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# Municipal panel data analysis for solid waste, local governments and citizen participation

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**ABSTRACT**

**BACKGROUND AND OBJECTIVES:** Solid waste management in Ecuador is the responsibility of the municipal autonomous decentralised governments and is structured in a value chain from waste collection to final disposal. This study aims to assess the impact of municipal governance, public engagement, and the presence of regulations on the quantity of solid waste collected and the probability of service delivery within the value chain. The existing body of research concerning solid waste management at the municipal level in Ecuador is relatively sparse, particularly in terms of longitudinal studies. This gap highlights the need for further investigation, as the current limitations in data hinder a comprehensive understanding of the subject.
**METHODS:** The estimation of the relationships was developed through panel data models, focusing on both the volume of collections and probability of providing recovery, storage, transfer and disposal services. The explanatory variables are quality of the territorial development and land use plan goals, targets and indicators. Furthermore, these factors involve the execution of the investment plan budget financial sustainability, efficiency of expenditure, fiscal dependence, participation system, participation mechanisms, participatory budget, control mechanisms, public accountability, ordinance, municipal agency and gross value added. The current study investigates solid waste collection and the delivery of services in the value chain as the dependent variables, analyzing data from 221 municipalities in Ecuador during the timeframe of 2017 to 2022.
**FINDINGS:** The findings indicate that in smaller municipalities, citizen participation –– either through participatory budgeting or control mechanisms – influences solid waste collection. In the realm of financial management, the significance of fiscal dependency and financial sustainability is prominent; however, the aspect of planning typically does not exhibit a considerable impact. The chances of offering services such as storage, transfers, and utilization, characterized by limited regulatory oversight, are shaped by fiscal reliance and the existence of relevant ordinances, with no observable effect from citizen participation.
**CONCLUSION:** The outcomes related to citizen participation and waste management are generally more favorable in smaller municipalities. This phenomenon can be linked to their enhanced social cohesion and less complex administrative systems, which promote the successful implementation of policies and initiatives that cater to the unique needs of the community. On the other hand, larger municipalities face greater challenges, such as bureaucracy and complexity in service coordination, which limits the impact of citizen participation. To increase the efficiency of solid waste management services in municipalities, irrespective of their size, it is crucial to innovate in fiscal management and to adopt clear regulatory frameworks.

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## INTRODUCTION

In Latin America, decentralisation has emerged as a dynamic and intricate process designed to bolster efficiency, equity, and governance in the provision of public goods. This initiative entails the transfer of authority, resources, and responsibilities from the central government to sub-national governments, which include local and regional authorities. The efficient provision of public goods is one of the main objectives of decentralisation because of the leading role they play in the economic and social development of the territory and the gains in improving efficiency and accountability in the provision of these goods (Forcaut and Wan, 2017). Various theoretical perspectives, such as fiscal federalism, can elucidate the relationship between decentralization and the supply of public goods. According to this theory, delegating fiscal and administrative duties to sub-national governments may lead to improved efficiency in the delivery of these goods (Forcaut and Wan, 2017). Emphasising the management of sub-national governments, Rondinelli *et al.* (1989) propose the theory of administrative decentralisation based on the idea that decentralisation can reduce bureaucracy and streamline decision-making processes, allowing for a faster and more appropriate response to local needs. The foundation of adequate public service provision, particularly in the realm of solid waste management (SWM), lies in effective municipal management. This involves essential elements such as comprehensive planning, sound financial management, and the involvement of citizens in the decision-making process. Municipal planning – through which local authorities define objectives, strategies and actions for urban and rural development – ensures the efficient provision of public services. The significance of territorial planning in urban contexts cannot be overstated, particularly regarding the sustainability of cities through effective water and waste management (Díaz-Barriga-Fernández *et al.*, 2017). This planning approach aids in establishing efficient waste collection routes, suitable disposal sites, and comprehensive recycling strategies (Ghiani *et al.*, 2014; Carmen-Niño *et al.*, 2023). However, the effectiveness of these planning initiatives can be compromised by factors such as insufficient infrastructure, unclear regulations, disorganized public policies, and a lack of financial support (Yukalang *et al.*, 2017; Tsypkin et al., 2020; Bernache-Pérez *et al.*, 2023). Enhancing citizen involvement and integrating the informal sector into SWM could serve as potential solutions to these challenges (Ferronato *et al.*, 2019). Financial management, understood as the capacity of municipal governments to manage their economic resources efficiently and transparently through tax collection, budget management and investment in infrastructure, is essential for the acquisition of collection equipment, construction of landfills and recycling plants and implementation of environmental education programmes (Guerrero *et al.*, 2013; Lohri *et al.*, 2014; Bartolacci *et al.*, 2018; Pinha and Sagawa, 2020). In addition to analyzing territorial planning and financial management, it is crucial to take into account the relationships among individuals and communities. This comprehensive approach facilitates the integration of social capital theory (Bourdieu, 1985; Putnam, 1993), which asserts that social networks, trust, and reciprocal norms can significantly bolster the efficiency of public institutions. Putnam (1993) suggests that communities with high levels of social capital are better able to manage public goods effectively, as cooperation and civic participation facilitate the implementation of public policies and the oversight of local officials. The concept of civic participation refers to the active role of the community in the municipal decision-making process, which is achieved through public consultations, neighborhood committees, and feedback systems. Specifically regarding SWM at the local level, this participation is essential for fostering sustainable development in communities, as it significantly influences public health, environmental sustainability, and economic vitality. As cities and communities continue to grow, the amount of waste generated increases proportionally, underscoring the need for effective waste management systems (Kala and Bolia, 2021). The concept of waste management extends beyond the mere final disposal of waste; it also incorporates the stages of collection, transportation, treatment, and frequently, the recovery of materials through recycling and alternative reuse strategies. While decentralisation processes seem to contribute to waste management (Aprilia *et al.*, 2011; Masood *et al.*, 2014; Nhubu *et al.*, 2021; Angouria-Tsorochidou *et al.*, 2022; Alvarado-Ibarra *et al.*, 2024), there is also evidence that interlinkages between municipalities

can generate economies of scale in terms of reduced average costs of infrastructure, collection and processing (Villalba *et al*., 2022), incentivising environmental governance processes. A significant challenge encountered by local governments is the establishment of waste management systems that are not only efficient and sustainable but also economically feasible. According to UN-Habitat (2010), well-structured waste management at the local level should include active community participation, implementation of appropriate technologies and adaptation to the specific conditions of each localityEvidence from empirical studies indicates that active citizen engagement is essential for the successful implementation of recycling programs and waste management efforts, as it encourages responsible practices and compliance with regulatory frameworks (UN-Habitat, 2010; Guerrero *et al*., 2013; Zaman, 2023). Citizen participation allows local communities to take the lead in the creation and management of waste projects, such as recycling centres, community composting or clean-up campaigns, initiatives that not only help reduce the amount of waste going to landfills but also strengthen the social fabric. Research focused on the evaluation of experiences and key determinants for successful SWM has underscored the crucial role of environmental consciousness within the general populace (Raghu and Rodriguez, 2021). Furthermore, it has been found that citizen involvement, the actions of local government, levels of education (Ranjith and Chowdhury, 2007), infrastructural challenges, and cultural aspects are also essential components (Zhang *et al*., 2024). Studies in places such as Pakistan, India, Iran and Vietnam seem to agree that the quality of SWM is the result of the interaction between environmental governance and citizen participation (Wu *et al*., 2020) and that the higher the educational and occupational level, the less satisfied the population will be and the more they will demand and, through participation in decision-making, more efficient actions in service provision will be put in place (Ranjith and Chowdhury, 2007; Masood *et al*., 2014; Pinnawala, 2016; Jomehpour and Behzad, 2020; Raghu and Rodriguez, 2021). Active citizen participation can significantly contribute to the collaboration with local governments aimed at refining waste collection services and advancing recycling programs, ultimately fostering more robust waste management policies. Nevertheless, the role of local governments is crucial in devising community incentives, such as rewards, that motivate engagement in solid waste management initiatives. The success of these programs is heavily reliant on the willingness of households to embrace recycling practices (Kala and Bolia, 2021). In the realm of community engagement, it is important to acknowledge that the effectiveness of citizen participation in SWM is contingent upon the size of the municipality. Empirical evidence seems to show that the smaller the population, the more efficient community management is and therefore the greater impact it has on the value chain of SWM, while in larger municipalities, this management is more complex, bureaucratic and less flexible, which limits citizen participation (Guerrero *et al*., 2015; Houwelingen, 2017; Benito *et al*., 2021; McDonnell, 2019 and 2022). Furthermore, the effectiveness of SWM can be shaped by the implementation of ordinances. Such regulations play a crucial role in promoting efficiency and ensuring the protection of the environment and the well-being of the community (Batista *et al*., 2021; Kiguli *et al*., 2023). It can also be influenced by the management model, either directly by the municipality or through outsourcing. There is a notable divergence of opinion within the academic literature concerning the optimal model for waste management. Some researchers assert that municipal management is not the most suitable approach, particularly in the context of larger municipalities (Pérez-López *et al*., 2016; Campos-Alba *et al*., 2021; Doussoulin and Colther, 2022). In contrast, other studies suggest that smaller municipalities are capable of managing waste efficiently (Romano and Molinos-Senante, 2020). With regard to the economic growth of municipalities, the literature provides evidence of a relationship that depends on the stage of development of the municipality; as the territory grows, waste generation increases, and only after a certain level of growth is reached are environmental practices introduced to compensate for this increase, showing an inverse relationship from there (Magazzino *et al.,* 2020). Research conducted in Peru, Brazil, Bolivia, and Mexico reveals that the effectiveness of recycling practices and municipal SWM programs in Latin America is significantly influenced by factors such as citizen engagement, municipal environmental governance, as well as the

educational attainment, age, and gender of the population (Bernal *et al*., 2020; De Oliveira et al., 2023; Alvarado-Ibarra *et al*., 2024). In the specific case of Ecuador, a decentralisation trajectory has been followed, marked by significant constitutional and legal reforms, such as the 2008 Constitution and the Organic Code of Territorial Organisation, Autonomy and Decentralisation (COOTAD in Spanish), which are the legal pillars governing the decentralisation process in the country. In Ecuador, local governments—comprising provincial, municipal, and parish entities, play a vital role in the enactment of public policies and the provision of various services to the community. Decentralised autonomous governments (DAGs) have exclusive, concurrent and complementary competencies in several key areas for local development and public wellbeing, such as land management through territorial order and development plans (TODPs) that promote sustainable land use and the balanced development of urban and rural areas. The responsibilities of DAGs include the provision of essential public services. This involves the management of drinking water resources, sewage systems, and the collection and treatment of solid waste. They are also tasked with maintaining public lighting and road infrastructure. In terms of environmental stewardship, DAGs implement policies and programs designed to protect the environment, conserve natural resources, and mitigate climate change effects. Additionally, they support productive and economic development by encouraging local economic activities. SWM in Ecuador has undergone a significant evolution in recent decades, marked by a growing effort by local and national authorities to improve waste management practices and reduce their environmental impact, regulated by a series of laws and policies that seek to establish a framework for proper waste management, such as the Environmental Management Law, passed in 1999, and the Organic Environmental Code of 2018. These legislation supports efforts to minimize waste generation, enhance material recovery, and ensure proper disposal methods, in addition to promoting the integration of waste management policies into local development frameworks (Ministerio del Ambiente, 2015). One of the main challenges in Ecuador is the limited capacity of municipalities to implement and maintain effective waste management systems. Numerous municipalities, particularly those situated in rural regions, face significant challenges due to insufficient financial and technical resources for the effective management of solid waste. The consequence of this situation has been an increased dependence on open dumping sites, which fail to comply with environmental regulations and present considerable threats to both public health and ecological integrity. Another problem is the lack of adequate infrastructure for selective collection and recycling; although pilot recycling programmes have been implemented in cities such as Quito, Guayaquil and Cuenca, they have not achieved sufficient coverage to have a significant impact on a national level (Chicaiza *et al*., 2020; Burneo *et al*., 2020). This issue is intensified by a lack of active citizen involvement in source separation programs, thereby impeding the establishment of more sustainable waste management systems. Given the local challenges of responding to sustainable development in the country and promoting nature conservation and public wellbeing, as well as the scarce empirical evidence available in the country and even more so at a municipal (cantonal) level, this study had two aims. The primary aim of this study was to assess whether advancements in the operational capacity of municipal government management and the involvement of citizens result in a greater quantity of waste collected, serving as the initial step in the value chain. The second aim was to ascertain whether these factors lead to an increase in the volume of waste collected during the initial phase of the value chain, and to evaluate if these factors influence the likelihood of subsequent processes within the value chain. This includes collection, which currently lacks explicit legal regulations and is often conducted through informal arrangements, as well as storage, transfer, utilization. In order to address the influence of citizen participation and municipal government management in the provision of local public services such as solid waste for the years 2017–2022 in the 221 Ecuadorian municipalities in Ecuador.

## MATERIALS AND METHODS

Information regarding the operational capabilities of municipal Decentralized Autonomous Governments (DAGs) was obtained from the National Council of Competencies (CNC, 2023) and the Census of Environmental Economic Information on Municipal DAGs provided by the National

Table 1: Components and indicators of the operational capability index (Consejo Nacional de Competencias, 2023)

| Dimension | Component | Indicator / Estimate |
|---|---|---|
| **Planning and spatial planning** | Quality of the TODP | This is constructed by identifying the errors in the formulation of objectives, goals and indicators of the TODP with respect to the total number proposed. |
| | Articulation of programmes and projects to the TODP | Number of projects whose linkage to the TODP goal is incorrect. Number of projects whose linkage to the competence is incorrect. Total number of programmes or projects entered. |
| | Goal fulfilment index (GFI) | The comparison procedure is applied with the best score in the fulfilment of goals. |
| **Financial management** | Investment budget execution<br>Financial sustainability<br>Efficiency in investment and capital spending<br>Fiscal dependence | Comparison with the best score is applied. Indicators are used, whose values range from 0 percent (%) to 100% and for which it is not possible to determine a range of optimal to poor performance of the indicator. |
| **Citizen participation** | Citizen participation system implemented | This includes: a call for participation, ordinance of approval, citizen participation system implementation and local planning council. |
| | Citizen participation mechanisms implemented | This includes: local citizens' assembly, public hearings, people's council, the empty chair (consists of the allocation of a space or chair within the sessions of the GADs, destined to a representative of the citizens. Although the empty chair representative does not have the right to vote, his or her participation allows the voice of the citizenry to be heard in the decision-making process) and consultation councils |
| | Participatory budget | This includes: participatory budgeting and percentage of budget allocated for participatory budgeting. |
| | Mechanism of social control by the citizenry | This includes: citizen oversight agencies, citizen observatories, community ombudsmen for the management of the DAG and user committees for the management of services. |
| | Implementation of the full accountability process | This includes: a delivered accountability report to the Citizen participation council (CPC), receipt of issues that citizens need to be informed of, the participation body / DAG creating a joint team for the accountability process, public deliberation and citizen evaluation of the accountability report carried out in person, a work plan to incorporate citizen suggestions, the DAG delivering the work plan to the citizen assembly, planning council and participation bodies for monitoring. |

Institute of Statistics and Censuses (INEC, 2023). The assessment of the operational capacity of the 221 municipal governments pertains to the extent to which the decentralized autonomous government can effectively exercise its competencies, functions, and responsibilities (CNC, 2023). To this end, the National Council of Competencies of Ecuador (Consejo Nacional de Competencias, 2024) estimates an operational capacity index (OCI) made up of three dimensions: territorial planning and organisation, financial management and citizen participation, which group together components and indicators (Table 1). The maximum score of the OCI is 30 points, with each dimension contributing a maximum of 10 points.

Concerning the dependent variable, the research focused on the volume of solid waste collected (in tonnes per month) and the provision of essential value chain processes—namely collection, storage, transfer, utilization, and final disposal, across all municipalities throughout the designated study period (INEC, 2023). Information on these variables is available longitudinally (2017 to 2022) and for all 221 municipalities, which requires the estimation of a panel data model. These variables have been considered based on what is proposed in the literature and the existing limitations of municipal-level data in Ecuador. Although the provincial and national levels offer opportunities to include other critical variables associated with demographic and economic considerations, there is a significant absence of trustworthy and systematic information at the municipal level. Despite global advances in technology, digital citizen participation (e-participation) has not been implemented in Ecuador, making it impossible to include it in the

estimation. First, the dependent variable concerning solid waste collection, quantified in tonnes per month, was examined using fixed or random effects panel data estimates. This methodology was implemented to account for the heterogeneity that stems from differences among municipalities or random variations. The existence of unobserved heterogeneity means that the regression error term contains not only the residuals of the estimation itself, which is part of the variability of the dependent variable not explained by the model, but also an error associated with unobserved heterogeneity (Wooldridge, 2010). Unobserved heterogeneity gives rise to a correlation between the error component and the explanatory variables, thereby hindering the ability to derive unbiased estimators. To overcome this bias, fixed effects estimation and random effects estimation have been proposed (Wooldridge, 2010; Montero, 2011). The first scenario suggests that unobserved heterogeneity arises from individual characteristics, which results in a correlation. In contrast, the second scenario posits that unobserved heterogeneity is a consequence of randomness, leading to the assumption that the correlation with the explanatory variables is nonexistent. The model that best explains the unobserved heterogeneity was selected by means of the Hausman test, whose hypothesis is based on the preference of the random effects model over the fixed effects model (Montero, 2011). Upon selecting the fixed effects model, it was necessary to determine the presence of heteroscedasticity (modified White test) and autocorrelation (Wooldridge test). The presence of one or both problems should be corrected using generalised least squares (GLS) for fixed effects (Wooldridge, 2010; Montero, 2011). In the first instance, the estimation of the solid waste variable y_it was conducted using a variety of components from the planning dimension (X_it), which includes the quality of the objectives, indicators, and goals associated with the TODP. The financial management component (Z_it) was also incorporated, which consists of budget execution for investments, financial sustainability, fiscal dependence, and the efficiency of capital expenditures. Additionally, the citizen participation component (W_it) was evaluated, comprising participatory budgeting, mechanisms for participation, and accountability measures. The existence of a municipal ordinance for management was treated as a dichotomous variable (V_it), assigned a value of zero if it is not present. Other relevant factors included the gross value added from the municipality's production (T_it) and whether the municipality directly manages the operations (U_it), which is also a dichotomous variable, taking a value of zero when managed by another entity, as specified in Eq. 1 (Pinha and Sagawa, 2020; Kala and Bolia, 2021):

$$y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{it} + \beta_3 W_{it} + \beta_4 V_{it} + \beta_5 U_{it} + \beta_6 T_{it} + \varepsilon_{it} \quad (1)$$

In addition, the execution of SWM value chain processes, which include collection, storage, transfer, recovery, and disposal, can be classified as dichotomous variables. This classification supports the use of discrete choice modeling through logit panel data, which is governed by a logistic distribution function. $y_{it}$ is the dichotomous variable associated with the provision of collection, storage, transfers, use and final disposal, with a value of zero if the municipality does not provide the service, while the explanatory variables are those used in Eq. 1. Each dependent variable is estimated using a logit model in panel data, both for fixed and random effects. As indicated, the selection of the determination of the appropriate model for each effect is based on the findings of the Hausman test. Utilizing the selected model, the marginal effects are derived from partial derivatives, demonstrating the variation in the probability of service provision resulting from a one-unit alteration in each indicator.

## RESULTS AND DISCUSSION

When analysing the behaviour of the provision of public services in the study period for all 221 municipalities, it is evident that only 53.46% of the municipalities carried out the process of SWM. These findings stem from Ecuador's commitment to the National Programme for the Integrated Management of Solid Waste (NPIMSW), which has been in operation for over a decade. The Ministry of Environment oversees the program, with municipal governments responsible for its execution. Additionally, the Organic Environmental Code, enacted in 2018, enforces the necessity of effective waste management strategies (Consejo Nacional de Competencias, 2019). In 2022, the management model employed by municipal governments was primarily directed towards direct

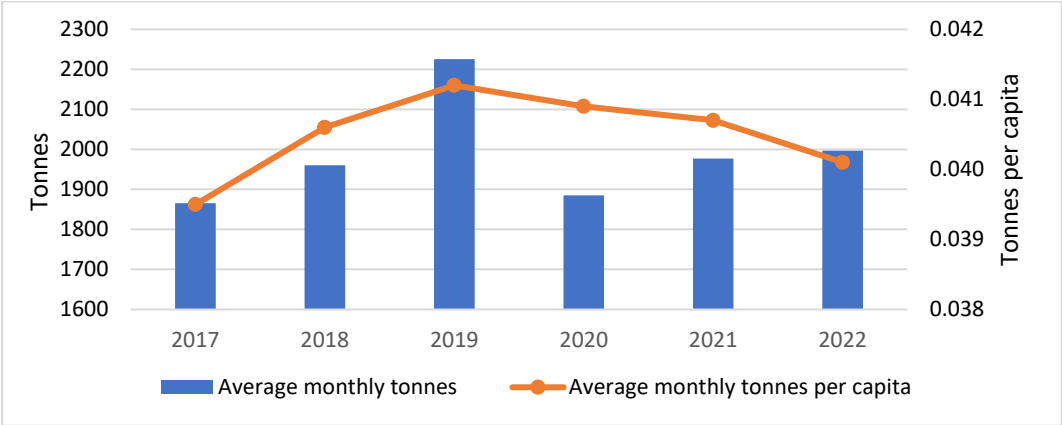



Fig. 1: Evolution of average monthly solid waste collection (2017–2022) (INEC, 2023)

or combined administration, which comprised 85% of the overall management approach. This was succeeded by joint public companies at 8.6%, municipal enterprises created by governmental bodies for service provision at 5.5%, and associations of municipalities, which involve the collaboration of multiple municipal governments for collective task execution, accounting for 0.9%. INEC (2023) outlines that the value chain associated with integrated solid waste management (SWM) is bifurcated into two distinct sources, regardless of the management model implemented. The initial source consists of fundamental services, including collection, source separation, and street cleaning, which are legally designated as the responsibility of municipal governments, typically underpinned by relevant ordinances. The second source relates to the overall value chain of integrated SWM, irrespective of the management model in place. This comprises storage, transport, transfer or collection, use and final disposal, all of which do not have defined regulations, giving rise to informality and commercial activity derived from these processes (Ministerio del Ambiente, 2015). The evolution of the results of the first source of the value chain (collection), despite the population increase, have not improved throughout the period analysed, neither in absolute terms of tonnes collected nor in per-capita terms. In terms of average monthly collection, 2019 stands out as the peak year. Conversely, 2020 experienced a reduction exceeding 300 tonnes per month, primarily due to the impacts of the sanitary emergency, restrictions on mobility, and enforced isolation measures. The situation gradually recovered without exceeding the results of 2019, reaching 40.15 kg per month per inhabitant by 2022 (Fig. 1).

The results in terms of the first source of the value chain (collection) can also be compared by cantonal population size, according to the classification proposed by the Environment Ministry (Ministerio del Ambiente), in which a canton is considered large if it has more than 300,001 inhabitants, medium between 50,0001 and 300,000, small between 15,001 and 50,000, and micro when less than 15,000 inhabitants. According to the data presented in Table 2, the monthly average of solid waste collected reached 1,996.75 tonnes by 2022. The municipalities with the largest populations reported an average collection of 48,917.58 tonnes per month, contrasting sharply with the smaller cantons, which averaged only 231.19 tonnes. This indicates that while total waste collection increases with population size, the per-capita collection remains modest, averaging 38.54 kg per month. The canton of Tiwintza had the lowest per-capita collection, whereas Las Naves recorded the highest at 112.11 kg for the year 2022.

In the context of SWM, only 53.39% of municipalities deliver a complete range of services across different management modalities. The value chain particularly underscores the importance of collection, street cleaning, and final disposal processes, which are carried out by more than 90% of municipalities on average. Nonetheless, the level of service provision tends to be lower in larger cantons. Of the total waste

Table 2: Variables associated with SWM by canton (Municipality) size for the year 2022 (INEC, 2023)

| Variables | Large | Medium | Small | Micro | Total or overall average |
|---|---|---|---|---|---|
| N° municipalities | 6 | 34 | 43 | 138 | 221 |
| Solid waste (tonnes per month collected) | 48,917.58 | 3,510.91 | 962.35 | 231.19 | 1,996.75 |
| Proportion of municipalities providing SWM services | 33.33% | 59.80% | 54.26% | 67.39% | 53.39% |
| Proportion of municipalities with collection ordinances | 83.33% | 97.06% | 93.02% | 92.02% | 92.76% |
| Proportion of municipalities with direct management | 60.00% | 73.53% | 95.35% | 85.50% | 85.00% |
| Proportion of municipalities with service charges | 100% | 97.06% | 95.35% | 93.47% | 94.54% |
| Proportion of municipalities that provide training for citizens | 33.33% | 26.47% | 46.51% | 36.23% | 36.65% |
| Proportion of municipalities that have received technical assistance | 20.00% | 61.76% | 62.79% | 55.97% | 56.81% |
| Proportion of municipalities with waste collection processes | 33.33% | 11.76% | 30.23% | 23.18% | 23.07% |
| Proportion of municipalities with final management processes | 83.33% | 94.12% | 95.35% | 94.92% | 94.57% |
| Proportion of municipalities with transfer processes | 16.67% | 2.94% | 0.00% | 2.17% | 2.26% |
| Proportion of municipalities with collection processes | 83.33% | 100% | 100% | 100% | 99.54% |
| Proportion of municipalities with sweeping processes | 50.00% | 97.06% | 97.67% | 97.82% | 96.38% |
| Proportion of municipalities with storage processes | 16.67% | 17.65% | 4.65% | 15.94% | 14.02% |

disposed of, 54.5% is managed in sanitary landfills, 28.2% in temporary cells, and 17.3% in dumps (INEC, 2023). The processes of storage, transfer and use are the ones with the lowest percentage of provision regardless of the population size of the municipality. Additionally, most municipalities have ordinances for waste collection and, in general terms, for waste management, as this is the direct competence attributed to them by the Organic Environmental Code, but not for the additional processes of the value chain, which could explain the low rate of provision of these services. These ordinances are also associated with charging for the service, but according to INEC (2023), the subsidy granted by the municipal governments was 47.3% of the amount of the service, which amounted to 27 million USD for the year 2022. The assessment of municipal governments' operational capacity as a determinant of their effectiveness in solid waste collection reveals, as illustrated in Fig. 2, that the Operational Capacity Index (OCI) has generally progressed from 2017 to 2022, although a regression is apparent in the last year. This improvement has been driven by the dimension of planning related to the TODP, which is the best evaluated, followed by citizen participation and, in last place, financial management, showing weaknesses in resource management.

The analysis for the year 2022, particularly when considering population size, demonstrates that the operational capacity indices are largely similar, although the largest municipalities exhibit slightly diminished results. The dimensions of planning, financial management, and citizen participation each possess a maximum indicator value of 10 points. Therefore, the cumulative maximum value of the index, derived from the sum of these dimensions, totals 30 points. This implies that higher results are indicative of greater operational capacity, as demonstrated in Table 3.

The higher the values of the quality of the TODP, the articulation of projects and the compliance rate, the better the quality of the planning carried

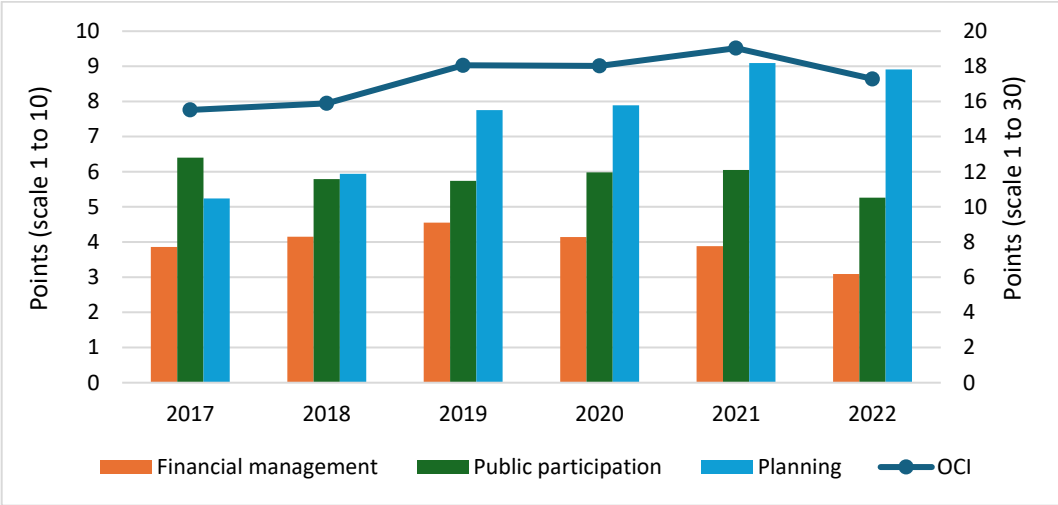



Fig. 2: Evolution of the municipal OCI (2017–2022) (CNC, 2024)

Table 3: Municipal management and citizen participation by canton size (municipality) for the year 2022 (CNC, 2023)

| Dimension / Indicator | Large | Medium | Small | Micro | Overall average | Maximum value |
|---|---|---|---|---|---|---|
| Planning | | | | | | |
| Quality of the TODP | 1.44 | 1.49 | 1.41 | 1.40 | 1.44 | 1.54 |
| Articulation of TODP projects | 1.28 | 1.48 | 0.49 | 1.46 | 1.46 | 1.54 |
| Compliance Index | 5.67 | 6.24 | 6.23 | 5.95 | 6.03 | 6.92 |
| Financial Management | | | | | | |
| Investment budget execution | 1.81 | 2.12 | 2.06 | 2.06 | 2.06 | 2.50 |
| Financial sustainability | 0.42 | 0.22 | 0.17 | 0.24 | 0.22 | 2.50 |
| Expenditure efficiency | 0.13 | 0.17 | 0.10 | 0.11 | 0.12 | 2.50 |
| Fiscal dependence | 0.87 | 0.69 | 0.63 | 0.70 | 0.68 | 2.50 |
| Citizen Participation | | | | | | |
| Participation system | 1.71 | 1.59 | 2.14 | 1.80 | 1.83 | 2.86 |
| Participation mechanisms | 1.28 | 0.88 | 1.16 | 1.03 | 1.03 | 2.62 |
| Participatory budget | 0.16 | 0.37 | 0.35 | 0.36 | 0.35 | 0.95 |
| Control mechanisms | 0.09 | 0.04 | 0.04 | 0.05 | 0.04 | 0.71 |
| Public accountability | 1.65 | 1.82 | 2.21 | 1.98 | 1.99 | 2.86 |
| OCI | 16.36 | 17.08 | 17.98 | 17.15 | 17.28 | 30 |

out by the municipal governments. Likewise, a more effective implementation of the investment plan, coupled with financial sustainability, optimal resource utilization, and diminished fiscal reliance, leads to superior results in the indicators of financial management. In this scenario, budget execution emerges as the metric with the most significant values, while the performance indicators related to financial sustainability, spending efficiency, and fiscal dependence fall short of even the average benchmark the scale. In the Andean region, the municipalities that reported the best OCI performance, slightly exceeding 20 points, were: Guano and Riobamba (province of Chimborazo), Cañar (province of Cañar), San Miguel de Urcuquí (province of Imbabura) and Quito, Mejía and Rumiñahui (province of Pichincha). In the coastal region, the highest-performing municipalities were: Pasaje and Piñas (province of El Oro), Atacames (province of Esmeraldas), Guayaquil and Samborondón (province of Guayas), and Santo Domingo (province of Santo Domingo de los Tsáchilas). The municipalities with the lowest

performance, around 10 points, were San Cristóbal (Galápagos), Muisne (Esmeraldas) and Sucumbíos (province of Sucumbíos). In the Amazon region, the municipality of Sucumbíos stood out with a performance score of 10.65 points, as no other municipalities demonstrated exceptional results. Additionally, the Andean region did not present any municipalities with significantly low scores. To test the relationship between solid waste collection (tonnes/month), we made panel data, fixed effects (FE) and random effects (RE) estimates for all municipalities as well as for each population size group. The selection of the Hausman test was based on its capacity to effectively account for the heterogeneity in the data, which in turn validated the assumptions and rectified the heteroscedasticity issues identified in the fixed effects model. The results for all five models are detailed in Table 4.

The fixed effects model was chosen for the estimation of all municipalities, both medium and small. However, due to the presence of heteroscedasticity, a GLS correction was applied to the panel data. In contrast, random effects were employed for the remaining municipalities, which include large and micro entities. In all cases the gross value added of production (equivalent to the gross

Table 4: Panel data estimation for solid waste collection (tonnes/month) by municipality size

| Variables | Total (FE GLS) | Large (RE) | Medium (FE GLS) | Small (FE GLS) | Micro (RE) |
|---|---|---|---|---|---|
| **Quality of the TODP goals** | -1177.671 | -67037.15* | 1364.025 | -9.460976 | 3.7605 |
| | (1837.07) | (35952.66) | (1895.447) | (522.956) | (18.346) |
| **Quality of the TODP targets** | 1663.591 | 4298.397 | 2968.25 | -562.0477 | 19.7618 |
| | (1799.39) | (42591.31) | (1854.263) | (487.912) | (16-995) |
| **Quality of the TODP indicators** | 2505.634 | 20468.06 | -208.849 | 123.037 | -0.7735 |
| | (1797.32) | (64264.78) | (1889.315) | (479.780) | (17.182) |
| **Budget execution of the investment plan** | -153.1595 | -6486.683 | 559.481 | 21.040 | 0.1935639 |
| | (443.618) | (11258.18) | (407.033) | (121.771) | 4.513661 |
| **Financial sustainability** | 4594.658*** | 664.7579 | 93.7492 | 808.802*** | -5.7927 |
| | (890.247) | (8972.528) | (571.702) | (252.535) | (14.153) |
| **Efficiency of expenditure** | -744.152 | -3398.213 | -11.4724 | -548.675* | 4.6511 |
| | (1100.327) | (8107.959) | (886.412) | (310.202) | (11.180) |
| **Fiscal dependence** | 2831.954* | 28347.2 | -1956.161** | 1594.467*** | 29.364 |
| | (1457.3) | (20810.4) | (821.711) | (406.329) | (19.380) |
| **Participation system** | 88.3598 | 4035.535 | 140.6384 | -16.017 | 2.8237 |
| | (324.773) | (8508.567) | (318.683) | (106.625) | (3.7364) |
| **Participation mechanisms** | 19.8009 | 1867.815 | -1444.565*** | -112.473 | -0.8556 |
| | (479.257) | (8176.541) | (423.602) | (129.812) | (5.7974) |
| **Participatory budget** | 4861.322*** | -30319.77 | 274.4882 | -417.331 | 28.920** |
| | (1446.706) | (30114.83) | (1338.315) | (404.101) | (14.562) |
| **Control mechanisms** | 8057.146*** | -4782.181 | 2986.632 | 1526.289** | -15.6472 |
| | (2249.045) | (17605.57) | (2232.035) | (620.901) | (26.604) |
| **Public accountability** | 244.7293 | -1515.257 | -823.4892** | 249.565* | -2.1526 |
| | (390.647) | (11511.33) | (409.805) | (135.083) | (3.8772) |
| **Ordinance** | 1119.522 | 23699.04 | -1481.042** | 833.26*** | 15.83896** |
| | (753.347) | (15695.27) | (656.402) | (219.897) | (8.0643) |
| **Municipal agency** | -766.449 | 19029.42 | -214.311 | -554.231** | 77.2502*** |
| | (733.574) | (12399.48) | (591.435) | (244.648) | (13.742) |
| **Gross value added** | 0.00024** | 0.0030*** | 0.00589*** | 0.0028*** | 0.000067 |
| | (0.00012) | (0.00067) | (0.000063) | (0.00014) | (0.00004) |
| **Constant** | -6827.579*** | -22496.69 | 2346.257 | -1642.29*** | 134.788*** |
| | (1971.578) | (60825.82) | (1922.964) | (621.434) | (36.047) |
| **Wald chi$^2$** | 136.54*** | 110.72*** | 9965.74*** | 805.50*** | 57.11*** |
| **Hausman** | 66.13*** | 0.44 | 35.74*** | 29.51*** | 4.38 |
| **$R^2$ overall** | 0.0535 | 0.9326 | 0.9770 | 0.5903 | 0.0241 |
| **$R^2$ within** | 0.020 | 0.6250 | 0.5517 | 0.1713 | 0.0755 |
| **$R^2$ between** | 0.0696 | 0.9999 | 0.9802 | 0.6968 | 0.0240 |
| **Rho** | 0.9650 | 0.9386 | 0.8723 | 0.8513 | 0.9532 |

Note: Values in brackets are standard errors. Variables significant at 1% ***, 5% **, 10% *.

Table 5: Marginal effects (partial derivatives) of the estimation of the logit model in panel data for SWM processes

| Variables | Collection (FE) | Storage (RE) | Transferences (RE) | Use (RE) | Final disposal (RE) |
|---|---|---|---|---|---|
| Quality of the TODP goals | 0.0223 | 0.0301 | 0.0291 | 0.1236* | -0.0305 |
| | (0.0494) | (0.0329) | (0.0489) | (0.0668) | (0.0573) |
| Quality of the TODP targets | -0.0302 | -0.0136 | 0.0025 | 0.0300 | 0.0465 |
| | (0.0475) | (0.0162) | (0.0498) | (0.0640) | (0.0555) |
| Quality of the TODP indicators | 0.0856* | -0.0160 | 0.0967* | -0.0017 | 0.0702 |
| | (0.0485) | (0.0179) | (0.0498) | (0.0641) | (0.0572) |
| Budget execution of investment plan | -0.0243* | -0.00003 | -0.0159 | -0.0180 | -0.0081 |
| | (0.0145) | (0.0026) | (0.0128) | (0.0149) | (0.0156) |
| Financial sustainability | 0.0381 | 0.0215 | 0.0223 | -0.0268 | -0.0515 |
| | (0.0373) | (0.0212) | (0.0279) | (0.0337) | (0.0361) |
| Efficiency of expenditure | 0.0176 | -0.0094 | -0.3343*** | -0.0234 | 0.2913*** |
| | (0.0338) | (0.0118) | (0.0526) | (0.0328) | (0.0421) |
| Fiscal dependence | -0.0802 | -0.0719 | 0.1690*** | 0.17203*** | -0.1773*** |
| | (0.0492) | (0.0596) | (0.0411) | (0.0534) | (0.0511) |
| Participation system | -0.0083 | -0.0002 | 0.0049 | 0.0120 | 0.0036 |
| | (0.0116) | (0.0024) | (0.0098) | (0.0122) | (0.0121) |
| Participation mechanisms | -0.0059 | -0.0007 | 0.0156 | 0.0051 | -0.0114 |
| | (0.0164) | (0.0036) | (0.0144) | (0.0178) | (0.0177) |
| Participatory budget | -0.0184 | 0.0059 | -0.0992*** | -0.0082 | 0.0078 |
| | (0.0472) | (0.0115) | (0.0480) | (0.0505) | (0.0512) |
| Control mechanisms | 0.0822 | 0.0009 | 0.0651 | 0.0618 | 0.0763 |
| | (0.0767) | (0.0144) | (0.0589) | (0.0817) | (0.0786) |
| Public accountability | -0.0085 | 0.0082 | 0.0008 | -0.0254* | 0.0096 |
| | (0.0121) | (0.0090) | (0.0110) | (0.0140) | (0.0134) |
| Ordinance | 0.5296*** | -0.0320 | -0.1131*** | 0,1411*** | 0.4341*** |
| | (0.0464) | (0.0280) | (0.0249) | (0,0272) | (0.0205) |
| Municipal agency | 0.0264 | -0.0300 | -0.0326 | 0,0013 | -0.0003 |
| | (0.0299) | (0.0275) | (0.0207) | (0,0376) | (0.0314) |
| Wald $chi^2$/LR | 89.88*** | 139.35*** | 95.50*** | 47.83*** | 192.65*** |
| Hausman | 28.32** | 8.16 | 11.24 | 8.20 | 228.19*** |

Note: Values in brackets are standard errors. Variables significant at 1% ***, 5% **, 10% *.

domestic product per municipality) was significant, having a positive effect on solid waste collection. At the aggregate level, the results indicate that some indicators of financial management are significant, but not those related to territorial planning. A clear and substantial correlation was found between the collection of solid waste and both financial sustainability and fiscal dependency. Furthermore, regarding citizen engagement, the presence of participatory budgets, an increased allocation of budgetary resources to these initiatives, and a higher number of oversight mechanisms contribute positively to the efficiency of solid waste collection. Neither the existence of by-laws nor the provision of the service by the municipality and third parties influences waste collection, at least at the aggregate level. When grouping municipalities according to population size, different results were obtained. The significant variables differ between groups: as the population size per municipality decreases, participatory budgets tend to be significant in explaining the volume of solid waste collected, in the sense that it has no impact on large municipalities but has an impact on micro municipalities. Larger population municipalities face greater difficulties in fostering citizen participation, which in turn exacerbates the challenges associated with service delivery. In large municipalities, the quality of the objectives in territorial planning has an inverse influence, which can be explained by the fact that the TODP priorities are oriented towards other areas. In medium-sized municipalities, there is an inverse relationship with fiscal dependence, participation mechanisms and accountability, which are the result of prioritising other municipal competencies, such as security or access to drinking water. The

implementation of ordinances and the reliance on municipal service delivery in smaller municipalities significantly bolster solid waste collection efforts. Furthermore, citizen involvement through control mechanisms in small municipalities and participatory budgeting in micro municipalities plays a crucial role in this enhancement. These findings perhaps show that as the size of municipalities decreases, citizen participation is relevant in community management. With respect to SWM value chain services, discrete choice panel data models were estimated for all municipalities. In the context of storage, transfer, recovery, and disposal, random effects models were chosen based on the acceptance of the null hypothesis from the Hausman test. Conversely, fixed effects models were applied specifically for the provision of collection. The marginal effects in terms of partial derivatives of these estimates are shown in Table 5.

The estimates of service provision probabilities in the SWM value chain did not take into account the gross value added from production, as it was found to be statistically insignificant across all evaluations. Reasons may consider that the service is provided by the municipality and depends on fiscal resources (Plata-Díaz *et al*., 2014), it is the population and urbanisation that determines waste generation (Cheng *et al*., 2020) or the service charging policy (Magazzino *et al*., 2020). The findings indicate that only the existence of by-laws regulating waste management was statistically significant for the probability of providing waste collection services and the probability increases by 52.96% when by-laws are in place. Regarding the storage or temporary disposal of waste for transport, no significant variables were identified since this is one of the services that is provided by a smaller proportion, as is the transfer to recovery or treatment. When considering the probability of executing the transfer service, it is observed that superior quality of the TODP indicators and diminished fiscal reliance enhance this probability. In contrast, increased efficiency in financial allocation, a more inclusive budgetary process, and the establishment of ordinances are associated with a lower probability of service provision. This trend reflects the lack of sufficient regulatory frameworks governing the services within the value chain, aside from the collection aspect. Waste recovery or treatment, which includes recycling, increases the likelihood of provision as fiscal dependence (central government resources) decreases and there are ordinances for regularisation and control. The implementation of ordinances significantly raises the chances of executing final disposal services, which entail the deposition of waste in locations designed to minimize environmental and health impacts, such as sanitary landfills. Additionally, the collection services, regulated by these ordinances, are characterized as the most structured and formalized services in this context. In spite of this, the probability of providing the final disposal service diminishes as dependence on the central government decreases. The disparity between waste generation and waste collection is concerning, particularly given that waste collection is a service subsidized by municipal governments. However, the situation becomes increasingly alarming when examining other components of the waste management value chain, notably in storage, transfer, and utilization services. These aspects lack regulatory frameworks and are predominantly managed by informal operators. Collection and disposal services have the highest coverage (over 90% on average) and are foreseen in the different municipal ordinances, which largely explains the results in terms of collection volume and the likelihood of providing both services. In smaller municipalities, as noted by Putnam (1993) and Bourdieu (1985), levels of social capital and proximity between citizens and local governments facilitate more direct and participatory interaction. This "social capital", encompassing relationships of trust and reciprocity, enhances the efficiency of managing public goods like solid waste. The smaller scale of the population allows participatory mechanisms, such as participatory budgeting or neighbourhood committees, to be more effective, translating into a better capacity to respond to local needs. Research by Guerrero *et al*. (2013) also supports this view, highlighting that in smaller municipalities, citizen participation is key to the success of recycling programmes and other aspects of SWM. The intimate relationship between citizens and local authorities fosters a spirit of cooperation and supports the oversight of regional policy implementation. The implementation of community recycling programmes and environmental education tends to be more effective when citizens are actively involved in the creation and management of projects

. Conversely, larger municipalities tend to experience more limitations regarding citizen participation. The increased bureaucracy and administrative complexity inherent in these settings contribute to the difficulties encountered in the successful execution of participatory mechanisms. Houwelingen (2017) points out that as population size increases, the ability of local institutions to foster participation diminishes, as the distance between citizens and decision-makers grows. Findings from Benito *et al*. (2021) reinforce this viewpoint, revealing that municipal governments in more populous cities confront a range of complex challenges. These challenges include heightened service demands and the requirement for coordination among multiple entities, which subsequently weakens the role of citizen participation in shaping management outcomes. Additionally, the greater diversity of problems and priorities in larger municipalities means that waste management must compete with other pressing issues, such as security or access to basic services, limiting the attention that can be devoted to citizen participation in SWM. McDonnell (2019) also notes that political efficacy and satisfaction with public services decline as the size of the municipality increases, which can lead to lower participation and, consequently, less influence on waste management outcomes. The study's findings suggest that innovations in SWM in smaller municipalities are closely linked to citizen participation. The establishment of community recycling facilities and the promotion of composting projects serve as notable instances of how local communities can effectively spearhead SWM efforts. These efforts are strengthened by citizen involvement, which, as noted by UN-Habitat (2010), is essential for promoting responsible behaviour in waste management. The engagement of citizens in local governance facilitates the implementation of more sustainable initiatives that are specifically designed to meet the needs of the community, including programs focused on environmental education and awareness. Regarding fiscal management, financial sustainability remains a challenge in smaller municipalities, as dependence on external funding is high. Bartolacci *et al*. (2018) highlight the importance of efficient and transparent fiscal management in local governments, including optimising revenue and expenditures related to SWM services. Introducing innovative funding strategies, such as public-private partnerships and pay-as-you-go systems for waste generation, may significantly bolster the financial feasibility of these services, particularly in smaller municipalities with limited resources. This study aligns with previous research that underscores the key role of citizen participation in SWM. Specifically, studies such as those by Aprilia *et al.* (2011) and Masood *et al.* (2014) have demonstrated that active citizen engagement in waste management contributes to greater efficiency and sustainability, particularly in smaller municipalities. These studies also emphasise that environmental education and awareness are essential for the success of SWM policies, which is reflected in the findings of this study. However, this study contributes new insights by showing that in larger municipalities, citizen participation does not have a significant impact on waste collection. This observation diverges from the conclusions drawn by Wu *et al*. (2020), who argue that citizen participation is consistently significant, regardless of the size of the municipality. The results of this study indicate that waste management in larger municipalities depends more on financial and structural factors, such as fiscal sustainability and the presence of regulations, than on citizen participation. The study provides new findings on the relationship between fiscal sustainability and the provision of SWM services. Municipalities that diminish their reliance on external financial resources tend to experience enhanced effectiveness in waste collection efforts. This finding implies that local governments should actively pursue opportunities to broaden their revenue bases and lessen their dependence on central government funding, which would further promote greater independence in the management of public services.

## CONCLUSION

The study provides an in-depth analysis of how municipal administration, public participation, and the implementation of ordinances affect the processes of solid waste collection and the feasibility of delivering services across the value chain, encompassing storage, transfer, recovery, and final disposal. It specifically targets 221 municipalities in Ecuador over the period from 2017 to 2022, utilizing panel data models to elucidate the influence among critical variables. One of the most relevant findings of the study is that citizen participation has a significant

impact in smaller municipalities, where the proximity of the community and local administration allows for more direct interaction. Mechanisms such as participatory budgeting and social control enable citizen participation to affect solid waste collection processes. In contrast, this influence is often less visible in larger municipalities, which may be attributed to the challenges posed by administrative complexity and bureaucratic systems that limit the capacity for effective citizen involvement. Participation is influenced to the extent that it is mediated by the size of the locality. It is also affected by the existence of by-laws and reliance on the municipality providing collection services. In the case of larger municipalities, none of these relationships are evident, since their governance is managed by third-party organizations, such as public enterprises or coalitions of municipalities. In terms of financial management, the importance of fiscal dependence and financial sustainability should be highlighted, as it is a subsidised service that involves budgetary outlays of close to 50% of the amount of the service. Overall, the planning aspect does not appear to make a substantial impact on the volume of collections or the delivery of other. The likelihood of providing the value chain services associated with storage, transfers and recovery, being the least regulated, is affected by fiscal dependency and the existence of ordinances, with no evidence of the influence of citizen participation. In Ecuador, solid waste management is an area that is progressing, having made considerable strides, yet it still grapples with critical challenges. The resolution of these issues is contingent upon the development of a comprehensive regulatory framework and the embrace of sustainable practices. Its long-term success is associated with the capacity of municipalities to implement these policies, the improvement of infrastructure and active citizen participation. The study adds significant scientific value by demonstrating how financial management, including fiscal sustainability and dependence on external funding, plays a critical role in the effectiveness of SWM services. While this relationship has been previously explored in academic discourse, the present study contributes fresh empirical insights, particularly relevant to the Ecuadorian setting, where local governments grapple with specific challenges stemming from decentralization and limited financial resources. The findings have practical implications for policymakers; the results suggest that municipalities, particularly those with smaller populations, should focus on strengthening participatory mechanisms, such as participatory budgeting and community oversight, to improve SWM outcomes. The study indicates that in larger municipalities, where the effect of citizen engagement is often limited, it is advisable to prioritize innovations in financial management and regulatory frameworks to bolster the quality of service provision. One of the key contributions of this study is its focus on the differing roles of citizen participation and financial management across municipalities of varying sizes. Unlike previous studies that typically addressed these factors in isolation or in a generalised context, this research offers a more nuanced analysis, revealing how municipal size mediates the effectiveness of these factorsThrough the application of a panel data analysis encompassing various municipalities in Ecuador over an extended period, this study offers substantial empirical evidence advocating for the formulation of customized solid waste management policies that cater to municipalities of varying sizes. The research also contributes to the literature by identifying that, while citizen participation is effective in smaller municipalities, financial sustainability and the presence of ordinances are more decisive in larger municipalities. This distinction is crucial for crafting policies that address the unique challenges faced by both types of municipalities. The findings are highly applicable in the context of local governance and environmental policy, particularly in developing countries where decentralised governance and financial constraints are common. This study offers critical insights that policymakers can leverage to develop solid waste management policies that are more effectively aligned with the unique needs and operational capacities of municipalities of various sizes. For instance, smaller municipalities can be encouraged to develop community-driven initiatives with strong participatory mechanisms, while larger municipalities should focus on improving fiscal management and regulatory compliance to optimise waste management services. Moreover, the analysis points to the significance of creating clear and structured guidelines to manage all aspects of the SWM value chain, which should encompass more than just the processes of collection and final disposal. This approach has the potential to lessen informal

practices and bolster the provision of services, including waste storage and transfer, which are commonly deficient in Ecuador and analogous contexts. Several constraints have been identified within the study that may impact the interpretation of its outcomes: 1) the study is centered on data derived from Ecuador, which could potentially limit the extent to which the findings can be generalized to other countries characterized by different governance systems, socio-economic environments, or cultural norms related to waste management. Concequently, while the outcomes are particularly pertinent to Ecuador and may extend to other Latin American countries, it is important to approach the application of these findings to regions with substantially different contexts with a degree of caution.; 2) while the study examines the impact of municipal size on SWM effectiveness, other factors such as geographic location, urbanisation levels, and cultural attitudes towards waste were not fully explored, 3) the study predominantly utilizes quantitative panel data to evaluate the connections among citizen engagement, financial management, and SWM. However, it does not delve deeply into qualitative factors, such as the motivations behind citizen participation or the local political dynamics that could affect the implementation of SWM policies. Subsequent studies might consider employing qualitative approaches to enhance the depth of understanding regarding these influences; 4) since the data on municipal operational capacity and citizen participation were gathered from official sources, there is a possibility of reporting bias. Municipalities may overstate their operational capacity or the effectiveness of participatory mechanisms to align with national guidelines or reporting standards. The limitations highlighted suggest that, while the study yields important insights, its conclusions ought to be contextualized within the particular governance and socio-economic framework of Ecuador. Future research could address these limitations by expanding the geographic scope to include municipalities from other countries, examining the influence of other factors such as urbanisation and local governance practices, and incorporating qualitative data to provide a more holistic analysis of SWM challenges and solutions. Although there are certain limitations, this study represents a substantial advancement in the literature concerning SWM and decentralized governance. It delivers valuable insights that can assist policymakers and local authorities in their efforts to optimize the efficiency and sustainability of waste management systems.

## AUTHOR CONTRIBUTIONS

P. Hernández-Medina, the corresponding author, has contributed in the data analysis OCI and solid waste, interpreted the results, and preparing the manuscript. D. Pinilla-Rodríguez prepared all the figures and interpretation of the results.

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## CONFLICT OF INTEREST

The authors declare that there are no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, were observed by the authors.

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## ABBREVIATIONS

| | |
|---|---|
| *%* | Percent |
| *CNC* | Ecuador's National Council of Competencies |
| *CPC* | Citizen participation council |
| *COOTAD* | Organic Code of Territorial Organisation, Autonomy and Decentralisation |
| *DAGs* | Ecuador's decentralised autonomous governments |
| *FE* | fixed effects |
| *GFI* | Goal fulfilment index |
| *GLS* | Generalised least squares |
| *INEC* | Institute of Statistics and Censuses |
| *Kg* | Kilograms |
| *NPIMSW* | National Programme for the Integrated Management of Solid Waste |
| *OCI* | Operational Capacity Index |
| *RE* | Random effects |
| *SWM* | Solid waste management |
| *TODPs* | Territorial order and development plans |
| *Wald chi²* | Goodness-of-fit test (overall significance of explicative variables) |
| *Hausman* | Hausman test for fixed or random effects selection |
| *$R^2$ overall* | Proportion that the model can explain of the variability of the dependent variable |
| *$R^2$ within* | Proportion of the variability of the dependent variable over time that the model is able to explain |
| *$R^2$ between* | Proportion that the model is able to explain of the variability of the dependent variable across municipalities |
| *Rho* | Represents the proportion of the variance that is due to differences across municipalities |

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