forward (Huang et al., 2020). Moreover, this study can contribute to countries' policymakers to analyze the trade-offs in the development of the municipal solid waste management system with case studies offering more transparency on economic incentives and economic deterrents a manufacturer faces.

2. Literature

A key to growing economic and environmental sustainability is the efficient use of resources through recycling materials. Waste has a resource value in the long run. Developing the handling of wastes through better recycling practices would be less expensive than undoing in the future the damage to the environment and human health caused by current malpractices (Richard, Mario, Javier, et al., 2011). In Malaysia, the consumption of local manufacturing companies in recycling their materials is high due to cost savings. Aside from recycling their materials, manufacturing companies hire external recycling companies for them to mesh their products and turn them into flake-forms (Wahab, Abidin & Azhari, 2007). In the electronic industry, a manufacturer will always prefer to recycle, given that the recycling cost is not high. Products from remanufacturers and new products from the original manufacturers compete with each other in the market. Due to repairing technologies, the value of remanufactured products is always less than the value of new products (Nengmin Wang, Qidong He, Bin Jiang, 2019). A consumer can purchase a

remanufactured product in the market without a doubt if its quality is the same as purchasing a new product. Consumers would favour eco-friendly companies since they would want to conserve and maintain the environment. Manufacturing companies must apply the eco-friendly method for them to preserve their customers and compete in their industry (Bolaji Ishola, 2019). An example of green production is Fujifilm's QuickSnap, wherein they have been using the remanufacturing-recycle strategy for them to produce new and remanufactured products at the same value, function, and quality since the 1990s. Undoubtedly, the business has not encountered any problem with their method of producing their products; hence they have earned the trust of consumers and gained a high profit at the same time (Banomyong et al., 2010). Several industries, particularly the electronic industry (Nnorom, 2010), using remanufacturing can have faster growth and obtain more profit than traditional manufacturing (Geyeretal et al., 2007). The material recycling industry creates opportunities for an economy to grow, thus resulting in an increase or decrease in a country's economic growth. In the US, the industry produces 0.757 million jobs, 36.6 billion in wages, and accumulates 6.7 billion in tax revenues (REI 2016). Overall, it suggests that the recycling industry creates 1.6 jobs for processing every 1,000 tons of materials (Park et al., 2015). By all means, different industries would go for recycling activities since it has lower economic costs than economic benefits; hence it lessens the firms' financial cost and operational unproductivity (Franchetti, 2009; Rehman Khan and Yu, 2020).

Recycling Rate for Municipal Solid Waste would be used to determine the degree of sustainability for materials used in a respective circular economy, from the material being extracted, used as virgin raw material on a production line, processed as disposal, recycled, and used as recycled material back on the production line for new products (Razzaq et al., 2021). Recycling Rate of each sampled population, which is to determine the percentage in each respective economy towards the practice of recycling their household waste among all disposal, by this variable, this research can provide a stronger understanding and correlation between recycling rate data and municipal solid waste provided by institutional sources (Ko et al., 2020).

The idea of the relationship between per capita income and environmental degradations was early realized by Environmental Kuznets Curve (EKC) hypothesis by Simon Kuznets around the 1950s, which is presented with an inverted U-shaped relationship (Kuznets, 1955), as the inference from such relationship discovered, economic growth is certainly relevant to the topic of waste management, but not exactly positioned if the role of which is set to be the solution-finder or the source of the problem. In the further research conducted with Granger causality tests, Today-Yamamoto causality tests, and ML approach (Causal Direction from Dependency algorithm), verifying the theory of Environmental Kuznets Curve has shown that EKC is still a valid theory for the data collected for the case studies in Switzerland in which GDP per capita increases with a decrease of Municipal Solid Waste (resources or materials processed by end-of-life waste treatment) (Magazzino,2020) Therefore, this paper is using GDP per capita, Recycling Rate, and Municipal Solid Waste (Environmental Degradation) to provide extensive research with the basis of EKC. Moreover, when it comes to the employment rate in the economy, it is found that every 1% of municipal solid waste recycled in the state of Florida can lead to 0.4% job growth in the waste management sector during the fixed effect regression test conducted by George Washington University (Liu et al., 2019).

In Nigeria, another study was about the recyclable resources from Municipal Solid Waste (MSW) to evaluate if its energy-saving potentials produce economic and environmental benefits. Ayodele et al. (2018) used the total annual amount of MSW generated because it directly correlates with population growth rate and financial stability. The gross domestic product (GDP) measures income level to know if there is economic development or economic recession. Moreover, it is assumed from the study that the relationship between population increase and MSW generation is a means to determine the future MSW generated based on the projected national population growth increase and Gross Domestic Product (GDP). The recycling of waste has been presented to be beneficial in terms of energy, economic, social, and environmental in Nigeria. It is learned from the study that for an effective implementation recycling program initiative in Nigeria, adequate regulatory and policy measures must be put in place by the government for a municipal solid waste management plan to succeed. The citizens must also be well informed about waste segregation right from their neighbourhood to enhance the recycling process and programs (Ayodele et al., 2018).

Corresponding to this, Razzaq et al. (2021) asserted the effect of municipal solid waste (MSW) on environmental quality and economic development in the United States. Over the years, there have been aggregate analyses using municipal solid waste recycling, environmental, and economic indicators through the national scale. This study investigates the relationship between MSW recycling, economic growth, carbon emissions, and energy efficiency utilizing quarterly data from 1990 to 2017. Granger causality test was used to evaluate the bidirectional causality between energy efficiency and carbon emissions, energy efficiency and economic growth, economic growth and carbon emissions, unidirectional causality from municipal solid waste recycling to economic growth, carbon emissions, and energy efficiency. There is a piece of empirical evidence that could lead to the relationship between material recycling and carbon emissions at a national level. In line with this, the economic impact of municipal solid waste recycling at the country level is missing in the United States. These limitations lead the researchers and policymakers unable to evaluate the net effect of recycling on overall environmental pollution and economic growth. Municipal solid waste recycling and energy efficiency do not only stimulate economic growth but also significantly reduce carbon emissions. Therefore, the carbon

emissions-reducing effect of recycling and energy efficiency is higher in the long term than in the short term. These conclusions imply that any policy intervention concerning MSW Recycling significantly causes environmental pollution and economic growth.

On the contrary, from the previous studies, Masui et al. (2000) found out that internalization of waste management leads to an increase in the price of goods. The cost of waste management will increase exponentially. This cost is not so high as long as the incineration process is predominant, but it will reach a high level once the incineration process cannot meet the waste disposal constraint. As a result, recycling activities will increase the employment rate and affect the economy. The increase in incineration management as a method of waste reduction will lead to more carbon emissions. It implies a need to look for other optimal waste reduction policies and deal with global warming (Masui et al., 2000). The challenges of Solid Waste Management are associated with the primary aspects of the waste sector (e.g., waste generation and inadequate waste collection, transport, treatment, and disposal processes). The priority of a sustainable solid waste management program is to shift from traditional waste dumps that are cost-intensive and hazardous to the environment towards proper waste management systems that retain efficient resources within the economy (Kumar et al., 2017). Das, Lee, et al. (2019) aim to comprehensively describe current technologies, strategic innovations, and monitoring tools that account for the adverse effects of improper solid waste management on the environment.

Waste management has been an issue in the Philippines. The Republic Act 9003, known as the Ecological Solid Waste Management Act of 2000, was passed to ensure the protection of the environment and resource conservation and recovery. Waste generation is linked with urbanization, economic development, and population growth. A study by Domingo, S. N., & Manejar, A. J. A. (2021) conducted a process evaluation of the implementation of the Ecological Solid Waste Management act of 2000 (RA 9003). They reviewed the provisions and foundation of the Ecological Solid Waste Management Act of 2000 (RA 9003) and related policies to RA 9003 and conducted case studies on local government implementation of RA 9003.

Waste management mechanisms varied per country according to their generation patterns and waste characterization for their data analysis. The variables also showed interdependence with income levels and economic development. For example, the higher the country's GDP and per capita income, the higher the amount of waste they generate. The passing of RA 9003 or Ecological Solid Waste Management Act of 2000 provided in-depth waste management systematic approach. With this passed law and the Local Government Code, the segregation and collection of residential solid waste are mandated to the barangay level while special and hazardous wastes were to the municipal/city LGUs. This law is also the foundation of the establishment of a solid waste management board that would oversee the carrying out of the solid waste management plan. However, it is a long-term process since there are backlogs from missing data and components, resulting in a delay. There are instances of unorganized collection schemes, non-cooperation of the constituents, unfit collection of vehicles, and ineffective routes of collection service. The barangays handled waste segregation and collection while municipalities were in charge of the hazardous wastes. There are limitations in resources from the barangay level, so it made them dependent on the municipal initiatives. There is a limited fund for waste collection equipment, labor, and facilities that can support a more effective collection and segregation system. LGUs do not also have the fund to maintain sanitary landfills and adopt new technology.

The study recommended that if national government agencies and local government units have access to reliable, updated data and information, they will be more effective in identifying the volume generation of solid wastes in the country and will not rely on projections given by the NSWMC. The data must also be disaggregated on a national level so that LGUs can implement better in their planning and decision-making activities. There should be an allotted budget for solid waste management for clustering waste, and these facilities can also be part of the national government's Build, Build, Build program.

It is presumed based on different countries that a high degree of recycling rate may correspond to a positive correlation with national economic growth. Using the Municipal Solid Waste (in tons) of different regions, it would be possible to understand how the volume of generated waste in different regions affects both overall economic growths. With that, it is expected that there is a strong positive relationship between the dependent variable (GDP) and the independent variable (Recycling Rate) (Municipal Solid Waste). Material recycling to a country's economic growth is the way to determine if the utilization of recycled materials may ultimately reduce the cost of production (Ko et al., 2020) (Gutowski et al., 2013)

Recycling can be challenging for manufacturing industries, but it can be a valuable tool for reducing and sustaining solid waste materials with the right approach. Wang et al. (2018) presented their findings from three aspects, the manufacturer's recycling choice, supply chain controllability, and influence on retailers and manufacturers. Based on their results, they found out that manufacturers will always choose to recycle and remanufacture used products as long as the cost is not too high. The investments in recycling channels can reduce the unit-recycling cost and improve the controllability and efficiency in the supply chain. A recent study from Ko et al. (2020) aimed to quantify the economic value of sustainable recycling waste management policies and provide policy direction to resolve the waste management crisis in South Korea. They used the population sample to measure if people are willing to pay as an indicator for the recyclable waste volume rate disposal bags to solve the solid waste management crisis. Based

on their results, they've analyzed that people are willing to pay more to eliminate the inconvenience of not being able to discard recyclable waste. Thus, the total amount of WTP (willing to pay) would improve the recyclable waste disposal capacity to handle 4.51% of the generated recyclable waste. To achieve the recycling rate goal, the manufacturer needs to match the capabilities of the recycling system. Although a solid waste crisis occurred, individuals who were able to discard their recyclable waste were more willing to pay. The usual inconvenience is influential on WTP, and the analysis shows that improvements to the system are needed for everyone (Ko et al., 2020).

Environmental issues arising from solid waste generation have failed to be looked over during industrial and economic development (Liu et al., 2015). Due to the simple operation and low-cost involvement, such open dumps are used extensively in underdeveloped and developing countries. Traditional waste management pathways are highly cost-intensive; it becomes less feasible in under-developed or developing countries. The situation in underdeveloped countries is equally alarming due to unplanned human settlements and industrial establishments pouring out substantial amounts of solid waste into the environment. Figures showed countries like Nigeria, Bangladesh, Sudan, and Ethiopia are the crucial contributors to solid waste production among underdeveloped countries (Kawai and Tasaki, 2016). The under-developed and developing countries face improper waste management due to the lack of infrastructure and proper waste processing channels.

In contrast, if it is befalling in developed countries, it is directly related to injudicious use of resources (e.g., high solid waste output). The application of economic tools such as cost-benefit analysis plays a pivotal role in ensuring the benefits to society by aiding in the formulation of better policies such as those for the waste management sector (Dobraja et al., 2016). Huang et al. (2011) stated the importance of economic valuation of waste management before defining the most cost-effective waste management system. This study states that waste management varies among the country's financial status. However, there are some low-cost techniques like proper composting and vermicomposting for better waste treatment. This technique extensively studied a variety of tools for economic assessment on solid waste management scenarios. It can be helpful in under-developed and developing nations that maintain the flow of the waste-to-wealth cycle and generate substantial employment.

3. Research Method

This study will conduct a historical quantitative analysis with cross-sectional data which include Austria, South Korea, the Philippines, Spain, Switzerland, and the United States as these nations or states have more chronologically complete data from 1990 - 2018. The study will employ systematic empirical regression analysis to examine the effect of environmental factors on the individual economy. The study will also compare each country's regression result with one another to determine the correlation between environmental quality variables and economic growth-related variables, which is to be used as our statistical verification for the hypothesis made.

The Environmental Kuznets Curve (EKC) in which the correlation between environmental degradation and economic growth is verified, and the degree of correlation may differ in accordance to the advancement of each economy's development; as a result, there are patterned chronological changes found by the study. Therefore, in this study, we would take EKC as our fundamental basis, Municipal Solid Waste (MSW) generation per capita as the environmental degradation factor, and GDP growth (different units) as the measurement for economic growth to conduct empirical verification of the theory (Kuznets, 1955).

Extensively, this study will also consider the recycling rate as one of the reverse factors against municipal solid waste generation per capita, which is considered as an environmental degradation factor (Razzaq et al., 2021). Each country or state's recycling data will be examined by various statistical methods, which include regression analysis, causality test, stationarity test, and cointegration test to provide a sound picture of the correlation between recycling rate and municipal solid waste, which will later be used to examine the relationship with economic growth.

Overall, this study is to determine the relationship between municipal solid waste (MSW) in terms of generation per capita, waste treatment, and the impact on the economy. To understand whether these two categories are highly or weakly correlated, this study would firstly process our obtained data, including quantitative data of MSW in different geographical locations (mostly data from developed economies to provide a complete statistical outcome across different economic development phrases) as environmental degradation factor and GDP growth per capita (%) with Environmental Kuznets curve as our basis to provide a clearer picture of the chronological correlation between our selected environmental issue, municipal solid waste on Y-axis and economic growth, economic growth on X-axis. (Kuznets, 1955) The relationship with the basis of the EKC model can be examined by the Granger causality test.

The municipal solid waste generated in the OECD countries has risen mostly in line with private consumption expenditure and GDP. The amount and composition of municipal waste vary widely among OECD countries; this is linked to levels and patterns of consumption, urbanization rates, income levels, lifestyles, and national waste management practices (OECD, 2020). The countries

database gathered from the OECD table gives the recycled, material consumption, and waste disposal rate. This database distinguishes between total municipal solid waste and waste-derived only from rural and urban households (Johnstone & Labonne, 2004).

This study utilizes annual MSW and recycling rate data published by OECD in which the MSW is measured in thousands of tonnes, and the recycling rate is calculated in percentile form as the result of recycled materials divided by total annual MSW generated in the year. For the economic measurement - GDP data including GDP annual growth rate and GDP growth rate per capita. The study utilizes the data published by World Bank, and all figures are adjusted after inflation by using current US\$ or current local currency unit, which is to provide a clearer picture of economic measurement for chronological comparison

$$GDPPC = \beta_0 + \beta_1 \text{Recycling Rate} + \beta_2 \text{Envi Degradation} + \beta_3 \text{Waste Management} + u$$

$$RGDP = \beta_0 + \beta_1 \text{Recycling Rate} + \beta_2 \text{Envi Degradation} + \beta_3 \text{Waste Management} + u$$

The normality of residuals is the assumption that residuals are normally distributed. If the p-value is less than the level of significance, then the null hypothesis is rejected, and thus the residuals are not from a normal distribution. If the p-value is greater than the level of significance, then the null hypothesis is accepted.

If the variance of the regression residuals of the model is time-varying, the parameters and their standard errors are said to be biased and inefficient. This condition is known as heteroskedasticity and, if uncorrected, could lead to wrong conclusions and decisions on the part of the investigator. To detect the presence of heteroskedastic disturbances in the residuals, the White Heteroskedasticity Test will be used.

$$u^2 = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_1^2 + \alpha_5 X_2^2 + X_3^2 + \alpha_6 X_1 X_2 + \alpha_7 X_1 X_3 + \alpha_8 X_2 X_3 + v_t$$

where u^2 is the squared regression residuals regressed against the explanatory variables, their squares, and cross products.

Most economic time series data have unit roots which show that their means and variances are not time-invariant. If this is the case, a univariate series is said to be non-stationarity and cannot be used for regression with other non-stationary univariate series because of the risk that their results may be spurious. The only exception to this rule is when the time series data of all variables have identical unit-roots. The widely used unit root test is the so-called Augmented Dickey-Fuller (ADF) test. The basic equation for testing the stationarity of a time series is given by the following:

$$\Delta x_t = \alpha_0 + \alpha_1 t + \beta x_{t-i} + \sum \varphi \Delta x_{t-i} + \varepsilon_t$$

Where the first difference of the series, Δx_t , is regressed against lagged of its original level series, time, and lagged values of itself. If the estimated value of β is more negative than MacKinnon's critical values, the series is said to be stationary. Otherwise, it is non-stationary and therefore has a unit root. The augmented portion of the test is to correct for any serial correlation in the variable.

An efficient test in determining the optimal lag length is to minimize the Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), or Bayesian Information Criterion (BIC) for each lag length on a trial-and-error basis. For the Akaike Information Criterion (AIC), which is a popular test, the formula is as follows:

$$\ln AIC = (2k/n) + \ln (RSS/n)$$

Where k is the number of regressors including intercept, n is the number of observations, and RSS is the regression sum of squares. After experimenting with a sufficient number of lags in the model, the one which produces the smallest AIC would indicate the appropriate or optimal lag length.

Structural stability test refers to the stability of the coefficients of a regression model between different time periods. In this study, such a test will be performed using Chow Breakpoint Test. A structural change could mean a change in the intercept, a change in the slope coefficients, or a change in both the intercept and slope coefficients. Either way, the results would imply structural instability, and the model cannot be used for policy analysis and forecasting.

A Specification error test is associated with the specification of the model regarding the inclusion of an irrelevant variable, the exclusion of relevant variable, or the functional form of the model. A Specification error creates biased or inconsistent regression

estimators, and the inconsistency can still be there even when the sample observation increases. To determine the specification of the model, this study used the equation:

$$\hat{Y}_i = \hat{\beta}_1 + \hat{\beta}_2 X_{2i} + \hat{\beta}_3 X_{3i} + \gamma \hat{Y}_i^2$$

Panel Regression Test is a combination of cross-section data and time series. The same unit cross-section is measured at different times. Parameter estimation in the regression analysis with cross-section data is settled by estimating the least-squares method called Ordinary Least Square (OLS). Regression Method Data Panel will give the result of estimation, which is Best Linear Unbiased Estimation (BLUE).

Three approaches can be used in estimating the regression model using panel data: Common Effect Model or Pooled Least Squares (PLS), Fixed Effect Model, Random Effect Model.

Considering the panel regression model, where Z_i is the unobserved time-variant heterogeneity across the panel data $i = 1, \dots, n$.

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_i + u_{it}$$

Our goal is to estimate β_1 which is the effect of X_i on Y_i . Letting $\alpha_i = \beta_0 + \beta_2 Z_i$ we obtain

$$Y_{it} = \alpha_i + \beta_1 X_{it} + u_{it}$$

Having individual-specific intercepts α_i , $i = 1, \dots, n$, where each of these can be understood as the fixed effects of entity i , which is the fixed effects model as shown below,

$$Y_{it} = \beta_1 X_{1,it} + \dots + \beta_k X_{k,it} + \alpha_i + u_{it}$$

where $i = 1, \dots, n$ and $t = 1, \dots, T$. The α_i are entity-specific intercepts that capture heterogeneities across panel data. The fixed effects (FE) model eliminates the effect of unobserved heterogeneity. But, with different levels of engagement and different sizes, it is necessary to check heteroskedasticity problems and autocorrelation. In case heterogeneity is present, random effects (variance components model) provides the option to take into account heterogeneity across panel data in the regression coefficients. That is,

$$Y_{it} = \beta_0 + \beta_1 X_{1,it} + \dots + \beta_k X_{k,it} + \alpha_i + u_{it}$$

As the research method to be developed to better understand the cause-effect relationship between our variables, Municipal Solid Waste, Recycling Rate, and economic performance, the study aims to analyze time-series data with Granger causality test. There are several null hypotheses that would be presumed, including 1). Municipal Solid Waste (MSW) does not granger cause an impact on the growth of annual GDP per capita (Economic Growth) 2). Recycling Rate (RR) does not granger cause an effect on the annual growth rate of GDP per capita (Economic Growth); by accepting or rejecting any of these three aforementioned null hypotheses, the study can first determine that if the theory of Environmental Kuznets Curve is still empirically verifiable in the modern developed economies as well as which IV among MSW and Recycling Rate is bringing stronger impact to the economic growth regardless of whether the impact is positive or negative. If there is no alternative hypothesis accepted during the process of running the Granger Causality Test, both IVs used with lag, including municipal solid waste (MSW), recycling rate, and GDP related statistics, will be used to run for T-test as this can further ensure that each IV with lag is significant with less noise on predicting the future outcome.

$$\begin{aligned} \Delta MWS_{it} &= \sum_{k=1}^p \beta_k \Delta MWS_{i,t-k} + \sum_{k=0}^p \theta_k \Delta GDPGR_{i,t-k} + u_{i,t} \\ \Delta GDPGR_{it} &= \sum_{k=1}^p \beta_k \Delta GDPGR_{i,t-k} + \sum_{k=0}^p \theta_k \Delta MWS_{i,t-k} + v_{i,t} \end{aligned}$$

$$\begin{aligned} \Delta RR_{it} &= \sum_{k=1}^p \beta_k \Delta RR_{i,t-k} + \sum_{k=0}^p \theta_k \Delta GDPGR_{i,t-k} + u_{i,t} \\ \Delta GDPGR_{it} &= \sum_{k=1}^p \beta_k \Delta GDPGR_{i,t-k} + \sum_{k=0}^p \theta_k \Delta RR_{i,t-k} + v_{i,t} \end{aligned}$$

$$\begin{aligned} \Delta RR_{it} &= \sum_{k=1}^p \beta_k \Delta RR_{i,t-k} + \sum_{k=0}^p \theta_k \Delta MVA_{i,t-k} + u_{i,t} \\ \Delta MVA_{it} &= \sum_{k=1}^p \beta_k \Delta MVA_{i,t-k} + \sum_{k=0}^p \theta_k \Delta RR_{i,t-k} + v_{i,t} \end{aligned}$$

4. Results and Discussion

The purpose of this study was to discuss the effects of environmental factors on variables such as municipal solid waste (MSW), MSW per capita, and recycling rate to socioeconomic factors such as population and economic performance from selected countries or economies. The results from the data gathering show that the socio factor such as population had a positive impact on MSW generated.

The data obtained with relevance to this study had initially demonstrated a clear upward moving trend in terms of municipal solid waste (MSW) generated (tonnes in thousands) from most of the selected countries in this research. Rising MSW generation around the globe could be the consequence of various factors behind where industrialization, economic activities, and growth of population could all be classified as different types of contributors to the phenomenon. Therefore, this study would look into the correlation of MSW with various factors with statistical methods employed to conclude the most consequential factor among our proposed variables and the causality of each pair.

This research was devoted to understanding the causality and correlation of proposed factors ranging from different aspects, including population, which was to create our major variable used for further statistical analysis - municipal solid waste per capita, a measurement that can help us to create a clearer comparison between respective economies with better objectivity. The variable of recycling was used to find out the proportion of reused material in the respective economy selected in this research, and lastly, GDP Growth per capita would be used to assess the causality effect with recycling rate validating the hypothesis - Recycling Rate (RR) does not granger cause a positive effect on GDP annual growth rate (GDP Growth per capita data).

Table 1.1: Panel Regression (South Korea)

Dependent Variable: Economic Growth (GDP per Capita)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.044201	0.191587	0.230709	0.8193
Municipal Solid Waste	0.000129	0.000313	0.412543	0.6833
Recycling Rate	-0.068290	0.177718	-0.384258	0.7039
R-squared	0.042345	Mean dependent var		0.069748
Adjusted R-squared	-0.031321	S.D. dependent var		0.121804
S.E. of regression	0.123697	Akaike info criterion		-1.244270
Sum squared resid	0.397823	Schwarz criterion		-1.102825
Log-likelihood	21.04191	Hannan-Quinn criter.		-1.199971
F-statistic	0.574824	Durbin-Watson stat		1.997795
Prob(F-statistic)	0.569795			

Table 1.1 represents the panel least-squares of Municipal Solid Waste (MSW), Recycling Rate (RR) to Economic Growth (EG). Both, MSW, and RR are significant with a p-value ≥ 0.05 ; $p = 0.6833$ and $p = 0.7039$. The coefficient showed that there was a direct relationship between MSW and the dependent variable, EG. While the coefficient of RR shows that there was an inverse relationship with the dependent variable, EG. Therefore, for every one unit of increase in MSW, there was a 0.000129 increase in EG. On the other hand, for every one unit of increase in RR, there was a -0.068290 decrease in EG.

Table 1.2: Granger Causality Test

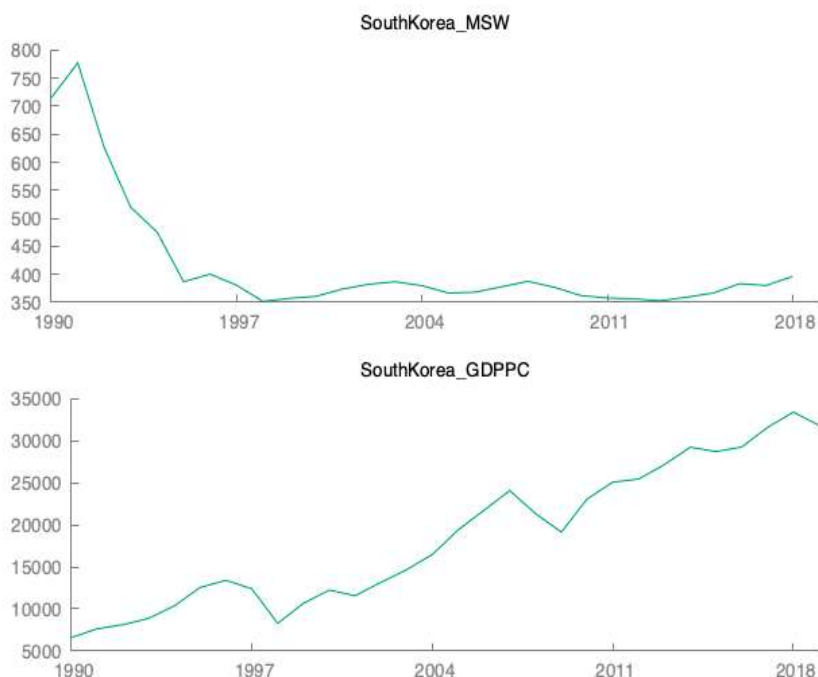
Lags: 1			
Null Hypothesis:	Obs	F-Statistic	Prob.
MSW does not Granger Cause EG	28	0.52568	0.4752
EG does not Granger Cause MSW		0.04931	0.8261
RR does not Granger Cause EG	28	0.72450	0.4028
EG does not Granger Cause RR		0.18786	0.6684
RR does not Granger Cause MSW	28	0.27167	0.6068
MSW does not Granger Cause RR		1.62211	0.2145

(Economic Growth - EG) (Recycling Rate - RR) (Municipal Solid Waste per 1,000 population - MSW)

For the South Korean data regarding municipal solid waste, recycling rate, and economic growth, which was calculated based on percentage growth of individual country's annual GDP per capita, Granger Causality Test was employed to verify two key null hypotheses 1). Municipal Solid Waste (MSW) does not granger cause an impact on the growth of annual GDP per capita (Economic Growth) 2). Recycling Rate (RR) does not granger cause an effect on the annual growth rate of GDP per capita (Economic Growth)

The result of the Granger Causality Test showed that hypothesis 1, where the null hypothesis of municipal solid waste does not granger cause an impact on economic growth, was not rejected as the result of 0.4752 probability which was higher than the conventional critical value of 0.05. The second hypothesis in which the null hypothesis of Recycling Rate (RR) does not granger cause an effect on the annual growth rate of GDP per capita (Economic Growth) is not rejected with 0.4028 probability which was higher than a conventional critical value of 0.05.

Time-series plot (South Korea)



In terms of time-series plot data which was employed to verify the theoretical basis of this research, South Korea had illustrated a clear evident Environmental Kuznets Curve (EKC) in partial range, which was the later stage of the post-industrial stage as environmental degradation factor, municipal solid waste per capita (MSW) decrease rapidly in the 1990s while the earlier stage of EKC cannot be verified due to chronological availability of municipal solid waste data.

Table 2.1: Panel Regression (USA)

Dependent Variable: Economic Growth (GDP per Capita)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.228763	0.107424	-2.129543	0.0428
Municipal Solid Waste	0.000378	0.000136	2.773749	0.0101
Recycling Rate	-0.095289	0.087041	-1.094766	0.2837
R-squared	0.273821	Mean dependent var		0.035755
Adjusted R-squared	0.217962	S.D. dependent var		0.016994
S.E. of regression	0.015028	Akaike info criterion		-5.460094
Sum squared resid	0.005872	Schwarz criterion		-5.318649
Log-likelihood	82.17136	Hannan-Quinn criter.		-5.415795
F-statistic	4.901932	Durbin-Watson stat		1.196481
Prob(F-statistic)	0.015616			

Figure 2.1 represents each of the panel least-squares of Municipal Solid Waste (MSW) and Recycling Rate (RR) to Economic Growth (EG). MSW was significant with a p-value ≤ 0.05 , $p = 0.0101$. While the RR was insignificant with a p-value ≥ 0.05 ; $p = 0.2837$. The coefficient showed that there was a direct relationship between MSW and the dependent variable, EG. However, the coefficient for RR showed an inverse relationship to the dependent variable. For every one unit of increase in MSW, there was a 0.000378 increase in EG, and for every one unit of increase in RR, there was a -0.095289 decrease in EG.

Table 2.2: Granger Causality Test

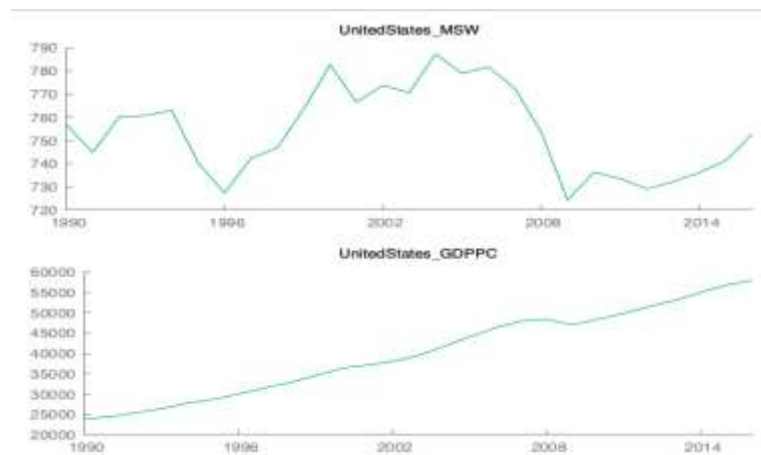
Lags: 1			
Null Hypothesis:	Obs	F-Statistic	Prob.
MSW does not Granger Cause EG	28	0.71739	0.4050
EG does not Granger Cause MSW		0.22793	0.6372
RR does not Granger Cause EG	28	0.41354	0.5260
EG does not Granger Cause RR		1.07859	0.3090
RR does not Granger Cause MSW	28	0.00365	0.9523
MSW does not Granger Cause RR		0.09563	0.7597

(Economic Growth - EG) (Recycling Rate - RR) (Municipal Solid Waste per 1,000 population - MSW)

For the data of the United States regarding municipal solid waste, recycling rate, and economic growth, which was calculated based on percentage growth of individual country's annual GDP per capita, Granger Causality Test is employed to verify two key null hypotheses 1). Municipal Solid Waste (MSW) does not granger cause an impact on the growth of annual GDP per capita (Economic Growth) 2). Recycling Rate (RR) does not granger cause an effect on the annual growth rate of GDP per capita (Economic Growth).

The result of the Granger Causality Test showed that hypothesis 1, where the null hypothesis of municipal solid waste does not granger cause an impact on economic growth, was not rejected as the result of 0.4050 probability which was higher than the conventional critical value of 0.05. The second hypothesis in which the null hypothesis of Recycling Rate (RR) does not granger cause an effect on the annual growth rate of GDP per capita (Economic Growth) was not rejected with 0.5260 probability which was higher than the conventional critical value of 0.05.

Time-series plot (United States)



In terms of time-series plot data which was employed to verify the theoretical basis of this research, the United States had illustrated a clear evident Environmental Kuznets Curve in full range, from an earlier stage of economic expansion with environmental degradation factor, municipal solid waste (MSW per capita) rising to a certain point, and enter environmental improvement phase as MSW per capita dropping after entering 2000s.

Table 3.1: Panel Regression (Spain)

Dependent Variable: Economic Growth (GDP per Capita)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.321915	0.262456	-1.226548	0.2336
Municipal Solid Waste	0.000574	0.000330	1.738599	0.0967
Recycling Rate	0.326039	0.770042	0.423404	0.6763
R-squared	0.141225	Mean dependent var		0.038650
Adjusted R-squared	0.059436	S.D. dependent var		0.093255
S.E. of regression	0.090442	Akaike info criterion		-1.851758
Sum squared resid	0.171773	Schwarz criterion		-1.704502
Log-likelihood	25.22110	Hannan-Quinn criter.		-1.812691
F-statistic	1.726712	Durbin-Watson stat		1.510660
Prob(F-statistic)	0.202179			

Figure 3.1 represents each of the panel least-squares of Municipal Solid Waste (MSW) and Recycling Rate (RR) to Economic Growth (EG). Both MSW, and RR were significant with a p-value ≥ 0.05 ; $p = 0.0967$ and $p = 0.6763$. The coefficient of MSW and RR showed that there was a direct relationship with the dependent variable, EG. Therefore, for every one unit of increase in MSW, there was a 0.000574 increase in EG. Likewise, for every one unit of increase in RR, there was a 0.326039 increase in EG.

Table 3.2: Granger Causality Test

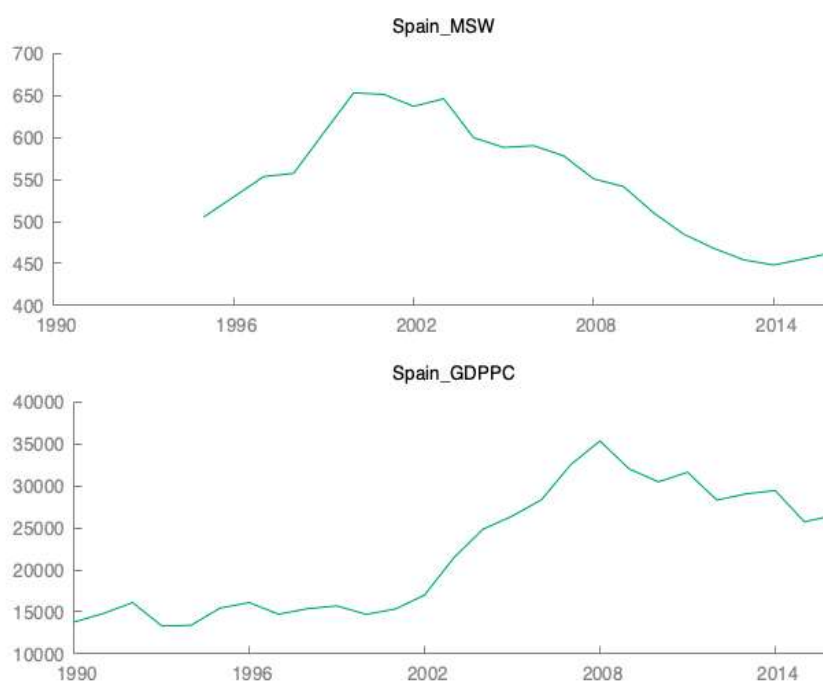
Lags: 1			
Null Hypothesis:	Obs	F-Statistic	Prob.
MSW does not Granger Cause EG	23	4.05206	0.0578
EG does not Granger Cause MSW		0.15488	0.6981
RR does not Granger Cause EG	28	0.11685	0.7353
EG does not Granger Cause RR		0.08809	0.7691
RR does not Granger Cause MSW	23	6.90003	0.0162
MSW does not Granger Cause RR		0.06136	0.8069

(Economic Growth - EG) (Recycling Rate - RR) (Municipal Solid Waste per 1,000 population - MSW)

For the data of Spain regarding municipal solid waste, recycling rate, and economic growth, which was calculated based on percentage growth of individual country's annual GDP per capita, Granger Causality Test is employed to verify two key null hypotheses 1). Municipal Solid Waste (MSW) does not granger cause an impact on the growth of annual GDP per capita (Economic Growth) 2). Recycling Rate (RR) does not granger cause an effect on the annual growth rate of GDP per capita (Economic Growth).

The result of the Granger Causality Test showed that hypothesis 1, where the null hypothesis of municipal solid waste does not granger cause an impact on economic growth, is not rejected as the result of 0.0578 probability which was higher than the conventional critical value of 0.05. The second hypothesis in which the null hypothesis of Recycling Rate (RR) does not granger cause an effect on the annual growth rate of GDP per capita (Economic Growth) is not rejected with 0.7353 probability which was higher than the conventional critical value of 0.05.

Time-series plot (Spain)



In terms of time-series plot data which was employed to verify the theoretical basis of this research, Spain had illustrated a clear evident Environmental Kuznets Curve in full range, from an earlier stage of economic expansion with environmental degradation factor, municipal solid waste (MSW per capita) rising to a certain point, and enter environmental improvement phase as MSW per capita dropping after entering 2000s.

Table 4.1: Panel Regression (Switzerland)

Dependent Variable: Economic Growth (GDP per Capita)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.023519	0.227764	0.103261	0.9185
Municipal Solid Waste	0.000285	0.000447	0.637174	0.5296
Recycling Rate	-0.556377	0.593557	-0.937360	0.3572
R-squared	0.032744	Mean dependent var		0.039086
Adjusted R-squared	-0.041660	S.D. dependent var		0.087527
S.E. of regression	0.089332	Akaike info criterion		-1.895222
Sum squared resid	0.207484	Schwarz criterion		-1.753778
Log-likelihood	30.48072	Hannan-Quinn criter.		-1.850924
F-statistic	0.440081	Durbin-Watson stat		1.556050
Prob(F-statistic)	0.648693			

Figure 4.1 represents each of the panel least-squares of Municipal Solid Waste (MSW) and Recycling Rate (RR) to Economic Growth (EG). The MSW and RR were insignificant with a p-value ≥ 0.05 ; $p = 0.5296$ and $p = 0.3572$. The coefficient showed that there was a direct relationship between MSW and the dependent variable. However, the coefficient for RR shows an inverse relationship to the dependent variable. For every one unit of increase in EG, there was a 0.000285 increase in MSW, and for every one unit of increase in RR, there was a -0.556377 decrease in EG.

Table 4.2: Granger Causality Test

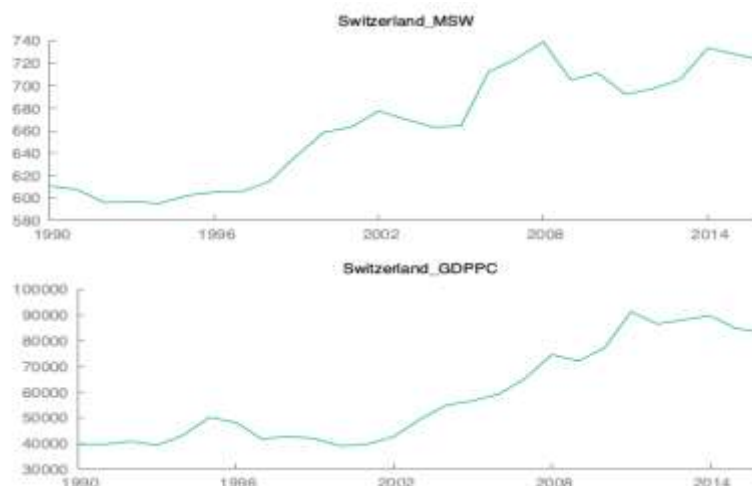
Lags: 1			
Null Hypothesis:	Obs	F-Statistic	Prob.
MSW does not Granger Cause EG	28	0.50656	0.4832
EG does not Granger Cause MSW		0.96141	0.3362
RR does not Granger Cause EG	28	1.05920	0.3133
EG does not Granger Cause RR		0.01475	0.9043
RR does not Granger Cause MSW	28	7.29051	0.0123
MSW does not Granger Cause RR		0.02761	0.8694

(Economic Growth - EG) (Recycling Rate - RR) (Municipal Solid Waste per 1,000 population - MSW)

For the data of Switzerland regarding municipal solid waste, recycling rate, and economic growth, which was calculated based on percentage growth of individual country's annual GDP per capita, Granger Causality Test is employed to verify two key null hypotheses 1). Municipal Solid Waste (MSW) does not granger cause an impact on the growth of annual GDP per capita (Economic Growth) 2). Recycling Rate (RR) does not granger cause an effect on the annual growth rate of GDP per capita (Economic Growth).

The result of the Granger Causality Test showed that hypothesis 1, where the null hypothesis of municipal solid waste does not granger cause an impact on economic growth, is not rejected as the result of 0.4832 probability which is higher than the conventional critical value of 0.05. The second hypothesis in which the null hypothesis of Recycling Rate (RR) does not granger cause an effect on the annual growth rate of GDP per capita (Economic Growth) is not rejected with 0.3133 probability which is higher than the conventional critical value of 0.05.

Time-series plot (Switzerland)



In terms of time-series plot data which was employed to verify the theoretical basis of this research, Switzerland had illustrated possible Environmental Kuznets Curve in partial range, from an earlier stage of economic expansion with environmental degradation factor, municipal solid waste (MSW per capita) rising to an evident peak around 2008.

Table 5.1: Panel Regression (Philippines)

Dependent Variable: Economic Growth (GDP per Capita)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.051824	0.290389	-0.178464	0.8597
Municipal Solid Waste	0.000610	0.001624	0.375620	0.7101
R-squared	0.005198	Mean dependent var		0.057103
Adjusted R-squared	-0.031646	S.D. dependent var		0.080363
S.E. of regression	0.081625	Akaike info criterion		-2.106896
Sum squared resid	0.179890	Schwarz criterion		-2.012599
Log-likelihood	32.54999	Hannan-Quinn criter.		-2.077363
F-statistic	0.141091	Durbin-Watson stat		1.649245
Prob(F-statistic)	0.710134			

Figure 5.1 represents each of the panel least-squares of Municipal Solid Waste (MSW) to Economic Growth (EG). MSW was significant with $p\text{-value} \geq 0.05$; $p = 0.7101$. The coefficient of MSW showed that there was an inverse relationship with the dependent variable, EG. Therefore, for every 1 unit of increase in MSW, there was a 0.000610 increase in EG.

Table 4.2: Granger Causality Test

Lags: 1

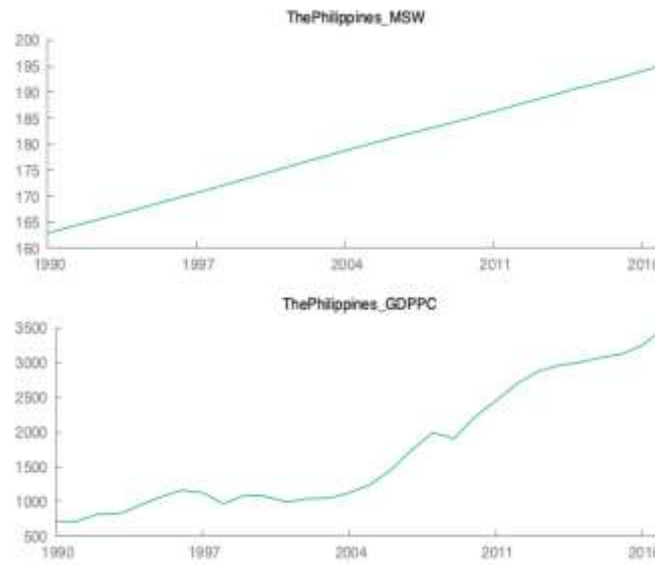
Null Hypothesis:	Obs	F-Statistic	Prob.
MSW does not Granger Cause EG	28	0.02039	0.8876
EG does not Granger Cause MSW		1.75157	0.1977

(Economic Growth - EG) (Recycling Rate - RR) (Municipal Solid Waste per 1,000 population - MSW)

For the data of the Philippines regarding municipal solid waste and economic growth, which was calculated based on percentage growth of an individual country's annual GDP per capita, Granger Causality Test is employed to verify one key null hypothesis¹. Municipal Solid Waste (MSW) does not granger cause an impact on the growth of annual GDP per capita (Economic Growth).

The result of the Granger Causality Test showed that hypothesis 1, where the null hypothesis of municipal solid waste does not granger cause an impact on economic performance, is rejected as the result of 0.8876 probability which was lower than the conventional critical value of 0.05, indicates that no granger causality relationship between MSW towards Economic Performance.

Time-series plot (Philippines)



In terms of time-series plot data employed to verify the theoretical basis of this research, the Philippines has not illustrated an evident Environmental Kuznets Curve because the data of environmental degradation factor cannot be seen with any fluctuation suggested by the theoretical basis of EKC.

5. Conclusion and Policy Recommendation

This study aims to identify if municipal solid waste (MSW) and material recycling in terms of recycling rate (RR) affect a country's overall economic growth (GDP per capita). The researchers hypothesized that there was a significant relationship between MSW and RR to the GDP per capita. The researchers used selected OECD countries, namely, South Korea, the USA, Spain, Switzerland, and the Philippines utilizing their annual data from 1990 to 2018. This study employed panel regression analysis to examine the effect of environmental factors on the individual economy and Granger Causality test with the basis of the Environmental Kuznets Curve (EKC) to conduct empirical verification of the theoretical basis.

Based on the panel regression analysis results for each country, the researchers found out that municipal solid waste (MSW) had a significant positive effect on a country's economic growth (GDP per capita). If MSW generated increases, the economic growth also increases, and vice versa; therefore, MSW and economic growth have a direct relationship. However, for material recycling, Spain was the only country that has shown a positive relationship between material recycling (Recycling Rate) and economic growth (GDP per capita). While the rest of the selected countries have shown no significant effect on the country's economic growth.

However, based on the time-series data that have collected for each country's municipal waste per capita (MSW per capita) and GDP per capita, Environmental Kuznets Curve, the theoretical basis was verified where an expanding economy with upward-sloping growth of GDP per capita could result in different level of environmental degradation which was the higher amount of municipal solid waste in the case of this research. Within the time range of the research, countries with an expansion of economic growth in terms of GDP per capita have illustrated a conspicuous change in the amount of municipal solid waste generation from the earlier stage of economic development when environmental decay betides to a turning point where the amount of municipal solid waste peaked and eventually forming a dome-shaped slope after environmental improvement occurs which results in amelioration to environmental degradation factor, municipal solid waste per capita in the case of this research. In terms of the data of the Philippines, the environmental degradation factor was still on the rise to a turning point in the coming days since the country was currently experiencing fast economic growth where large increases of GDP per capita can be seen.

In terms of the result of the Granger causality test, there was no significant result indicated between the pair of municipal solid waste to economic dependent variables as well as the pair of recycling rate to economic growth, which also suggested the null hypothesis of no Granger causality or the determining factor of either of two independent variables to each responding dependent variable. The results of the granger causality test were confirmed bidirectionally between municipal solid waste per capita (MSW), GDP per capita growth in %(EG), and Recycling Rate (RR).

Solid Waste Management plays a big role in every country since any activity we do basically generates waste. The selected OECD Countries and the Philippines have their own policies and movements implemented to minimize waste. In the Philippines, an act

providing for an ecological solid waste management program, creating the necessary institutional mechanisms and incentives, declaring certain acts prohibited and providing penalties, appropriating funds, therefore, and for other purposes also known as republic act 9003 was created a year after the Payatas Tragedy in 2000. Mountains of garbage collapsed, leading to the loss of hundreds of human lives. The purpose of the act is to protect the environment and the Filipino people. The Department of Environment and Natural Resources (DENR) also implemented a program to assist the Local Government Units in executing the RA 9003. According to DENR, the project's significant contribution was expected to enhance the country's economic development through formalizing waste collection and recycling and promotion of job opportunities. It also helped the economy to reduce reliance on imported oils and increase power generation. However, due to limited resources/funds given by the government, the implemented policies were not fully maximized. According to RA 9003, collection, transport, and disposal of solid waste are the responsibility of the local government unit (LGU). In Metro Manila, 85 percent of solid waste generated was collected while rural and poor areas were not brought to notice as required by law, leading to uncollected waste in rivers and water bodies, causing water pollution and flooding. Aside from insufficiency of funds, education and public awareness towards the citizens are essential in order to fully maximize the RA 9003. Lack of environmental awareness of the community was a hindrance in the program. Therefore, spreading awareness to create the right attitude amongst the citizens to be active in doing solid waste management activities was one of the major factors to execute the act.

In Korea, the volume-based waste fee system (VBWSF) was implemented in 1991 to attempt to reduce the quantity of waste and increase the rate of recycling. The objective of the VBWSF system was 1.) to impose waste treatment costs on each polluter based on the amount of waste generated, 2.) to provide free collection service for recyclable wastes, consequently inducing a reduction in generation of wastes at source and encouraging the collection of recyclable wastes. This idea was to segregate waste consisting of domestic waste, food waste, business waste, public purposes, and construction waste leading to five kinds of waste bags. Different fees according to the size and regions were paid by the residents. Koreans were obligated to segregate their waste because, if not, approximately \$1000 must be paid if violations were made. In addition, the government allows multi-purpose bags that could be used as litter bags in the area to help reduce the use of plastic bags. Undoubtedly, the system helped the local government, citizens, and even different companies reduce waste and increase recycling in the MSW sector.

"Pay-as-you-throw" programs, also known as unit pricing or variable-rate pricing, was one of the policies implemented in the United States. A person is charged for the collection of the municipal solid waste, depending on the amount she/he throws away. However, in some places, fees are fixed regardless of the amount of waste they throw, or there was a fee for each bag. The idea of this created a direct economic incentive to increase recycling and decrease waste. There are three essential factors that play a major role in a country; 1.) environmental sustainability wherein less waste and more recycling is seen, meaning fewer natural resources need to be used. 2.) economic sustainability, whereas it covers solid waste management expenses 3.) equity means fairness among the area residents; they only pay for what they throw away.

A municipality in Spain had the same practice as Switzerland in regards to the "pay-as-you-throw" with an addition of the door-to-door collection system. The idea of the "pay-as-you-throw" was based on the principle of "who recycles and reduces, pay less." Thus, the variable part of the waste tax depends on the waste generation of refuse and packaging. Standardized bags of known volume are used as a counter, and the use of bags was mandatory.

Similar to the volume-based waste system (VBWSF) of Korea, Switzerland practices the "polluter pays principle". A person cannot use any bag to dispose of their trash. Wastes were segregated with their own bags, and the price was aligned with their size. Moreover, recyclables shouldn't be thrown away, including PET bottles, glass, cardboard, paper, tins, aluminium, and batteries, into the trash bag. Consequently, not segregation of the waste into their proper bags and putting out the trash at the designated time is an offence in Switzerland, thus obligated to pay for the fine.

References

- [1] Al-Kaabi, Z., Pradhan, R., Thevathasan, N., Chiang, Y., Gordon, A., & Dutta, A. (2017). Potential value-added applications of black liquor generated in the paper manufacturing industry using recycled fibres. <https://doi.org/10.1016/j.jclepro.2017.02.074>
- [2] Asif R, Arshian S, Arsalan N, Ming-Lang T, and Ming K. L. (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, ISSN 0921-3449, <https://doi.org/10.1016/j.resconrec.2020.105372>
- [3] Ayodele, T., Alao, M., & Ogunjuyigbe, A. (2018). Recyclable resources from Solid municipal WASTE: Assessment of its Energy, economic and environmental benefits in Nigeria. <https://doi.org/10.1016/j.resconrec.2018.03.017>
- [4] Bartelings, H., & Sterner, T. (n.d.). Household waste management in a SWEDISH Municipality: Determinants of waste Disposal, recycling and composting. <https://doi.org/10.1023/A:1008214417099>
- [5] Bartolacci, F., Cerqueti, R., Paolini, A., & Soverchia, M. (2019). An economic efficiency indicator for assessing income opportunities in sustainable waste management. <https://doi.org/10.1016/j.eiar.2019.05.001>
- [6] Beccarello, M., & Foggia, G. (2018). Moving towards a circular economy: Economic impacts of higher material recycling targets. <https://doi.org/10.1016/j.matpr.2017.11.115>
- [7] Bruvoll, A., Halvorsen, B., & Nyborg, K. (2002). Households' recycling efforts. [https://doi.org/10.1016/S0921-3449\(02\)00055-1](https://doi.org/10.1016/S0921-3449(02)00055-1)

- [8] Burgess, M., Holmes, H., Sharmina, M., & Shaver, M. (2020). The future of UK PLASTICS recycling: One bin to rule them all. <https://doi.org/10.1016/j.resconrec.2020.105191>
- [9] Blömeke, S., Rickert, J., Mennenga, M., Thiede, S., Herrmann, C., Goodland, R., & Allwoodetalb. (n.d.). Recycling 4.0 – Mapping smart solutions to remanufacturing and recycling operations. *Procedia CIRP*, 90(2020), 600-605.. <https://doi.org/10.1016/j.procir.2020.02.045>
- [10] Chen, C., & Liu, L. (2014). Pricing and quality decisions and financial incentives for sustainable product design with recycled material content under price leadership. *International Journal of Production Economics*, 147, 571-708. <https://doi.org/10.1016/j.ijpe.2013.04.016>
- [11] Chen, Y., & Chen, T. (2018). Fair sharing and eco-efficiency in green responsibility and green marketing policy. <https://doi.org/10.1016/j.ijpe.2018.09.003>
- [12] Craighill, A., & Powell, J. (1999). Lifecycle assessment and economic evaluation of recycling: A case study. [https://doi.org/10.1016/0921-3449\(96\)01105-6](https://doi.org/10.1016/0921-3449(96)01105-6)
- [13] Das, S., Lee, S., Kumar, P., Kim, K., Lee, S., & Bhattacharya, S. (2019). Solid waste management: Scope and the challenge of sustainability. <https://doi.org/10.1016/j.jclepro.2019.04.323>
- [14] Daskalopoulos, E., Badr, O., & Probert, S. (1998). An integrated approach to municipal solid waste management. [https://doi.org/10.1016/S0921-3449\(98\)00031-7](https://doi.org/10.1016/S0921-3449(98)00031-7)
- [15] DA, W., Abidin A. and Azhari, C.H (2007). Recycling Trends in the Plastics Manufacturing and Recycling Companies in Malaysia. *Journal of Applied Sciences*, 7: 1030-1035.
- [16] Dinan, T. (2002). Economic efficiency effects of alternative policies for reducing waste disposal. <https://doi.org/10.1006/jeem.1993.1046>
- [17] Dobos, I., & Floriska, A. (2006). The resource conservation effect of recycling in a Dynamic Leontief model. <https://doi.org/10.1016/j.ijpe.2006.12.038>
- [18] Domingo, S. N., & Manejar, A. J. A. (2021). *An Analysis of Regulatory Policies on Solid Waste Management in the Philippines: Ways Forward*. Retrieved December 9, 2021, from <https://pidswebs.pids.gov.ph/CDN/PUBLICATIONS/pidsdps2102.pdf>.
- [19] Durant, D., & Lucas, A. (2018). Manufacturing a better planet: Challenges arising from the gap between the best intentions and social realities. <http://dx.doi.org/10.3390/recycling3020017>
- [20] Eichner, T., & Pethig, R. (2002). Product design and efficient management of recycling and waste treatment. <https://doi.org/10.1006/jeem.2000.1126>
- [21] Emery, A., Davies, A., Griffiths, A., & Williams, K. (2006). Environmental and economic modelling: A case study of municipal solid waste management scenarios in Wales. <https://doi.org/10.1016/j.resconrec.2006.03.016>
- [22] Feo, G., & Polito, A. (2015). Using economic benefits for recycling in a separate collection centre managed as a "reverse supermarket": A sociological survey. <https://doi.org/10.1016/j.wasman.2015.01.029>
- [23] Filho, W., Ellams, D., Han, S., Tyler, D., Boiten, V., Paço, A., Balogun, A. (2019). A review of the socioeconomic advantages of textile recycling. <https://doi.org/10.1016/j.jclepro.2019.01.210>
- [24] Gu, Y., Zhou, G., Wu, Y., Xu, M., Chang, T., Gong, Y., & Zuo, T. (2020). Environmental performance analysis on resource multiple-life-cycle RECYCLING system: Evidence from waste Pet bottles in China. <https://doi.org/10.1016/j.resconrec.2020.104821>
- [25] Gutowski, T. G., Allwood, J. M., Herrmann, C., & Sahni, S. (2013). A Global Assessment of Manufacturing: Economic Development, Energy Use, Carbon Emissions, and the Potential for Energy Efficiency and Materials Recycling. *Annual Review of Environment and Resources*, 38, 81-106. Annual Reviews. <https://doi.org/10.1146/annurev-environ-041112-110510>
- [26] Hagnell, M., & Åkermo, M. (2019). The economic and mechanical potential of closed-loop material usage and recycling of fibre-reinforced composite materials. <https://doi.org/10.1016/j.jclepro.2019.03.156>
- [27] He, L., & Yuan, H. (2020). Investigation of construction waste recycling decisions by considering consumers' quality perceptions. <https://doi.org/10.1016/j.jclepro.2020.120928>
- [28] Huang, L., Zhen, L., & Yin, L. (2020). Waste material recycling and exchanging decisions for industrial symbiosis network optimization. <https://doi.org/10.1016/j.jclepro.2020.124073>
- [29] Huang, Q., Chen, G., Wang, Y., Xu, L., & Chen, W. (2020). Identifying the socioeconomic drivers of solid waste recycling in China for the period 2005–2017. <https://doi.org/10.1016/j.scitotenv.2020.138137>
- [30] Huang, W., Lin, D., Chang, N., & Lin, K. (2002). Recycling of construction and demolition waste via a mechanical sorting process. [https://doi.org/10.1016/S0921-3449\(02\)00053-8](https://doi.org/10.1016/S0921-3449(02)00053-8)
- [31] Ishola, B. (2019). Handling Waste in Manufacturing: Encouraging Remanufacturing, Recycling and Reusing in the United States of America. *Procedia Manufacturing*, 39, 721–726. doi:10.1016/j.promfg.2020.01.444
- [32] Klassen, R., & Angell, L. (1998). An international comparison of environmental management in operations: The impact of manufacturing flexibility in the U.S. and Germany. [https://doi.org/10.1016/S0272-6963\(97\)00037-5](https://doi.org/10.1016/S0272-6963(97)00037-5)
- [33] Ko, S., Kim, W., Shin, S.-C., & Shin, J. (2020). The economic value of sustainable recycling and waste management policies: The case of a waste management crisis in South Korea. *Waste Management*, 104(-), 220-227. <https://doi.org/10.1016/j.wasman.2020.01.020>
- [34] Kristanto, G. A., Gusniani, I., Ratna, A. (2015). The performance of municipal solid waste recycling program in Depok, Indonesia. *International Journal of Technology*, 6(2), 264.
- [35] Lebleu, T. (2021). *Tackling the waste issue: an economic, social and environmental priority*. <https://solarimpulse.com/news/tackling-the-waste-issue-an-economic-social-and-environmental-priority>.
- [36] Lee, S., Kim, J., & Chong, W. (2016). The causes of the municipal solid waste and the greenhouse gas emissions from the waste sector in the United States. <https://doi.org/10.1016/j.wasman.2016.07.022>
- [37] Li, J., Mei, M., Han, Y., Hong, M., & Man, Y. (2019). Life cycle Cost assessment of recycled PAPER manufacture in China. <https://doi.org/10.1016/j.jclepro.2019.119868>
- [38] Liu, Y., Park, S., Yi, H., & Feiock, R. (2019). Evaluating the employment impact of recycling performance in Florida. *Waste Management*, 101, 283-290. doi:10.1016/j.wasman.2019.10.025
- [39] Liu, Z., Li, K., Tang, J., Gong, B., & Huang, J. (2020). Optimal operations of a closed-loop supply chain under a dual regulation. <https://doi.org/10.1016/j.ijpe.2020.107991>

- [40] Magazzino, C., Mele, M., & Schneider, N. (2020). The relationship between municipal solid waste and greenhouse gas emissions: Evidence from Switzerland. *Waste Management*, 113, 508-520. <https://doi.org/10.1016/j.wasman.2020.05.033>
- [41] Masui, T., Morita, T., & Kyogoku, J. (2011). Analysis of recycling activities using a multi-sectoral economic model with material flow. [https://doi.org/10.1016/S0377-2217\(99\)00242-8](https://doi.org/10.1016/S0377-2217(99)00242-8)
- [42] Nakamura, S. (1999). An interindustry approach to analyzing economic and environmental effects of the recycling of waste. [https://doi.org/10.1016/S0921-8009\(98\)00031-7](https://doi.org/10.1016/S0921-8009(98)00031-7)
- [43] Nguyen, K., Chuang, Y., Chen, H., & Chang, C. (2020). Impacts of socioeconomic changes on municipal solid waste characteristics in Taiwan. <https://doi.org/10.1016/j.resconrec.2020.104931>
- [44] Paes, M., Medeiros, G., Mancini, S., Bortoleto, A., Oliveira, J., & Kulay, L. (2019). Municipal solid waste management: Integrated analysis of environmental and economic indicators based on life cycle assessment. <https://doi.org/10.1016/j.jclepro.2019.119848>
- [45] Pati, R., Vrat, P., & Kumar, P. (2006). Economic analysis of paper recycling vis-à-vis wood as raw material. <https://doi.org/10.1016/j.ijpe.2005.08.006>
- [46] Pluskal, J., Šomplák, R., Nevrlý, V., Smejkalová, V., & Pavlas, M. (2020). Strategic decisions leading to sustainable waste management: Separation, sorting and recycling Possibilities. <https://doi.org/10.1016/j.jclepro.2020.123359>
- [47] 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 & Recycling*, 166(105372). <https://doi.org/10.1016/j.resconrec.2020.105372>
- [48] Richard GM, Mario M, Javier T. (2011). Optimization of the recovery of plastics for recycling by density media separation cyclones. *Resour Conserv Recycl*, 55(4), 472–482
- [49] Rogetzer, P., Silbermayr, L., & Jammerneegg, W. (2019). Sustainable sourcing including capacity reservation for recycled materials: A newsvendor framework with price and demand correlations. <https://doi.org/10.1016/j.ijpe.2019.03.014>
- [50] Sanchez, F., Boudaoud, H., Camargo, M., & Pearce, J. (2020). Plastic recycling in additive manufacturing: A systematic literature review and opportunities for the circular economy. <https://doi.org/10.1016/j.jclepro.2020.121602>
- [51] Seik, F. (1998). Recycling of domestic waste: Early experiences in Singapore. [https://doi.org/10.1016/S0197-3975\(97\)00060-X](https://doi.org/10.1016/S0197-3975(97)00060-X)
- [52] Shmelev, S., & Powell, J. (2005). Ecological-economic modelling for strategic regional waste management systems. <https://doi.org/10.1016/j.ecolecon.2005.09.030>
- [53] Shi, X., Mukhopadhyay, A., Zollinger, D., & Grasley, Z. (2019). Economic input-output life cycle assessment of concrete pavement containing recycled concrete aggregate. <https://doi.org/10.1016/j.jclepro.2019.03.288>
- [54] Sormunen, P., & Kärki, T. (2019). Recycled construction and demolition waste as a possible source of materials for composite manufacturing. <https://doi.org/10.1016/j.jobe.2019.100742>
- [55] Treloar, G., Gupta, H., Love, P., & Nguyen, B. (2003). An analysis of factors influencing waste minimization and use of recycled materials for the construction of residential buildings. <https://doi.org/10.1108/14777830310460432I>
- [56] Trujillo L, J. C., Carrillo B, B., Charris V, C. A., & Iglesias P, W. J. (2013). The environmental Kuznets curve (ekc): An analysis landfilled solid waste in Colombia. *Revista Facultad de Ciencias Económicas*, 21(2), 7–16.
- [57] Wang, N., He, Q., & Jiang, B. (2018). Hybrid closed-loop supply chains with competition in recycling and product supply markets. *International Journal of Production Economics*. doi:10.1016/j.ijpe.2018.01.002
- [58] Wang, X., Han, J., Mo, Z., Chu, C., Tang, J., Meng, J., and Miller, G. (n.d.). Health risk assessment of lead for children in tinfoil manufacturing and e-waste recycling areas of Zhejiang Province, China. 10.1016/j.scitotenv.2012.04.002
- [59] World Bank. (n.d.). *Trends in Solid Waste Management*. WHAT A WASTE 2.0 A Global Snapshot of Solid Waste Management to 2050. <https://datatopics.worldbank.org/what-a-waste/trends-in-solid-waste-management.html>
- [60] Yamada, T., Hasegawa, S., Kinoshita, Y., Yamada, S., Inoue, M., Rosebrock, C., & Bracke, S. (2018). Process integration concept for waste reduction among manufacturing planning, modularization and validation. <https://doi.org/10.1016/j.promfg.2018.02.129>
- [61] Yandle, B., Bhattarai, M., & Vijayaraghavan, M. (2004). Environmental Kuznets Curves: A Review of Findings, Methods, and Policy Implications, 2. https://www.researchgate.net/publication/242758524_Environmental_Kuznets_Curves_A_Review_of_Findings_Methods_and_Policy_Implications
- [62] Yu, Y., Yazan, D., Bhochhibhoya, S., & Volker, L. (2021). Towards circular economy through industrial symbiosis in the dutch construction industry: A case of Recycled CONCRETE AGGREGATES. <https://doi.org/10.1016/j.jclepro.2021.126083>
- [63] Zaman, A. (2013). Identification of key assessment indicators of the zero waste management systems. <https://doi.org/10.1016/j.ecolind.2013.09.024>
- [64] Zhao, W., Leeftink, R., & Rotter, V. (2009). Evaluation of the economic feasibility for the recycling of construction and demolition waste IN China-The case of Chongqing. <https://doi.org/10.1016/j.resconrec.2009.09.003>
- [65] Zhou, X., Huang, A., Cui, B., & Sutherland, J. W. (2021). Techno-economic Assessment of a Novel SmCo Permanent Magnet Manufacturing Method. *Procedia CIRP* 98, 2021, 127-132. <https://doi.org/10.1016/j.procir.2021.01.017>