Exploring Socioeconomic Factors of Waste Generation in Addis Ababa, Ethiopia

Agimasie Demewoz Ali

Institute for Environment and Sustainable Development, Tongji University, Shanghai, 200092, China

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Abstract- This study was conducted to examine socioeconomic factors that affect the Municipal Solid Waste (MSW) generation level in Addis Ababa city administration. In this paper, the researcher used both descriptive and econometric analysis. The study used a fixed effect regression model for econometric analysis. The study's empirical result indicates that population density has a positive and statistically significant effect on municipal solid waste generation. In contrast, secondary school enrollment and environmental protection clubs in school have a negative and statistically significant impact on municipal solid waste generation. This suggests that the composition of these waste types may remain relatively stable over time. Consequently, this study emphasizes the need for the city administration to enhance its urban planning, management, and implementation capacity. The city administration should also encourage the formation of Environmental Protection Clubs in schools and other community groups because it can effectively reduce waste generation. Education and awareness programs should also be strengthened to improve solid waste management practices.

***Index Terms*-** MSWM Practice, Addis Ababa, Fixed Effect, System Dynamics

I. Introduction

Addis Ababa is characterized by a fast population increment due to migration from different rural areas. The environmental and hygienic conditions of the town become an additional serious problem facing from time to time, and people are suffering from living in such waste management on the one hand and steady growth of solid waste drawback on other aspect are yet the main indicators of the city [1]. The rapid population increase and economic growth of the city brought a large quantity of solid waste. The piles of waste dumped lawlessly on open areas, in gullies, and river courses are undisputable evidence of the poor solid waste management system of the city that has ultimately caused a foul smell, obstruction of drains, and destroyed the aesthetics of the city. The prevailing literature concentrate on generation rate, physical properties, and composition. h

Like other developing-country cities, Addis Ababa confronts issues related to poorly managed solid waste operations. While cities produce an increasing amount of waste, the efficiency of their solid waste collection and disposal systems is deteriorating [2].

MSWM is one of the basic services that are currently receiving wide attention in many cities and towns in Ethiopia. This is mainly because SWs that are generated in most towns of Ethiopia are not appropriately handled and managed [3].

According to Abebe, Worku [4], Ethiopia is still struggling to deal with the problem of proper management of solid wastes. Municipal solid waste collection, transportation, and disposal have become a major concern for municipalities in most Ethiopian cities due to the present rate of urbanization. The production of residential, commercial, and industrial waste is a widespread process that takes place in every household, building, commercial establishment, and industrial facility. It also occurs in public spaces such as streets, parks, and vacant areas within communities. This wide distribution of waste sources makes the collection of municipal solid waste challenging and complex in most cities. In addition to this, as stated by Abebe, Worku [4], [5], many cities face problems such as a lack of manpower and equipment and financial constraints.

Municipal solid waste (MSW) generation is influenced by a wide range of socioeconomic factors. Understanding the relationship between these factors and waste generation rates is crucial for effective waste management strategies.

In the early days, researchers established a relationship between socioeconomic factors and HSW generation.

A study by Adams, Boateng [6] investigated urban areas in Senegal and found a positive correlation between population density and MSW generation rates. Similarly, Liu, Li [7] examined cities in China and reported that higher population densities were associated with increased MSW generation. These findings suggest that as population density increases, so does the volume of waste generated. The relationship between population density and MSW generation is complex and influenced by various factors. Urbanization plays a crucial role in this dynamic. As urban areas grow, population densities tend to rise, resulting in increased waste generation due to factors such as changes in consumption patterns, lifestyle choices, and socioeconomic factors [8].

Additionally, infrastructure and waste management systems heavily influence the waste generation patterns in densely populated areas. Efficient waste collection, recycling facilities, and disposal options can mitigate the negative impact of high population densities on waste generation rates [9]. Local policies, public awareness campaigns, and education on waste reduction practices also play essential roles in shaping waste-generation behaviors [10]. High population densities can pose challenges for waste management systems, such as increased logistical demands, limited space for landfills, and potential environmental and health risks if waste is not appropriately managed. However, population density can also present opportunities for sustainable waste management practices. Dense urban areas are often more conducive to implementing efficient waste collection systems, promoting recycling initiatives, and exploring innovative waste-to-energy technologies [11]. The literature review shows a clear relationship between population density and municipal solid waste generation rates. Higher population densities are generally associated with increased waste generation. However, the influence of population density on waste generation is not solely determined by population size. Various factors, including urbanization, infrastructure, waste management systems, and socioeconomic factors, contribute to this relationship.

The enrolment of children in schools can also play a role in waste generation patterns. A study by [12] conducted in South Africa indicated that school enrolment positively influenced waste reduction and recycling practices within households. The researchers found that parents of enrolled children were more likely to be aware of waste management practices and implement them in their homes, leading to lower waste generation rates. Education and school enrolment can influence waste generation through various mechanisms and factors. Education provides individuals with knowledge about the environmental impact of waste, waste reduction strategies, and recycling techniques, empowering them to make informed decisions [13]. Furthermore, education can shape attitudes and values towards sustainability, fostering a sense of responsibility and pro-environmental behavior [14].

A study by Kumar, Bhattacharyya [15] conducted in Indian cities found that higher budgetary allocations for waste management were associated with reduced waste generation rates. Similarly, a study by Alzamora and Barros [16] in Swedish municipalities highlighted the positive impact of increased MSWM budgets on waste reduction and recycling rates. The relationship between the MSWM budget and waste generation rates is influenced by various factors. Budget constraints and insufficient funding can limit the implementation of waste management strategies and infrastructure development, potentially leading to higher waste generation [17]. Insufficient funds for waste collection, recycling facilities, and landfill management may result in inadequate waste management practices and increased waste generation.

Dealing with the environmental costs of rapidly growing economic development, urbanization, and improving living standards in cities have increased the quantity and complexity of generated waste, representing an unprecedented challenge [18]. This is particularly true in the area of solid waste management. The issue of solid waste management highlights a growing concern. Despite the rising amount of waste generated in cities, the effectiveness of their collection and disposal systems is diminishing. A study conducted in 2018 by Adedara, Taiwo [19] revealed that in urban areas across African regions, only 44% of the solid waste produced is collected, while a significant portion is either haphazardly discarded in various dumping sites on the outskirts of urban centers or temporarily stored in scattered empty lots throughout the city [19, 20].

Solid waste management in Addis Ababa City began approximately thirty years ago. However, over time, the service has struggled to keep up with the evolving demands. The solid waste collection service is currently unsatisfactory, leading to the common sight of scattered waste in many areas throughout the city [21]. However, the municipal solid waste collection service is not functioning properly. The disposal site situated at one corner of the city is also the main determining factor for the collection and disposal of waste in the city. This means that only those people close to the dump sites benefit. The existing number of dump sites and trucks is inadequate to handle the volume of solid waste generated. In densely populated Kebeles, the majority of people live 0.5 – 1.00 km from accessible roads where transfer containers are located when the recommended distance is 150 m from the housing units [22].

Currently, in Addis Ababa, solid waste is increasing beyond the municipal governors' management capacity; the waste volume totals more than three million cubic meters per year, with the prospect of increasing by a constant rate of 2.1 cubic meters per person annually [23]. However, the UN's (2016) estimate shows that only 65 percent of the waste generated in the city is collected, with the rest being disposed of in open sites, drainage channels, and rivers. This fact can be observed by strolling on the street of Addis Ababa city. The government had structured a process where SMEs and privately owned sanitation companies work with the government's sanitation entities in line with Proclamation No.513/2007. Despite the government's procedural mechanisms put in place to cope with the above problem, the matter of solid waste disposal seems far from being resolved due to the lack of technology, technical know-how, financial capacity, poor institutional structure, and understanding of the community required to manage solid wastes by the service providers properly [24].

The population growth rate of the urban population in Ethiopia, according to [25], is estimated in most metropolitan areas, especially small urban centers, doubling every 15-25 years. In line with this, Yohanis [26] described that economic development and population growth in urban areas result in increased solid waste generation, which demands municipalities in Ethiopia be prepared for such challenges. Getahun, Beyene [27] stated that poor solid waste management threatens sustainable development posing urban growth, which results in environmental pollution. Similarly, Amare [28] also noted that poor solid waste management devastates the environment.

Research conducted by Gebretsadkan [29] identified the absence of rules and regulations and public education on solid waste management and problems related to site selection for solid waste disposal, solid waste collection, and transportation techniques aggravated by socioeconomic factors. However, there are research undertaken on MSWM [26, 30-33], it is important to conduct another research with a specific socioeconomic context to confirm and extend the generalizability of the existing findings. Hence, this study was focused on examining socioeconomic factors of Municipal Solid Waste generation in the Addis Ababa City Administration.

II. Methodological Framework

Data and Data Source

Annual data were collected from Addis Ababa sub-cities (i.e., Akaki Kaliti, Nefass Silk Lafto, Kolfe, Keraniyo, Gulele, Lideta, Kirkos, Arada, Addis Ketema, Yeka, and Bole) to analyze the effect of socioeconomic variables on MSWM. Though the city currently has 11 sub-cities, the newest Lemikura Sub-city is excluded due to data constraints. To examine socioeconomic factors of MSW generation, the study uses data covered from 2015-2020. These data were collected from the Addis Ababa Bureau of Education, the Ethiopian Statistical Service, and the Addis Ababa Cleansing Management Agency.

Study variables

The dependent variable for this study is the yearly amount of waste generated in tons for each sub-city. And the explanatory variables are presented as follows:

- Population density: population density is calculated as the midyear population divided by the square kilometers of land. The data is computed at an annual level data point for each sub-city.
- Primary school enrollment: the data is the number of official primary school-age children enrolled in primary education collected from the Addis Ababa education bureau. The data is disaggregated at the sub-city level.
- Secondary school enrollment: like primary school enrollment data, the data is disaggregated at the sub-city level.
- Environmental Protection Club in School: the Environmental Protection Club is a group of concerned students, educators, and volunteers dedicated to increasing environmental awareness and minimizing individual environmental effects within a school community. The data is obtained from the education bureau at the sub-city level.
- Budget for Municipal Solid Waste Management: the data is the annual approved budget for Addis Ababa Cleansing Management Agency for the purpose of MSWM.

Method of Data Analysis

Statistical analyses have been carried out to examine the impact of socioeconomic factors on MSWM, using the following methods: First, descriptive statistics (i.e., mean and standard deviation) of the variables (both dependent and independent) were calculated over the sample period which states using descriptive statistics methods helps the researcher in picturing the existing situation and allows relevant information. Then, a correlation analysis between dependent and independent variables was made. Finally, the fixed effect regression model was employed, including all of its assumptions, panel unit root, and panel co-integration. Data collected from different sources were analyzed by using STATA 17 software package and Python 3.8.

Model Specification

In order to achieve the objectives of the study, the researcher prepared data comprising both time series and cross-sectional elements; such data set is known as panel data or longitudinal data. As a result, the study used panel regression. First and perhaps most importantly, the advantages of using a panel data set are that it can address a broader range of issues and tackle more complex problems with panel data than would be possible with pure time series or pure cross-sectional data alone. Second, it is often of interest to examine how variables, or the relationships between them, change dynamically (over time) [34].

To do this using pure time-series, data would often require a long run of data simply to get a sufficient number of observations to conduct meaningful hypothesis tests. But by combining cross-sectional and time series data, one can increase the number of degrees of freedom, and thus the power of the test, by employing information on the dynamic behavior of a large number of entities at the same time. The additional variation introduced by combining the data in this way can also help mitigate multicollinearity problems that may arise if time series are modeled individually. Third, by appropriately structuring the model, it is possible to remove the impact of certain forms of omitted variables bias in regression results. In analyzing the socioeconomic variables of Municipal Solid Waste Generation of Addis Ababa City between 2015-2020 using a statistical model, the study adopts the empirical model used by Mazzanti, Montini [35], [36-38].

The model was used to examine the effect of socioeconomic variables on municipal solid waste generation. The model specified the dependent variable Solid waste generation as a function of population density, primary school enrollment rate, secondary school enrollment rate, environmental protection club school, and budget for MSWM represents explanatory variables. The model is specified thus:

Mathematically, the model setup may have as described in the following equation:

$$Y_{it} = \alpha_i + \beta x_{it} + u_{it} \qquad (1)$$

Where Y_{it} is the dependent variable, α_i is the intercept term, β is a parameter to be estimated on the explanatory variables, x_{it} is a vector of observation on the explanatory variables and u_{it} is the error term; i =1, 2, … T; t=1, 2, … N.

The general representation of the model to estimate the effect of socioeconomic factors on waste generation level is given in the equation below.

$$MSWM = f(PD, PER, SER, EPC, BMSWM) \qquad (2)$$

Where;

$MSWM$ = Municipal Waste Generation (in cubic meters)

PD = Population Density (Persons per square kilometer)

PER = Primary School Enrollment Rate (in Percent)

SER = Secondary School Enrollment Rate (in Percent)

EPC = Environmental Protection Club in School (in number)

$BMSWM$ = Budget for Municipal Solid Waste Management (in Birr)

f = Functional Relationship

Equation (2) is represented as:

$$MSWM_{it} = \beta_0 + \beta_1 PD_{it} + \beta_2 \mathrm{PER}_{it} + \beta_3 SER_{it} + \beta_4 EPC_{it} + \beta_5 BMSWM_{it} + u_{it} \qquad (3)$$

Where;

β_0 is intercept

β_1-β_5 are slope or coefficient of explanatory variables

$MSWM_{it}$ is the waste generation of the i^{th} sub-city

PD_{it} annual population density of the i^{th} sub-city

PER_{it} is primary school enrollment of the i^{th} sub-city

SER_{it} is secondary school enrollment of the i^{th} sub-city

$BMSWM_{it}$ is the budget for municipal solid waste management of the i^{th} sub-city
u_{it} is error term
'i' and 't' represent the cross-section and time period, respectively

III. Result

The descriptive statistics for the dependent and independent variables are presented below. The dependent variable is generated waste. The independent variables were PD, Primary school enrollment, secondary school enrollment, number of environmental protection clubs in school, and allocated budget for municipal waste management were used to see the effect of socioeconomic factors on municipal waste generation. Table (1) below presents the descriptive statistics of the dependent and independent variables.

Table 1: Descriptive statics of dependent and independent variables

Variables	Mean	Max	Min
MSWM	34783.42	51361.00	22309.00
PD	23043.61	49234.89	3050.20
PER	60129.67	128648.00	20103.00
SER	13997.13	24369.00	3078.00
EPC	74.10	139.00	21.00
BMSWM	21673505.11	35169293.92	10751772.93

Source: Own Computations Using STATA 17

The summary statistics contain different characteristics of data used in the analysis. Based on the table, the mean of solid waste generated in the sub-cities was 34783 tons per year. The waste generation is ranged from 22309.00 tons to 51361.00.
The average population density per sub-city was 23043.61%. The maximum population density per sub-city is 23043.61, recorded in Addis Ketema-Sub City in 2020.

The mean value of primary school enrollment was 60129.67. the value indicates the average primary school per sub-city per year. The maximum and minimum levels of primary school enrollment in sub-cities are 128648.00 and 20103.00, respectively.

The average secondary school enrollment was about 13997.13, while the capacity to secondary school enrollment ranged between 24369 and 3078. The mean value of the number of environmental protection clubs in school was 74. The maximum number of was of environmental protection club 139, which was registered in Kolfe Keraniyo-Sub City in 2016. Meanwhile, the minimum value was 21 and was recorded in Lideta-Sub City 2015. Finally, it is noted that the dependent variable is normally distributed where the importance of the Jarque-Bera test was greater than 5%, which shows the normal distribution of the variable which reflects the data of Sub-cites (i.e., Akaki Kaliti-Sub City, Nefas Silk-Lafto-Sub City, Kolfe Keraniyo-Sub City, Gulele-Sub City, Lideta-Sub City, Kirkos-Sub City, Arada-Sub City, Addis Ketema-Sub City, Yeka-Sub City, Bole-Sub City) in six years.

Correlation Analysis

Figure (1) illustrates a heatmap that displays the results of the correlation analysis conducted to examine the relationships between socioeconomic factors related to waste management and generation. The heatmap utilizes Blue and Red colors to represent specific correlation intervals, ranging from -1 to 1. This comprehensive analysis provides valuable insights into the correlations between waste generation patterns and potential influencing factors. The correlation analysis reveals, across almost all sub-cities, there is a positive correlation between Population density (PD) and Municipal solid waste generation level (MSWM). This indicates that as the population density increases, the amount of municipal solid waste generated also tends to increase. The high positive correlations in these areas emphasize the need for effective waste management strategies to address the growing waste generation associated with dense population centers.

On the other hand, the analysis also uncovers significant negative correlations between the budget for municipal solid waste management (BMSWM) and the Municipal solid waste generation level in nearly all sub-cities. This suggests that higher budget allocations for waste management are associated with lower waste generation levels. These findings highlight the importance of financial investment and resource allocation in implementing efficient waste management practices.

Additionally, the correlation analysis reveals negative correlations between secondary and primary school enrollments and municipal solid waste generation levels in most subsites. This implies that higher school enrollments are associated with lower waste generation levels. These findings indicate that school educational initiatives and awareness programs might play a crucial role in waste reduction and management efforts.

Furthermore, the heatmap correlation analysis provides insights into specific sub-cities. The presence of an environmental protection club in schools (EPC) shows a negative correlation with the Municipal Solid waste generation level in Lideta, Kirkos, Arada, Yeka, and Bole Sub-cities. This indicates that sub-cities with active environmental protection clubs tend to have lower levels of waste generation. It highlights the positive impact of such clubs in promoting waste reduction practices and environmental consciousness among students.

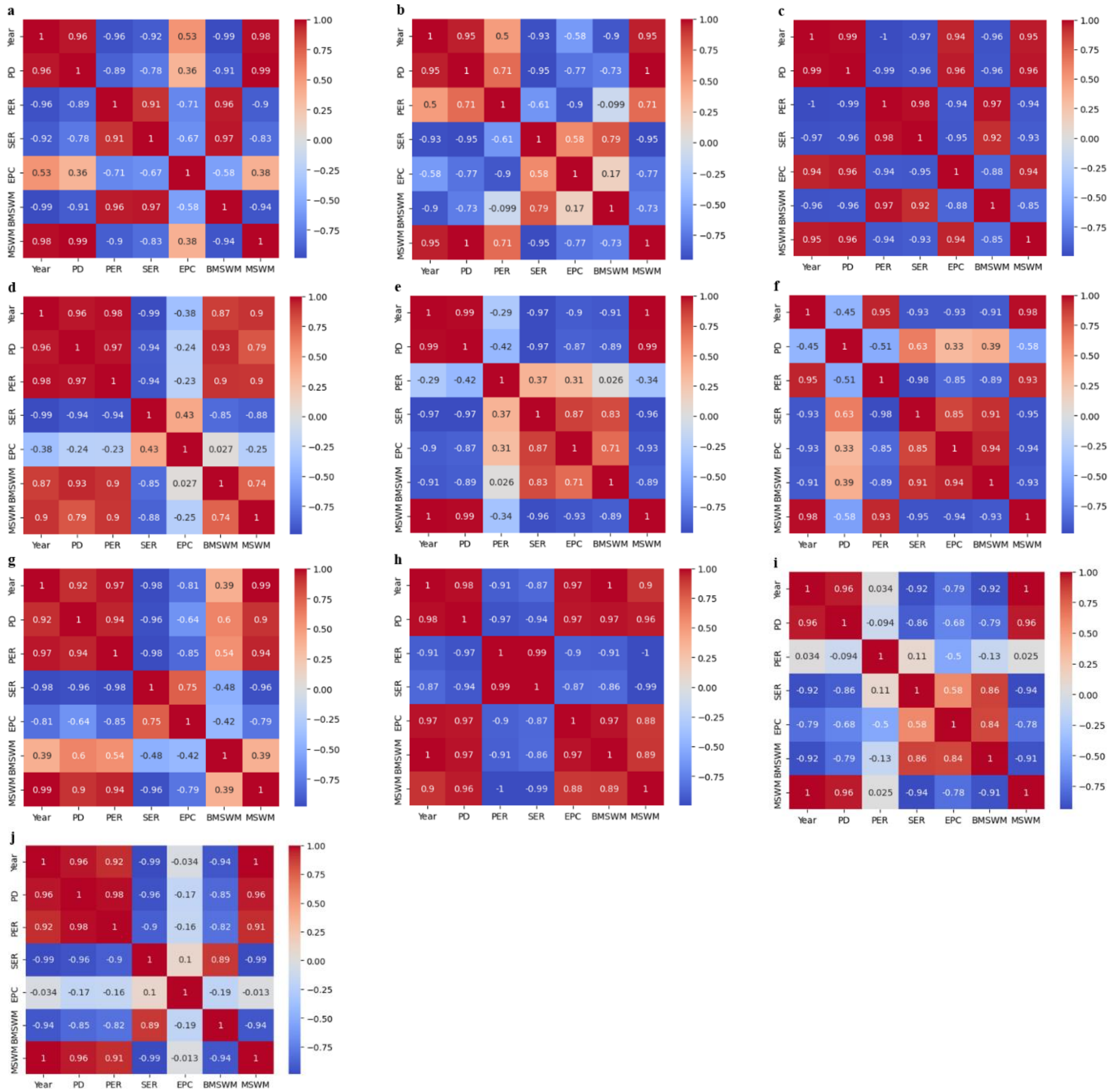

Figure 1: Heatmap about socioeconomic factors with MSW generation level:

a) Akaki Kaliti-Sub City; b) Nefas Silk-Lafto-Sub City; c) Kolfe Keraniyo-Sub City; d) Gulele-Sub City; e) Lideta-Sub City; f) Kirkos-Sub City; g) Arada-Sub City; h) Addis Ketema-Sub City; i) Yeka-Sub City; j) Bole-Sub City

Source: Own Analysis Based on Addis Ababa Cleansing Management Agency Data

Result of Regression Analysis

Once data are cleaned up and evaluated to enable us to make a precise analysis, the next step is to report with estimations' results aligning with prior expectations and theory setups. In a sense, the researcher checked all the necessary tests in panel datasets, such as estimating coefficients using pooled OLS, fixed effects, and random effects models, and scrutinized these findings with both empirical and theoretical aspects. As it might be clear to all of us, the first test that should be performed is the F-test in order to decide the estimation technique which will be used. That is either the Pooled OLS or fixed effect. In this study, such a process has been done through the rule of thumb where the F-test tests the fixed effects. For example, if the null hypothesis is failed to reject, we are to mean in favor of pooled OLS regression; otherwise, the researcher tends to prefer the fixed effects model. In this regard, the researcher performed pre-tests. In accordance, the null hypothesis failed to accept the premises. As a result, the researcher is forced to choose fixed effects estimation.

In fact, the researcher also checked the Hausman test, which is the pertinent statistical test for choosing fixed effects or random effects. And the test seems to suggest the application of fixed effects against its counterpart of the random effects panel data model. The reason to do so is that it has a robust advantage in eliminating the issues of serial auto-correlation and multi-co-linearity.

To elaborate more here, below is described what was done in a detailed manner, in line with the objective of the researcher and statistical tests consulted. The researcher was interested in the determinants of differences in the solid waste generation between sub-cities and therefore started off by using the "between estimator." The between estimator is the OLS estimator from regression of y_{it} on an intercept and x_{it} for sub-city *i* and time *t*. This estimator exclusively focuses on the variance between sub-cities. In other words, it provides information on whether cub cities with, e.g., a high population density have higher waste generation levels or not. It is thus straightforward to use the between estimator to analyze the differences in waste generation level between sub-cities. In addition, this estimator averages over the observed period. Consequently, it has the benefit of measuring the impact of long-term differences in waste generation.

However, one of the paper's objectives was to see the factors of variation of solid waste generation level amongst the sub-cities of interest. However, the statistical tests performed tend to go against that. For this apparent reason, focusing on the between estimator seems useless. And, without even considering the statistical tests, the between estimator has two essential drawbacks, which disapproved of its usage in this specific analysis. Firstly, it may be biased as it relies on the assumption that the sub-city-specific effects are independent of the other covariates in the model. A second drawback is that researchers lose information by averaging over the period. Indeed, the between estimator only considers the panel's cross-sectional variation.

The researcher estimates a reduced form linear specification to include the broad range of MSWM determinants outlined in the previous section. However, the benchmark and the alternative pooled OLS specification rely on essential assumptions that are tested. Several statistical checks were performed to test the underlying model assumptions. The model has been checked for multi-co-linearity problems, which may break down OLS estimation. First, a visual analysis of the data has been done. To this end, the study used matrix graphs plotting each relevant variable against each other (Figure 2). Environmental protection club in school (EPC) and, to some extent, the primary school enrollment show a linear relationship with other variables. But, statistical tests (like VIF) did not indicate any issues of severe multi-co-linearity. Therefore, the researcher proceeds with this group of variables.

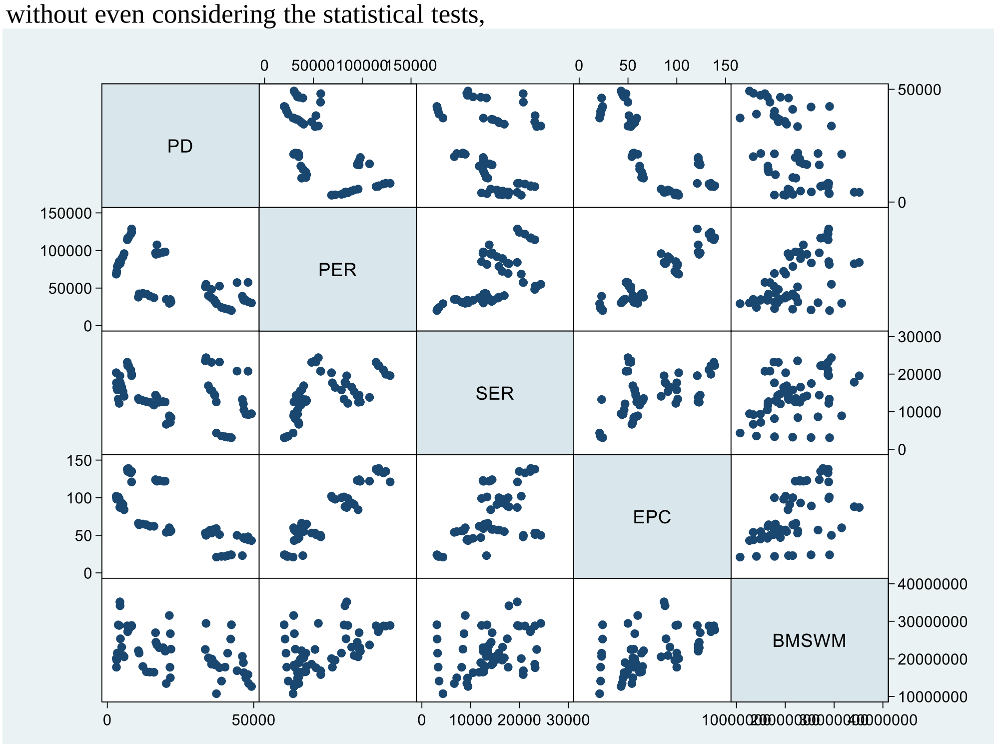

Figure 2: Graph Matrix of Explanatory Variables
Source: Own Computations Using STATA 17

Beyond that, the author performs several additional statistical tests to check the assumptions underlying the OLS model. That is, first, checked the homoscedasticity condition of the error term have checked. Due to the characteristics of the panel in which the study pooled sub-cities, it is highly likely that the standard errors are not constant across the panel but rather clustered at the sub-city level. But the homoscedasticity assumption is indeed failed to be rejected by the Breusch-Pagan test (P-value=0.698). Therefore, the test assured as there is no degree of serial correlation of the error term at the country level too.

Next, the researcher investigates whether these sub-city-specific effects are correlated with the regressors, as this would raise endogeneity issues. To this end, the study first examines the presence of time and sub-city-fixed effects. A simple F-test on the coefficients of time dummies could reject the assumption of a common time intercept (p-value = 0.00). However, a similar test indicates that the pooled OLS model is misspecified as it does not include sub-city-specific effects, which appear to be present.

Afterward, the study investigates whether the sub-city-specific effects will likely correlate with the regressors. The regression results of the random and fixed effects estimator, respectively, have been reported (Table 2). The Hausman test also suggests that the sub-city-specific effects may not be considered random (p-value = 0.00). Therefore, the regression results of the fixed effects estimator are preferred above those of the random effect panel estimators, which are likely to suffer from endogeneity bias.

Lastly, the analysis indicates that the explanatory variables do a poorer job of explaining the within sub-city variation over time. This indicates that waste generation level is persistent over time and are expected to adapt only slowly to changes in underlying socioeconomic factors. Nonetheless, the fixed effects estimation broadly confirms the results of the other specifications.

The estimation results of the panel analysis are reported in Table (2). In both regressions, the dependent variable is the waste generation level, as defined in the previous section. The different explanatory variables that were used in the analysis are reported in the first column. The following columns (Table 2) show the estimation results of the panel estimators described above, which will be discussed below.

Table 2: Results of panel data analysis (dependent variable: municipal waste generation)

VARIABLES	Random Effect	Fixed Effect
PD	0.0665	0.638***
	(0.108)	(0.154)
PER	0.221***	-0.0502
	(0.0582)	(0.0866)
SER	-0.670***	-0.911***
	(0.200)	(0.253)
EPC	94.84	-190.3**
	(62.15)	(85.62)
BMSWM	-0.000209**	-0.000161**
	(8.88e-05)	(6.41e-05)
Constant	26,870***	53,370***
	(6,550)	(13,827)
Observations	60	60
R-squared	0.70	0.682
Number of SC_ID	10	10

Note: *** p<0.01, ** p<0.05, * p<0.1 shows statistically significant at 1%, 5%, and 10% level, respectively. Standard errors are in parentheses.
Source: Own Computations Using STATA 17

As can be shown in (Table 2) above, the first specification in the second column reports the random effect estimation results, and the next third column indicates the fixed effect estimation result. In both specifications, robust standard errors are shown between brackets. The estimated model contains the key explanatory variables which were identified in previous literature and also had explanatory power in this study. These are Population density, Primary school enrollment, Secondary school enrollment, Environmental protection club in school, and Budget for MSWM. Based on the Hausman test, the fixed effects estimator's results should be preferred over the random effect estimator result.

Moreover, the Hausman test indicated these fixed effects are correlated with the explanatory variables. Therefore, only the fixed effects estimator is consistent. The results of the panel estimations interpretations for specific variables are given as follows.

Population density (PD) could be one factor affecting Municipal solid waste generation level. According to the fixed effects estimation, population density exhibits a positive and statistically significant effect on municipal solid waste generation at the 1% significance level. This implies population density is a threat to the environment, leading to increased production of municipal solid waste. This implies the volume of waste generated will also change due to the growing population, which is also related to changing consumption patterns and lifestyles. The changing consumption patterns are seen in the daily lives of urban residents, such as the habit of buying fast food that absolutely produces, for example, disposable food containers. This consumption pattern greatly affects the increase in waste generation [39]. A similar study conducted by [40] indicated that increasing the population would increase waste generated from population activities, and this causes environmental damage both directly and indirectly [40, 41].

Secondary school enrollment (SER) has a negative, positive, and statistically significant (with a 1% level of significance) impact on the waste generation level. And this is the fact that the residents' educational level can significantly impact the success of awareness programs aimed at improving solid waste management practices. A study conducted by Irwan, Basri [42] indicates that the more a family is educated and aware of the negative consequences of improper solid waste management, the more they recognize the importance of effective solid waste management. Gu, Jiang [43] in Suzhou City/East China, Benítez, Lozano-Olvera [44] in Mexicali/Mexico, and Monavari, Omrani [45] in Ahvaz City/Iran found that the education level of the household head has a negative effect on the rate of household waste generation, i.e., increasing in education level abeles to decrease waste level.

Another variable that significantly affects municipal solid waste generation is the environmental protection club in school (EPC). This variable represents a group of concerned students, teachers, and volunteers dedicated to raising environmental awareness, facilitating the cleaning movement, and reducing environmental impact as individuals and as a school community. The variable has a negative effect on waste generation at a five percent significance level. The reason behind this is the Environmental Education Club plays a vital role by encouraging the development of skills, attitudes, and motivations that allow citizens to make informed decisions and take responsible actions that include environmental considerations [46].

The last variable associated with municipal solid waste generation level is the BMSWM, which is negatively significant at the five percent level. The intuition behind this is there are programs related to capacity development, awareness raising, policy design, and related activities under MSWM. Hence the budget is a driving force for achieving these programs.

IV. Conclusion and Recommendation

The study finds that population density is a significant factor for the municipal solid waste generation level, with a positive impact. This suggests that increasing population density threatens the environment, leading to increased production of municipal solid waste. The study also highlights that changing consumption patterns and lifestyles are associated with the growing population, further influencing the volume of waste generated.

Furthermore, the study finds that secondary school enrollment negatively and statistically significantly impacts waste generation, indicating that residents' educational level is crucial in promoting effective solid waste management practices. The study suggests that awareness programs aimed at improving solid waste management practices are more successful among families with higher levels of education. Moreover, the study shows that the presence of an Environmental Protection Club in schools has a negative impact on waste generation at a five percent significance level. This highlights the significant role such clubs play in raising environmental awareness and facilitating the cleaning movement, which contributes to reducing the environmental impact as individuals and as a school community. The study indicates that the budget allocated for MSWM has a negative and significant impact on the waste generation level, implying that adequate funding is essential for achieving programs related to capacity development, awareness raising, policy design, and other related activities.

Overall, the findings suggest that addressing socioeconomic factors, such as population density, education, and adequate funding for waste management, is crucial in mitigating the environmental impact of municipal solid waste generation. The study also highlights the importance of promoting effective solid waste management practices through awareness programs and environmental protection clubs in schools.

The study recommends further research to examine the impact of educational interventions on solid waste generation level. Conduct a comprehensive study to evaluate the effectiveness of awareness programs aimed at promoting solid waste generation and management practices among different educational groups. Assess the outcomes of these interventions in terms of waste reduction, behavior change, and community participation. Identify effective strategies for reaching and engaging diverse educational backgrounds.

Also, further assessment on role and impact of Environmental Protection Clubs is recommended. Assess their effectiveness in raising student engagement, promoting behavioral change, and cultivating a culture of environmental stewardship helps to Identify best practices and recommendations for scaling up these initiatives.

Conduct a detailed analysis to understand the relationship between the budget allocated for MSWM and waste generation levels is important. Evaluate the efficiency and effectiveness of current budget allocation mechanisms can help to propose strategies for optimizing resource allocation to achieve desired waste management outcomes.

Finally, if the data permits, the analysis can be enhanced by including more cities in the country. Comparing other cities of the world is also possible. Analyzing the effects of policy interventions on MSWM is possible.

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AUTHORS

First Author – Agimasie Demewoz Ali, Institute for Environment and Sustainable Development, Tongji University, Shanghai, 200092, China, E-mail: demewoza@gmail.com