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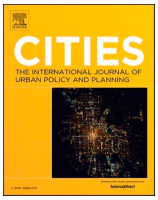

Determinants of inefficiency in the provision of public parks and gardens services

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ABSTRACT

This study examines the efficiency of public parks and gardens management in 202 Spanish municipalities with populations between 5000 and 50,000 inhabitants. Using Data Envelopment Analysis (DEA) with double bootstrapping, efficiency scores are estimated while correcting for bias and assessing key inefficiency determinants. The results indicate that only 1 % of municipalities achieve efficiency under constant returns to scale, while 10 % do so under variable returns, highlighting significant inefficiencies and the potential for resource optimisation.

Several factors significantly influence efficiency. Higher population density (−21.65), income levels (−49.84), and cadastral property values (−3.16) improve efficiency, likely due to economies of scale, increased citizen demand for service quality, and stronger financial oversight. Conversely, higher tax burdens (+0.2188), political concentration (+33.20), and a larger immigrant population (+90.99) correlate with lower efficiency, suggesting weakened expenditure control, reduced accountability, and increased pressure on public space management.

The study proposes targeted policy recommendations to address these inefficiencies. Inter-municipal cooperation is encouraged to improve efficiency, particularly in smaller municipalities where shared services could reduce costs. Citizen oversight mechanisms should be reinforced to enhance governance transparency and accountability. Additionally, municipalities with high tax burdens or larger immigrant populations should implement strategies ensuring sustainable public space management. Smart technologies, such as IoT-based irrigation systems and automated maintenance, could further optimise efficiency.

By integrating DEA with double bootstrapping, this study provides a robust framework for evaluating municipal efficiency. The findings offer insights for policymakers seeking to improve public resource management while ensuring sustainable and inclusive urban green spaces.

1. Introduction

The local public sector faces several challenges in the efficient management of resources, particularly in an economic environment characterised by budgetary constraints and increasing demand for quality services. The quality of urban parks and gardens is of great importance for the quality of life of citizens, contributing significantly to the well-being of the population, environmental sustainability and local economic development (Pérez-López et al., 2015; Rouhi et al., 2016; World Health Organization, 2016). The efficiency of the management of these services is a topic of growing interest in economic and public policy research, especially in the context of Spanish municipalities, which have experienced significant financial pressures due to the recent economic crisis and the restructuring of public budgets (Alloza et al., 2022; Bank of Spain, 2023). Nevertheless, despite the importance of green spaces in urban planning and the numerous benefits they provide (UNEP, 2012; UNESCO, 2017; WHO, 2016), there is a lack of comprehensive studies that examine the factors that influence the efficiency of green space provision and management.

This study aims to fill the existing gap in the literature by conducting a comprehensive investigation of the factors that contribute to inefficiency in the provision of parks and gardens services in Spanish municipalities. By using an advanced methodology based on Data Envelopment Analysis (DEA) with double bootstrap (Simar & Wilson, 2007), we aim to provide a more accurate picture of the internal and external factors that influence municipal efficiency. This will enable public managers to design more effective policies. The main objective of this study is to identify and analyse the sources of inefficiency in the

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provision of public parks and gardens services in Spanish municipalities. This will be achieved by assessing the impact of socio-economic, political and demographic factors on the efficiency of the management of these services. This study focuses on several key aspects to comprehensively analyse the efficiency of municipal management of parks and gardens in Spanish municipalities with populations between 5000 and 50,000 inhabitants. The main objective is to quantify inefficiencies in service provision using Data Envelopment Analysis (DEA). This methodology allows for an assessment of relative efficiency by comparing municipalities in terms of resource use and service output, thus identifying potential areas for improvement in local government management.

Another critical aspect of this study is the identification of key determinants that explain the variability in efficiency across municipalities. These determinants fall into three broad categories. First, financial factors include the tax burden, the income level of the municipality's residents and the cadastral value of property. These indicators provide insight into the financial capacity of local governments and their ability to allocate resources efficiently. Second, socio-demographic factors such as population density, the proportion of elderly residents and the immigration rate are taken into account, as they can influence service demand and operational efficiency. Third, political factors play a role in municipal efficiency, with variables such as the political orientation of the local government and the political strength of the ruling party examined to understand the governance-related effects on efficiency.

Finally, based on the results obtained and comparisons with previous studies on public service efficiency, the study aims to propose concrete recommendations to improve the management of parks and gardens in Spanish municipalities. These recommendations will focus on strategies that municipalities can implement to optimise the use of resources, improve service quality and achieve greater operational efficiency.

The need for this study is justified for several reasons:

a) The relevance of parks and gardens to quality of life and economic development.

Parks and gardens are central to the development of sustainable and healthy urban environments. In their 2016 and 2012 reports respectively, international organisations such as the World Health Organization (WHO) and the United Nations Environment Programme (UNEP) have highlighted the importance of urban green spaces in promoting public health and enriching quality of life. Parks and gardens have been shown to improve the physical and mental well-being of citizens, while generating positive externalities at the economic level. These include an increase in the value of nearby property and the attraction of tourism (Lener & Poole, 1999). In the context of Spanish municipalities, the management of parks and gardens is particularly important given urban growth and the need to ensure equitable access to these services. However, high levels of debt and budgetary constraints resulting from the economic crisis have hindered the effective allocation of public resources (Bank of Spain, 2023). It is therefore imperative to optimise the management of these services to ensure their long-term sustainability and facilitate local economic development (Benito et al., 2020).

b) Gaps in the existing literature.

Despite the extensive research on efficiency in the management of municipal public services, most studies have focused on specific areas such as public transport, lighting or waste collection (Benito et al., 2013; Pina & Torres, 2001; Prado & García, 2007). However, there is a lack of research focusing on the efficiency of park and garden management, despite the growing importance of this issue on the public agenda. This study is one of the first to use double bootstrap data envelopment analysis to assess the efficiency of park and garden management in Spanish municipalities. The DEA technique has been widely used to assess efficiency in a variety of contexts. However, few studies have focused on the parks and gardens sector. Furthermore, the double bootstrap approach corrects for the intrinsic bias in efficiency estimates, thus providing more robust and reliable results (Simar & Wilson, 2007).

c) Contribution to the improvement of public policy

The results of this study will have direct implications for public managers, enabling them to identify areas with the greatest potential for improvement in the management of urban parks and gardens. By identifying the factors that contribute to inefficiency, it will be possible to design more precise and adapted public policy strategies, tailored to the specific needs and circumstances of each municipality. This will facilitate a more effective allocation of public resources, a reduction in operating costs and an increase in citizen satisfaction with municipal services. This paper makes an innovative contribution to the literature on efficiency in public management by applying, for the first time, the double bootstrap DEA model to assess the efficiency of parks and gardens in a Spanish context. Furthermore, it considers some exogenous factors (economic, political, demographic) that have not been considered together in previous studies, thus providing a more comprehensive and detailed perspective on the determinants of efficiency in the provision of these services. In addition, the study has an applied focus, whereby the findings can be used by local government decision-makers to improve resource management and facilitate the implementation of more efficient policies in the delivery of public services. It is hoped that this study will contribute to both the academic literature and the practice of local public management.

The paper is structured as follows: the next section reviews the literature related to research on the topic in question; section three presents the methodology used; section four presents the results and discussion; and finally, conclusions, policy implications and limitations of the research are drawn.

2. Literature background

Efficiency in the provision of municipal public services has been widely analysed in the literature due to the importance of optimising the use of resources in a context of budgetary constraints. A variety of methodological approaches have been used to assess efficiency, and several studies have examined the determinants of efficiency in different public services, although there is still a paucity of literature specific to the management of parks and gardens. This section presents a detailed review of the methodological approaches used to evaluate municipal efficiency, a comparative analysis of the methodologies used, the main studies on efficiency in Spanish municipalities and the justification for the approach adopted in this paper.

2.1. Methodological approaches to measuring municipal efficiency

The assessment of efficiency in the management of municipal public services has been based on two main approaches: non-parametric methods, such as DEA, and parametric methods, such as stochastic frontier analysis (SFA).

DEA, developed by Charnes et al. (1978), is a non-parametric method that evaluates the relative efficiency of a set of decision-making units (DMUs) using linear programming. Its main advantage is the flexibility to handle multiple inputs and outputs without making assumptions about the production function, which makes it particularly suitable for assessing efficiency in the public sector, where services are often heterogeneous and difficult to quantify with a predefined mathematical function. However, DEA has an important limitation: it does not distinguish between inefficiency and statistical noise, so results can be biased if the data contain random variability or measurement errors. To mitigate this problem, techniques such as the bootstrap proposed by Simar and Wilson (2007) have been developed to provide more robust statistical inference.

In contrast, SFA, introduced by Aigner et al. (1977), is a parametric approach that models efficiency through a production function in which inefficiency is separated from random error by including a stochastic disturbance term. Unlike DEA, SFA allows the distinction between inefficiency and uncontrollable external factors that may affect the output of utilities. However, its main limitation is the need to specify a functional form of the efficiency frontier, which may introduce bias in the estimation if the relationship between inputs and outputs is not modelled correctly.

In addition to DEA and SFA, combined approaches have been developed to improve the precision of the estimates. For example, Simar and Wilson (2007) propose using Tobit regression models in a second step after DEA to analyse the factors affecting efficiency, thus allowing a richer interpretation of the determinants of inefficiency. In addition, recent studies have incorporated spatial interdependence models to capture the impact of neighbouring municipalities on the efficiency of public service provision (Balaguer-Coll et al., 2019; Narbón-Perpiñá et al., 2020). These models allow for the analysis of spatial externalities, although they require georeferenced databases and more complex methodologies.

Table 1 summarises the above.

2.2. Critical comparison of methodologies used in previous studies

The use of DEA and SFA in the evaluation of municipal efficiency has generated a debate as to which is the best methodology for this purpose. In the academic literature, both techniques have been applied with different approaches depending on the context and objectives of the study.

A review of previous studies shows that DEA has been widely used in the evaluation of municipal public services due to its ability to handle multiple inputs and outputs without making assumptions about the functional form of production (Balaguer-Coll et al., 2019; Benito et al., 2010; De Borger & Kerstens, 1996). However, its inability to distinguish between inefficiency and random noise has led some researchers to combine it with statistical techniques such as bootstrapping (Simar & Wilson, 2007) or second-stage regression models.

On the other hand, the use of SFA has been less frequent in studies of municipal efficiency, but some work has demonstrated its usefulness in evaluating services where a well-defined production function is available, such as drinking water management (García-Sánchez, 2006) or solid waste collection (Benito et al., 2013). However, the need to specify a functional form is a significant limitation, especially when studying heterogeneous municipal services.

Recent studies have attempted to overcome the individual limitations of DEA and SFA through combined approaches. For example, Balaguer-Coll et al. (2019) and Narbón-Perpiñá et al. (2020) have applied spatial regression models together with DEA to analyse the efficiency of municipal management, taking into account interdependencies between municipalities. These approaches provide a more comprehensive view of the factors influencing efficiency, although their application is more complex and requires detailed spatial data.

In the Spanish context, the efficiency of local government has been the subject of numerous studies in recent decades. For example, Giménez and Prior (2007) analysed the efficiency of Catalan municipalities and concluded that larger municipalities tend to be more efficient due to economies of scale. Similarly, Benito et al. (2010) examined the efficiency of municipalities in the region of Murcia and found that tax effort and debt levels have a significant impact on efficiency.

Several studies have also examined the influence of political factors on municipal efficiency. Bosch et al. (2012) found that municipalities governed by conservative parties tend to be more efficient, possibly due to greater discipline in public spending. However, Pacheco et al. (2021) argue that greater fiscal capacity may lead to a relaxation of fiscal discipline, which reduces efficiency.

Another relevant aspect in the literature is the influence of intermunicipal cooperation on efficiency. As mentioned above, Balaguer-Coll et al. (2019) and Zafra-Gómez et al. (2020) suggest that small municipalities can improve their efficiency by sharing resources and services with neighbouring municipalities, a strategy that has been successfully applied in other European countries.

2.3. Lack of specific studies on parks and gardens

Despite the wealth of literature on the efficiency of municipal services, very few studies have focused on the management of parks and gardens. Benito et al. (2010), among others, analysed this service in Spanish municipalities, but their conclusions were limited by the fact that only 13 % of municipalities showed efficient performance in the management of parks and gardens. Internationally, studies have tended to focus on sectors such as public transport (Pina & Torres, 2001), water supply (García-Sánchez, 2006) or waste collection (Benito et al., 2013), leaving a significant gap in the detailed analysis of services such as the maintenance of urban green spaces, which are becoming increasingly important due to sustainability and urban livability policies promoted by international organisations (UNEP, 2012; WHO, 2016).

Furthermore, although research has included parks and gardens as an additional variable in global studies on municipal efficiency (Narbón-Perpiñá et al., 2020; Zafra-Gómez et al., 2010), the specific factors that determine the efficiency of their management have not been comprehensively studied. This study aims to fill this gap by contributing to the understanding of how financial, socio-demographic, and political elements influence the provision of this essential service.

2.4. Rationale for using double bootstrap DEA in this study

Given that the objective of this study is to assess the relative efficiency of municipalities in managing parks and gardens, the use of DEA with double bootstrap is the most appropriate methodological option for several reasons:

Table 1
Methodological approaches to measuring municipal efficiency.

Methodology	Description	Strengths	Weaknesses
DEA	Non-parametric method based on linear programming that compares decision units (municipalities) according to their relative efficiency.	Requires no assumptions about the production function. Allows for multiple inputs and outputs. Identifies 'best practices' within the sample.	Sensitive to outliers. Does not allow direct statistical inference. Does not capture stochastic effects.
SFA	A regression-based parametric method that models an efficiency frontier and includes an error term to capture random factors.	It allows statistical inference. Discriminates between inefficiency and statistical noise. Suitable for large samples.	Requires assumptions about production function. Less flexible in including multiple outputs.
Tobit and regression models	Parametric methods used to assess factors affecting efficiency. They are often used after DEA.	Exogenous variables can be controlled. They are useful in second stage analysis.	They may introduce bias if efficiency is not the only relevant factor.
Spatial interdependence models	Spatial regressions include efficiency effects between neighbouring municipalities.	They capture externalities between municipalities. More realistic in regional studies.	Requires high quality spatial data. The model is more complex.

- Flexibility to assess multiple inputs and outputs. Unlike SFA, DEA allows multiple variables to be analysed simultaneously without the need to specify a functional form of the output, which is particularly useful for services such as parks and gardens management, where it is not always possible to model outputs conventionally.
- Correction of bias in efficiency estimates. The use of the double bootstrap proposed by Simar and Wilson (2007) allows the bias inherent in DEA estimates to be corrected and more accurate statistical inferences to be made.
- Identifying explanatory factors for efficiency. In the second stage of the analysis, the efficiency scores obtained by DEA are used as the dependent variable in a truncated regression, which makes it possible to analyse the impact of exogenous variables such as the tax burden, population density and the political orientation of the local government.

This approach represents a methodological improvement over previous studies and provides a more robust basis for analysing the effectiveness of parks and gardens management.

2.5. Determinants of local government efficiency: Exogenous factors

The literature has identified several exogenous factors that affect local government efficiency, including economic, political and socio-demographic characteristics. In this sense, da Cruz and Marques (2014) establish a taxonomy of these factors by classifying them as natural, citizen-related, institutional and legacy determinants.

Studies such as those by Šťastná and Gregor (2011, 2015) in the Czech Republic and Pacheco et al. (2021) in Chile show that the wealth, unemployment rate and political structure of a municipality directly affect the efficiency of governance. In Spain, Zafra-Gómez et al. (2010) found that smaller municipalities with a higher proportion of immigrants tend to have more difficulties in managing resources efficiently.

The influence of political factors on efficiency has also been the subject of several studies. Bosch et al. (2012) found that efficiency is higher in municipalities with conservative and less fragmented governments, suggesting that local managers with a higher concentration of power can implement more effective policies without the obstacles of coalition governments. These results are supported by the findings of Ashworth et al. (2014), who found that political competition and the level of citizen participation are key factors in improving efficiency.

2.6. Gaps in the literature and contribution of this study

Despite the extensive literature on efficiency in local government, research on efficiency in the management of parks and gardens is scarce. This paper contributes to the existing literature by providing a detailed analysis of the factors that determine efficiency in the management of this specific service in Spanish municipalities. The application of double bootstrap DEA guarantees more robust and accurate results than those obtained with traditional techniques, which is an important methodological innovation. Moreover, this study has the potential to inform more efficient public policies, as it identifies the determinants of inefficiency and provides evidence-based recommendations. The results will help local managers to improve resource allocation and contribute to the academic literature by offering new perspectives on efficiency in the provision of essential public services.

3. Methodology

The present study is based on quantitative research aimed at assessing the efficiency of the management of parks and gardens services in Spanish municipalities with between 5000 and 50,000 inhabitants, and at analysing the exogenous factors that could influence the variability of efficiency between municipalities. This range of population size was chosen to avoid including tiny municipalities, where the provision of parks and gardens services could be significantly limited by budgetary constraints, and large cities, where the size of the municipality could lead to biases due to economies of scale.

The analysis period refers to the most recent year with full data availability (this research was carried out in 2024), which ensures the relevance and timeliness of the study. Data used to calculate the efficiency ratios and analyse their determinants come from various official sources, which are listed below. Data include information on the financial resources allocated to the management of parks and gardens, as well as the socio-demographic and political characteristics of the municipalities.

The methodology follows a two-stage approach proposed by Simar and Wilson (2007). In the first stage, DEA is used to estimate the technical efficiency of each municipality in managing its parks and gardens. Then, in the second stage, the efficiency values obtained in the first stage are regressed on a set of exogenous variables through a truncated regression corrected by a bootstrap procedure, which allows the identification of the main determinants of efficiency.

This approach is particularly suitable for assessing efficiency in the context of municipal services, as it allows a comparison between several decision units (in this case municipalities) without the need to specify a predefined functional form for the relationship between inputs and outputs.

To ensure the reliability and robustness of the results, an exhaustive data-cleaning process was carried out, addressing both missing values and possible inconsistencies in the variables used in the study. The DEA methodology is highly sensitive to the presence of extreme values and outliers, so specific procedures were applied to ensure the quality of the sample before calculating the efficiency indices.

In the first phase of the analysis, municipalities with null or incorrect values for some of the selected variables were identified and certain units were excluded from the study. As a result, the final sample consisted of 202 Spanish municipalities with between 5000 and 50,000 inhabitants, which guaranteed the representativeness of the data and avoided bias in the efficiency estimates.

However, in addition to eliminating incomplete data, it was essential to ensure that the sample was not biased by the presence of municipalities with outliers that could distort the results. To this end, three methods widely used in the literature for detecting outliers in DEA models were applied:

1. Wilson (1993, 1995)

FEAR 2.01 software was used to analyse the homogeneity of the sample and to detect potential outliers using log-ratios.

The municipalities identified as potential outliers were examined in detail. Although one unit (mun152) was identified as having a significantly higher than average total expenditure on parks and gardens maintenance, its uniqueness was supported by other high scores such as a larger area of green space and an exceptionally high number of urban parks. As this municipality had no measurement errors or structural inconsistencies, it was decided to keep it in the sample, as its exclusion could have removed relevant information for the analysis.

2. Procedure of Simar (2003) and use of order-m

The Order-m DEA method was used, a technique developed to reduce the influence of extreme values in efficiency estimation. This method allows a more robust efficiency frontier to be constructed by using randomly generated subsets of data at each iteration of the model (Amaral et al., 2022).

Estimates were made at different values of m, allowing the stability of the efficiency coefficients at different levels of truncation to be assessed.

Several municipalities were identified that initially appeared super-efficient or inefficient, but whose coefficients stabilised as the value of

m increased, indicating that their presence did not significantly bias the sample.

To assess the robustness of the procedure, more reasonable fitting parameters were chosen (m = 50 in input orientation and m = 75 in output orientation). These values identified seven agglomerations with unusually low output efficiency values. However, after checking the information in the original databases, no errors or inconsistencies were found in the datasets.

Municipality 152, which the Wilson procedure had also flagged, had an atypically high value in one of the results (area of green space), which justified its extreme behaviour in terms of efficiency without implying the need to exclude it.

3. Procedure of De Witte and Marques (2010)

The robust unoriented frontier method proposed by these authors has been implemented to identify influential observations in DEA models.

This procedure allows to reduce the influence of extreme values in the efficiency estimation by adjusting the weights of the observations identified as outliers.

Some municipalities were found to have significant outliers, but after carrying out robustness tests and re-estimating, it was found that these cases did not significantly affect the overall results.

4. Robustness analysis: Effect of outliers on the results

To ensure that the presence of these units did not affect the overall analysis, the procedures of Wilson (1993), Simar (2003) and De Witte and Marques (2010) were repeated, temporarily eliminating the municipalities identified as outliers to check whether their exclusion significantly altered the efficiency indices of the other units.

Ultimately, the results showed that:

- The presumed influence of these outliers was minimal, as the changes in the efficiency estimates were negligible.
- The elimination of these municipalities did not significantly alter the efficiency rankings obtained, confirming the validity and stability of the results.
- The efficiency scores were not artificially inflated, but reflected the real heterogeneity of local authority parks and gardens management.

Considering these analyses, it was decided to retain the sample of 202 municipalities in its entirety, without excluding any units as outliers. This decision was based on the following aspects:

- Use of advanced outlier detection techniques. A combination of methods widely validated in the scientific literature (Wilson, Simar with Order-m and De Witte and Marques) was used.
- Stability of the results. The elimination of outlier municipalities did not significantly modify the efficiency indices, indicating that their impact on the overall estimate is small.
- Validity of the observed data. Excluding municipalities simply because they represent extreme values could lead to a loss of relevant information and distort the interpretation of the results. The DEA methodology allows the assessment of efficiency in contexts of high heterogeneity, so the exclusion of municipalities with unique expenditure structures and outcomes could have a negative impact on the external validity of the study.

One input variable and four output variables have been defined to assess technical efficiency in the provision of parks and garden services.

-Input:

WPARK: Annual expenditure on parks and gardens. Taken from statistics published annually by the Spanish Ministry of Finance.

-Outputs (they appear in the Local Infrastructure and Equipment Survey carried out annually by the Spanish Ministry of Public Administration):

PARKURB: Number of public urban parks.

PARKINF: Number of playgrounds.

GARDEN: Number of gardens.

ZGREEN: Square metres of the total area of green space.

The output variables have been chosen to reflect the level of service provision in terms of infrastructure available to citizens. These variables allow comparisons between municipalities of different sizes and socio-demographic characteristics.

One key concern when applying DEA to public services is ensuring that efficiency estimates reflect actual resource management and service provision, rather than merely capturing the existence of infrastructure that may no longer be maintained. In the case of municipal parks and gardens, some municipalities might have large green areas and park infrastructures but invest very little in their maintenance, potentially leading to misleading efficiency scores if only physical infrastructure is considered as an output.

To address this issue, the model incorporates an input-oriented approach where efficiency is defined as the capacity to minimize costs while maintaining a minimum level of service provision. This ensures that municipalities that reduce spending without delivering an adequate level of maintenance and service will not be classified as efficient.

Furthermore, robustness checks were conducted to verify that municipalities with very low expenditures but large pre-existing infrastructure were not ranked as highly efficient. These checks included:

- *Re*-estimating efficiency scores excluding municipalities in the bottom 10 % of maintenance expenditure.
- Comparing rankings using an output-oriented DEA model to ensure that efficiency is not driven solely by cost minimization.
- Examining municipalities with extreme efficiency scores to confirm that low-spending municipalities were not systematically ranked as efficient.

The results confirmed that municipalities that significantly reduce their expenditures while failing to maintain their parks and gardens properly are not among the most efficient in the sample. This validates the model's ability to differentiate between efficient resource management and simple cost-cutting at the expense of service quality.

The existence of water features such as lakes, fountains or riverbanks within parks can significantly influence their attractiveness and increase visitor demand, which in turn can affect the perceived efficiency of park management. In addition, maintaining green areas with high irrigation requirements consumes additional water resources and operating costs, which could also influence efficiency scores. While these factors are undoubtedly relevant, the lack of systematic and comparable data on the extent of water features in parks across municipalities prevents their direct inclusion as a variable in the model. However, their impact may be partially captured through the expenditure variables, since municipalities with large water-dependent green areas or extensive water features are likely to exhibit higher operational costs related to irrigation and maintenance.

In addition, the square metres of green space (ZGREEN) included as an output indicator serves as a proxy for irrigation needs, as municipalities with larger green spaces typically require more water and maintenance. However, future research could refine this approach by incorporating more detailed data on irrigation costs, water consumption or the presence of water bodies within parks. This would allow a more precise assessment of how these factors influence efficiency.

In the second stage of the analysis, exogenous variables are included to explore the determinants of efficiency in providing parks and gardens services. These variables reflect the financial, socio-demographic and political characteristics of municipalities, building on previous studies that have shown that these factors influence the efficiency of local governments (Balaguer-Coll et al., 2019; Šťastná & Gregor, 2015). The

selected variables are:

TBURDEN: Tax burden (local taxes per capita). Taken from statistics published annually by the Spanish Ministry of Finance.

A key determinant of the efficiency of municipal services is economic wealth, often measured by GDP per capita. However, due to limitations in data availability at the municipal level, this study uses two proxy variables that effectively capture the economic characteristics of municipalities:

INCOME: An estimated income level for each municipality, divided into 10 categories from the lowest income (level 1) to the highest income (level 10), obtained from the Instituto R. Klein of the Autonomous University of Madrid.

HOUSEV: Average cadastral value of dwellings in the municipality, obtained from the Spanish Cadastre, reflecting property wealth and serving as an indicator of municipal revenue capacity.

These two variables provide a robust approximation of municipal economic conditions, capturing both income levels and the wealth embedded in real estate. Previous research has shown that higher-income municipalities tend to have greater administrative capacity and citizen oversight, which can lead to higher efficiency levels in public service management (Piña & Avellaneda, 2017).

PDENSURB: Population density per urbanised km2. Information from the Spanish Institute of Statistics and Cadastre.

POLITICS: Political affiliation of local government (binary variable, 1 for conservative, 0 for other). Information from the Spanish Ministry of the Interior.

HERFINDAHL: Index of political concentration measured by the Herfindahl index. Information from the Spanish Ministry of the Interior.

POP65: Percentage of population over 65. Data from the National Institute of Statistics.

POP15_24: Percentage of population aged 15–24. Data from the National Institute of Statistics.

SCHOOL: Proportion of school-age population (under 16 years). Data from the National Institute of Statistics.

UNEMPLOY: Municipal unemployment rate. Data from the National Institute of Statistics.

INMGR: Immigrants as a percentage of the total population. Data from the National Institute of Statistics.

The role of immigration in municipal efficiency is an important but often overlooked factor. The inclusion of the share of immigration as an explanatory variable in this study is based on the premise that demographic dynamics have an impact on the demand for services and the allocation of resources. Municipalities with higher immigrant populations may face increased pressure on public services, including parks and gardens, due to population growth, higher turnover rates and different patterns of use of public spaces. In addition, rapid demographic change can pose challenges for long-term infrastructure planning and maintenance, potentially affecting efficiency.

While immigration does not inherently reduce efficiency, its impact on urban planning, resource allocation and demand for services justifies its inclusion. The results provide insight into whether municipalities with higher immigrant populations experience significant efficiency differentials, and whether these effects are related to administrative challenges or socio-economic disparities.

ININD: Industrial activity index. It was obtained from the R. Klein Institute of the Autonomous University of Madrid.

ICOMM: Business activity index. It was obtained from the R. Klein Institute of the Autonomous University of Madrid.

ITURIST: Tourism activity index. It was obtained from the R. Klein Institute of the Autonomous University of Madrid.

IACTEC: General business activity index. It was obtained from the R. Klein Institute of the Autonomous University of Madrid.

Moreover, our study is consistent with the taxonomy of efficiency determinants proposed by da Cruz and Marques (2014), who, as mentioned above, classify these factors into natural, citizen-related, institutional and legacy determinants:

- Natural determinants: The tourism activity index (ITURIST) and population density in urbanised areas (PDENSURB) capture the spatial and economic characteristics of municipalities, which have been shown to influence local service provision.
- Citizen-related determinants: Variables such as immigrant share (INMGR), elderly population (POP65) and unemployment rate (UNEMPLOY) reflect the socio-demographic composition of municipalities and influence both service demand and resource allocation.
- Institutional determinants: Political ideology (POLITICS) and political concentration (HERFINDAHL) help to assess the impact of governance structures on efficiency.
- Legacy determinants: Tax burden (TBURDEN), income level (INCOME) and indices of economic activity (ININD, ICOMM, IACTEC) provide insight into the financial and economic constraints on local government.

By integrating these variables into our analysis, we can comprehensively assess determinants of municipal efficiency, following a framework previously validated in the literature (da Cruz & Marques, 2014).

The variables and their basic descriptors are listed in Table 2.

DEA is a non-parametric technique used to measure the relative efficiency of decision-making units (DMUs, in this case, municipalities) that use multiple inputs to produce multiple outputs. DEA makes it possible to identify which municipalities are efficient in the use of their resources and which are inefficient compared to the most efficient.

As mentioned above, in this study an input-oriented DEA model has been used, which means that the objective is to assess the extent to which municipalities could reduce the use of resources (parks and gardens expenditure) while maintaining the same level of output production (parks and gardens infrastructure). Three types of returns to scale were considered:

- DEA-CRS (Constant Returns to Scale): It assumes that all municipalities operate under constant returns to scale.
- DEA-VRS (Variable Returns to Scale): It allows the capture of variable economies of scale that may affect smaller or larger municipalities.
- DEA-NIRS (Non-Increasing Returns to Scale): Used to assess situations where communities may experience diminishing returns as they grow.

The traditional DEA methodology estimates the relative efficiency of each decision unit (in this case, municipalities) by comparing its input

Table 2
Statistical descriptors of the variables.

Variable	Mean	Standard Deviation	Minimum	Maximum
WPARK	290,150,90	314,979,62	777,29	1,890,315,36
PARKURB	10,20	11,17	1	104
PARKINF	4,71	5,37	1	36
GARDEN	5,09	5,89	1	41
ZGREEN	144,674,89	195,740,62	3140	1,509,578
TBURDEN	527,36	303,58	138,164	2824,63
INCOME	4,90	2,14	1	10
PDENSURB	7953,34	4121,77	2011,973	29,493,999
HOUSEV	44,65	28,53	6823	175,898
POLITICS	–	0,47	0	1
HERFINDAHL	0,41	0,09	0,195	0,74
POP65	0,17	0,06	0,038	0,368
POP15_24	0,11	0,02	0,057	0,147
SCHOOL	0,15	0,03	0,06	0,229
UNEMPLOY	13,27	3,99	5	25
INMIGR	0,12	0,14	0,011	0,776
ININD	28,18	48,75	1	452
ICOMM	28,77	24,84	2	126
ITURIST	38,91	138,75	1	1370
IACTEC	24,31	24,71	1	180

and output levels with the efficiency frontier constructed from the observed sample. However, this method can be subject to bias, especially when the sample is limited or there are outliers.

The bootstrap procedure generates multiple replicate samples from the original data to correct for potential bias in the efficiency estimate. This provides a more accurate estimate of the true efficiency by removing the dependence on a single sample and reflecting the inherent variability in the data (Simar & Wilson, 1998, 2007). The procedure consists of three main steps.

1. First bootstrap: Correction of bias in the efficiency estimate

Standard DEA analysis calculates an efficiency frontier based on the observed data of the decision units (in this case, municipalities). However, this estimate may be subject to sampling bias, as the frontier is defined only based on the most efficient units within the available sample. An initial bootstrap procedure is used to correct this problem by generating several replicate samples of the original population.

At this stage, B bootstrap samples (typically 1000 or more) are generated by resampling with replacement, which means that some units may appear more than once in the sample, while others may be omitted. In addition, in each sample, the observed values of the inputs and outputs are slightly modified by the addition of controlled random noise, so that the estimates reflect the inherent variability of the data.

The efficiency frontier is recalculated using the same DEA model as in the original data for each bootstrap sample. This allows us to obtain a corrected distribution of efficiency values, removing sampling bias and providing more representative estimates of each municipality's current performance.

The distribution generated in the bootstrap samples is then used to adjust the efficiency scores obtained in the original DEA analysis. The result is a set of corrected efficiencies representing less biased and more accurate values of each municipality's true efficiency level.

This procedure improves the precision of the efficiency estimates and ensures that the values obtained are more stable, allowing for more rigorous analyses at later stages.

2. Truncated regression to analyse the factors explaining efficiency

Once the corrected efficiencies are obtained, the factors that explain the differences in efficiency between municipalities are analysed using a truncated regression model.

The corrected efficiency obtained in the first bootstrap is used as the dependent variable, while socio-economic, political and demographic factors that may influence municipal efficiency are included as explanatory variables. These include:

- Municipal tax burden (TBURDEN): To assess whether higher tax collection leads to more efficient management or whether, on the contrary, it creates inefficiencies.
- Urban population density (PDENSURB): To determine whether there are economies of scale in the management of parks and gardens in more densely populated municipalities.
- Level of economic activity (ININD, ICOMM, ITURIST): To analyse the impact of industrial, commercial and tourist activity on municipal efficiency.

As the efficiency values are bounded in the interval [0,1], traditional ordinary least squares (OLS) regression is not applicable as it could produce predictions outside this range. To solve this problem, a truncated regression is used, which limits the estimation to the allowed interval and ensures that the predictions are consistent with the nature of the data.

The estimated coefficients allow us to analyse the influence of different factors on municipal efficiency. However, it is necessary to use a second bootstrap procedure to improve the validity of the results, as these coefficients may be subject to inferential errors due to the structure of the data.

3. Second bootstrap: Robust statistical inference

The third step in the procedure is to apply a second bootstrap to the truncated regression to obtain more precise and reliable estimates of the coefficients of the explanatory factors.

New bootstrap samples are generated from the original data and the truncated regression process is repeated for each sample. This approach allows variations in the coefficient estimates to be simulated and reflects the uncertainty inherent in the data and model structure.

From the coefficients obtained in each of the samples, an empirical distribution of the estimators is constructed. In this way, it is possible to calculate more realistic confidence intervals, since the errors are not assumed to be normal, as in conventional regression.

Instead of relying on theoretical standard errors, percentiles of the bootstrap distribution are used to assess the robustness and significance of each coefficient. If the confidence interval of a coefficient does not contain the value zero, it can be concluded with greater certainty that the variable has a significant impact on municipal efficiency.

The double bootstrap procedure in DEA has been widely used in efficiency studies of public service provision, allowing for bias correction in efficiency scores and more robust inferential analysis.

A relevant example of its application is in the water sector, where performance benchmarking is critical to ensure service quality and regulatory compliance. Several studies have shown that the use of double bootstrap improves efficiency estimates and allows for a better understanding of external factors influencing performance (De Witte & Marques, 2010). Their study applied double bootstrap DEA to benchmark international water utilities, identifying determinants of efficiency beyond operational cost structures.

Other applications in the water sector have confirmed the benefits of this methodology, particularly in correcting biases introduced by traditional DEA estimation and increasing the robustness of second-stage regressions (Carvalho & Marques, 2011; Marques et al., 2014). These findings validate the use of double bootstrapping in the evaluation of public service efficiency, and support its application in this study of municipal park and garden management.

The regression model at this stage has the following form: **Equation Section (Next)**(1.1)

$$\hat{\hat{\delta}}_j = \beta_0 + \beta_1 TBURDEN + \beta_2 INCOME + \beta_3 PDENSURB + \beta_4 HOUSEV + \beta_5 POLITICS + \beta_6 HERFINDAHL + \beta_7 POP65 + \beta_8 POP15\_24 + \beta_9 SCHOOL + \beta_{10} UNEMPLOY + \beta_{11} INMIGR + \beta_{12} ININD + \beta_{13} ICOMM + \beta_{14} ITURIST + \beta_{15} IACTEC + \varepsilon_j$$

Algorithm II proposed by Simar and Wilson (2007) has been used as this approach produces consistent coefficient estimates and allows valid inference by applying a bootstrap at this second stage. Algorithm II was chosen because it provides better results when the sample size is relatively large and the corrected estimates are more precise.

To ensure the validity of the model, the separability condition was

checked, which requires that the support of the output variables does not depend on the exogenous variables. This ensures that the results obtained in the first stage of the DEA are not biased by the inclusion of uncontrollable variables in the analysis.

In addition, robustness tests were carried out by eliminating outliers, if applicable, and comparing the results obtained with different model specifications. Non-parametric tests (Kolmogorov-Smirnov and Mann-Whitney) were also used to check that differences between conditional and unconditional parameters were not statistically significant, confirming that the model results were robust and reliable.

Despite the efforts made to ensure the robustness of the results, certain limitations need to be taken into account. The sample is limited to municipalities with a population between 5000 and 50,000, which may limit the generalisability of the results to larger or smaller cities. In addition, the analysis is carried out for a single year, which does not allow for possible variations in efficiency levels over time.

We recommend that future research extend the sample, include longitudinal analyses to capture the evolution of efficiency over time, and apply the latest methodological advances in efficiency evaluation, such as nonparametric dynamic analysis.

4. Results and discussion

The analysis of technical efficiency using the DEA model applied to Spanish municipalities has shown that, out of the 202 municipalities studied, only two municipalities were classified as relatively efficient under the constant returns to scale (CRS) hypothesis. This percentage, which represents approximately 1 % of the total sample, suggests that the management of parks and gardens services in most municipalities is far from achieving an optimal use of available resources.

Moreover, the application of the variable returns to scale (VRS) model results in an increase in the number of efficient municipalities to 20 units, representing 10 % of the total. This increase is notable and indicates the presence of economies of scale in the delivery of these services. This indicates that a considerable number of municipalities are operating with increasing returns to scale, which suggests that they could enhance their efficiency by expanding their operations or collaborating with other municipalities to share resources and optimise their utilisation.

The observed average inefficiency of 94 % in the CRS model indicates that, on average, municipalities could reduce the utilisation of resources by 94 % to maintain the same level of service. This inefficiency is a cause for concern and is consistent with other studies that have identified high levels of inefficiency in the management of municipal services in Spain (Balaguer-Coll et al., 2010; Benito et al., 2010). However, the application of bootstrapping techniques to correct for bias has resulted in a slight improvement in efficiency, indicating that the initial results may have overestimated inefficiency.

Table 3
Synthesis of DEA efficiency indices.

	Index	%
Technical efficiency (DEA-CRS input model)		
Average efficiency	0,06	6
Efficient units	2	0,99
Average inefficiency	0,94	94
Inefficient units	200	99,01
Technical efficiency (DEA-VRS input model)		
Average efficiency	0,19	19
Efficient units	20	9,9
Average inefficiency	0,81	81
Inefficient units	182	90,1
Efficiency of scale (DEA-CRS/DEA-VRS input model)		
Average efficiency	0,316	31,6
Efficient units	2	0,99
Average inefficiency	0,684	68,4
Inefficient units	200	99,01

Table 4
DEA model comparison.

	Mínimum	Mean
CCR (DEA-CRS)	0,0018	0,0606
BCC (DEA-VRS)	0,0052	0,1905
SBM-Min	0,0012	0,1422

Table 3 presents a summary of the results obtained in the calculation of the efficiency indices. It can be observed that the average efficiency is low, with only 6 % of the municipalities identified as economically efficient. When considering pure technical efficiency, the percentage rises slightly to 19 %. This indicates that, on average, and theoretically, the municipalities could reduce their input consumption by 81 % if they were adequately sized and managed.

Given the deterministic and biased nature of these radial measures, it is necessary to be cautious in interpreting the results. For this reason, it was considered relevant to bootstrap the efficiency measures (Simar & Wilson, 2000). A non-radial measure, Tone's SBM (Tone, 2001), was also calculated to compare with the previous models' estimates. Table 4 summarises the results obtained.

Table 4 shows that the average efficiencies obtained with each estimation method are alarmingly low. However, the results with the SBM-Min model imply a lower average efficiency than with the DEA-VCR model, since this model projects the units on the frontier, but at the furthest position within a range.

A relevant methodological concern in this study is whether municipalities with very low spending on park maintenance could still appear efficient simply because they have pre-existing infrastructure. Several robustness tests were conducted to address this issue.

First, the efficiency scores were re-estimated, excluding municipalities that reported expenditures in the lowest 10 % of the sample. The results showed that efficiency rankings remained largely stable, indicating that efficiency is not solely driven by cost minimization but also by how well resources are managed relative to service provision.

Second, an output-oriented DEA model was estimated, where efficiency was defined as the ability to maximize public service provision given a set level of inputs. The results confirmed that municipalities with low spending, but poor service provision did not appear among the most efficient, reinforcing the validity of the input-oriented model.

Finally, a case-by-case analysis of municipalities with extreme efficiency scores was conducted. The findings confirmed that no municipality with nearly zero expenditure was classified among the most efficient, ensuring that efficiency rankings are not distorted by

Table 5
Results of the second stage algorithm-II.

Determinants Analysis (Simar & Wilson, 2007, 2011a, 2011b)				
Variables	Estimated coefficient	95 % Confidence Intervals		Influence
TBURDEN	0,2188 (s)	-0,0088	0,4475	Unfavourable
INCOME	−49,8493(s)	−96,8667	−20,238	Favourable
PDENSURB	−0,0006 (s)	−0,0181	0,01402	Favourable
HOUSEV	−31,604 (s)	−76,929	−0,758	Favourable
POLITICS	36,631(s)	−46,46	57,464	
HERFINDAHL	33,2013(s)	−7,03E+01	1,42E+02	Unfavourable
POP65	415,769(s)	23,2988	785,6583	Unfavourable
POP15_24	−34,423(s)	−689,873	625,6056	Favourable
SCHOOL	368,9919(s)	−332,3975	1025,9374	Unfavourable
UNEMPLOY	−10,352(s)	−28,7382	11,467	Favourable
INMIGR	90,9902(s)	48,279	183,3563	Unfavourable
ININD	69,767(s)	30,483	14,5936	Unfavourable
ICOMM	86,257(s)	3445	17,7704	Unfavourable
ITURIST	−15,603(s)	−60,167	16,457	Favourable
IACTEC	−18,83(s)	−4,04E+01	−8,68E+00	Favourable

(s) indicates that the estimated parameter is significant at 5 %.
(ns) indicates that the estimated parameter is not significant.

municipalities that do not invest in maintenance.

These findings confirm that the DEA model appropriately differentiates between genuine efficiency and mere budget reduction, providing reliable insights into municipal park and garden management.

After applying the first four steps of Simar and Wilson's algorithm II, we obtain indices corrected for the inherent bias, which are used in the second stage of the regression. Table 5 provides the estimated coefficients for each of the exogenous variables analysed.

The model shows high explanatory power, as all environmental variables show statistical significance. This implies that the inefficiency identified in the previous phase is not only due to poor management but could also be attributed to the municipality's inherent characteristics. Moreover, the results obtained in this study are consistent with the four-category framework of determinants of efficiency proposed by da Cruz and Marques (2014), reinforcing the idea that local government efficiency is shaped by a complex interplay of economic, demographic, institutional and spatial factors, as outlined in the taxonomic framework of da Cruz and Marques (2014).

The negative effect of the TBURDEN variable on the level of efficiency would suggest that local government, faced with the availability of more resources, relaxes management and tends to waste, increase expenditure (Worthington & Dollery, 2000) and engage in propaganda (Lyndsay, 1976). In the literature on public efficiency, the relationship between tax pressure and efficiency is not linear, but depends on a number of institutional, political and administrative factors. One of the most studied mechanisms in this area is the concept of the “soft budget constraint” (Kornai, 1986), which argues that when governments have access to higher tax revenues, they may have less incentive to optimise the use of resources. In municipalities with high tax revenues, the pressure to improve efficiency is reduced as the available resources allow high levels of expenditure to be maintained without the need to optimise them.

Another important mediating factor is the impact of bureaucracy and administrative structure on municipal efficiency. Municipalities with high tax revenues tend to develop more complex administrative structures, which can lead to inefficiencies in public expenditure management (Asatryan & De Witte, 2015). A higher tax burden can be associated with more rigid administrative procedures and slower decision-making processes, which can hinder the efficient implementation of parks and gardens maintenance and management policies. Studies in Germany have shown that a more complex tax structure can lead to delays in the execution of expenditure, which reduces the efficiency of municipal service provision (Geys et al., 2010). In the Spanish context, municipalities with a higher tax burden have been found to spend a significant proportion of their budget on administrative costs, which has a negative impact on the efficiency of operational services, including the maintenance of parks and gardens (Benito et al., 2010; Zafra-Gómez et al., 2010).

A third mediating factor is the relationship between fiscal capacity, political pressure and accountability. Where municipalities rely heavily on fiscal transfers or have a large margin of own revenues, there may be less pressure from citizens to optimise resources. In municipalities with high tax revenues, citizens may perceive that services are sufficiently funded, so the demand for greater efficiency in public management is lower. On the other hand, in municipalities with lower tax revenues, the pressure to optimise spending and justify each investment is usually greater, which encourages efficiency in municipal management (Bosch et al., 2012).

In Spain, the absence of effective accountability mechanisms in some municipalities with a high tax burden may contribute to the observed inefficiencies in the management of local public services (Guillamón & Cuadrado-Ballesteros, 2020; Zafra-Gómez et al., 2010).

On the other hand, the empirical finding of Pacheco et al. (2021) that higher fiscal capacity leads to higher current spending, which reduces efficiency, is confirmed. Similar conclusions are reached by most of the empirical research in this area (Ashworth et al., 2014; Balaguer-Coll et al., 2002, 2007; Balaguer-Coll & Prior, 2009; Borge et al., 2008; Kalb, 2010; Moore et al., 2005; Šťastná & Gregor, 2015; Sung, 2007), justifying that greater availability of funds leads to less budgetary constraints and management rigour. The other two variables analysed relating to the level of wealth of the municipality and its inhabitants, INCOME and HOUSEV, are also significant, but with a different sign to that obtained for the tax burden. This may be because municipalities with a higher percentage of wealthy citizens tend to manage parks and gardens better due to greater citizen pressure and demand for quality public services (Afonso & Fernades, 2008; Balaguer-Coll et al., 2013; Cordero Ferrera et al., 2017; Narbón-Perpiñá et al., 2020). Residents with greater resources tend to be more politically organised, have better access to information and demand greater transparency in local government. Their participation in public consultations, neighbourhood associations and citizen audits contributes to more rigorous oversight of public spending, which encourages local governments to optimise available resources. Efficiency in these municipalities is therefore not only a consequence of greater budget availability, but also of greater citizen control and demand for quality services.

Another key factor is the greater capacity for municipal management and planning in municipalities with higher per capita income. These local governments tend to have more professional administrative structures and technical teams that are better equipped to optimise resources. They are also able to offer more competitive salaries, which attract highly qualified urban planning and environmental management staff. In addition, investment in advanced maintenance technologies, such as smart irrigation sensors, drones for inspecting green spaces and computerised management systems, can reduce costs and improve operational efficiency. This would support the idea proposed by Kalb (2010) that municipal wealth should be reflected in a greater supply or better quality of public goods and services. In countries such as Germany and the Netherlands, studies have shown that the wealthiest municipalities are the ones that invest the most in technological solutions for managing public spaces, a pattern also observed in Spain with the implementation of predictive maintenance systems (Correia et al., 2022).

Finally, greater financial stability and the ability to attract private investment are essential. Municipalities with high tax revenues can plan their budgets with greater stability, avoiding cuts in the maintenance of parks and gardens and reducing uncertainty in the execution of expenditure. In addition, their attractiveness to private investment facilitates the sponsorship of public space rehabilitation projects and the financing of cultural and sporting events in these areas, thereby reducing the financial burden on the municipality. This phenomenon has been observed in cities such as Barcelona and Madrid, where the private sector has made a significant contribution to the modernisation and maintenance of urban parks. Consequently, the efficiency of these municipalities is not only due to their financial capacity, but also to their ability to manage their resources sustainably through strategic alliances with the private sector (Janoschka & Mota, 2020).

The results indicate that higher population density in urbanised areas (PDENSURB) is positively associated with greater efficiency in park and garden management. This finding suggests that municipalities with denser populations can optimise resources more effectively, reducing unit costs for maintenance services.

The significant nature and sign of the relationship between the degree of efficiency obtained and the population density of the municipality analysed would indicate the possibility of taking advantage of economies of scale in this service. This result can be explained by several mediating factors. In high-density municipalities, parks and gardens are used more intensively, allowing maintenance costs to be spread over more users. The grouping of the population determines a greater demand for open spaces to compensate for the lack of private outdoor spaces in dwellings due to population concentration (Nogueira & Camanho, 2013). Also, in densely populated areas, the management of public space tends to be more technological, which favours operational

efficiency. Similarly, in densely populated cities, citizen pressure on the quality of public space maintenance is greater, which favours more efficient management (Cerdá Institute, 2017).

Although this study does not explicitly analyse inter-municipal cooperation, these findings suggest that efficiency improvements are related to urban structure and service concentration, rather than purely to administrative size. Future research could explore whether inter-municipal cooperation -especially in low-density areas- can generate efficiency improvements similar to those observed in high-density municipalities.

Although several studies have not found a link between efficiency and the political characteristics of municipalities (Balaguer-Coll et al., 2007; Balaguer-Coll et al., 2019; Benito et al., 2010; Bosch et al., 2012; Pacheco et al., 2021), this research has found a significant correlation. This finding is in line with previous research on municipal governance in Europe, which has observed that a lack of political turnover may reduce the pressure to improve efficiency because municipal managers face less competition and fewer incentives to optimise public resources (Voorn et al., 2017). Municipalities with more political fragmentation may be more efficient because the existence of different political groups generates more debate and control over the use of the budget. On the other hand, corruption and lack of transparency may also act as mediating factors in municipalities with low political turnover, affecting the efficiency of public service management. In our case, management is considered more efficient in municipalities with conservative governments. Municipalities with a high concentration of power, on the other hand, relax their behaviour. This is because they are under less pressure to justify their management or do not have to agree with their decisions with other political groups.

The results of the selected demographic variables show that the behaviour of the young population in parks and gardens for sporting, recreational or social purposes, which is not always appropriate, could lead to higher maintenance costs and more demanding infrastructures, which would oblige the competent authorities to manage the municipal budget more responsibly and in a more timely manner to have sufficient resources and maintain the sustainability of the service.

First, the reasonable hypothesis regarding the effect of the variable SCHOOL would be that a larger school population would have a positive effect on efficiency, both if it is considered as an indicator of the level of schooling of the population and as an indicator of a higher percentage of this population group. In both cases, the demand for these green spaces and outdoor recreation areas will be greater, both because of the promotion of a healthy and active lifestyle by schools and because of the greater number of users, which would lead to demands on and control by public management. However, the results of the analysis do not support the proposed hypothesis and show an unfavourable influence. According to Pacheco et al. (2014), this can be explained by linking the percentage of schooling to the wealth of the municipality, arguing that greater resources would lead to lax budgetary constraints and therefore greater inefficiency. However, as discussed above, this study does not find such a relationship between wealth and efficiency.

The variables UNEMPLOY (unemployment) and INMIGR (immigration) can be considered as socio-economic indicators that reflect the vulnerability of a region and pose economic challenges to the municipality, as they increase the cost of public services (Loikkanen et al., 2011). Unemployment, which has become a structural problem in the Spanish economy, forces many resources to be allocated to cover benefits, limiting the availability of funds for other non-essential services. This situation could lead to a more efficient allocation of resources, as suggested by our analysis, where a higher unemployment rate could be correlated with an improvement in efficiency levels. Another possible explanation for the positive relationship between unemployment and efficiency is the greater availability of labour and the existence of municipal public employment programmes. In municipalities with higher unemployment, local governments can take advantage of employment programmes and government subsidies to hire people to maintain parks and gardens, which reduces operating costs and increases efficiency. Moreover, in contexts of high unemployment, administrations can negotiate service contracts on more favourable terms, optimising the use of public resources. This effect is reinforced by the greater willingness of the unemployed to accept positions in temporary municipal programmes, which ensures a stable workforce and reduces the cost of outsourcing services (Paccione, 2003).

On the other hand, the variable IMMIGR shows a different behaviour than UNEMPLOY, confirming the hypothesis proposed by Loikkanen et al. (2011). The negative relationship between immigration and efficiency could be due to language barriers, integration processes and increased pressure on municipal services. Municipalities with higher proportions of immigrant populations may face difficulties in planning the maintenance of parks and gardens due to increased demand for other essential services such as education and housing, which may affect the allocation of resources. In addition, if the immigrant population has lower levels of civic participation or less access to channels of communication with the administration, there may be less pressure from citizens to optimise efficiency than in communities with a more organised citizenry. This reduced oversight may result in less efficient management of public spaces.

When analysing the effect of economic indicators on efficiency, we find that it increases when industrial and commercial activity decreases and tourism activity increases. Other studies have found this negative effect of industrial activity due to more resources from taxes (Balaguer-Coll et al., 2013), which leads to a similar reading to the sign obtained by TBURDEN. To understand these results, it is important to identify the factors that mediate these relationships. The negative relationship between industrial and commercial activity and efficiency may be due to the prioritisation of other public services and environmental impacts. In municipalities with a high concentration of industrial and commercial activity, local governments may spend a higher proportion of their budget on road infrastructure, transport, environmental regulation and industrial waste management, while neglecting the maintenance of parks and gardens. In addition, pollution from industrial activity can accelerate the deterioration of green spaces, increasing maintenance costs and reducing perceptions of efficiency. Another key factor is that these municipalities tend to have higher building densities and less available land for green spaces, which can make park management more costly and less of a priority in municipal planning.

On the other hand, the need to maintain a good urban image and investment in beautifying public spaces largely explains the positive relationship between tourism and efficiency. In municipalities with a tourism-based economy, the quality of the urban environment is a key factor in attracting visitors, which is why local governments allocate more resources and implement better park and garden management strategies. The value of this service as a tourist attraction would support the effect obtained, as also shown by other studies (Cordero et al., 2017; Giménez & Prior, 2007; Pérez-López et al., 2015). In addition, many tourist destinations have additional funding from tourism companies and private sponsorship programmes for the conservation of green spaces. This reduces the financial burden on local authorities. Also, in tourist cities, parks and gardens are often used as recreational spaces for visitors, which increases their visibility and encourages greater monitoring and maintenance.

In conclusion, while industrial and commercial activity can have a negative impact on efficiency by diverting attention and resources away from other more urgent municipal services, tourism activity encourages better management of public spaces as these are fundamental to the visitor experience and the image of the municipality. These results show how the economic structure of a municipality determines its investment priorities and the efficiency with which it provides urban services.

Finally, the economic activity index reinforces the argument that in a municipality with wealthier residents, residents will be more demanding and exercise tight control over resource management to ensure quality services in line with their lifestyle.

An important aspect to consider in the management of urban parks is the presence of water features and the associated costs of irrigation. Parks with lakes, fountains, or riverbanks tend to attract more visitors, potentially increasing the demand for maintenance and influencing efficiency levels. Additionally, green areas with extensive irrigation requirements impose higher operational costs, which may impact efficiency scores.

Although this study does not include explicit variables related to the presence of water bodies or irrigation costs, their effects are indirectly captured through total municipal expenditure on parks and gardens. Municipalities with large water-dependent parks or high irrigation costs tend to exhibit higher spending levels, which is reflected in the DEA efficiency scores.

To further examine this issue, a correlation analysis was conducted between the total area of green spaces (ZGREEN) and municipal expenditure, showing a significant positive relationship. This suggests that municipalities with larger green spaces tend to require higher maintenance and irrigation costs, reinforcing the idea that irrigation expenses are reflected in the expenditure variables included in the model.

Future research could improve upon these findings by incorporating detailed data on water consumption and irrigation costs, allowing for a more refined analysis of how these factors influence efficiency in urban park management.

To check the separability that characterises the validity of the data, the significance of the differences between the parameters based on the conditional (Simar & Wilson, 2007) and unconditional (Daraio & Simar, 2005) efficiency measures was analysed. Table 6 shows the estimated coefficients for both measures. Hypothesis tests have been calculated to confirm that the differences between the two measures are not statistically significant.

The non-parametric tests carried out (Kolmorov-Smirnov, Mann-Whitney and bootstrap for Kolmorov-Smirnov) show that the conditional and unconditional parameter samples come from the same population. This verifies that the separability condition is met, which gives relevance to the results obtained in our research.

Although the results are robust and consistent with the literature, some limitations should be considered. Firstly, the sample is limited to municipalities with between 5000 and 50,000 inhabitants, which may affect the generalisability of the results to larger or smaller cities. In addition, the analysis is carried out for a single year, so it does not capture changes in efficiency over time. This may limit the ability to assess how changes in municipal governance or economic conditions affect efficiency over time.

Table 6
Conditional and unconditional coefficient estimates.

Determinants	Estimated coefficients SW (2007)	Estimated coefficients DS (2005)	95 % confidence intervals SW (2007)	
TBURDEN	0,2188	0,1986	−0,0088	0,4475
INCOME	−49,8493	−43,705	−96,8667	−20,2380
PDENSURB	−0,0006	−0,0006	−0,0181	0,0140
HOUSEV	−31,604	−2992	−76,929	−0,7579
POLITICS	36,631	3361	−46,4599	57,4637
HERFINDAHL	33,2013	30,1347	−70,3159	141,5556
POP65	415,769	389,9853	23,2988	785,6583
POP15_24	−34,423	−30,6277	−689,8730	625,6056
SCHOOL	368,9919	364,097	−332,3975	1025,9374
UNEMPLOY	−10,352	−10,0139	−28,7382	11,467
INMIGR	90,9902	84,4076	48,279	183,3563
ININD	69,767	53,013	30,483	14,5936
ICOMM	86,257	73,872	34,450	17,7704
ITURIST	−15,603	−14,051	−60,167	16,457
IACTEC	−18,83	−14,9987	−40,4239	−86,758

5. Conclusions, policy implications, and limitations of the research

5.1. Strengthening the link between conclusions and research objectives

This study provides a comprehensive analysis of the efficiency of municipal management of parks and gardens in 202 Spanish municipalities with populations between 5000 and 50,000 inhabitants. By applying DEA with double bootstrapping, we corrected for potential bias and obtained robust efficiency estimates. The research aimed to quantify inefficiencies in these municipalities and to identify the main socio-economic, political and demographic determinants that influence efficiency.

One of the main challenges in applying DEA to municipal efficiency assessment is the sensitivity of efficiency scores to extreme observations. In this study, a robust outlier detection approach was applied, integrating the methodologies of Wilson (1993), Simar (2003) with Order-m DEA, and De Witte and Marques (2010). The results confirmed that while some municipalities exhibited extreme levels of inefficiency, these observations were not statistical anomalies, but rather reflected real differences in municipal management practices.

The application of order-m DEA was particularly useful as it allowed for a more robust estimation of the efficiency frontier, reducing the influence of extreme observations without compromising the validity of the dataset. Given the stability of the efficiency rankings across different values of m, we can be confident that the results reflect true efficiency differences rather than data bias.

Future research could explore additional robust DEA models that incorporate outlier correction mechanisms while maintaining the representativeness of the sample. In addition, using non-parametric techniques that incorporate contextual variables could provide further insights into the drivers of municipal inefficiency and refine the understanding of the determinants of efficiency in local government management.

This study had three main research objectives:

- To determine the degree of inefficiency in the management of municipal parks and gardens in Spain. The results confirm that municipalities operate at sub-optimal levels of efficiency, with only 1 % classified as fully efficient under constant returns to scale (DEA-CRS). This highlights significant inefficiencies that could be addressed through better resource allocation and policy interventions.
- To identify the socio-economic, political and demographic factors that influence efficiency. The results indicate that variables such as tax burden, income levels, population density, political structure and employment rates play a crucial role in shaping local government efficiency. These findings provide a deeper understanding of the structural and governance determinants of public service performance.
- To suggest policy strategies to improve efficiency. Based on the empirical findings, the study presents specific and actionable recommendations that local governments can implement to improve service delivery and optimise municipal resources.

5.2. Low overall efficiency

The analysis confirms that municipal management of parks and gardens in Spain is highly inefficient. Only 1 % of municipalities (2 out of 202) were classified as efficient under DEA-CRS and 10 % under DEA-VRS, indicating that most of them have significant room for improvement in resource use.

The results suggest that municipalities could reduce input use by up to 94 % without compromising service quality. These findings are consistent with previous research on inefficiencies in Spanish local governments (Balaguer-Coll et al., 2010; Benito et al., 2010) and highlight the need for structural reforms to optimise public service delivery.

The evidence suggests that inefficiencies may stem from administrative fragmentation, lack of coordination between departments and limited use of modern management tools.

Furthermore, this study highlights the importance of carefully selecting output variables in municipal efficiency analysis to ensure that efficiency estimates reflect actual service delivery rather than the mere existence of infrastructure. The use of several robustness checks confirmed that municipalities that reduce expenditure but do not maintain their parks and gardens are not classified as highly efficient.

The DEA methodology used in this study demonstrates that efficiency analysis can effectively capture both cost-effectiveness and the ability to maintain an adequate level of public service provision. Future research could build on these findings by incorporating qualitative indicators of service quality, such as citizen satisfaction surveys or remote sensing data on vegetation health, to further refine efficiency measures in public green space management.

5.3. The role of economies of scale and inter-municipal cooperation

The results strongly support the idea that many municipalities could benefit from economies of scale in the provision of parks and gardens services. Smaller municipalities in particular could improve their efficiency through inter-municipal cooperation, either by managing services jointly, sharing resources or outsourcing to specialised service providers operating at a larger, more efficient scale.

In the Scandinavian countries and Germany, regional cooperation structures facilitate the provision of shared services, significantly improving operational efficiency (Cedergren et al., 2021; Niehaves & Krause, 2010). These models demonstrate that inter-municipal cooperation can lead to cost savings, improved service quality and better resource allocation.

However, the implementation of inter-municipal cooperation models in Spain faces challenges such as administrative fragmentation and regulatory barriers. Many municipalities operate under different legal frameworks, fiscal structures and governance models, making cooperation difficult. Financial incentives and standardised governance frameworks could help overcome these obstacles and encourage municipalities to work together more effectively.

5.4. Determinants of efficiency and their policy implications

The second-stage truncated regression analysis identified several key determinants of efficiency, revealing both expected and novel insights into municipal service management:

- Tax burden does not improve efficiency: Higher municipal tax revenues do not necessarily lead to better management.
- Income level affects efficiency: Wealthier municipalities show higher efficiency, likely due to greater public scrutiny and administrative capacity.
- Population density promotes efficiency: Urban municipalities benefit from economies of scale, leading to more cost-effective infrastructure investment.
- Political competition boosts efficiency: Conservative-led municipalities tend to be more efficient, while low political competition is associated with inefficiency.
- Unemployment affects efficiency: Municipalities with higher unemployment rates are more efficient, possibly due to greater fiscal constraints.
- Immigration affects efficiency: A higher immigrant population increases the demand for services and strains resources.

5.5. Methodological advances

From a methodological perspective, this study demonstrates the advantages of using DEA with double bootstrapping, which corrects for bias and provides more reliable efficiency estimates. This technique represents an improvement over traditional DEA models, particularly for research in municipal services where exogenous variables play a crucial role.

Future research should consider extending this approach to other public services to ensure more accurate efficiency assessments across sectors. The validation of the separability condition and the consistency of the results through non-parametric tests strengthens the reliability of our findings.

5.6. Recommendations for policy implementation

Based on the findings of this study, several policy recommendations are proposed to improve the efficiency of parks and gardens management in Spanish municipalities. These recommendations focus on improving inter-municipal cooperation, strengthening budgetary control, using tourism for funding, implementing smart technologies and addressing socio-demographic challenges. Each recommendation is designed to be specific and actionable, ensuring that local governments can implement concrete strategies to optimise resource allocation and improve service provision.

5.6.1. Improving inter-municipal cooperation

The findings suggest that many smaller municipalities could benefit from economies of scale, but currently operate inefficiently due to their limited capacity and resources. One of the most effective ways to improve efficiency and reduce costs is through inter-municipal cooperation, where municipalities share resources, jointly manage services or coordinate procurement processes.

To promote inter-municipal cooperation, a legal framework should be established to facilitate collaboration. This could include:

- Creating regional agreements for the joint provision of municipal services, particularly for smaller municipalities that struggle to manage parks and gardens efficiently on their own.
- Introducing financial incentives from regional and national governments to encourage local governments to engage in collaborative arrangements.
- Developing technology-enabled coordination mechanisms, such as digital platforms, that enable municipalities to effectively plan shared service provision.

5.6.2. Strengthening budgetary control in high-tax municipalities

The study found that municipalities with higher tax revenues tend to be less efficient, suggesting that increased financial resources do not necessarily translate into better management. This may be due to weaker budgetary discipline, leading to inefficiencies in the allocation of expenditure.

To address this issue, local governments should introduce stronger financial control mechanisms and accountability measures, including:

- Performance-based budgeting, which links budget allocations to efficiency outcomes and service quality metrics.
- Regular efficiency audits to identify wasteful spending and optimise resource allocation.
- Public budget monitoring platforms to enhance citizen participation in budget decisions and ensure that resources are allocated efficiently and transparently.
- Promoting external audits and independent evaluations to ensure that local governments follow best practices in financial management.

5.6.3. Using tourism to manage parks and gardens

Communities with high levels of tourism have a unique opportunity to generate additional revenue for the maintenance and enhancement of parks and gardens. Well-maintained green spaces contribute

significantly to tourism appeal and urban attractiveness, making them an essential component of local economic development.

To capitalise on this, municipalities should:

- Promote public-private partnerships (PPPs) in communities with strong tourism sectors. Private sector companies - particularly in the hospitality and real estate sectors - could co-finance park maintenance and improvement projects.
- Introduce tourism-related tax mechanisms, such as eco-tourism fees or voluntary visitor contributions, to fund the maintenance and development of green spaces.
- Develop corporate-sponsored urban beautification projects, where companies contribute to park renovation efforts in exchange for branding or sponsorship rights.

These strategies would allow municipalities to reduce their dependence on municipal budgets, while ensuring that visitors contribute to the sustainability of public spaces.

5.6.4. Implementing smart technologies in public services

The use of digital solutions and smart technologies has been shown to improve the efficiency of public service management, particularly in the maintenance of parks and gardens. By using automated systems, remote monitoring and data-driven decision making, municipalities can reduce operating costs and improve service quality.

Key recommendations include:

- Using IoT sensors for automated irrigation management, optimising water use based on soil moisture and weather conditions.
- Using drones for park inspections to quickly identify maintenance issues, pest infestations or infrastructure deterioration.
- Developing digital citizen engagement platforms that allow residents to report maintenance issues, provide feedback and participate in community initiatives.
- To successfully implement these technologies, local governments should:
- Invest in staff training programmes to equip staff with the skills needed to manage and operate these advanced systems.
- Seek funding from national innovation programmes or EU-backed smart city initiatives to help cover the costs of digital transformation.

5.6.5. Tackling social and demographic challenges

The study has highlighted how socio-demographic factors influence the efficiency of municipalities, particularly those with high unemployment and large immigrant populations. While municipalities with higher unemployment rates tend to be more efficient, those with larger immigrant populations face greater pressure on services, leading to lower levels of efficiency.

To address these inequalities, municipalities should:

- Develop inclusive urban planning strategies that ensure green spaces are accessible to all residents, regardless of socio-economic background.
- Implement community-led initiatives that involve migrant populations in park maintenance and urban greening projects, promoting social integration while improving service efficiency.
- Introduce multilingual communication strategies and engagement forums to improve the participation of diverse communities in local decision-making.
- Establishing job creation programmes within municipal services, such as hiring unemployed residents for urban greening projects, contributing to both service efficiency and local employment.

5.6.6. Incorporating quality-based efficiency measures

While this study assesses efficiency based on infrastructure availability and resource allocation, future policies should incorporate qualitative indicators to ensure that public services not only optimise resource use but also effectively meet citizens' needs.

Local governments should consider:

- Conducting citizen satisfaction surveys to measure the quality of park services.
- Using satellite imagery and remote sensing to monitor vegetation health and green space conditions.
- Developing performance-based contracts for park maintenance companies to ensure that service providers are incentivised to maintain high-quality urban green spaces.

5.7. Limitations of the study

While this study provides valuable insights into the effectiveness of municipal parks and gardens management, certain methodological and data limitations must be acknowledged:

1. Due to the lack of official GDP per capita data at the municipal level, this study used INCOME and HOUSEV as proxies for municipal wealth. While these indicators correlate with economic prosperity, the lack of direct GDP data may introduce some bias.
2. The efficiency analysis primarily considers quantitative infrastructure measures rather than qualitative indicators of service quality. Future research should include user satisfaction surveys, vegetation health indices or remote sensing data to refine efficiency assessments.
3. The study finds statistically significant associations between socio-economic and demographic factors and efficiency. However, it does not establish causal relationships. Future research could use quasi-experimental methods (e.g. difference-in-differences or instrumental variable approaches) to explore causal effects more rigorously.

CRediT authorship contribution statement

Bernardino Benito: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **María del Carmen Conesa-Pérez:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **María-Concepción Parra-Meroño:** Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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