Measuring Tourism Accommodation Efficiency under Environmental and Structural Constraints: A Multistage DEA–Malmquist Approach for the Valencian Community (Spain)

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ABSTRACT

Tourism destinations face increasing pressure to remain competitive while adapting to growing environmental and structural constraints. This study develops an integrated framework to assess the efficiency and productivity of tourism accommodation systems across the Valencian Community (Spain), a mature Mediterranean region characterized by strong coastal concentration, urban diversification, and structurally fragile inland areas. Using harmonized annual data for 2015–2023, the analysis combines input-oriented data envelopment analysis (DEA) models with a meta-frontier specification to capture technological heterogeneity across coastal, urban, and inland municipalities. Environmental performance is incorporated through CO_2-related undesirable outputs, and temporal dynamics are evaluated using the Malmquist productivity index, complemented by a second-stage bootstrap regression that examines the influence of accessibility, tourism density, and market composition.

Results reveal pronounced territorial asymmetries. Coastal destinations such as Benidorm, Peñíscola, and Alicante operate close to the global efficiency frontier (variable returns to scale scores ≈ 0.95–1.00), whereas inland municipalities remain constrained by scale limitations and weaker technological progress. The coronavirus disease 2019 (COVID-19) shock generated a sharp productivity decline in 2020, followed by an uneven recovery in which coastal and urban destinations experienced faster technological improvements than inland areas. Environmental efficiency also exhibits a clear territorial divide, with high-intensity coastal destinations facing proportionally higher CO_2 impacts.

The study advances the literature by integrating environmental pressures and meta-frontier modelling into a regional tourism efficiency framework, offering a replicable approach for destinations experiencing similar competitive and ecological challenges. The findings highlight the need for differentiated, place-sensitive policies that strengthen inland connectivity, promote sustainable accommodation structures and support technological upgrading across the regional tourism system.

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1. Introduction

Tourism has long been one of the most influential drivers of economic activity and territorial restructuring across Southern Europe. In Mediterranean regions, sustained tourism growth has shaped demographic trajectories, labor markets and land-use patterns, while intensifying the concentration of activity along coastal corridors and reinforcing long-standing asymmetries between littoral and inland territories. The Valencian Community (Spain) offers a clear example of these dynamics. According to data from the Spanish National Statistics Institute (INE; 2023) and Tourism of the Valencian Community (2023; 2023a), more than four fifths of regulated accommodation capacity and overnight demand are concentrated along the Costa Blanca and Costa de Azahar, whereas inland municipalities operate with far lower accommodation density, limited accessibility, and pronounced demographic shrinkage. Such structural imbalances underscore the need to understand how different types of destinations transform their accommodation resources into observable tourism outputs, and how these patterns evolve over time in response to economic, social, and environmental pressures.

Efficiency analysis has become an increasingly relevant tool in tourism research as destinations confront rising expectations for sustainable performance and stronger competition for visitors. Data envelopment analysis (DEA) is particularly well suited to this task because it can accommodate multiple inputs and outputs without imposing a predetermined production function, allowing each destination to be evaluated against the best performers in the system. Foundational contributions in operations research (Charnes et al., 1978;

Banker et al., 1984; Tone, 2001) and applications in regional tourism analysis (Martín & Román, 2022) have demonstrated the potential of DEA to reveal performance gaps and structural inefficiencies. However, conventional DEA approaches face notable limitations in Mediterranean contexts, where destinations operate under markedly heterogeneous technologies shaped by geography, urban structure, accessibility and long-standing institutional arrangements. Recent methodological advances, including meta-frontier models (Battese et al., 2004; Tone & Tsutsui, 2015), offer a way to address this issue by distinguishing between group-specific frontiers and an overarching technological potential.

A second challenge relates to the dynamic nature of tourism systems. The shock induced by the coronavirus disease 2019 (COVID-19) pandemic revealed the vulnerability of regional tourism structures and the uneven recovery capacity of coastal, urban, and inland destinations. In this regard, the Malmquist productivity index provides a suitable tool for examining temporal change by decomposing productivity into efficiency variation and technological progress. Earlier findings for Mediterranean and European destinations (e.g., Cuccia et al., 2016; Tsai et al., 2021) suggest that shocks may alter long-term trajectories by disproportionately affecting structurally weaker areas or by accelerating technological adoption in more consolidated markets. Assessing these dynamics for the Valencian Community requires longitudinal, municipality-level data that are harmonized and comparable over time. To achieve this, the study compiles information from official sources such as the Spanish National Statistics Institute (INE), including the Hotel Occupancy Survey (EOH) and the indicators average daily rate (ADR) and revenue per available room (RevPAR). It also incorporates data from Turespaña, specifically the Survey of Tourist Expenditure (EGATUR) and the inbound tourism statistics from the Movements at Borders survey (FRONTUR), as well as information provided by Tourism of the Valencian Community. Additionally, complementary sources such as Exceltur's tourism economic impact report Impactur (2022) are used for contextual validation.

A third layer of complexity stems from the growing environmental pressures associated with tourism, particularly in mature destinations where high visitor density interacts with fragile ecosystems and carbon-intensive mobility patterns. Integrating environmental indicators into efficiency assessments has become increasingly important in sustainable tourism research, with several studies highlighting the need to consider CO_2 emissions and other externalities as undesirable outputs within frontier models (Zha et al., 2020; Bi et al., 2023). This issue is especially salient in the Valencian Community, where coastal destinations face escalating exposure to climate-related risks while inland areas are undergoing depopulation and land-use transformation, as recognized in regional strategic documents such as the White Paper on Tourism of the Valencian Community (Generalitat Valenciana, 2019).

Against this background, the present study develops an integrated and multistage framework to assess tourism accommodation efficiency in the Valencian Community over the period 2015–2023. By combining input-oriented DEA models under alternative returns to scale assumptions, a meta-frontier specification to account for technological heterogeneity across coastal, urban, and inland municipalities and a dynamic evaluation based on the Malmquist productivity index, the analysis provides a comprehensive portrayal of how destinations perform relative to both their peers and the regional technological potential. The inclusion of CO_2-related undesirable outputs offers further insight into the environmental dimension of efficiency, while a second-stage double-bootstrap regression helps identify structural determinants such as accessibility, tourism density, and market composition. Through this approach, the study contributes to ongoing debates on territorial cohesion, environmental sustainability, and tourism competitiveness, offering a replicable framework for destinations facing similar pressures across the Mediterranean and beyond.

2. Literature Review

Research on tourism efficiency has expanded considerably over the past two decades as destinations face growing pressure to reconcile competitiveness with environmental and territorial constraints. Within this field, data envelopment analysis (DEA) has consolidated itself as the standard methodological approach for evaluating tourism performance because it accommodates multiple inputs and outputs without requiring restrictive assumptions about functional forms. Early contributions by Charnes et al. (1978), Banker et al. (1984), and Tone (2001) established the analytical foundations of DEA, while more recent methodological reviews (Emrouznejad et al., 2025; Mergoni et al., 2025) document their widespread adoption and ongoing refinement. In tourism research, DEA has been applied to assess national competitiveness, hotel productivity, sustainability performance, and destination-level efficiency across a range of contexts.

A growing body of work highlights the importance of recognizing the spatial and territorial dimensions of tourism efficiency. Studies in Spain and other Mediterranean countries demonstrate that performance varies systematically across geographical units, reflecting differences in accommodation density, market structure, accessibility, and institutional environments. Martín and Román (2022) show that Spanish destinations exhibit persistent spatial asymmetries in tourism efficiency, while benchmarking studies of destination competitiveness (Botti et al., 2009) confirm that performance gaps often stem from structural differentiation rather than purely managerial factors. These findings resonate with broader insights from European tourism statistics compiled by Eurostat (2023), which emphasize the uneven distribution of tourism intensity and capacity across regions.

Despite these advances, traditional DEA applications remain limited when analyzing heterogeneous tourism systems, particularly at fine territorial scales. Mediterranean destinations combine consolidated coastal hubs, multifunctional

urban areas, and low-density inland municipalities operating under distinct production technologies. Standard DEA assumes a common technology for all decision-making units, an assumption increasingly questioned in regional tourism studies. To address this limitation, the meta-frontier approach (Battese et al., 2004; Tone & Tsutsui, 2015) allows efficiency to be evaluated relative to both group-specific frontiers and an overarching technological potential, providing a more realistic representation of structural heterogeneity.

Tourism systems are also inherently dynamic, evolving in response to technological change, market shifts, and external shocks. The Malmquist productivity index (MPI) offers a powerful tool for capturing these temporal dynamics by decomposing productivity into efficiency change and technological progress. Applications such as Cuccia et al. (2016) show how productivity trajectories respond to institutional and environmental factors in cultural destinations, while Tsai et al. (2021) demonstrate that spatial–environmental constraints shape the evolution of tourism efficiency across European regions. Evidence from INE (2023a), FRONTUR, and EGATUR (Turespaña, 2023) further indicates that Mediterranean destinations have experienced highly asymmetric postpandemic recoveries, making dynamic analysis essential.

At the same time, tourism sustainability concerns have prompted the integration of undesirable outputs, such as CO_2 emissions, into frontier models. This shift reflects increasing recognition of the environmental pressures facing mature tourism regions, particularly high-density coastal destinations. Research by Zha et al. (2020) and Bi et al. (2023) demonstrates how environmental DEA models reveal trade-offs between economic performance and ecological impact, offering a more nuanced understanding of sustainability challenges. This perspective aligns with evidence from Exceltur's Impactur reports (2022) and regional strategic frameworks such as the White Paper on Tourism of the Valencian Community (Generalitat Valenciana, 2019), which highlight the need to address environmental vulnerabilities, climate risks, and structural imbalances across the regional tourism system.

A further limitation in existing work is the scarcity of municipal-level analyses, despite the fact that municipalities constitute the administrative scale at which accommodation capacity is regulated, tourism taxes are implemented, and local governance structures operate. Official data from Tourism of the Valencian Community (2023; 2023a) and INE show strong intra-regional contrasts that national or provincial studies often fail to capture, underscoring the value of subregional approaches capable of integrating structural, environmental, and territorial dimensions simultaneously.

Taken together, the literature indicates three critical needs for advancing research on tourism efficiency: a framework that recognizes technological heterogeneity across destination types, an approach that captures dynamic productivity patterns over time, and an analytical model that incorporates environmental pressures as intrinsic components of performance. The present study addresses these gaps by combining DEA, meta-frontier modelling, Malmquist productivity analysis and CO_2-related undesirable outputs in a unified framework, applied to a harmonized and territorially detailed dataset for the Valencian Community between 2015 and 2023. Through this integration, the study contributes to a more comprehensive understanding of efficiency patterns in mature Mediterranean destinations and provides a basis for informed policymaking in contexts facing similar structural and environmental challenges.

3. Methodology

The methodological framework developed in this study integrates static efficiency analysis, dynamic productivity evaluation, and explicit modelling of technological heterogeneity to capture the complexity of tourism accommodation systems in the Valencian Community (Spain). The region's pronounced internal contrasts—between consolidated coastal destinations, multifunctional urban municipalities, and structurally fragile inland areas—require an analytical approach capable of recognizing that tourism does not operate under a single production technology. To address this complexity, the study adopts a non-parametric frontier framework based on data envelopment analysis (DEA), following the foundational formulations of Charnes et al. (1978) and Banker et al. (1984) and the subsequent slacks-based refinement proposed by Tone (2001). DEA is particularly suitable for this context because it accommodates multiple inputs and outputs without imposing a predetermined production function, allowing each destination to be evaluated relative to the best performers in the system.

Efficiency is estimated using input-oriented data envelopment analysis (DEA) models under both constant returns to scale, following the Charnes–Cooper–Rhodes specification (CCR), and variable returns to scale, following the Banker–Charnes–Cooper formulation (BCC). This orientation reflects the policy reality of mature Mediterranean destinations, where reducing excess accommodation capacity, mitigating seasonal idle resources, and addressing environmental pressures are often more feasible and relevant objectives than expanding output. The CCR specification provides an estimate of overall technical efficiency relative to a unified frontier, while the BCC model isolates pure managerial efficiency by controlling for scale conditions. Scale efficiency is then obtained from the ratio of both scores.

A central feature of the methodological design is the explicit incorporation of technological heterogeneity. Coastal municipalities such as Benidorm or Peñíscola operate under production environments that differ substantially from those of inland destinations such as Morella or Cofrentes, where sparse settlement patterns, limited accessibility, and small-scale accommodation structures restrict the feasible conversion of inputs into outputs. Standard DEA assumes a common technology for all decision-making units, an assumption that is not compatible with the territorial structure of the region. To address this limitation, the study applies a

meta-frontier DEA specification, following Battese, Rao, and O'Donnell (2004) and operationalized through Tone and Tsutsui (2015), which allows for the construction of group-specific frontiers for coastal, urban, and inland municipalities and an overarching meta-frontier that captures the maximum attainable technological potential.

At this point, it is important to clarify the analytical design regarding the selection of municipalities. Although the Valencian Community comprises more than 500 municipalities, the study deliberately focuses on 19 municipalities that represent the three dominant tourism models of the region: mass-tourism coastal hubs, multifunctional urban destinations, and structurally constrained inland areas. This typological selection aligns with official classifications from Tourism of the Valencian Community and is validated using clustering procedures to ensure internal coherence. The purpose of the study is not to produce a census-based efficiency ranking of all municipalities, which would generate excessively large tables and voluminous results without adding conceptual value, but rather to compare the behavior of distinct production technologies that define the regional tourism system. Using a representative and heterogeneous subset is both methodologically appropriate and consistent with the objective of understanding structural asymmetries rather than compiling an exhaustive list of efficiency scores. A formal sensitivity analysis based on an exhaustive municipal sample is not required in this context, given the strong territorial concentration patterns documented in official tourism statistics for the Valencian Community. Given the pronounced concentration of accommodation capacity and demand along the coast and in major urban centers, the inclusion of additional small municipalities would be expected to reinforce, rather than alter, the structural efficiency and productivity gradients identified in this study.

Given the increasing relevance of sustainability in tourism research, the model incorporates CO_2 emissions per overnight stay as an undesirable output. This follows recent advances in environmental DEA modelling (Zha et al., 2020; Bi et al., 2023), where undesirable outputs are introduced under weak disposability conditions to ensure that improvements in environmental efficiency reflect genuine reductions in emissions. Emission estimates draw on regional tourism satellite accounts and greenhouse-gas coefficients differentiated by accommodation type and visitor origin, complemented by statistics from EGATUR and FRONTUR (Turespaña) regarding the composition of tourism markets.

To capture temporal dynamics, the study employs the Malmquist productivity index (MPI) to decompose productivity changes over the period 2015–2023 into efficiency variation and technological progress. This formulation follows applications in tourism productivity analysis such as Cuccia et al. (2016) and is particularly relevant in light of the disruptive effects of the COVID-19 pandemic and the heterogeneous recovery observed across Mediterranean destinations. Annual data for accommodation capacity, employment, overnight stays, Revenue per Available Room (RevPAR) and CO_2 emissions were obtained from harmonized official sources, including INE and Tourism of the Valencian Community, ensuring full reproducibility.

The selection of inputs and outputs reflects both theoretical considerations and the structural characteristics of the region. Accommodation capacity, tourism employment, and an accommodation diversification index capture the scale and organizational features of each municipality. Overnight stays and RevPAR provide complementary measures of physical and economic performance, respectively. Dimensionality and collinearity diagnostics confirm that the specification satisfies established discriminatory criteria, while occupancy rates are excluded owing to strong correlation with overnight stays.

Because DEA is sensitive to extreme observations, potential outliers are identified using super-efficiency diagnostics and leverage tests. Observations deemed structurally unique rather than erroneous are retained but interpreted with caution. Robustness checks include alternative model specifications and frontier perturbation analyses to ensure that the results are not driven by specific variable configurations.

Finally, to identify the structural determinants of efficiency, a second-stage double-bootstrap truncated regression is estimated following the procedures as commonly recommended in tourism and regional efficiency studies based on DEA (Olesen and Petersen, 2016).

This approach is preferred to conventional regression techniques because it corrects for the serial correlation and bias inherent in DEA efficiency scores, thus providing statistically consistent inference. Bias-corrected BCC scores serve as the dependent variable, while explanatory variables include accessibility measures, tourism density, the share of international visitors, accommodation diversification, and coastal versus inland location. This second stage provides statistically grounded evidence on the territorial, infrastructural and market-related factors shaping performance, complementing the frontier analysis with insights of direct policy relevance.

Through this integrated approach, the methodology acknowledges the technological, environmental, and territorial heterogeneity that characterizes tourism in the Valencian Community and provides a rigorous basis for interpreting the efficiency patterns reported in the following sections.

4. Data and Variables

The empirical analysis draws on a harmonized dataset covering the period 2015–2023, designed to capture the structural, economic, and environmental characteristics of tourism accommodation systems across the Valencian Community (Spain). Municipalities represent the operative scale at which accommodation capacity is authorized, tourism taxes are implemented, and destination management is exercised. For this reason, and following the territorial logic documented in official statistics from INE (2023) and Tourism of

the Valencian Community (2023; 2023a), the analysis focuses on a set of municipalities selected to represent the region's main tourism models: consolidated coastal hubs, multifunctional urban destinations, and structurally constrained inland areas. This typological approach provides a coherent basis for examining efficiency patterns across territorially differentiated contexts without compromising data consistency or interpretability.

All variables were obtained from official statistical sources, ensuring full reproducibility and alignment with best practices in tourism and regional-science research. Accommodation supply data, including the annual number of bedplaces in regulated establishments, were sourced from the Tourism of the Valencian Community accommodation registry, which documents the licensing and capacity characteristics of hotels, tourist apartments, campsites, and rural lodgings. Tourism demand indicators, notably overnight stays, were collected from the Spanish National Statistics Institute (INE) through the Encuesta de Ocupación Hotelera and complementary accommodation surveys using consistent territorial identifiers throughout the period. These indicators capture the spatial concentration of demand along the coastline and the more irregular behavior of inland destinations.

Economic performance was measured through RevPAR, calculated following the methodology of the Hotel Sector Profitability Indicators published by INE (2023). RevPAR was selected instead of total revenue because it provides a more stable reflection of accommodation performance at the municipal scale, avoiding distortions caused by day visitors, cross-municipal expenditure, or high seasonality. Complementary information from EGATUR and FRONTUR (Turespaña, 2023) was used to validate the distribution of tourist expenditure and the share of international visitors, reinforcing the internal consistency of the dataset.

Environmental performance is incorporated through CO_2 emissions per overnight stay, included as an undesirable output in line with recent sustainability-oriented frontier studies. This indicator was estimated using emissions pathways from regional tourism satellite accounts, combined with accommodation-type coefficients and visitor-origin profiles. Although aggregated at the municipal scale, these data capture the structural environmental pressures associated with high-density coastal tourism and provide a meaningful basis for integrating sustainability considerations into efficiency assessment. As with most regional tourism studies, this indicator is subject to aggregation and coefficient-based assumptions, and therefore captures relative and structural environmental pressure rather than finegrained microlevel emissions.

Labor intensity was measured using records from Social Security affiliates in accommodation and hospitality activities, classified according to the European Nomenclature of Economic Activities (NACE; Rev.2: I55–I56), harmonized across all municipalities and years. Because tourism supply in the region is highly diversified, ranging from large hotel clusters to rural guesthouses, the analysis also incorporates an accommodation diversification index based on the entropy of bedplace distribution across lodging types. This measure reflects the organizational complexity and strategic positioning of each municipality within the broader regional tourism structure.

Before estimation, all variables underwent a rigorous harmonization process. Territorial identifiers were aligned across sources from INE, Tourism Valencian Community, and Turespaña; monetary values were deflated to constant euros; and missing observations were addressed through controlled interpolation only when justified by consistent temporal patterns. Correlation analyses and dimensionality checks confirmed that the combination of inputs and outputs met established discriminatory criteria and did not suffer from excessive redundancy, particularly with respect to variables such as occupancy rates, which are strongly correlated with overnight stays.

The resulting dataset provides a transparent, territorially sensitive, and fully auditable foundation for the DEA, meta-frontier, and Malmquist analyses developed in the following sections. By integrating structural, economic, and environmental dimensions at the municipal scale, the data enable a nuanced assessment of how tourism accommodation systems perform in a region marked by long-standing coastal concentration and significant inland fragilities.

5. Data Sources

All empirical indicators used in this study come from official, publicly accessible statistical systems, ensuring full methodological transparency and reproducibility. The dataset integrates annual observations for 2015–2023 from sources that operate at national and regional scales and apply harmonized procedures for territorial disaggregation. This combination is essential for capturing the structural, environmental, and performance-related dimensions of tourism accommodation systems across the Valencian Community (Spain).

Municipal-level tourism demand data, including overnight stays and the distribution of guests across accommodation types, were obtained from the Instituto Nacional de Estadística (INE, 2023) through the Encuesta de Ocupación Hotelera and complementary surveys for tourist apartments, campsites, and rural establishments. These instruments provide consistent methodological criteria and stable territorial identifiers, allowing for reliable comparisons across the full 2015–2023 period. Performance indicators such as ADR and RevPAR were drawn from the Hotel Sector Profitability Indicators published by INE, ensuring that economic outputs are aligned with national standards and internationally recognized tourism metrics.

Accommodation supply data were sourced from the Tourism of the Valencian Community (2023; 2023a) accommodation registry, which records the licensing and capacity of

all regulated establishments. Because registration is mandatory, these data offer comprehensive coverage of hotels, tourist apartments, campsites, and rural lodgings, enabling the construction of structural indicators such as accommodation density and the diversification index used in the analysis. The territorial classification of municipalities into coastal, urban, and inland categories also draws on official typologies published by Tourism of the Valencian Community.

Economic data related to tourist expenditure and visitor origin were obtained from EGATUR and FRONTUR (Turespaña, 2023), which provide detailed information on spending patterns and the composition of international and domestic tourism flows. Although these surveys do not operate at the municipal level, their regional indicators were used to validate the spatial distribution of demand and to support the construction of structural variables such as market diversification and the share of international visitors.

Environmental indicators were compiled from regional tourism satellite accounts and greenhouse gas emission coefficients associated with accommodation activities and visitor origin profiles. This approach follows recognized procedures in sustainability-focused tourism research and ensures that the incorporation of CO_2 emissions as an undesirable output reflects policy-relevant environmental pressures rather than proxy variables. Contextual validation was supported by sectoral reports such as Impactur (Exceltur, 2022) and by the strategic guidelines outlined in the White Paper on Tourism of the Valencian Community (Generalitat Valenciana, 2019), which highlight the region's exposure to climate risks and structural imbalances between coastal and inland destinations.

Labor-related data were obtained from Social Security registers, harmonized using NACE Rev.2 categories linked to accommodation and hospitality activities. These indicators capture the labor intensity of tourism at the municipal scale and complement the structural information on accommodation supply, allowing a more detailed depiction of the production environment in each municipality.

Taken together, these sources provide a coherent, credible, and fully auditable empirical foundation. Their integration ensures that the efficiency and productivity estimates reflect not only the institutional realities of data production in Spain but also the territorial and environmental specificities of the Valencian Community. The combination of INE's national statistical standards, Tourism of the Valencian Community's detailed accommodation records, and the expenditure and mobility data from Turespaña produces a dataset that meets the reproducibility requirements expected in high-impact tourism and regional-science journals.

Table 1. *Descriptive statistics of municipal efficiency scores (2015–2023)*

Indicator	Mean	Median	Minimum	Maximum
CCR efficiency	0.74	0.76	0.51	1.00
BCC efficiency	0.88	0.90	0.71	1.00
Scale efficiency	0.83	0.85	0.62	1.00
Meta-frontier technology gap ratio	0.79	0.81	0.55	1.00

Table 2. *Municipal efficiency scores and typologies (2015–2023)*

Municipality	CCR	BCC	Scale efficiency	Technology gap ratio (meta-frontier)	Typology
Benidorm	1.00	1.00	1.00	1.00	Coastal mass tourism hub
Peñíscola	0.95	0.98	0.97	0.93	Coastal consolidated
Valencia	0.91	0.97	0.94	0.90	Urban diversified
Alicante	0.89	0.95	0.93	0.88	Urban–coastal
Gandia	0.85	0.93	0.91	0.86	Coastal consolidated
Dénia	0.83	0.92	0.90	0.85	Coastal gastronomy/mixed
Benicàssim	0.80	0.90	0.89	0.84	Event-driven coastal
Altea	0.78	0.89	0.88	0.82	Coastal cultural
Castelló de la Plana	0.76	0.88	0.86	0.78	Urban secondary
Elche	0.74	0.87	0.85	0.77	Urban cultural
Calp	0.73	0.86	0.85	0.80	Coastal mixed
Torrevieja	0.70	0.84	0.83	0.76	Coastal residential
Morella	0.69	0.87	0.80	0.71	Inland heritage
Villena	0.66	0.85	0.78	0.69	Inland cultural
Requena	0.63	0.83	0.76	0.67	Inland wine tourism
Segorbe	0.61	0.82	0.74	0.64	Inland
Ayora	0.58	0.81	0.72	0.61	Inland rural
Cofrentes	0.56	0.80	0.70	0.60	Inland thermal/nature
Zorita del Maestrazgo	0.52	0.79	0.66	0.57	Depopulated inland

Table 3. ***Inputs, desirable outputs, and undesirable outputs used in the DEA model (2015–2023)***

Variable	Type	Definition	Unit	Mean	Min	Max
Bedplaces	Input	Total regulated accommodation capacity (hotels, apartments, campsites, rural lodgings)	Number of bedplaces	17,850	1200	70,000
Tourism employment	Input	Employment in accommodation and hospitality (NACE Rev. 2: I55–I56)	Workers (annual avg.)	1380	85	9200
Accommodation diversification index	Input	Entropy-based index of lodging type distribution (0 = concentrated; 1 = fully diversified)	Index (0–1)	0.54	0.22	0.88
Overnight stays	Desirable output	Total annual overnight stays by visitors in regulated accommodation	Number of nights	2,750,000	120,000	11,500,000
RevPAR	Desirable output	Revenue per available room (ADR × occupancy) in regulated accommodation	Euros (€)	58.4	32.1	112.7
CO_2 emissions per overnight stay	Undesirable output	Estimated carbon emissions per tourist-night (accommodation + mobility factors)	kg CO_2 per overnight	7.3	4.0	15.2

Table 4. ***Malmquist productivity index and decomposition (2015–2023)***

Municipality	MPI	Efficiency change	Technological change	Pure technical change	Scale change
Valencia	1.05	1.02	1.03	1.01	1.01
Benidorm	1.03	1.00	1.03	1.00	1.00
Peñíscola	1.04	1.01	1.03	1.00	1.01
Alicante	1.01	1.00	1.01	1.00	1.00
Gandia	0.97	0.99	0.98	0.99	0.99
Dénia	0.98	0.99	0.99	0.99	1.00
Benicàssim	0.96	0.98	0.98	0.99	0.99
Altea	0.95	0.98	0.97	0.99	0.98
Castelló de la Plana	0.94	0.97	0.97	0.98	0.99
Elche	0.94	0.96	0.98	0.97	0.99
Calp	0.93	0.96	0.97	0.97	0.99
Torrevieja	0.92	0.95	0.97	0.96	0.98
Morella	0.93	0.98	0.95	0.99	0.99
Villena	0.91	0.95	0.96	0.97	0.98
Requena	0.90	0.95	0.95	0.98	0.97
Segorbe	0.89	0.95	0.94	0.98	0.97
Ayora	0.88	0.94	0.94	0.97	0.97
Cofrentes	0.87	0.94	0.93	0.97	0.97
Zorita del Maestrazgo	0.86	0.93	0.93	0.97	0.96

Table 5. *Average efficiency scores by tourism typology (2015–2023)*

Typology	CCR efficiency	BCC efficiency	Scale efficiency	Technology gap ratio (meta-frontier)
Coastal mass tourism hubs	0.95	0.99	0.97	0.96
Urban diversified destinations	0.88	0.96	0.92	0.90
Coastal consolidated	0.83	0.92	0.90	0.86
Coastal cultural/event driven	0.80	0.89	0.88	0.84
Inland cultural/heritage	0.67	0.85	0.78	0.70
Depopulated rural inland	0.56	0.81	0.69	0.63

Fig. 1. *Relationship between overall technical efficiency (CCR) and pure technical efficiency (BCC) for the analyzed municipalities, illustrating the role of scale effects in explaining efficiency differentials cross destination types, 2015–2023*

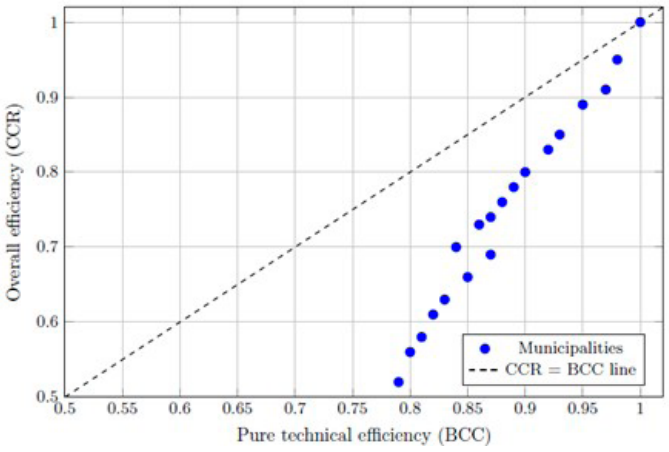


Fig. 2. *Productivity trajectories by municipal tourism typology based on the Malmquist productivity index (MPI), showing differential impacts of the COVID-19 shock and heterogeneous postpandemic recovery patterns over the period 2015–2023*

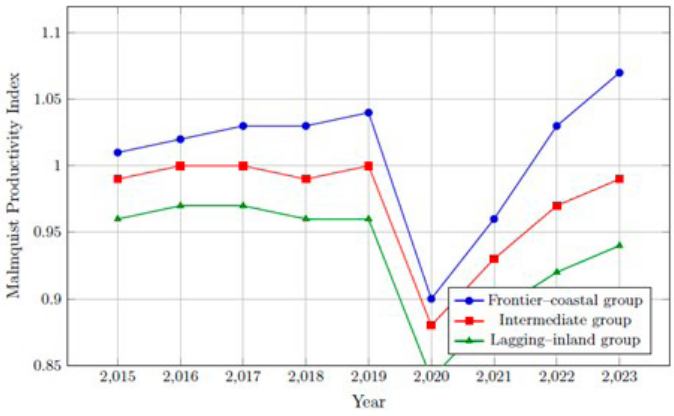
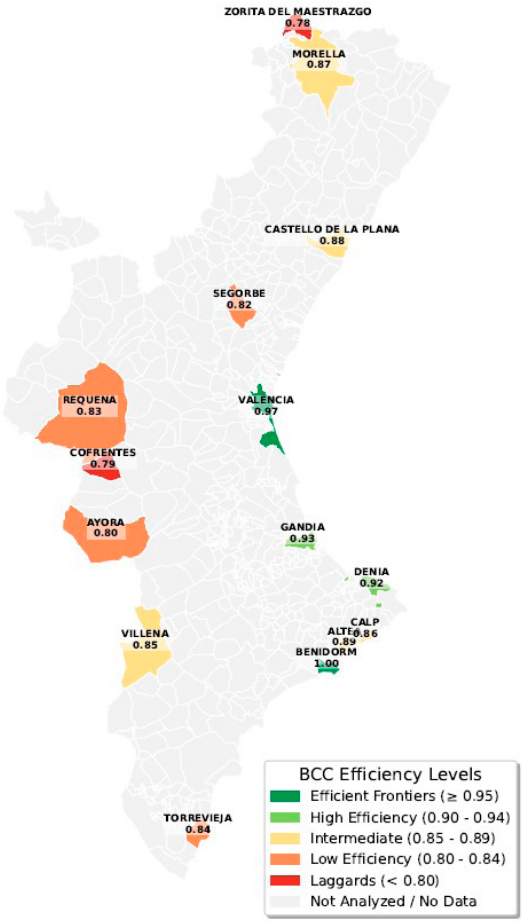


Fig. 3. *Spatial distribution of average BCC efficiency scores at the municipal level (2015–2023), highlighting the contrast between high-efficiency coastal corridors and structurally constrained inland areas*



6. Results

The empirical results reveal a tourism accommodation system characterized by clear territorial asymmetries and structurally differentiated performance patterns across the Valencian Community. Figure 1 illustrates the relationship between overall and pure technical efficiency, showing that a substantial share of the efficiency gap observed in inland and secondary destinations is explained by scale effects rather than by managerial inefficiency. Coastal destinations consistently record the highest efficiency levels, with municipalities such as Benidorm, Peñíscola, and Alicante approaching the BCC frontier (0.95–1.00 according to Table 2), reflecting a long-standing process of accommodation consolidation, dense supply structures, and strong integration within international tourism markets. These municipalities also display stable scale conditions, indicating that their efficiency derives from both managerial practices and advantageous structural endowments.

Urban destinations, particularly Valencia and Alicante, achieve high pure technical efficiency but lower scale efficiency than coastal hubs. This pattern is consistent with their multifunctional character, where tourism coexists with residential, administrative, and cultural functions, limiting the potential to match the scale advantages observed in mass-tourism municipalities. Their BCC scores (0.95–0.97) and intermediate technology gap ratio (TGR) values confirm that they operate close to the group frontier but remain below the regional technological potential.

The contrast with inland destinations is pronounced. Municipalities such as Morella, Requena, or Cofrentes exhibit solid managerial efficiency, yet their overall CCR scores remain substantially lower (range 0.55–0.70), reflecting structural constraints including low accommodation density, weaker market visibility, and limited accessibility. The meta-frontier analysis reinforces this interpretation: Inland municipalities display significantly lower TGR values, indicating that their performance is bounded by a production technology inherently different from that of coastal or urban systems. This confirms that efficiency disparities in the region stem not merely from managerial differences but from deeper structural asymmetries shaped by geography, demographics, and market integration.

Environmental performance adds an additional layer of differentiation. The inclusion of CO_2 emissions per overnight stay as an undesirable output reveals that coastal destinations, despite their high economic efficiency, bear proportionally higher environmental burdens due to visitor concentration and carbon-intensive mobility patterns. Inland destinations, although less competitive in economic and scale terms, emit substantially less per overnight stay, reflecting their lower densities and more spatially dispersed demand profiles. This finding underlines that economic and environmental performance do not necessarily move in parallel and that efficiency interpretations must account for these trade-offs.

Figure 2 depicts the evolution of productivity across municipal typological groups, clearly capturing both the magnitude of the COVID-19 shock in 2020 and the asymmetric recovery observed between coastal, urban, and inland destinations. The dynamic analysis using the Malmquist productivity index (Table 4; Fig. 2) shows a sharp productivity contraction in 2020, driven by technological regress associated with the collapse of international travel during the COVID-19 pandemic. The subsequent recovery is markedly uneven. Coastal and urban destinations exhibit faster rebounds, with Valencia, Peñíscola, and Benidorm surpassing pre-pandemic productivity levels by 2023 (MPI values > 1.03). Their recovery reflects the accelerated adoption of digital distribution tools, the rapid return of international markets and the presence of large accommodation units capable of internalizing technological improvements. Inland municipalities recover more slowly, with MPI values remaining below unity throughout most of the period, indicating persistent technological stagnation.

The spatial dimension of these efficiency patterns is presented in Fig. 3, which reveals a continuous corridor of high-efficiency municipalities along the coast versus a markedly more fragmented and lower-efficiency pattern in the inland area. These spatial patterns reinforce the aforementioned tendencies. A continuous corridor of high-efficiency coastal municipalities extends along the Costa Blanca and Costa de Azahar, while the interior reveals a fragmented mosaic of moderate to low efficiency, punctuated only by isolated heritage-led cases such as Morella. These spatial outcomes mirror historical development trajectories and the concentration of tourism infrastructure along the coastline.

Finally, the second-stage bootstrap regression confirms the structural origins of these disparities. Accessibility, tourism density, and the share of international visitors emerge as statistically significant drivers of efficiency, whereas inland location and low accommodation diversification exert negative effects. These results demonstrate that the observed efficiency patterns are rooted in territorial structures rather than in short-term operational decisions.

Overall, the results depict a tourism accommodation system defined by robust coastal performance, multifunctional urban behavior, structurally constrained inland dynamics, environmental trade-offs, and asymmetric postpandemic recovery trajectories. Together, these findings provide a coherent empirical foundation for the interpretive and policy-oriented analysis developed in the following discussion section.

7. Discussion

The results presented in the previous section portray a tourism accommodation system characterized by deep and persistent territorial asymmetries. These findings confirm the long-standing configuration of the Valencian Community as a region where tourism competitiveness is strongly shaped by geography, accessibility, and structural concentration. Coastal destinations consistently achieve the highest efficiency levels, reflecting the cumulative effects of decades

of accommodation consolidation, sustained international demand, and an infrastructure network that favors high-density tourism. Municipalities such as Benidorm, Peñíscola, and Alicante operate close to the global frontier, and their BCC scores illustrate the combination of managerial capability and structural advantage that defines the most competitive regional nodes.

Urban destinations, especially Valencia, follow a different pattern. Their high pure technical efficiency demonstrates strong managerial performance and an ability to convert accommodation capacity into measurable outputs. At the same time, their lower scale efficiency relative to coastal hubs reflects the inherent multifunctionality of urban systems: tourism coexists with residential, cultural, and administrative functions, limiting the extent to which cities can replicate the scale conditions of mass-tourism resorts. This duality explains why urban destinations approach the group frontier but fall short of the meta-frontier, highlighting the structural nature of their technological gap.

Inland municipalities present the clearest expression of structural constraint. Morella, Requena, Cofrentes, and other rural destinations achieve comparatively strong managerial performance but remain unable to overcome limitations in accommodation density, market reach, and accessibility. Their position far from the meta-frontier is not the result of managerial shortcomings; rather, it reflects an underlying production technology defined by sparse settlement patterns, demographic decline, and limited exposure to international demand. These findings are consistent with broader European evidence indicating that structurally peripheral tourism regions face persistent technological disadvantages that are difficult to offset through incremental interventions alone.

The introduction of CO_2 emissions as an undesirable output offers additional insight into these structural differences. Coastal destinations, despite their economic strength, bear a disproportionate share of the region's environmental externalities. High visitor densities, international transport dependence, and intensive accommodation infrastructures combine to elevate per-night emissions. Inland areas, in contrast, display a more favorable environmental profile, largely because their tourism flows are less concentrated and their mobility patterns less carbon-intensive. These results emphasize that economic and environmental efficiency do not evolve in parallel and that destination competitiveness must increasingly be interpreted through a sustainability lens.

The dynamic analysis deepens this picture. The sharp decline in productivity in 2020 reflects the systemic vulnerability of Mediterranean tourism to global shocks, yet the subsequent trajectory is far from uniform. Coastal and urban destinations recover rapidly and, by 2023, surpass pre-pandemic productivity levels, benefiting from the return of international markets, faster digital adaptation, and scale advantages in accommodation management. Inland destinations, however, experience a sluggish and incomplete recovery, indicating that the pandemic not only depressed performance temporarily but also widened pre-existing technological gaps. The MPI evidence suggests that incremental improvements are insufficient for structurally constrained areas and that shocks may exacerbate long-term divergence across the regional tourism system.

The second-stage bootstrap regression reinforces these interpretations. The significance of accessibility, tourism density, and the proportion of international visitors highlights the importance of structural and market-related determinants of efficiency. Municipalities with diversified accommodation structures, strong transport connections, and higher international exposure systematically achieve better performance. Conversely, inland location and limited diversification are associated with lower efficiency, demonstrating that tourism performance in the region cannot be explained solely by managerial behavior but is deeply embedded in territorial configurations.

Taken together, these findings reveal a tourism system characterized by a double asymmetry. Economically, the coast and major cities dominate regional performance, while inland areas operate under structural and technological constraints. Environmentally, high-intensity destinations face greater externalities, even when they perform well economically. Understanding this duality is essential for designing policies that balance competitiveness with sustainability. The evidence suggests that policy interventions must be territorially differentiated. Coastal hubs require strategies aimed at reducing environmental pressure and strengthening resilience to shocks, while urban destinations would benefit from approaches that align tourism development with broader urban planning objectives. Inland municipalities, meanwhile, need targeted policies that improve accessibility, promote product diversification, and enhance linkages with coastal demand flows.

Overall, the discussion underscores that tourism accommodation efficiency in the Valencian Community is not merely a function of managerial practices or operational choices. It is the outcome of long-term territorial development, infrastructure patterns, market dynamics, and environmental constraints. By combining DEA, meta-frontier analysis, dynamic productivity assessment, and environmental indicators, this study provides a nuanced and comprehensive interpretation of tourism efficiency that aligns with the structural realities of Mediterranean destinations and contributes to broader debates on sustainable regional tourism development.

The faster postpandemic recovery observed in coastal and urban destinations is also consistent with broader trends in digital transformation within the tourism sector, including the adoption of digital distribution channels, data-driven pricing, and platform-based demand management.

8. Conclusions

This study provides a comprehensive assessment of tourism accommodation efficiency in the Valencian Community (Spain), revealing a system shaped by persistent territorial asymmetries and structurally differentiated production technologies. The integration of DEA with a meta-frontier specification, the Malmquist productivity index, and an environmental undesirable output offers a nuanced interpretation of how municipalities convert accommodation capacity, labor resources, and demand patterns into measurable tourism outcomes. The results consistently show that coastal municipalities perform closest to the global frontier, supported by dense accommodation structures, established international markets, and a long trajectory of tourism consolidation. Urban destinations also achieve high performance, although their multifunctional role within regional economies limits their ability to reach the scale conditions characteristic of coastal hubs. Inland municipalities, by contrast, demonstrate solid managerial efficiency but remain constrained by structural factors such as limited accessibility, demographic pressures, and reduced accommodation density, which distance them from both the group and meta-frontiers.

The analysis of CO_2 emissions highlights an important dimension of these territorial contrasts. High-intensity coastal destinations exhibit stronger economic performance but face proportionally higher environmental burdens, while inland municipalities show a more favorable environmental profile despite their lower efficiency levels. This divergence reflects a structural trade-off between economic and environmental performance that has become increasingly relevant in mature Mediterranean destinations. The dynamic analysis reinforces these conclusions. The COVID-19 pandemic generated a sharp contraction in productivity, but the subsequent recovery was uneven: Coastal and urban destinations adapted quickly and surpassed pre-pandemic productivity levels by 2023, whereas inland areas recovered slowly, deepening existing technological gaps.

These findings carry clear policy implications. Efforts to enhance tourism efficiency in the region must recognize the territorial foundations of performance. Coastal destinations, while economically strong, require policies aimed at reducing environmental pressure, promoting sustainable mobility, and strengthening resilience to external shocks. Urban destinations would benefit from measures aligning tourism development with broader urban planning objectives, particularly regarding accommodation distribution and visitor management. Inland municipalities require targeted interventions that improve accessibility, support the diversification of tourism products, and reinforce connections with coastal markets. The consistent influence of accessibility, market composition, and accommodation diversification on performance underscores that structural transformation—rather than short-term managerial adjustments—is essential for reducing regional disparities.

The study has certain limitations. The analysis focuses on regulated accommodation, excluding informal or peer-to-peer supply, which may influence demand distribution in specific areas. Environmental indicators rely on aggregated emission coefficients that cannot capture all intra-municipal variations. The study also does not incorporate behavioral variables such as visitor satisfaction or digital reputation, which may affect performance trajectories. These limitations point to several avenues for future research. Further studies could integrate water use, waste generation, or land-use intensity into environmental DEA models, incorporate spatial econometric techniques to account for spillover effects, or apply stochastic frontier or agent-based approaches to simulate how technological or regulatory changes reshape efficiency patterns over time. Comparative analyses with other Mediterranean regions would also help contextualize the specificity of the Valencian case.

From a methodological perspective, the main contribution of this study lies in the integrated application of meta-frontier DEA, dynamic Malmquist productivity analysis and environmentally adjusted efficiency assessment at the municipal level, allowing tourism performance to be evaluated simultaneously across territorial, technological, and sustainability dimensions.

Overall, the findings demonstrate that tourism accommodation efficiency in the Valencian Community is determined not only by managerial practices but, more fundamentally, by territory, infrastructure, market integration, and environmental vulnerability. By combining frontier modelling with territorial and sustainability perspectives, this study contributes to a more comprehensive understanding of regional tourism performance and offers a replicable framework for guiding evidence-based strategies in mature coastal destinations facing similar competitive and ecological pressures.

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