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Analysing productivity and technical change in museums: A dynamic network approach

María José del Barrio Tellado[1]
Luis César Herrero Prieto[2]

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Resumo

A avaliação da eficiência das instituições culturais vem se mostrando uma área muito fértil para pesquisas teóricas e aplicadas. No entanto, até o momento, poucos estudos se concentraram na análise dinâmica da eficiência e na estimativa da produtividade para medir a sensibilidade dessas instituições ao progresso tecnológico. Este artigo fornece uma abordagem a esses dois objetivos para uma amostra de museus públicos na Espanha, aplicando técnicas não paramétricas, como o modelo Dynamic-Network DEA, e calculando os índices dinâmicos de Malmquist correspondentes. Isso implica propor uma função de produção desagregada em etapas produtivas e intervalos de tempo, com insumos inter-relacionados horizontalmente (links) e verticalmente (carry-overs). Os resultados mostram que a produtividade dos museus permanece praticamente estável por um longo período de tempo, o que confirma parcialmente a hipótese da doença do custo de Baumol adaptada aos museus. No entanto, a decomposição dos índices em efeitos catch-up e frontier-shift revela um crescimento substancial da produtividade na fase de criação da oferta cultural, devido a um deslocamento da fronteira de resultados, bem como melhorias significativas na eficiência dos museus na fase de prestação de serviços que visem atrair visitantes. Isso também reflete uma mudança nas prioridades de gestão dos museus, onde os objetivos relacionados à visibilidade e divulgação e atividades de impacto social assumem especial importância.

Palavras-chave: Economia de museus, avaliação de eficiência; Dynamic Network DEA.

Resumen

La evaluación de la eficiencia de las instituciones culturales está demostrando ser un área muy fértil para la investigación teórica y aplicada. Sin embargo, hasta ahora pocos estudios se han centrado en el análisis dinámico de la eficiencia y en la estimación de la productividad

[1] Department of Accounting and Finance. University of Valladolid, Spain.

[2] Department of Applied Economics. University of Valladolid, Spain.

para medir la sensibilidad de estas instituciones al progreso tecnológico. El presente trabajo proporciona una aproximación a estos dos objetivos para una muestra de museos públicos en España aplicando técnicas no paramétricas como el modelo Dynamic-Network DEA, y calculando los correspondientes índices dinámicos de Malmquist. Esto implica plantear una función de producción desagregada en etaàs productivas e intervalos de tiempo, con inputs interrelacionados horizontalmente (links) y verticalmente (carry-overs). Los resultados muestran que la productividad de los museos se mantiene prácticamente estable durante un largo periodo de tiempo, lo que confirma en parte la hipótesis de la enfermedad de costes de Baumol adaptada a los museos. No obstante, la descomposición de los índices en efectos catch-up y shift-frontera revela un crecimiento sustancial de la productividad en la etapa de creación de la oferta cultural, debido a un desplazamiento de la frontera de resultados, así como mejoras significativas en la eficiencia de los museos en la etapa de prestación de servicios orientados a la atracción de visitantes. Esto también refleja un cambio en las prioridades de gestión de los museos, donde los objetivos relacionados con la visibilidad y las actividades de difusión e impacto social cobran especial importancia..

Palabras clave: Economía de los museos, evaluación de la eficiencia, Dynamic Network DEA.

Abstract

The efficiency evaluation of cultural institutions is proving to be a highly fertile area for theoretical and applied research. Nevertheless, few studies have thus far focused on the dynamic analysis of efficiency and on estimating productivity to gauge how receptive these institutions are to technological progress. The present work provides an approach to these two goals for a sample of public museums in Spain by applying a non-parametric technique, the dynamic-network DEA model, and by calculating the corresponding dynamic Malmquist indices. This involves positing a production function broken down into production activities and time intervals, with inputs that are inter-related horizontally (production links) and vertically (time carry-overs). Results show that museum productivity remains practically stable over a long period of time, thus partly confirming the hypothesis of Baumol's cost disease adapted to these activities. Nevertheless, breaking down the indices into catch-up and shift-frontier effects reveals substantial growth in productivity at the stage involving the creation of the cultural supply, due to a displacement of the results frontier as well as significant improvements in museum efficiency at the stage involving the provision of services geared towards attracting visitors. This also reflects a change in museums' functional priorities, where the goals related to visibility and activities involving dissemination and social impact prove to be particularly important.

Keywords: Economics of museums, efficiency evaluation, Dynamic Network DEA.

1. Introduction

Museums are one of the most representative cultural institutions, and their mission involves preserving, collecting, researching, and disseminating cultural heritage which tends to be difficult to express through real outcomes in the market. Nevertheless, works addressing the performance evaluation of museums have recently given rise to abundant literature [1]–[7], proving the usefulness of analysing the accountability of these public institutions. However, few studies have thus far focused on the dynamic analysis of efficiency and on estimating productivity over time [8], [9]. This is interesting for the analytical purpose of appraising how sensitive museums are to technological change and how they are able to incorporate innovations that might affect their long-term production structure. Productivity studies in the field of culture are primarily based on Baumol and Bowen [10], whose cost disease hypothesis can be adapted from the performing arts to cultural heritage institutions, since these are likewise eminently labour-intensive activities that involve an intrinsic cultural capital that is unique and therefore irreplaceable, at least in its prime version. Consequently, the inherent rise in costs cannot be offset by significant gains in productivity, which inevitably leads to the economic impasse of these activities if no alternative revenue is available by increasing prices or securing funding.

Nevertheless, it is true that ongoing improvements in the area of information and communication technologies and innovations in the digital economy are having a major impact in the cultural sector, and particularly in the field of cultural heritage [11]. These innovations not only affect both how and how easily demand for access to cultural goods may be gained as well as improvements in certain management and maintenance processes related to cultural resources, but might also provide the foundation for new cultural products and therefore new audiences [12]. Technology and innovation can ultimately modify the scope and mission of cultural heritage institutions because new sources of economic and cultural value and new business models are emerging, and where, in the case of museums, the functions of education and dissemination are increasingly valued as well as their institutional visibility [13].

2. Research aim

The main research aim is to analyse the efficiency of a sample of state-owned museums over time as a way of estimating their productivity and gauging how permeable these institutions are to technological progress. We implement a production function broken down into various production stages and time intervals. This approach is very appropriate for cultural institutions such as museums, since first we are able to distinguish between activities that are under managerial control (cultural production) and services that depend on public willingness (attracting visitors); and second, we can consider permanent resources acting as carry-overs over time, such as the artistic collection and the museum building themselves. Non-parametric techniques are applied, specifically the dynamic-network data envelopment analysis (DN-DEA) [14], [15], to estimate efficiency indicators by stage and by intervals. Additionally, the dynamic Malmquist indicators and their breakdown into catch-up and frontier-shift effects are calculated to analyse museum productivity and to determine what might cause variations due to improvements in efficiency or a displacement in the results frontier. The empirical application is focused on a Spanish sample of state-owned museums, which represent the purest and most accredited fine-arts and archaeological museums in the country, over an ample time period (2008-2015). To the best of our knowledge, this is the first time that this complex approach with vertical and horizontal inter-reliant inputs has been applied to museums. Our purpose is not to evaluate how a specific innovation affects museum efficiency in the long term but to estimate productivity over time, on the basis of a multi-output production function, where new facilities and equipment have been integrated. The limitations of adopting such an approach have also been highlighted.

3. Literature Review

Research on evaluating museums' efficiency has grown enormously, adopting different methodological approaches[3] and analysing numerous case studies such as museums in Italy [2], [6], [9], Spain [4], [5], [8], Belgium [1], Iran [7] and many other countries. Most of these studies posit a scenario in which an ample array of inputs is used to generate multiple outputs,

[3] See [39] for different analytical perspectives on the efficiency assessment of cultural institutions, as well as [40] specifically for museum behavior analysis.

consistent with the diversity of tasks usually assigned to these institutions. They manage a unidirectional production function between resources and outcomes, without distinguishing the degree control of different activities carried out by the museums or over time. This makes it impossible to determine separately the degree to which the entity's different objectives are being achieved. It also makes disentangling the roots of inefficiency throughout the production process a more difficult task.

The work by Mairesse and Vanden Eeckaut [1] might be seen as the first attempt to open up the black box of the production function and to uncover how museums undertake their activities, as well as identify the resources used and the products obtained in each of these activities. This study identifies three activities to be carried out by museums: Conservation, research, and communication, and their impact on the public. Each one of these activities consumes and produces different inputs and outputs, with the aim being to evaluate the performance of each museum independently for each activity. Nevertheless, this approach overlooks the existence of interrelations between the different activities carried out in the museum. There are no links between functions in the form of interrelated inputs and, moreover, there is no global efficiency indicator for each entity, only by groups of functions.

Following a similar line to the above, for different samples of Italian museums Basso et al. [3] and Basso and Funari [16] propose four independent DEA models for each of the four perspectives analysed on a balanced scorecard (BSC). During the second stage, these partial indicators are combined to obtain a global efficiency indicator for each institution. In this case, the aim is not so much to analyse the way in which the processes are carried out at the institution taking into account their time sequence and interrelations, but rather to gauge the efficiency with which the production process of cultural services in museums is undertaken from different perspectives in terms of management.

Some subsequent works have focused their attention on how the production process is carried out in museums, identifying the sequence in which the activities are conducted at the institution and the existence of intermediate outputs of an activity that are included as inputs in a subsequent activity. One example is del Barrio-Tellado and Herrero-Prieto [17], who identify a two-stage production function to examine the performance of a group of Spanish public museums. During the first stage, the entities consume economic resources to generate the institution's cultural offer, whilst during the second stage, the scheduled services become an intermediate input in the process for obtaining the final output, which is measured in terms

of visitor numbers. This approach allows for an evaluation of an initial process geared purely towards running the entity, whilst the second stage evaluates the provision of the service in conditions that are partially beyond managerial control, since they require the decided will of the public to participate therein [18]. Here, a network-DEA model is used [19], [20], [21], which allows the causes of inefficiency to be clarified by providing global performance indicators and by stages. The production scheme in stages is also taken as a reference in the work of Guccio et al. [6]. Here, however, the goal focuses on evaluating performance only at the stage in which the cultural offer is put together, seeking to gauge what effects certain contextual variables related to potential demand for services and museum governance have on efficiency during this first stage.

Within this array of works, few studies have included a dynamic perspective in museum efficiency analysis. Mairesse and Vanden Eeckaut [1] highlight the suitability of window analysis since museums tend to schedule activities over a number of years, which points to the appropriateness of taking intervals that gradually shift as a time reference. Other works [8], [9] have measured total factor productivity over a time period using Malmquist indices, and their breakdown into changes brought about by technological progress that shift the optimum (frontier technique) or through improvements in management (approaching the optimum). Nevertheless, these approaches do evidence certain limitations. Firstly, they consider all of the inputs as annual consumables, overlooking the fact that some inputs, particularly in the case of museums housing art collections or regarding museum facilities, are not fully consumed during each year but are permanent over time and that, far from diminishing, they actually increase thanks to new acquisitions, contributions, or investments. Secondly, calculating productivity for a period of the complete production function does not allow for any distinction to be drawn between the contrasting performance of the various stages of the production process. Finally, efficiency analysis for consecutive years involves constantly reconsidering the production frontier so as to adapt it to the informative structure of each year. As a result, there may be discrepancies between efficiency improvements and productive changes that affect the optimal frontier, and that need to be considered.

Our work seeks to overcome these difficulties by applying a DN-DEA model [14], [15], which considers the internal structure of entities divided into stages with inter-reliant inputs, as well as the existence of permanent dynamic resources that link the activity carried out in different periods of time. This model generates efficiency indices for each activity and each period, as well as a calculation of productivity through the dynamic Malmquist indices, and

their breakdown into changes in the optimum (frontier-shift) or improvements in the specific efficiency of the institutions (catch-up effects). The limitations of the DN-DEA model with dynamic Malmquist indices are basically related to the problem of dimensionality [22], which means that we should not increase the number of variables too much (inputs and outputs) in order to ensure the discriminatory power of the results. To the best of our knowledge this model has not been used yet to evaluate efficiency of cultural institutions, except for the case of libraries[23]. Other works have evaluated museums [17], dance companies [24], and archives [25] using a network-DEA model but without a dynamic approach.

4. Method and Material

4.1. Methodological Approach

Our aim is to analyse how performance develops and to measure the productivity of a group of museums over an eight-year time span (2008–2015). To do this, as a reference we take a production function that seeks to model the activities carried out by these entities over time. This first involves considering that there are two stages in a museum's production process and provision of services that may be distinguished; one concerned with putting together and managing the offer of culture, which is under the control of those responsible for the institution, and the second involving the public impact, which partly depends on visitors' decisions to visit the museum. Secondly, it should be remembered that the outcomes from the first stage constitute the resources used in the second, acting as intermediate inputs or links. Finally, there are certain capital elements that are not exhausted, but that remain over time and which make up the primary base of museums' existence as cultural institutions.

Figure 1. Museum production function for a multi-stage and multi-interval approach.

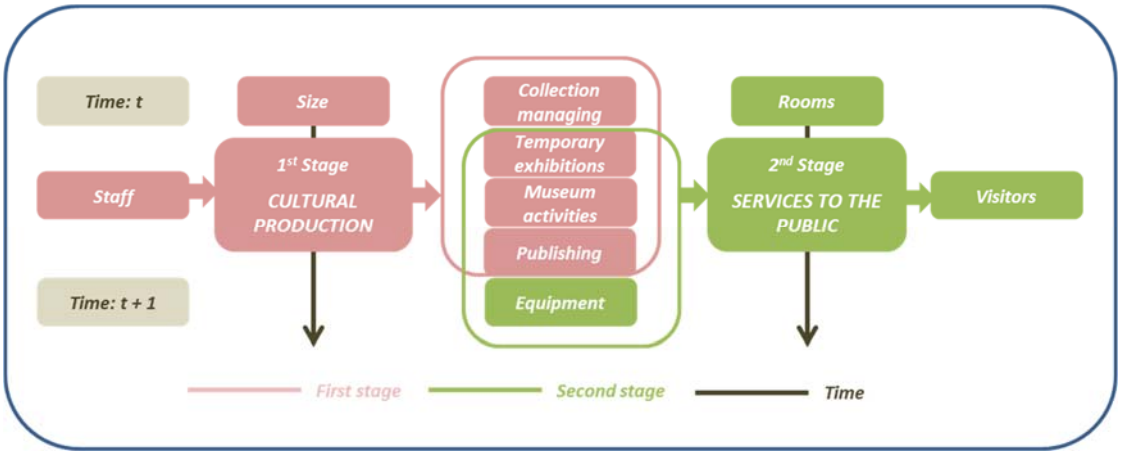

Figure 1 provides a schematic representation of museums' production function following the previously mentioned analytical approach, which is now explained in detail. During the first stage, museums have work and capital resources available to schedule a series of activities linked to the institution's aims. Work resources correspond to the services provided by the employees and represent an input that is consumed each year. Capital resources correspond to the art collection and to the museum building itself and constitute the main basis of the museum's cultural heritage, perceived as an asset. These resources are not consumed each year but remain over an indefinite period of time so that the institution's aims can be met. Moreover, these are also protected goods that are not freely available and that might therefore see new incorporations (acquisitions, recompilations, donations) or an updating of the principal capital equipment (reforms or extensions to the building). Since it is difficult to objectivize and standardize the value of the art collection, which is fundamentally diverse in its nature and theme due to the multiplicity of museums, we will simplify the value of the capital endowment through the size of the museum in terms of surface area. This operative solution is applied in numerous studies [2], [4], [8] since it constitutes a representative measure of the building's magnitude, which on many occasions is an emblematic historical monument, and it provides an indirect measure of the scope of the collection[4]. This cultural capital is considered as carry-over because, as pointed out, it is not consumed in a year but remains over time. Finally, these work and capital resources are used to create the cultural production of museums and which is reflected in various outputs, namely: Number of temporary exhibitions scheduled, publications (guides, catalogues, dissemination material, research articles), various museum activities (educational workshops, conferences, concerts, and seminars), and finally activities involving the management of the

[4] Quantitative measurement of a museum's cultural value remains one of the challenges facing economic analysis. It cannot be confined to the number of exhibits in the collection, given the disperse nature thereof, nor is it possible to consider qualitative external evaluations, since these tend to be applied to the collection as a whole and fail to draw any distinction between the various pieces. Indeed, cultural value might only prove possible by estimating stated preferences through the contingent valuation method or even following tourist valuation standards (TripAdvisor and so on) that would surely tip the balance towards collections that are better known or more accessible to tourists. However, positing any such technique or approach would fall well outside the scope of the present research. We therefore assume that indicators of museum size tend to be linked to the museum's importance or to the historical value of the building where it is housed, such that these are then taken as a proxy of the cultural value.

collections (incorporations, loans to other institutions, new acquisitions) which also act as a proxy of the impact and scope of the cultural collection itself.

All of these intermediate outputs are linked to the main functions of museums such as conservation, research, training, dissemination and exhibiting the art collection, and they are directly associated to the tasks of museum management during the first stage. Nevertheless, the first three results (exhibitions, publications, and activities) make up the cultural production that is actually geared towards attracting visitors and that can be seen as intermediate inputs (links) during a second production process that is also associated with the function of exhibiting and disseminating, yet which lies outside managerial control, since it depends on the decisions of the public who visit the museums. During this stage, the museum's facilities are used as an additional capital resource, with many of these facilities being linked to complementary visitor services (gift shop, audio-guide, audiovisual means, web, etc.). This new equipment is taken as new input in the second stage of the production function. Finally, we consider another capital resource, the number of rooms open to the public, which also acts as an indicator of the scale of the works on display and of the magnitude of the museum. This variable is included in the model in the same terms as the size of the museum in the first stage; in other words, as a dynamic endowment resource, namely a carry-over, since in both instances, its permanence over time is guaranteed.

On the basis of this approach for the museum production function, we apply a DN-DEA method which was pioneered by Bogetoft et al. [14], based on the dynamic approaches of the production function of Färe and Grosskopf [26], [19] and Cook et al. [21]. We specifically follow the non-radial SBM (slacks-based-measure) DN-DEA model proposed by Tone and Tsutsui [15] that does not therefore require proportional changes in inputs and outputs, which fits in well with the hypothesis of the production structure of museums as a case study, while offering a measure of strong efficiency by including the information relative to the slacks in the efficiency indices. We particularly consider a technological hypothesis of constant returns to scale and a non-oriented model[5], which takes into account excesses in inputs as well as

[5] Constant returns to scale is usually applied as the hypothesis for evaluating cultural institutions [2] [17] [7], as this gives rise to a stricter range of efficiency scores. Our sample is also very homogeneous in terms of museum size (once we have removed star-museums and so-called house-museums), such that we then find this technical hypothesis more appropriate. We also take a uniform non-oriented model to allow managers to

defects in outputs. In our application, we assume the equal weighting hypothesis, both for the stages of the production functions as well as for the time periods considered[6].

The mathematical development of this model can be consulted in Tone and Tsutsui [15]. The calculations for the empirical application studied were carried out with the DEA-SOLVER-PRO version 14.0 program. Applying the program provides an index of global efficiency (ρ_o^*) for each museum o ($o = 1, \dots, n$), taking the value of 1 for efficient units and a value of below 1 for those operating below the optimum level. The model also calculates the efficiency indices for each museum's activity k ($k = 1, \dots K$) from the production function (δ_{ok}^*), for each time period t ($t = 1, \dots, T$), (π_o^{t*}) and for each activity in each time period (ρ_{ok}^{t*}).

All of these efficiency ratios are measured in relative terms based on the optimal frontier of each period for each production stage and do not take into account possible frontier shift. As a result, it is not possible to ensure that an improvement in the efficiency ratios is always reflected in an increase in the productivity of the units over a given time interval, since there might be a shift in the technological frontier, for instance due to a recession that leads productivity to stagnate. Likewise, an extension of the production frontier brought about by technological changes might conceal less efficient behavior by the units over time. In this way, the Malmquist indices offer an extremely suitable tool, since they provide information regarding changes in total productivity of the factors involved in a production process, taking into account changes in efficiency as well as shifts in the technological frontier.

Following Caves et al. [27], it is possible to calculate the Malmquist productivity index (μ) using the efficiency indices shown in terms of distance, as the quotient of an institution's distance to the frontier in period t and that unit's distance to the frontier in period t+1. Applying the decomposition proposed by Färe et al. [28], changes in productivity brought about by changes in efficiency (catch-up term) (ϒ) are separated from those caused by technological change (frontier-shift) (σ), as follows:

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maximize outputs or minimize inputs in the first and second production stages, respectively, which seems to be the most reasonable, although other behaviours are also possible.

[6] Considering different weights for each stage should be well justified by experts on the subject, which is why we prefer an equal balance for both, and all the years should be valued the same because we wish to estimate productivity over natural periods of time.

$$\mu = \Upsilon \,.\, \sigma$$

Traditional Malmquist indices measure changes in productivity assuming a black-box production function, where neither the possible links between activities nor the dynamic capital resources interrelated over time are taken into account. It is not therefore possible to determine whether the different performance of the various stages into which we divide the production function can determine institutions' overall productivity or whether this is due to the unequal progress of efficiency during the time periods considered. We are thus able to define dynamic Malmquist indices linked to the DN-DEA model [29]; in other words, those that take into account inputs interrelated between activities involved in the production process and over time.

We can first calculate the part of the index that reflects the dynamic evolution of efficiency between two time periods (dynamic catch-up term) as follows [29]:

$$\Upsilon_{ok}^{t\to t+1} = \frac{\rho_{ok}^{t+1^*}}{\rho_{ok}^{t^*}}$$

$$(o = 1, \dots, n; k = 1, \dots, K; t = 1, \dots, T-1)$$

In other words, we calculate the changes in efficiency between two periods of time as the quotient between the efficiency index for each activity and time period at point *t*+1 ($\rho_{ok}^{t+1^*}$) and at point t ($\rho_{ok}^{t^*}$) . A value >1 for this index indicates improvements in efficiency between the two periods, whereas a value <1 implies reductions in efficiency.

We can also calculate the part of the index that shows the shift in the frontier (dynamic frontier-shift term) [29]:

$$\sigma_{ok}^{t\to t+1} = \left[\frac{\rho_{ok}^{t^*}}{\pi_{ok}^{t(t+1)}} \times \frac{\pi_{ok}^{t+1(t)}}{\rho_{ok}^{t+1^*}}\right]^{1/2}$$

$$(o = 1, \dots, n; k = 1, \dots, K; t = 1, \dots, T-1)$$

where $\pi_{ok}^{t(t+1)}$ and $\pi_{ok}^{t+1(t)}$ represent the efficiency indices for an SBM model for activity k of the entity or in period t evaluated with regard to the frontier at t+1 and for the same entity and activity at time *t*+1 with regard to the frontier at t. A value for this index >1 indicates the frontier has advanced, whilst a value <1 implies a recession in the technological frontier.

In this way, the dynamic Malmquist index for the entity or, in activity k, will be given by:

$$\mu_{ok}^{t\to t+1} = \Upsilon_{ok}^{t\to t+1} . \sigma_{ok}^{t\to t+1}$$

$$(o = 1, \dots, n; k = 1, \dots, K; t = 1, \dots, T-1)$$

Based on the dynamic indices for each activity, it is possible to determine the global dynamic index $\mu_o^{t\to t+1}$ as the geometric mean of the previous ones.

$$\mu_o^{t\to t+1} = \prod_{k=1}^{K} \left(\mu_{ok}^{t\to t+1}\right)^{w_k}$$

$$(o = 1, \dots, n; k = 1, \dots, K; t = 1, \dots, T-1)$$

where w_k represents the weight of activity k, such that $\sum_{k=1}^{K} w_k = 1$.

4.2. Case Study

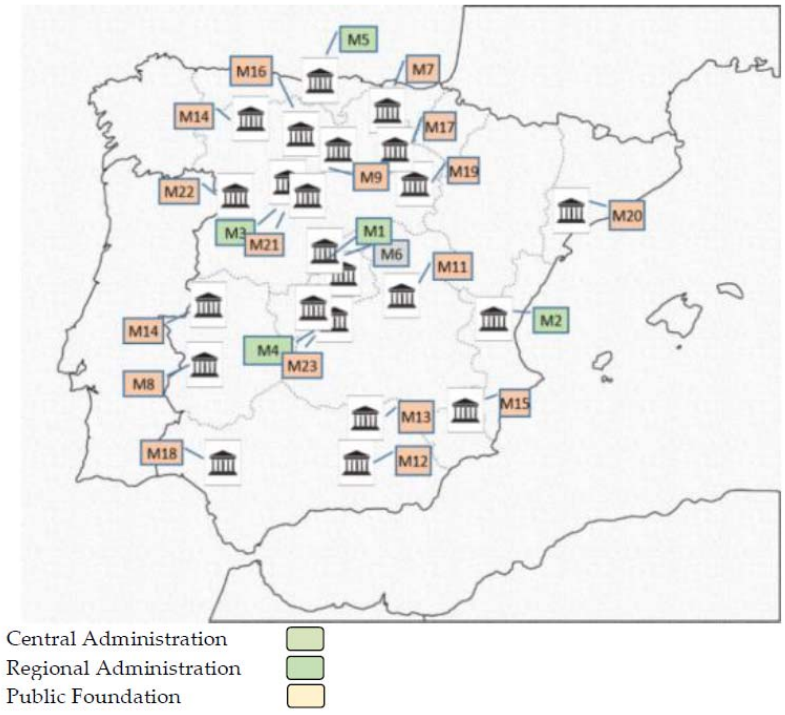
Considering the above methodological strategy, the case study involved in this present research consists of an institutional network of museums, the Spanish system of national museums, whose productivity we wish to measure and analyse over a period spanning from 2008 to 2015. All of these museums are owned by the state. On the one hand, they are made up of provincial museums, comprising the principal archaeological and fine arts collections at a provincial scale and mostly managed by the different regional governments, and on the other by so-called national museums, which emerged as a result of the specific nature and importance of their artistic collection and which embrace a certain thematic diversity. We exclude so-called house museums, dedicated to certain historical figures and that display a mainly ethnographical interest, as well as certain large and very well-known museums (the Prado National Museum and the Queen Sofia National Museum of Contemporary Art, for instance), which play a role as star museums and that might act as outliers in the sample. In all, the study is composed of a group of 50 museums, amongst which a survey was carried out, requesting information on the resources used and the main activities undertaken between 2008 and 2015. The survey and data gathered are available upon request from the authors of this research. Finally, answers were obtained from 23 representative museums of the whole sample and can be seen in Table 1 as well as in Figure 2, which deals with their location. In sum, this is a homogenous group of medium-size museums with a classical approach with regards to museum management, pursuing the missions of gathering, maintaining, studying, and disseminating the corresponding museum collection. Most of them are located in a wide range of provincial capitals, whose main aim has been to collect the archaeological, historical, and artistic remains at this territorial scale, whereas others, with a national brand, tend to have a more specific specialization.

Table 1. Museums in the sample.

Museum	Name	Location	Management(*)
M1	Museum of the National Library of Spain	Madrid	CA
M2	National Museum of Ceramics and Sumptuary Arts	Valencia	CA
M3	National Sculpture Museum	Valladolid	CA
M4	Sephardic Museum	Toledo	CA
M5	Altamira National Museum and Research Centre	Santillana del Mar (Cantabria)	CA
M6	Lázaro Galdiano Museum	Madrid	PF
M7	Álava Museum of Fine Arts	Vitoria-Gasteiz	RA
M8	Badajoz Provincial Museum of Archaeology	Badajoz	RA
M9	Burgos Museum	Burgos	RA
M10	Caceres Museum	Cáceres	RA
M11	Cuenca Museum	Cuenca	RA
M12	Casa de los Tiros Museum in Granada	Granada	RA
M13	Úbeda Archaeological Museum	Übeda (Jaen)	RA
M14	León Museum	León	RA
M15	Murcia Museum of Fine Arts	Murcia	RA
M16	Palencia Museu	Palencia	RA
M17	La Rioja Museum	Logroño	RA
M18	Seville Museum of Fine Arts	Sevilla	RA
M19	Soria Numancia Museum	Soria	RA
M20	Tarragona National Archaeological Museum	Tarragona	RA
M21	Valladolid Museum	Valladolid	RA
M22	Zamora Museum	Zamora	RA
M23	Santa Cruz Museum	Toledo	RA

(*) CA, Central Administration; PF, Public Foundation; RA, Regional Administration
Source: authors' own.

Figure 2. Location of the sample museums.



Considering a total of eight years of observations for these 23 museums, the degree of representativeness of the sample provides a sampling error of 5.3% with a 95% significance level. Nevertheless, with regards to the dynamic analysis approach, two-year time intervals have been taken and, consequently, we only consider four two-year periods, composed sequentially by the average of each two years for all the variables taken into account in the production function. The reason underlying this decision concerns the time available to museums to prepare most of their activities, such as temporary exhibitions and the like, which usually take over a year to set up. As a result of this reduction, we also avoid a dimensionality problem of the DN-DEA model [22], which might restrict its discriminatory power, and which thus requires a balanced set of inputs, outputs and number of DMU, museums in our case. Table 2 shows the descriptive statistics of the group of variables considered in the analysis and explained in the previous section, for the 23 museums taken into account in the study. First, we have variables involved in the primary stage of cultural programming, and that later lead to certain intermediate outputs (links) that also act as inputs in the second stage focused on attracting visitors. Throughout the whole process, we also take into account the presence of some permanent and dynamic resources which act as carry-overs, which are the museums themselves, expressed through the scope of their buildings in terms of surface area and the number of rooms used for exhibition purposes. Summing up, our model for evaluating efficiency and measuring productivity of a set of 23 representative publicly owned museums comprises two stages in the production process, which includes nine characterization variables (two inputs, two outputs, three links, and two carry-overs), for a time period divided into four intervals, comprising a total of eight years (2008–2015).

Table 2. Variables and descriptive statistics.

			2008/2009				2010/2011				2012/2013				2014/2015			
Variable	**Description (biannual average)**	**Role**	**Max**	**Min**	**Mean**	**St. Dev.**	**Max**	**Min**	**Mean**	**St. Dev.**	**Max**	**Min**	**Mean**	**St. Dev.**	**Max**	**Min**	**Mean**	**St. Dev.**
First stage																		
Staff	No. employees in the museum	input	108	11	33	23.45	106	11	34	23.95	99	11	36	25.37	95	10	35	25.77
Size	Surface area of museum in m^2	carry-over	13,722	426	3384	2791.14	13,722	426	3384	2791.14	13722	426	3384	2791.14	13,722	426	3384	2791.14
Collection managing	Collection movement (loans, acquisitions, addictions) Per 1,000	output	4.76	0	1.29	1.17	6.60	0	1.17	1.43	3.58	0	1.01	1.18	7.70	0	1.19	1.71
Links: intermediate outputs/inputs																		
Exhibitions	No. of exhibitions scheduled	link	11	0	4	3.06	10	0	4	2.75	11	0	5	3.35	16	0	5	4.00
Activities	No. of dissemination & educational activities	link	703	2	144	196.72	571	2	148	178.45	884	4	142	201.78	1304	4	186	287.51
Publishing	No. publications (research and dissemination)	link	35	0	8	9.96	55	0	9	13.26	33	0	5	8.53	33	0	5	9.46
Second stage																		
Facilities	No. of facilities and equipment	input	18	1	10	4.41	18	1	11	4.52	18	3	11	4.12	18	3	11	4.00
Rooms	No. of open rooms to public in the museum	carry-over	30	2	14	7.42	30	2	14	7.42	31	2	14	7.90	31	2	14	7.90
Visitors	No. Total visitors (free and fees)	output	328,006	11,100	87,237	96281.21	284,497	11,344	88,487	86837.74	296,583	12,439	86,029	82136.52	328,208	11,842	91,552	87101.96

Source: authors' own.

5. Results

Table 3 shows the descriptive statistics of the efficiency indices calculated for the museums in our sample and resulting from the methodological approach adopted in Section 3.1. The results reveal a global mean efficiency value for the period studied (2008–2015) of 0.2904, reflecting the substantial margin for improvement available in terms of technical efficiency for the institutions analysed. Nevertheless, it should be pointed out that the results to emerge from a DN-DEA model are always more restrictive than when applying a generic DEA model to a static multi-output production function (black-box), since museums are now evaluated by stages of activity and time periods. As a result, only three entities' performance is seen to be efficient over all of the periods and during all of the activities, even though the number of optimal cases is slightly higher in terms of intervals and stages of activity. Overall, it should be highlighted that the most efficient museums[7] correspond to national museums run by the Ministry of Culture, together with a few others located in well-known tourist areas (Toledo, Valencia, Seville), which points to the importance of national museum branding as well as the appeal of the area in which they are located vis-à-vis achieving higher efficiency rates, at least in terms of attracting higher numbers of visitors.

Table 3. Efficiency results: overall, period, and stage ratios.

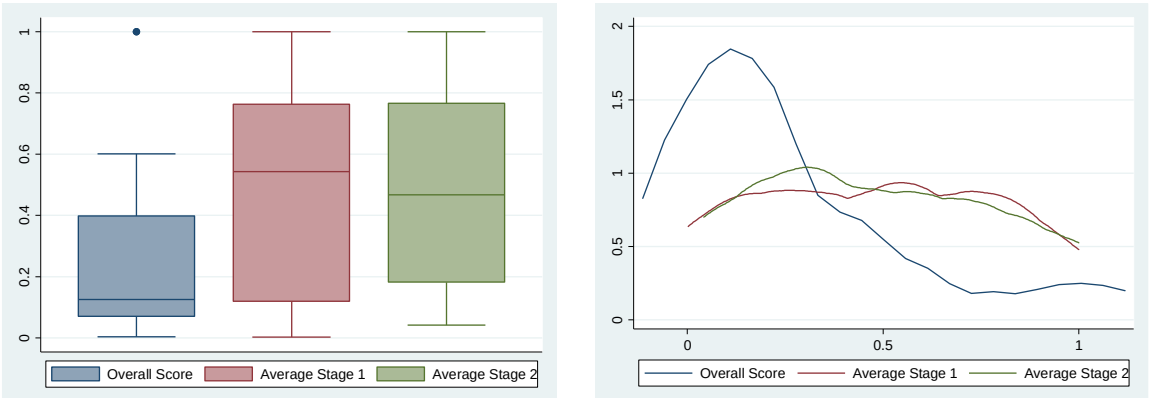
		Period 1	Period 2	Period 3	Period 4	Overall/Mean
Overall	Average	0.3482	0.3079	0.4901	0.3578	0.2904
	Max	1	1	1	1	1
	Min	0.0044	0.0025	0.0049	0.0022	0.0034
	St Dev	0.3998	0.3786	0.4377	0.4035	0.3282
	No. eff. mus.	6	5	8	6	3
Stage 1	Average	0.4735	0.3597	0.5993	0.437	0.4674
	Max	1	1	1	1	1
	Min	0.0031	0.0015	0.0031	0.0013	0.0023
	St Dev	0.3937	0.3806	0.4537	0.452	0.3529
	No. eff. mus.	7	5	10	8	4
Stage 2	Average	0.3688	0.4311	0.6222	0.4899	0.478
	Max	1	1	1	1	1
	Min	0.0244	0.0317	0.0488	0.0353	0.0419
	St Dev	0.4112	0.391	0.3795	0.3597	0.3365
	No. eff. mus.	6	6	9	6	4

Source: Authors' own.

[7] See Table A 1 in the Annex.

This is borne out by efficiency analysis in stages of the production process (Table 3) where, even though similar mean rates are achieved, the second stage, which involves attracting visitors, proves to be slightly more efficient (0.478) than the stage involving the formation of the cultural offer (0.4674). It should also be pointed out that this latter stage displays a more erratic or slightly recessive evolution over time, whereas performance in terms of attracting visitors evidences a significant improvement and a favourable evolution during the period analysed. The development in performance of these two stages might be seen as reflecting the tension between the principal functions assigned to museums [30], [31]: On the one hand, a function that is linked more to conservation and excellence and that can be related to the first stage in our production process and, on the other, a function related to leisure and cultural participation, which lies between culture and the public and that, in our case, would be associated with the second stage of the production process. The results point to a repositioning in institutions' priorities, with entities now focusing more on attracting visitors, which also provides them with a means of supplementing their revenue and ensuring sustainability [30]. Yet, it also offers a means through which museums can bolster their visibility, not only to society but also as a way of justifying themselves to policy-makers and sponsors within an organizational framework characterized by the principal-agent duality [32]. Figure 3 shows the function distribution of efficiency scores, confirming the results previously explained. Overall efficiency ratios are lower and less dispersed than for the two stages in the museum production process. Distribution in stages 1 and 2 is quite similar, although the results for service production to the public are higher and less dispersed.

Figure 3. Efficiency ratio distribution: Boxplot analysis and density functions.



The values obtained might lead to biased conclusions if we consider the efficiency measures presented as being relative. As pointed out in Section 3.1. it is not possible to analyze the absolute evolution of efficiency over a given period using the relative indices provided by our model, given that efficiency in each period is measured with reference to a different frontier that is recalculated based on fresh observations for the period. The Malmquist productivity indices enable us to include possible shifts in the technological frontier in the performance evaluation by providing information concerning the absolute production change of the entities evaluated, as well as specific improvements in their resource performance [29]. With this aim in mind, Table 4 shows the dynamic Malmquist indices for the whole group of museums included in the sample in the period analysed, distinguishing between the various production stages and breaking down the analysis into catch-up and frontier-shift effects.

The first most notable result is that museum productivity remains stable and reflects only a minimal gain of 0.04% during the period analysed, thus reflecting how impermeable these entities are to technical progress that can enhance their performance. This is also consistent with the hypothesis of Baumol's cost disease, since museum production is basically a labour-intensive activity involving non-substitutable and indivisible capital resources, such that factor productivity tends to remain constant and. Therefore, the mean cost keeps rising through time, leading to the activity's inevitable loss of viability unless gains are achieved through prices or other sources. In any case, and in light of Table 4, it is interesting to look at what happens with productivity indicators by production stages and in terms of Malmquist indicator decomposition. We can thus say that the first stage in the formulation of cultural offer is, broadly speaking, recessive with a 10% reduction in productivity over the period, even though a substantial improvement is evident when breaking down the effect, thanks to a shift in the technological frontier, specifically a 3% increase in productivity due to the frontier-shift effect. This may be explained by observing the primary data from museums' activity given that, in general terms, these entities have barely changed their capital and work goods over time, whereas the organization of exhibitions as well as the various dissemination activities, which are two intermediary outputs in this first stage, have improved substantially, particularly in the last interval.

Table 4. Dynamic Malmquist indices.

Stages		Malmquist	Catch-up	Frontier-shift
Overall	Average	1.0004		
	Max	2.1212		
	Min	0.317		
	St Dev	0.4097		
Div1(0.5)	Average	0.9034	0.8852	1.0346
	Max	2.3689	2.459	1.9057
	Min	0.1215	0.132	0.6283
	St Dev	0.4715	0.4721	0.2368
Div2(0.5)	Average	1.2217	1.3286	0.9305
	Max	3.3686	3.2219	1.4489
	Min	0.3152	0.709	0.4125
	St Dev	0.5774	0.5378	0.2472

Source: Authors' own.

It is, however, at the second stage involving attracting the public where the greatest gains in productivity can be seen, with a mean increase of 22% over the period studied. This is mainly due to catch-up effects; in other words, because of specific improvements in museum efficiency and by approaching optimal frontier behaviour. This implies assuming that efforts made in terms of cultural production and dissemination activities, which now constitute intermediate inputs in this production stage, have proven successful in terms of attracting the public for the group of museums in the sample. In sum, this also confirms museums' willingness to relaunch their educational and leisure function as a means of gaining outside projection and visibility. Nevertheless, the existence of certain favourable external effects should also be considered, such as the general increase in cultural consumption and interest in museums, which have come to form part of the range of leisure and free-time products.

The distribution ranges of the dynamic Malmquist indices (Figure 4) are narrower than those of the efficiency ratios, and confirm the lack of productivity gains, except in stage 2 of visitor service provision. Yet, one should ask; which museums are most productive? Is there a link between levels of efficiency and productivity or is there a trade-off? In light of the correlations between the efficiency ratios and the various Malmquist indices[8], no such direct link would seem to exist. It appears rather that each group of values is correlated with each other and that there are scarcely any significant cross relations. This is best reflected in the graph in Figure 5, which shows the efficiency and productivity values for the various museums during the whole of the period analysed where, in addition, we have sought to fit a third-order polynomial function. Three main results in fact emerge. Firstly, there seems to be a positive

[8] See Table A 2 in the Annex.

link between efficiency and productivity, albeit in the group of museums evidencing the worst ratios; in other words, those which are neither very efficient nor productive. These are, in sum, museums that are relatively stagnant because they suffer from less risky management or require new investment in renovation. Secondly, there is a group of museums that display high levels of efficiency but that evidence few or zero gains in productivity over time, and that are mainly national museums as well as those situated in tourist enclaves and whose high efficiency rates may be understood as being the result of external museum accreditation and contextual factors. The audience success of these museums has undoubtedly benefited inertially from the importance of their collection, the national brand, and/or the tourist appeal of the environment. Finally, there is a group of museums that are not as efficient in overall terms, but that achieve high productivity rates. These are mainly provincial museums that have made a substantial effort in terms of updating and increasing their internal cultural production.

Figure 4. Malmquist indices distribution: Boxplot analysis and density functions**;** source: Authors' own.

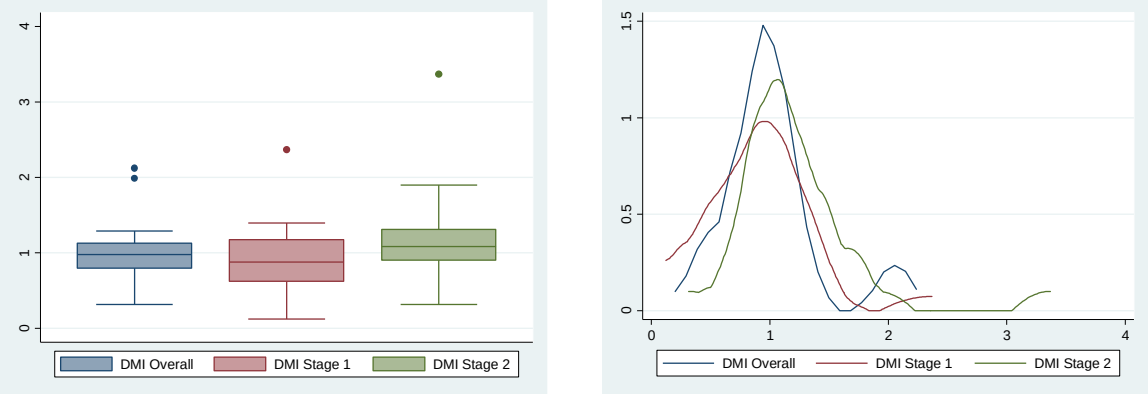
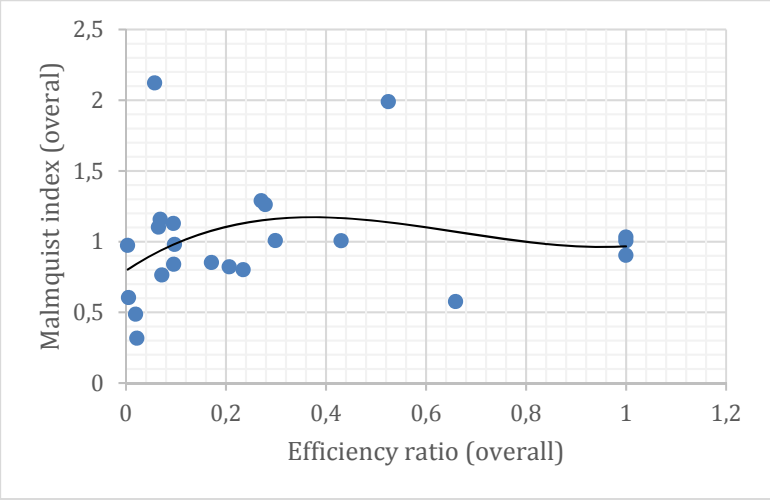


Figure 5. Efficiency vs. productivity in museums**;** source: Authors' own.



6. Discussion

Productivity studies in the field of culture are based on Baumol and Bowen [10], who highlight the inevitable financial asphyxia of the performing arts due to their production structure, which involves factors that are indivisible and hard to replace, such that the inherent rise in costs cannot be offset by significant gains in productivity. This approach is also applicable to other sectors, such as cultural heritage institutions, since these are also eminently labour-intensive activities that involve an intrinsic cultural capital that is unique and therefore irreplaceable, at least in its most primary version. Nevertheless, it does prove interesting to examine whether there might be improvements triggered by technological changes that could impact the productivity of these institutions, such as the digitization of cultural heritage, for instance in archives and libraries, as well as the extension of online consultation and loan-related activities in these institutions. Many studies evaluating the efficiency of archives and libraries have underpinned these aspects [25], [33] whereas in the area of museums, the scope and scale of innovation would appear to be more limited given the virtually irreplaceable nature, at least at present, of being able to enjoy a museum collection in situ and, therefore, the notion of the visit perceived as an experiential good. There is, however, an increasing number of studies that seek to gauge how museums have adapted various innovations and what impact these have had [34]–[37], particularly those affecting accessibility and communication, as well as changes in cultural supply arising from digitization processes.

Such is the line taken in the present study, which offers an approach to an efficiency evaluation analysis and an estimation of the productivity of a group of public museums in Spain over an extended time span. The methodological particularity lies in our considering a production function that is broken down into production stages and consecutive time intervals, taking into account inputs that are inter-related horizontally (production links) and vertically (time carry-overs). Latest generation frontier evaluation techniques have been applied, specifically the DN-DEA model [15], and the Malmquist dynamic indices associated to this model have been calculated which, to the best of our knowledge, have scarcely been used in the case of cultural institutions. Our purpose is not to evaluate how a specific innovation affects museum efficiency but to estimate long-term productivity, on the basis of a multi-output production function.

Our results evidence the existence of very slight changes in productivity, thereby reflecting museums' limited capacity to embrace technological changes and innovations that might drastically alter their production structure. Nevertheless, thanks to the breakdown of Malmquist indices into catch-up or frontier shift effects, certain specific productivity gains can be seen in some activities. Firstly, there is a slight improvement in productivity owing to the shift in the frontier of results connected to the stage at which museums compile their cultural offer, which is no doubt due to the efforts made when preparing temporary exhibitions and other activities related to dissemination and social impact during the period considered. These results, which in turn constitute intermediate inputs for museums' second stage of production involving providing visitors with services, have led to a substantial increase in productivity at this stage, due specifically to improvements in museums' efficiency in attracting visitors and catching-up the frontier of optimal behaviour, taking into account their resources. Both results, improving productivity in preparing cultural supply and attracting visitors, clearly reflect a shift in museums' priorities towards goals related to visibility and social impact.

Applied research of this nature, of which the present study is one example, does evidence certain limitations and challenges, with one such limitation concerning the sample and the available data, which have been very restricted. It would therefore be extremely interesting to consider the possibility of drawing on variables related to new equipment and technological resources, which affect both museum accessibility as well as the actual cultural production itself, where experiences involving augmented reality or audiovisual production complementing current cultural resources might have a significant impact on museums' input and output structure. Digitization of cultural collections can also drive the attraction of new consumers to museums as well as represent in itself a new kind of cultural production. One further factor that needs to be taken into account is the myriad of users of these institutions, which are not confined solely to visitor numbers but that also include online consultations and virtual visits, complementary uses of the artistic resources, and so on. The time interval considered is also a restriction, since most of these innovations are very recent, with some even having been developed and expanded during the Covid-19 pandemic. It would be interesting to extend the research to a broader and more recent time interval, which would lead to the incorporation of more specific indicators of innovation in museums. Thus, the results should be viewed with some caution, although the methodological approach stands as valid as a way to evaluate cultural institutions with a complex production function with inter-reliant resources.

Rather than reflecting the incorporation of significant technological changes and innovations that affect museums' long-term productivity, our research evidence that overall productivity seems to be stable considering an extended and complex multi-output production function divided into stages and time intervals. However, three is a significant technical change in the cultural production stage and there are efficiency improvements in attracting visitors. A shift in the managerial approach of these institutions together with a rethinking of their priorities seem to happen, where functions involving education, exhibition, and the social impact of their art collection on the public have taken on greater relevance [37], [38]. This also shows their willingness to enhance the visibility of these institutions and their integration as cultural products for leisure. Under this approach, and for the particular Spanish sample of museums chosen, national institutions as well as those museums located in tourist enclaves seem to stand a better chance of attracting visitors, whereas a number of provincial museums have evidenced substantial effectiveness in terms of their efforts regarding cultural production. Finally, issues concerning diversification and the creation of new cultural offerings to expand the ways in which museums may be accessed have no doubt been brought more sharply into focus given the restrictions imposed because of the Covid-19 pandemic. In this regard, the immediate future will throw up a number of interesting analytical challenges.

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ANNEX

Table A1. Efficiency scores and dynamic Malmquist indices by museums.

		Efficiency Scores				Dynamic Malmquist Indices				Catch-up Effect		Frontier-Shift Effect	
No.	**DMU**	**Overall**	**Rank**	**Stage 1**	**Stage 2**	**Overall**	**Rank**	**Stage 1**	**Stage 2**	**Stage 1**	**Stage 2**	**Stage 1**	**Stage 2**
Museum of the National Library of Spain	MUS1	1	1	1	1	1.0315	8	0.8349	1.2744	1	1	0.8349	1.2744
National Museum of Ceramics and Sumptuary Arts	MUS2	0.6593	4	0.7811	0.747	0.5756	21	1.0511	0.3152	0.5516	0.7641	1.9057	0.4125
National Sculpture Museum	MUS3	0.2346	10	0.3203	0.458	0.8011	18	0.5898	1.088	0.9388	1.4288	0.6283	0.7615
Sephardic Museum	MUS4	1	1	1	1	0.903	14	0.9527	0.8558	1	1	0.9527	0.8558
Altamira National Museum and Research Centre	MUS5	0.4305	6	0.7663	1	1.0057	10	1	1.0115	1	1	1	1.0115
Lázaro Galdiano Museum	MUS6	0.0654	18	0.05	0.1662	1.1018	7	0.7874	1.5418	0.7874	1.3294	1	1.1596
Álava Museum of Fine Arts	MUS7	0.0689	17	0.6651	0.0419	1.1571	5	1.2676	1.0563	1.1845	1.0557	1.0702	1
Badajoz Provincial Museum of Archaeology	MUS8	0.0974	13	0.0824	0.1477	0.9793	12	0.7926	1.21	0.7925	1.0925	1	1.1072
Burgos Museum	MUS9	0.072	16	0.283	0.0975	0.7631	19	0.3572	1.6303	0.4115	1.5154	0.8678	1.076
Caceres Museum	MUS10	0.0956	14	0.061	0.5874	0.8396	16	0.7436	0.9481	0.7435	1.2429	1	0.7629
Cuenca Museum	MUS11	0.0576	19	0.3574	0.077	2.1212	1	2.3689	1.8994	2.459	1.899	0.9637	1
Casa de los Tiros Museum in Granada	MUS12	0.0055	22	0.0287	0.2777	0.6038	20	0.2804	1.3002	0.2781	1.7755	1	0.7323
Úbeda Archaeological Museum	MUS13	0.2067	11	0.3138	0.5535	0.8211	17	0.621	1.0857	0.5761	1.3359	1.078	0.8127
León Museum	MUS14	0.2707	9	0.597	0.3409	1.2882	3	1.0645	1.5588	0.9244	1.076	1.1517	1.4489
Murcia Museum of Fine Arts	MUS15	0.2789	8	0.6309	0.2473	1.2614	4	1.211	1.3139	1.388	1.2217	0.8724	1.0755
Palencia Museum	MUS16	0.5248	5	1	0.7575	1.9888	2	1.1742	3.3686	1	3.2219	1.1742	1.0453
La Rioja Museum	MUS17	0.022	20	0.4	0.4989	0.317	23	0.1215	0.8269	0.132	0.709	0.9143	1.1662
Seville Museum of Fine Arts	MUS18	0.1713	12	0.0591	0.8404	0.8514	15	0.8763	0.8272	0.8759	1.0103	1	0.8187
Soria Numancia Museum	MUS19	0.0034	23	0.0023	0.1878	0.9728	13	0.7422	1.275	0.7485	1.2751	1	1
Tarragona National Archaeological Museum	MUS20	0.0194	21	0.1196	0.3414	0.4867	22	0.2327	1.0179	0.232	1.382	1	0.7366
Valladolid Museum	MUS21	0.2991	7	0.6883	0.5676	1.0066	9	1.1179	0.9063	1.2088	2.1566	0.9248	0.4203
Zamora Museum	MUS22	0.0951	15	0.5429	0.0584	1.1282	6	1.1948	1.0654	1.1267	1.0652	1.0605	1
Santa Cruz Museum	MUS23	1	1	1	1	1.0051	11	1.3966	0.7233	1	1	1.3966	0.7233

Source: Authors' own.

Table A2. Correlation analysis between efficiency ratios and Malmquist indices.

			Efficiency Ratios			Malmquist Index			Catching-Up		Shift-Frontier	
			Overall	**Stage 1**	**Stage 2**	**Overall**	**Stage 1**	**Stage 2**	**Stage 1**	**Stage 2**	**Stage 1**	**Stage 2**
Pearson (pw)	Efficiency ratios	Overall	1									
		Div1	0.8277 ***	1								
		Div2	0.8009 ***	0.5777 ***	1							
	Malmquist index	Overall	0.0861	0.3034	−0.1352	1						
		Div1	0.2473	0.4139 **	−0.0127	0.8141 ***	1					
		Div2	−0.1089	0.0849	−0.1989	0.7312 ***	0.2213	1				
	Catching-up	Div1	0.1370	0.3029	−0.0974	0.8233 ***	0.9321 ***	0.2664	1			
		Div2	−0.1093	0.0626	−0.0975	0.5814 ***	0.1967	0.8063 ***	0.2382	1		
	Frontier-Shift	Div1	0.3220	0.3005	0.2343	−0.0343	0.2354	−0.1994	−0.1146	−0.1402	1	
		Div2	−0.1102	0.0093	−0.2561	0.3281	0.0185	0.4507 **	0.1098	−0.1144	’−0.3613 *	1
Spearman (rho)	Efficiency ratios	Overall	1									
		Div1	0.8126 ***	1								
		Div2	0.7139 ***	0.4983 **	1							
	Malmquist index	Overall	0.2394	0.3522 *	−0.2055	1						
		Div1	0.4619 **	0.5944 ***	−0.0089	0.7994 ***	1					
		Div2	−0.2740	−0.2353	´−0.5161 **	0.4980 **	0.0296	1				
	Catching-up	Div1	0.4304 **	0.5416 ***	−0.0259	0.8282 ***	0.8600 ***	0.1460	1			
		Div2	−0.3500	´−0.3707 *	´−0.3793 *	0.1521	−0.1129	0.6399 ***	0.0398	1		
	Frontier-Shift	Div1	0.1076	0.1234	0.0584	0.1519	0.3467	−0.1534	−0.0761	−0.1475	1	
		Div2	−0.0754	0.0129	−0.2537	0.4146	−0.0168	0.5324 ***	0.0747	−0.1609	−0.2375	1
Kendal (tau)	Efficiency ratios	Overall	1									
		Div1	0.6801 ***	1								
		Div2	0.5191 ***	0.3239 **	1							
	Malmquist index	Overall	0.1431	0.1800	−0.1000	1						
		Div1	0.3022 **	0.3480 **	−0.0040	0.6522 ***	1					
		Div2	−0.1750	−0.1720	´−0.3720 **	0.3597 **	0.0119	1				
	Catching-up	Div1	0.3124 **	0.3388 **	0.0041	0.6977 ***	0.7381 ***	0.1008	1			
		Div2	−0.2455	−0.2429	−0.2227	0.0680	−0.1720	0.5000 ***	−0.0204	1		
	Frontier-Shift	Div1	0.1181	0.0976	0.0467	0.1215	0.2389	−0.0713	−0.0470	−0.1230	1	
		Div2	−0.0724	0.0121	−0.1336	0.3320 **	0.0280	0.3800 **	0.0612	−0.1336	−0.1824	1

Source: Authors’ own.