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Performance of cultural heritage institutions: A regional perspective

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ABSTRACT

Most studies on performance evaluation in the cultural sector are based on the efficiency assessment of a network of institutions. Nevertheless, very few works take territorial divisions as the case study. Under this approach, we design a spatial production function which merges several cultural resources in order to optimize the impact of a regional system of cultural institutions in terms of cultural production and use of services provided. The aim of this paper is therefore to evaluate the efficiency of cultural heritage institutions in Spain from a regional perspective. We take regional networks of museums and libraries as emblematic case studies over a long period, from 2002 to 2020. We first apply a dynamic-network DEA model to measure efficiency, which allows the production function to be divided into stages and time intervals, considering inter-reliant inputs between production phases and time lapses. We also apply truncated regression models to study the effect of external variables on regional cultural efficiency, especially those related to socioeconomic conditions in regions, the scope of the cultural and tourist sector, and institutional indicators. Results show that regional cultural efficiency depends on the level of training and on the demographic structure rather than on economic wealth. Differences are also found between the goals of cultural production and cultural consumption (visitor impact). These findings might prove useful for policy implications regarding resource allocation vis-à-vis defining and accomplishing cultural purposes at a regional scale, and also for revealing causes of inefficiency with a view to improving quality in institutions –which ultimately drives economic development.

1. Introduction

Most studies on performance evaluation in the cultural sector are based on the efficiency assessment of a network of institutions, taking them as the main objects to be analysed. There is therefore ample literature on performance evaluation of libraries, museums, symphony orchestras, theatres and many other cultural entities (see Refs. [1,2] for a survey). However, very few works take territorial divisions as the case study. Under this approach, a virtual territorial production function can be designed which includes several cultural resources and endowments concerning one particular branch of culture in order to optimize outcomes, defined mainly as cultural production and services to the public, i.e. demand success. These two goals are pursued with the basic meaning of impact of cultural institutions in a region, which could be interesting as a subject of cultural policy analysis; that is, recognizing the capacity of regional governments to define cultural goals and to decide resource allocation in this matter. This is the principal justification given to tackle efficiency evaluation of cultural institutions from a spatial perspective.

Indeed, this spatial focus proves both challenging and valuable in cultural and regional economics. Based on a similar optimisation approach for cultural heritage institutions in a given area –such as regions– we can analyse which perform better or worse and why. Two-stage evaluation models might thus be appropriate to study the effect of environmental variables on regional cultural efficiency, especially those related to the level of training and economic development, the scope of the cultural sector, the institutional setting, and so on [3,4]. The results could be useful for policy implications and for extending current knowledge on how institutions perform differently over areas, following not a managerial but a neo-institutional approach [5]. When adopting such an approach, it is important to analyse both the efficiency of the institutions themselves and the institutional environment that drives efficacy as well as the factors that pose obstacles to achieve this –especially when they are involved in economic development [6]. There is also an open question concerning whether or not expanding the

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autonomy of cultural institutions in a context of policy decentralization has really affected their performance as seems to have been the case of –for example– museums in Italy [7,8]. This raises the typical principal-agent problem that is distinctive of the provision of cultural goods and services [9], where cultural policy-makers (principal) may plan balanced aims of cultural production (quality and supply) and impact (audience success), but where managers of cultural institutions (agent) may be more interested in visibility purposes. Results from this research could therefore be useful as regards the possible trade-off between impact and cultural production, as well as the tension and responsibilities among curators and policy-makers.

Based on these premises, our main aim is to evaluate the efficiency of cultural heritage institutions from a regional perspective in Spain. We consider two of the most emblematic institutions in this area –museums and libraries– over a long period, from 2002 to 2020. We establish a homogenous production function divided into two stages. The first focuses on cultural production, taking into account the resources available to institutions, an intermediate result that links to the second stage, geared towards to the use of services; that is, cultural consumption. We therefore consider inter-reliant inputs between activities and between time intervals, since certain resources such as artistic and bibliographical collections – as well as cultural institutions themselves– may be seen as a kind of permanent cultural capital that does not end at a given period, but which remains and acts as carry-over throughout time.

We adopt a two-stage efficiency evaluation model as the methodological approach. First, we assess regional cultural performance through non-parametric techniques. Specifically, we apply dynamic-network DEA models [10] and build dynamic Malmquist indices to measure productivity and to study the effect of technological progress. Second, we estimate how environmental variables may determine regional efficiency, and we select socio-economic indicators which characterize regions' level of economic and cultural development. For this purpose, truncated regression models [11] are applied. This was also validated by a double robustness check.

The paper is organized as follows. After this introduction, a literature review on the performance of cultural heritage institutions is provided. The methodological strategy and materials related to the case study are then presented in depth in section three. Section four explains the results concerning the efficiency evaluation, productivity scores and the effect of external variables on regional performance. Finally, section five concludes and discusses.

2. Performance of cultural heritage institutions: a literature review

Evaluation of the performance of cultural heritage institutions (mainly museums, libraries and archives) is a subject of growing interest in the literature, in terms of the correct use of resources and the social impact generated. This type of study has so far been addressed from a microeconomic perspective, with each of the heritage institutions providing services to citizens being the main unit of analysis. Despite the existence of parametric approaches, the most commonly used method is non-parametric techniques. These initially use DEA and FDH models, with opaque production functions where –based on certain resources– services are obtained, without specifying how conversion takes place. This category includes works such as those by Refs. [12–14], in the case of museums, and [15–17], in the case of libraries. Based on these initial approaches, new methodological refinements have been introduced that have made it possible to show how the production function develops in cultural institutions, and to incorporate a temporal dimension into the analyses. This offers greater precision when identifying the causes of inefficiency and offers a more accurate understanding of how the performance of institutions evolves over a given period.

Works that introduce new specifications into the production function start from the concept of co-production that is inherent to the provision of cultural services [18]. The indispensable concurrence of user willingness for the provision and consumption of the service advocates dividing the process into two stages. The former allows the management and results when configuring the entity's cultural supply to be evaluated, while the latter refers to the final provision of the service –seen as an indicator of the entity's impact. The logical existence of interrelationships between the two stages makes it advisable to apply network-DEA (N-DEA) models that consider what effects the decisions taken at a previous stage may have on a subsequent stage. In this regard [19], apply SBM N-DEA models to evaluate of a group of Spanish museums, while [20,21] use a two-stage N-DEA model to evaluate a group of public libraries and historical archives, respectively, in Italy.

Introducing a temporal component into the performance analysis of cultural institutions has been addressed using different methodological approaches. A primary approach involves applying the DEA technique to calculate Malmquist productivity indices. To this category belong the works of [14,22] for museums, and [23–25] for libraries. Another approach is to apply Window-DEA models, as in the case of [26], to evaluate a group of archives in Italy. Following these first attempts to incorporate a temporal dimension into the analyses, dynamic-DEA (D-DEA) models provide further improvement by considering the time-delayed effect of certain inputs which –as in the case of collections in cultural institutions– are not consumed in each period, but which are maintained and increased as a basic mission of the institution. This category includes the work of [4], in the case of libraries, and [27], in the case of museums.

Another methodological contribution to studying the efficiency of heritage institutions is the incorporation of two-stage analysis, which makes it possible to assess efficiency in heterogeneous environments. In this case, in a first stage, a DEA model is implemented to estimate the efficiency indices, while in a second stage these indices are matched with certain external variables by means of a regression analysis. The works [19,28] for museums [29,30]; for libraries are in this line of research.

Furthermore, adopting a spatial perspective enables the evaluation approach to move towards a macroeconomic dimension, since it measures the performance of aggregate spatial units, such as regions, in the management of cultural resources and heritage institutions. This implies designing virtual territorial production functions which merge cultural resources to optimize outcomes defined as cultural production and demand success. This spatial approach has been applied in other areas such as the tourist sector, where the performance evaluation of tourist destinations is one of the most frequent and promising research lines in the area of economics of tourism [31,32]. There is also extensive literature on the evaluation of education systems from a spatial perspective [33], both at the levels of basic education [34] and higher education [35]. There are also numerous studies evaluating regional innovation systems [36,37], spatial tax administration [38] or energy production [39]. However, as far as we know, as yet there are no works evaluating the performance of cultural institutions from a spatial perspective; namely, designing a cultural production function with a territorial specification. There are some works on efficiency evaluation of cultural institutions that break down performance results with a spatial disaggregation, as for instance the case of Italian museums in terms of regions and the main geographical areas in Italy [3], libraries at a municipal scale in Flanders, Belgium [40] or performing arts firms for a sample of 11 European countries [41]. However, these approaches are not based on a spatial production function but on a managerial perspective, i.e. an optimisation strategy for institutions.

Our paper attempts to fill this gap in three dimensions: first, regional production functions are therefore defined with a spatial dimension for the efficiency evaluation model; second, a dynamic network approach is adopted to consider inter-reliant and inter-temporal inputs in a decomposed production function; and finally, a two-stage model is addressed, analysing the impact of external variables on regional efficiency rates.

3. Materials and methods

In line with the above, the main aim of this work is to gauge the efficiency of cultural institutions from a regional perspective. To this end, we design a virtual production function, with spatial specification, in which regions have a range of resources available to achieve the objectives pursued by these institutions, and which basically concern cultural production and use of their services; in other words, institutions' impact. This working hypothesis thus recognises the capacity of the regional authorities responsible for cultural policy to design or adapt cultural objectives, to focus the allocation of resources or to distinguish and consider the variables that can determine institutions' level of efficiency and productivity in the long term. We take two emblematic cases –museums and libraries. We therefore take much of a region's cultural heritage, since these embrace arts collections and bibliographical collections in the broadest sense, as well as the buildings which house them, and which also tend to be recognized elements of built cultural heritage. We also consider a long time period –from 2002 up to the most recently available data– in two-year intervals adjusted to statistical production, such that we are able to examine how efficiency changes over time and to calculate the productivity of the regional system of cultural institutions. The empirical application concerns Spain, a country divided into 17 autonomous regions and two autonomous cities, which have their own powers in cultural matters, such that regional governments enjoy substantial control in terms of management and resource allocation in this field. Spain is renowned for its wide-ranging cultural diversity, although it is subject to major regional economic disparities which can, to a certain degree, shape both the provision and use of these cultural goods.

We opt for a complex methodological design that divides the production function into two production stages and interconnected time lags. Two reasons justify such an approach. Firstly, two stages can be distinguished when cultural institutions fulfil their functions: one which concerns managing the resources for the production of cultural supply –and which is under the control of managers– and a second stage, which involves the consumption of goods and services, and which is co-produced by the public [18], since it depends on the latter's interests and decisions. Efficiency may thus be shaped by external variables which, to a certain extent, lie outside the management and support of these institutions, and which hinges on contextual socio-economic and institutional aspects. Moreover, in production terms, it should be remembered that certain basic outputs of museums and libraries' cultural production may be considered as intermediate input (links) for a second stage, which relates to the impact that institutions have in terms of consumption of their services. Secondly, when undertaking a dynamic analysis of efficiency, it should be borne in mind that certain resources are not exhausted over a period, but remain or even grow over time. This is how, for example, arts and bibliographical collections should be viewed, acting as they do as carry-overs between intervals, as well as the actual network of institutions (museums and libraries), and which constitutes a kind of dynamic cultural capital endowment for regions.

Under this perspective –namely that of a production function with inter-reliant inputs between production stages and intervals– we should consider the use of the latest generation efficiency evaluation models based on a non-parametric approach, so-called dynamic-network data envelopment analysis (DN-DEA) [10] and which has often been applied in the field of finance [42–45], health [46,47], tax administration [38], public services [48], and also in the cultural sector with specific examples of institutions such as dance companies [49], libraries [4,20], and museums [27]. To date, we are not aware of any of these techniques having been applied to evaluate territorial entities, such as the case in hand. Following on from this, Figs. 1 and 2 reflect the specification of regional production functions for the museum and library sector, respectively, in Spain.

As regards the system of museums (Fig. 1), regions first have the basic resources in terms of capital and labour –in other words, the employees and the regional museum network itself– to design basic cultural production, which is summed up in two fundamental activities: holding temporary exhibitions (small and large), and publications (research and dissemination). This stage is controlled by managers, since this is their responsibility, whereas the second production stage focuses on visitor impact. Here, temporary exhibitions, the actual museum collection and the creation of museum websites are taken as resources to attract visitors and therefore to measure what impact the public has. Exhibitions act as intermediate input (link) and the network of museums and their collections as dynamic carry-overs.

As regards regional library systems (Fig. 2), we also posit two interrelated stages of cultural production and use of their services. In the first, capital resources (system of libraries) and labour (employees) constitute the basic offer of making available to the public the services for loaning and consulting bibliographic material, and which we sum up in intermediate output as the number of user cards issued [50]. These constitute the basic set-up for measuring the subsequent impact in terms of the use of services and which therefore act as an intermediate link. In this stage, we also consider inter-library loans as complementary output controlled by managers. In the second stage, we add resources in the form of bibliographic collections and we measure the impact on consumption through the total number of users of regional libraries; in other words, the loan and consulting services, as well as visitors to complementary activities (exhibitions, cinema-forums, lectures, etc.). In this design, both the network of libraries and the bibliographical collection act as intrinsic dynamic resources (carry-overs).

Museums and libraries also perform other specific functions related to the preservation and dissemination of their collections, although these are tasks that merit consideration in efficiency studies that focus on evaluating institutions themselves and the activities they perform (see Refs. [4,27] and not so much on efficiency evaluation from a spatial perspective. Under this approach –and vis-à-vis considering the implications of cultural policy– we prioritize maximizing the results in terms of cultural production and use of services, which are basic objectives related to what effect institutions have at a regional level, so as to also determine which external variables might impact regions' performance. Following on from this clarification, Table 1 provides the descriptive statistics of the variables considered in the regional production function of museums and libraries for this study.[1]

Within the methodological approach, we consider a second key stage in the evaluation of regional efficiency; namely, analysing what impact the external variables that lie outside the production function might have on regional efficiency. For this, we consider four kinds of variables (see Table 2). First, we look at socioeconomic indicators, such as GDP per capita and educational attainment of the population. This can offer a positive relation, as is to be expected from cultural consumption, which is elastic vis-à-vis income and educational level [51]. The percentage of younger or older population can also impact the frequency of museum and library visits.[2] The second group of variables is linked to the size of the region's cultural sector. Here we aim to determine whether there is a feedback effect with cultural production and the use of these institutions' services in the sense that the denser a region's cultural productive tissue, the greater the economic growth and the greater also the propensity to consume cultural goods and services [41,52]. For this purpose, we consider regional government public expenditure on culture, the level of household cultural consumption, and the scale of

[1] The descriptive statistics for the whole period are offered and are available for each type of institution (2002–2020 for museums; 2002–2018 for libraries), taking into account that the statistical production for these institutions is published in even-numbered years.

[2] We consider the Senior group above the official age for retirement (65 years old) and a broad notion of Young people up to the age of 25, the average age of completion of university studies, which may determine in part the use of libraries for study purposes.

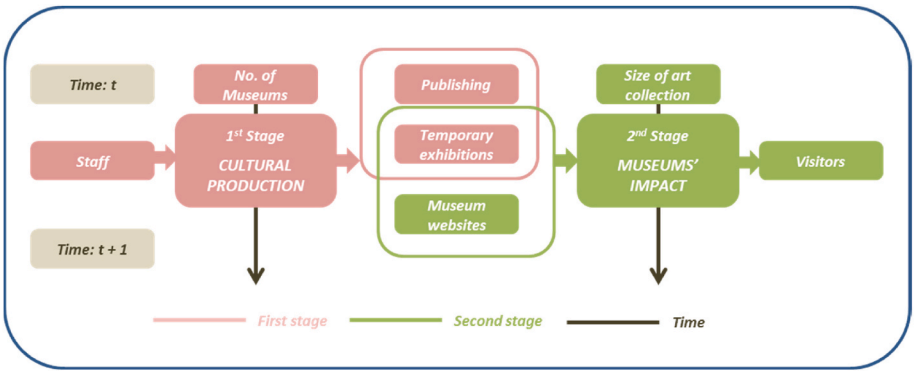


Fig. 1. Regional production function schedule for museums.

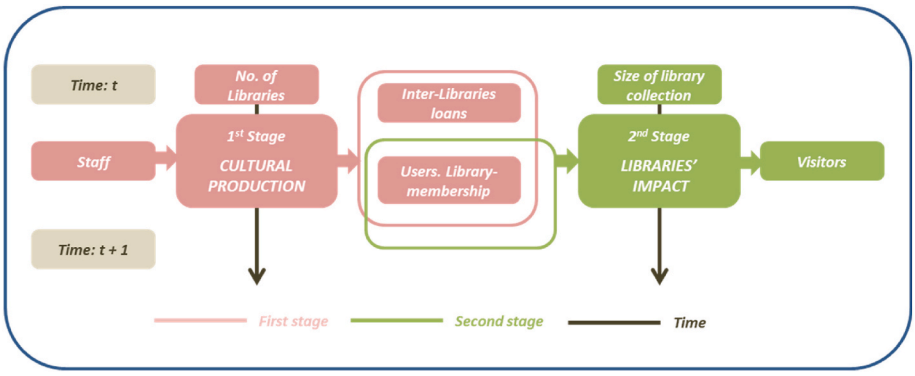


Fig. 2. Regional production function schedule for libraries.

Table 1
Variables of the regional production functions and descriptive statistics.

Variables	Description[a]	Role	Max	Min	Mean	St. Dev.
Museum staff	No. of employees in museums	Input	3,881	13	715.07	808.06
No. of museums	No. of museums in a region	Carry-over	239	2	73.81	59.40
Publications	No. of publications by museums	Output	401	1	83.464	86.60
Exhibitions	No. of temporary exhibitions scheduled by museums	Link	1287	1	189.66	205.74
Museums' collections	Regional size of museums' collection (units)	Carry-over	16,556,143	10,138	2,185,237.75	3,080,121.69
Websites	No. of museums with a website	Input	221	0	55.77	48.49
Visitors	No. of museum visitors	Output	17,816,035	14,457	2,708,913.70	3,253,508.57
Library staff	No. of employees in libraries	Input	5000	11	1056.35	1178.45
No. of libraries	No. of libraries	Carry-over	1,015	7	346.98	273.32
Interlibrary loans	No. of interlibrary loans	Output	33,856,812	5	791,333.65	3,701,339.50
Library cards	No. of library cards (library membership)	Link	5,565,886	1,358	946,948.90	1,116,522.00
Bibliographical collections	Regional size of the library's bibliographical collection (pieces)	Carry-Over	65,863,360	105,463	9,683,389.50	12,705,695.64
Visitors	No. of library visitors (circulation and other activities)	Output	43,462,530	26,829	10,361,284.35	11,265,592.14

[a] All variables are regionally specified.
Source: authors' own based on INE (www.ine.es) and CULTURAbase (www.culturaydeporte.gob.es)

cultural employment in the region. We also take into account the number of protected buildings in order to consider the concentration of cultural heritage elements in a region. The third group of variables are tourist indicators, which might have a greater effect on the impact of regional museum systems and also on libraries, as shown by the link between tourism and cultural participation [53]. We here consider the total number of travellers visiting a region, the scale of domestic tourism, and tourists whose trip is specifically driven by a cultural motivation (cultural tourism). Finally, the fourth group of variables are institutional indicators, through which we seek to ascertain whether the ownership or management status of the museum or library impacts its degree of efficiency [14]. We thus consider state (Ministry of Culture), regional (regional government) and local management (municipal and provincial) for museums and libraries. We have also added the section of ecclesiastical museums, given the weight this type of institution has. Table 2 shows the descriptive statistics of all these variables over the whole period.

Following our methodological strategy, we first apply a DN-DEA method pioneered by Ref. [54], based on the dynamic approaches of the production function of [55–57]. Starting from the first formulations, either radial or non-radial [10,46,58,59], several studies have contributed to the development of N-DEA and DN-DEA models, incorporating new specifications [60–64]. formulate stochastic extensions of deterministic models [65]. propose a game-DEA model for cases where there are few decision-making units and where the production function requires considering a large number of inputs and outputs [64,66].

Table 2
Environmental variables and descriptive statistics.

Environmental variables	Description[a]	Max	Min	Mean	St. Dev.
Wealth	Regional GDP per capita (thousands of euros)	35.24	11.60	21.87	4.68
Human capital	Inhabitants with higher education (regional %)	41.20	12.10	24.67	6.21
Young	Inhabitants under 25 years old (regional %)	38.55	18.39	25.96	4.31
Senior	Inhabitants over 65 years old (regional %)	26.17	9.69	17.70	3.85
Cultural public spending	Public spending on culture by the regional government (thousands of euros)	140.50	7.30	39.06	25.89
Cultural consumption	Average expenditure on culture per capita (euros)	472.70	81.01	261.96	85.67
Cultural employment	Employment in the regional cultural sector (thousands)	161.90	0.36	30.12	40.39
Heritage	No. of heritage goods under regional legal protection	3,474.00	0.000	754.85	866.45
Total tourism	No. of travellers coming to a region's hotels	2,168,168.00	2,745.00	402,021.73	504,641.62
Domestic tourism	No. of domestic travellers coming to a region's hotels	971,751.00	2,235.00	203,261.42	224,192.14
Domestic cultural tourism	No. of domestic travellers with a cultural purpose (thousands)	1,981.20	6.88	435.34	408.52
State museums	Percentage of museums run by central administration	75.00	0.00	8.96	16.17
Regional museums	Percentage of museums run by regional administration	55.56	0.00	17.50	12.80
Local museums	Percentage of museums run by local administration	75.49	0.00	37.48	18.68
Church museums	Percentage of museums run by the Catholic church	44.44	0.00	9.36	9.46
State libraries	Percentage of libraries run by central administration	83.33	2.37	14.96	18.62
Regional libraries	Percentage of libraries run by regional administration	63.71	0.00	11.55	10.03
Local libraries	Percentage of libraries run by local administration	87.99	0.00	53.70	24.45

[a] All variables are regionally specified.
Source: authors' own, based on INE (www.ine.es) and CULTURAbase (www.culturaydeporte.gob.es)

propose network DEA-R models when ratio and random data are considered in the research.

We specifically follow the non-radial SBM (slacks-based-measure) DN-DEA model proposed by Ref. [10] that does not therefore require proportional changes in inputs and outputs. This fits in well with the hypothesis of the production structure of regional networks of cultural institutions 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,[3] which takes into account excesses in inputs as well as defects in outputs.

According to these criteria, regions' overall efficiency when managing their museum and library systems can be estimated by solving the following optimisation problem:

$$\rho_o^* = \min \frac{\sum_{t=1}^{T} W^t \left[\sum_{k=1}^{K} w^k \left[1 - \frac{1}{m_k + p^{in}_{(k,h)} + q^{bad}_k} \left(\sum_{i=1}^{m_k} \frac{s^{t-}_{ik}}{x^t_{iok}} + \sum_{l=1}^{p^{in}_{(k,h)}} \frac{s^{in,t-}_{(k,h)l}}{z^{in,t}_{o(k,h)l}} + \sum_{c=1}^{q^{bad}_k} \frac{s^{bad,t-}_{kc}}{\omega^{bad,t}_{okc}} \right) \right] \right]}{\sum_{t=1}^{T} W^t \left[\sum_{k=1}^{K} w^k \left[1 + \frac{1}{r_k + p^{out}_{(k,h)} + q^{good}_k} \left(\sum_{i=1}^{r_k} \frac{s^{t+}_{ik}}{y^t_{iok}} + \sum_{l=1}^{p^{out}_{(k,h)}} \frac{s^{out,t+}_{(k,h)l}}{z^{out,t}_{o(k,h)l}} + \sum_{c=1}^{q^{good}_k} \frac{s^{good,t+}_{kc}}{\omega^{good,t}_{okc}} \right) \right] \right]}$$

subject to:

$$x^t_{iok} = \sum_{j=1}^{n} x^t_{ijk} \lambda^t_{jk} + s^{t-}_{ik} \; (\forall i, \forall k, \forall t)$$

$$y^t_{iok} = \sum_{j=1}^{n} y^t_{ijk} \lambda^t_{jk} - s^{t+}_{ik} \; (\forall i, \forall k, \forall t)$$

$$\lambda^t_{jk} \geq 0, s^{t-}_{ik} \geq 0, s^{t+}_{ik} \geq 0, (\forall i, \forall k, \forall t)$$

$$\sum_{j=1}^{n} z^{\propto,t}_{j(k,h)l} \lambda^t_{jk} = \sum_{j=1}^{n} z^{\propto,t}_{j(k,h)l} \lambda^t_{jh} \left(l = 1, \ldots, p^{\propto}_{(k,h)}, \forall (k,h), \forall t \right)$$

$$\sum_{j=1}^{n} \omega^{\propto,t}_{jkc} \lambda^t_{jk} = \sum_{j=1}^{n} \omega^{\propto,t}_{jkc} \lambda^{t+1}_{jk} \left(c = 1, \ldots, q^{\propto}_k, \forall k, t = 1, \ldots, T-1 \right)$$

We consider n regions that carry our K activities over the whole cultural production process, both for the regional museum network as well as for regional libraries. For all of these activities, regions consume m_k inputs and produce r_k outputs in each activity k, over T time periods. Additionally, each region produces p_{kh} intermediate outputs (links) in each activity k, which are incorporated as inputs into an activity of the subsequent production process h. Finally, each activity k of the production process has q_k carry-overs, which show the links between this activity in period t and period t+1. We call x^t_{ijk} $(i = 1, \ldots, m_k;\ j = 1, \ldots, n;\ k = 1, \ldots, K; t = 1, \ldots T)$ the observed input i consumed by region j in activity k, in period t; y^t_{ijk} $(i = 1, \ldots r_k;\ j = 1, \ldots, n;\ k = 1, \ldots, K; t = 1, \ldots T)$ the observed output i produced by region j in activity k, in period t; $z^{\alpha,t}_{j(k,h)_l} (j = 1, \ldots, n; l = 1, \ldots, p_{kh}; t = 1, \ldots T, \alpha = \textit{fix or free links})$ the observed link l produced by region j in activity k and consumed in activity h, in period t; and $\omega^{\alpha,t}_{jkc} (j = 1, \ldots, n; c = 1, \ldots, q_k;\ k = 1, \ldots, K;\ t = 1, \ldots T-1;\ \alpha = \textit{fix or free carry}-\textit{overs})$ the observed carry-over c of region j, in activity k, from period t to period $t+1$.

We call W^t the weight assigned to each period t (being $\sum_{t=1}^{T} W^t = 1$) and w^t, the weight assigned to each activity in the production process (being $\sum_{k=1}^{K} w_k = 1$). Moreover, we use s^{t-}_{ik} y s^{t+}_{ik} as the slacks for the inputs and for the outputs, respectively, and λ^t_{jk} the intensity corresponding to activity k of unit j for period t. In our application, we assume

[3] Constant returns to scale is the method usually applied as the hypothesis for specifically evaluating cultural institutions ([13] for museums and [19] for libraries), as this gives a stricter range of efficiency scores. Our sample is also very homogeneous in terms of regional cultural institutions' network (apart from those for the autonomous cities of Ceuta and Melilla, which could be considered too small) as for the similar competences on cultural resources and institutions that regions have in a large and decentralized country like Spain, such that we then find this technical hypothesis more appropriate. Table A1 (on line supplementary data) shows the regional distribution of the institutions under analysis (museums and libraries) in the period analysed. We also take a uniform non-oriented model to allow regions to 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.

the equal weighting hypothesis, both for the stages of the production functions as well as for the time periods considered.[4] We also assume that the links between stages may be fixed or free and that the carry-overs are fixed and non-discretional, in order to give flexibility in the inter-reliant inputs, while intertemporal resources deal with a given cultural capital (size of cultural institution networks and their artistic and bibliographical collections).

The program provides an index of global efficiency (ρ_o^*) for each region o ($o = 1,\ldots,n$), 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 stage of activity k ($k = 1,\ldots K$) from the production function (δ_{ok}^*), for each time period t ($t = 1,\ldots,T$), (π_o^{t*}) and for each stage in each time period (ρ_{ok}^{t*}).[5]

The model put forward to evaluate the performance of cultural heritage institutions from a regional perspective determines a regional production function with, respectively, seven and six relevant variables for museum and library networks, which is also divided into two stages and ten time lapses (nine for libraries). However, we have a relatively limited sample size of units (17 regions and two autonomous cities), which might suggest a dimensionality problem associated to DEA models [67] and, therefore, certain difficulties related to the discriminatory power of the results. In the case of conventional models, the generally accepted rule is that the number of observations should exceed three times the total number of inputs and outputs [68]. Nevertheless [69], points out that NDEA models exhibit greater discriminatory power than conventional models because different sub-units are created when breaking down the production process into different stages, which might be considered as expanding the sample. In the case of DNDEA models [70], proposes applying an equivalent rule to that of black-box models in order to achieve an acceptable level of discrimination. Even though the time window chosen for our study might cause a problem of dimensionality stemming from the link between the input-output space and the number of observations, in the terms set out by the latter author we opted to maintain it, given our interest in knowing how performance progresses over a longer time period, despite the impossibility of expanding the number of observations in this case.

In addition to the efficiency evaluation model –and following [71]– it is possible to calculate the Malmquist productivity index (μ) using the efficiency indices shown in terms of distance, as the quotient of a region's distance to the frontier in period t and that unit's distance to the frontier in period t+1. We are also able to define dynamic Malmquist indices linked to the DN-DEA model [72,73]; in other words, those that take into account inputs interrelated between activities involved in the production process and over time. The dynamic Malmquist rate for a region o, in activity K, will be given by:

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

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

where $\Upsilon_{ok}^{t\to t+1} = \frac{\rho_{ok}^{t+1^*}}{\rho_{ok}^{t^*}}$ expresses the part of the index that shows the dynamic evolution of efficiency between two time periods (dynamic catch-up term) and $\sigma_{ok}^{t\to t+1} = \left[\frac{\rho_{ok}^{t^*}}{\pi_{ok}^{t(t+1)}} \times \frac{\pi_{ok}^{t+1(t)}}{\rho_{ok}^{t+1^*}}\right]^{1/2}$ is the part of the index that shows the frontier displacement (dynamic frontier-sift term), being $\pi_{ok}^{t(t+1)}$ and $\pi_{ok}^{t+1(t)}$ the efficiency indices of a SBM model for an activity k, of a region o, in the period t, evaluated as regards the frontier in $t+1$ y, for the same region and activity in time $t+1$, regarding the frontier in t, respectively. A value > 1 for $\Upsilon_{ok}^{t\to t+1}$ expresses efficiency improvements between two periods and a value < 1 implies efficiency reductions. Likewise, a value for . $\sigma_{ok}^{t\to t+1} > 1$ means progress at the frontier, while a value < 1 means a backlash in the technological frontier.

From the dynamic indices for each activity, it is possible to determine the overall dynamic index $\mu_o^{t\to t+1}$ as the geometric mean of the above:

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

Finally, our work seeks to determine what effect certain variables that are external to the cultural institutions' regional networks and related to the socioeconomic features of the environment might have on the efficiency results. The aim is to determine external drivers of efficiency through a two-stage analysis by applying different regression models between divers and efficiency results. This approach has given rise to a large number of studies mainly dealing with Network-DEA models, such as [74] for banks [75], in the hotel industry, and [3,19] in the cultural heritage sector. However, there are fewer applications for Dynamic-Network DEA models ([4] for libraries, and [39] in the energy production sector).

For our purposes, we adopt the approach suggested by Ref. [11] –based on truncated regression and bootstrapping– to explain differences in the efficiency indices caused by the conditioning effect of external variables, in accordance with the following specification[6]:

$$\theta_k = \beta\, x_k + \varepsilon_k$$

where θ_k represents the set of efficient scores from the model of the previous stage, $\varepsilon_k \sim N(0, \sigma_\varepsilon^2)$ is a vector of error terms, and β is a vector of parameters for the series of independent and environmental variables x_k. Following the first algorithm in Ref. [11] involves the following three steps:

i. We apply maximum likelihood to estimate a β and σ_ε in the truncated regression of the efficiency scores previously obtained on a set of covariates z, using the subset of regions with scores below one ($\widehat{\mathrm{DEA}}_\mathrm{l} < 1$).
ii. We loop over the following three steps L times to obtain a set of bootstrapped estimates of the parameters β and σ_ε; namely, $\mathrm{B} = [(\widehat{\beta}^{'\mathrm{b}}, \widehat{\sigma}_\varepsilon^{\mathrm{b}})]_{\mathrm{b}=1}^{\mathrm{L}}$.
   For each region with ($\widehat{\mathrm{DEA}}_\mathrm{l} < 1$), we draw $\varepsilon_\mathrm{l}^{\mathrm{b}}$ from the following normal distribution: $\mathrm{N}(0, \widehat{\sigma}_\varepsilon^2)$ right–truncated at point $(1 - \widehat{\beta}^{'} z_\mathrm{l})$.
   We compute $\mathrm{DEA}_\mathrm{l}^{\mathrm{b}} = \widehat{\beta} z_\mathrm{l}^{'} + \varepsilon_\mathrm{l}^{\mathrm{b}}$, again for the region for which ($\widehat{\mathrm{DEA}}_\mathrm{l} < 1$) and estimate $\widehat{\beta}^{\mathrm{b}}$ and $\widehat{\sigma}_\varepsilon^{\mathrm{b}}$ by truncated regression and maximum likelihood using the artificial competitiveness scores computed in the previous step as the dependent variable.
iii. Finally, we use values in B and the original estimates to build a confidence interval for parameters β and σ_ε.

We specifically follow this first algorithm in Ref. [11], since it allows for the introduction of efficiency ratios based on non-radial distances [76], such as the dynamic-network SBM model used in the research. Consistency in the application of this method depends on complying with the condition of separability [77], which implies that the contextual variables do not influence the shape of the production set but the

[4] Nothing leads us to think that regional governments are prioritising one of the basic functions of their cultural institutions (production or visibility), but rather that they are assigning them equal weight. The same applies to the years of the period analysed, which are weighted equally. The opposite hypothesis would have required a session of experts and policy-makers to justify and decide a specific priority.

[5] For further details concerning the definition of the efficiency indices and the technical features of the model, see Ref. [10]. Calculations for the empirical application were carried out with the DEA-SOLVER-PRO version 14.0.

[6] In order to validate robustness results, Tobit Regression and Fractional Logic Regression models [4] are also applied.

Table 3
Efficiency and Malmquist results: overall and production stages.

Production phases		MUSEUMS		LIBRARIES	
		Eff. Score	Malm. Index	Eff. Score	Malm. Index
Overall	Average	0.4832	0.9450	0.3672	1.0294
	Max	0.9476	1.2156	0.6862	1.4339
	Min	0.3134	0.8231	0.1064	0.8036
	St Dev	0.1453	0.1176	0.1541	0.1569
Stage 1	Average	0.5879	1.0290	0.5525	1.0266
	Max	1.0000	1.1762	0.9114	1.7612
	Min	0.1523	0.9256	0.1759	0.6169
	St Dev	0.2352	0.0567	0.2162	0.3055
Stage 2	Average	0.6263	0.8827	0.6285	1.0506
	Max	1.0000	1.5965	0.9858	1.1753
	Min	0.3297	0.6835	0.3119	0.9708
	St Dev	0.2222	0.2449	0.1823	0.0527

Source: authors' own

position of each production unit within the set. We assume this condition is complied with, in that our sample size makes it virtually impossible to reject the null hypothesis of separability when applying the test proposed by Ref. [78].

4. Results

Table 3 shows the descriptive statistics of the efficiency indices estimated for both regional cultural production functions in accordance with the ND-DEA model. The model provides an overall efficiency index for the study period for museums (2002–2020) and libraries (2002–2018), as well as for each production stage of both types of cultural institutions. The model also provides an efficiency index for each of the years assessed and for each stage in each year (see on-line supplementary data Table A2). Overall, the average regional efficiency over the whole period and in both stages of management is relatively low −48.3% on average for museums and somewhat lower for libraries (37.6%)– reflecting a substantial margin for improvement in terms of technical efficiency for regions vis-a-vis these cultural institutions' networks. 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 regions are now evaluated by stages of activity and time periods. As a result, no region is seen to be efficient over the whole period and during all of the activities for the two cultural networks (museums and libraries), even though the number of optimal cases is slightly higher in terms of intervals and stages of activity (see on-line supplementary data Table A2). Apparently, the stage geared towards the impact on cultural consumption is always more efficient than the one of cultural production –both in museums and libraries (Table 3)– which may be indicative of greater regional institution interest in the functions of cultural service use, or may simply imply greater success in attracting visitors.

The evolution of efficiency ratios is relatively stable (Fig. 3), except for a slight recession in overall efficiency and cultural production ratios, especially in libraries over the 2008–2010 biennium, which may well be due to the effects of budgetary cutbacks resulting from the economic crisis in those years. Considering the estimation of productivity through the dynamic Malmquist indexes (Table 3), we can say that productivity growth is very weak and only positive for library systems, which grew by 3% in the period under analysis, mainly due to the increase in productivity in the visitor attraction function, which grew by 5%. In contrast, the productivity of museum systems is negative (−6%), although it is slightly positive in the cultural production function (2%). This backward trend can be explained by lower museum permeability to technical change [27] compared to libraries –which have incorporated more digital innovations in terms of how to access and consume cultural services– and because the museum data series includes the pandemic year 2020, which triggered a severe decline in the number of visitors.[7]

As regards the regional distribution of efficiency ratios, the main results are shown in Fig. 4, both for the overall average ratios and for the first and second stages of cultural production and visitor impact, respectively. It is worth mentioning that the region of Catalonia achieves the highest levels of efficiency, both in the museum system and in library management. The Balearic Islands and La Rioja are also above average in both sectors, while the regions of Andalusia, Murcia, Galicia, Castilla La Mancha, Navarra, and Madrid always register below-average levels of efficiency. Fig. 5 shows the geographical distribution of the overall efficiency indexes. Except for a slight coincidence in colour intensity in northern regions –which means a higher level of performance– the order of efficiency apparently reveals different regional ranges in library and museum management.[8]

This is confirmed in the pairwise regression analysis between all the efficiency indices obtained in the research when using Pearson's, Spearman's and Kendall's coefficients (Table 4). In fact, there are only significant and positive correlations between the overall efficiency of regional museums and the visitor impact stage (also with the impact stage of libraries), while the efficiency of library systems is positively related to the cultural production stage. In contrast, there is an inverse correlation between the two management stages (production and impact) for the two sectors, although this is only significant in the case of museums.

This indicates a certain trade-off between these two cultural functions, i.e., regions that are more efficient in cultural production are less efficient in visitor impact –especially where museums are concerned. This leads us to consider certain external drivers of efficiency, such as the cultural and tourist reputation of museums and the areas where they are located, which could determine the public success of museums, regardless of cultural institutions' efforts in terms of provision and management.

If we turn to the distribution functions and box-plot analysis of all the efficiency ratios obtained in the study (Fig. 6), some of the aforementioned results are confirmed. First, overall efficiency ratios are lower and less dispersed than stage ratios, for both museums and libraries, which demonstrates the more restrictive filter of the DN-DEA models. Second, the density functions of the cultural production stages for the two types of institutions display a similar shape, i.e., they follow a common pattern, while those corresponding to the overall efficiency ratios and the impact stage exhibit different shapes, with different and shifted maximums for museums and libraries, which suggests different determinants in their behaviour.

For this reason, it is interesting to analyse the sources of this disparity in regional efficiency ratios and to ascertain which external factors determine the performance of Spanish regions in the provision and use of cultural goods related to museum and library systems. As noted in the previous section, the environmental variables considered in this area are classified into four groups: regional socio-economic indicators related to wealth, level of education and age structure of the population; variables

[7] Data show that the cumulative Malmquist indices in the regional museum series are slightly positive in previous years. Moreover, it is revealing that efficiency in 2020 falls in the visitor impact stage, but rises in the cultural production phase (Fig. 3), which denotes the emerging effort of museums in the virtual cultural production in the context of confinement.

[8] The same applies to the evolution of efficiency ratios (Figure A1, on line supplementary data): most regions show a divergent pattern in the performance of museums and libraries, while only a few (Extremadura, Galicia, Madrid, and the Basque Country) show a similar evolution.

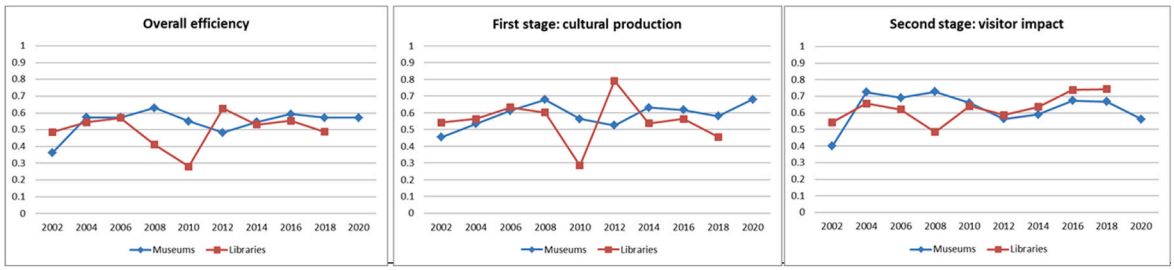


Fig. 3. Efficiency results evolution: overall and production stages.
Source: authors' own based on Table A2 (on-line supplementary data)

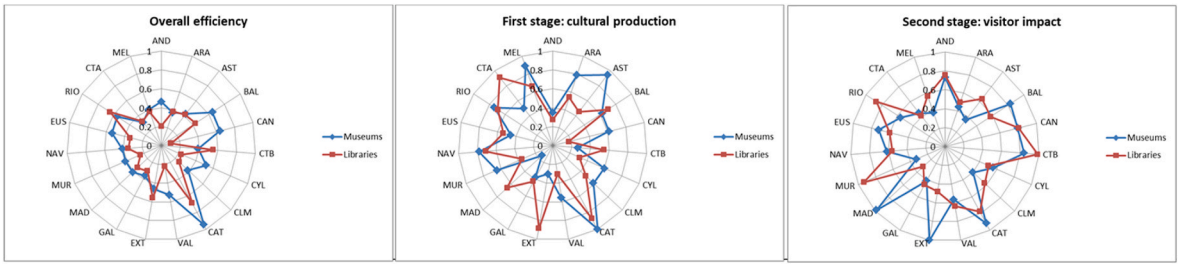
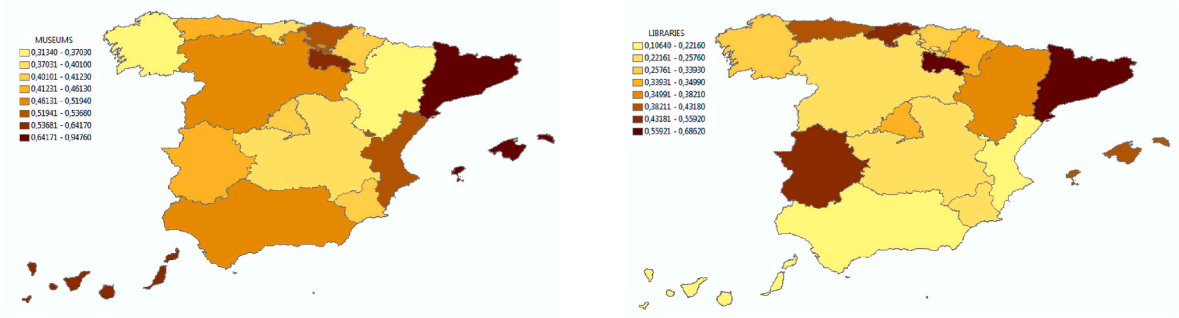


Fig. 4. Regional efficiency scores: overall and production stages.
Source: authors' own based on Table A3 (on line supplemental data)



(a) Museums (b) Libraries

Fig. 5. Geographical distribution of overall efficiency: regional museums and libraries.
Source: authors' own

linked to the size of the region's cultural sector in terms of cultural expenditure, employment and heritage endowments; tourism indicators referring mainly to the number and type of visitors; and finally, institutional aspects related to the ownership or management of cultural institutions. Following [11], we propose a truncated bootstrap regression (algorithm 1), taking as a reference the results of global efficiency and efficiency by stages of the DN-DEA model, for both regional production functions (museums and libraries). This model is relevant because it allows us to take into account the serial correlation between the DEA-based efficiency scores, and has been widely applied in second-stage regression models to estimate the influence of external factors on the efficiency ratios of several institutions such as libraries [4], archives [21] or museums [19], and also for performance analysis with a regional perspective, such as the case of cultural tourism destinations [79,80].

Nonetheless, in order to reinforce the robustness of the results, other econometric models have also been applied that prove to be appropriate to the case study of a dependent variable bounded in an interval between 0 and 1, such as the efficiency ratios [81]. In this vein, Tobit and FLR estimation models are applied. They also are statistically consistent, and the values obtained confirm the robustness of the results since they show no significant differences as regards the first model, in addition to which all the signs of the regressors remain stable, such that some results even reinforce the explanatory meaning of certain variables. Different previous tests have also been carried out to find the most suitable and explanatory model. Several iterations have been performed, testing and removing possible multicollinearity problems. The correlation matrix (see Table A4 in the on-line supplementary data) has been analysed and shows not very high ratios, except in the case of tourism, such that we decided to keep only one of the tourist variables in each estimation model. The Variance Inflation Factor (VIF) multicollinearity test has been validated and all the variables finally considered in the analysis record a value below 10 [82], as well as the mean of each group of variables in each regression model, reflecting the absence of multicollinearity problems. The coefficients obtained in the various tests are stable, thereby evidencing the robustness of our estimates.[9]

The results of the estimations for the ultimately valid and significant variables are presented in Table 5 for regional museum systems and Table 6 for libraries. Firstly –and as regards regions' efficiency in the

[9] Estimations were carried out using *Stata* software.

Table 4
Correlation analysis of efficiency ratios.

		Efficiency Ratios					
		Overall M	Stage1 M	Stage2 M	Overall L	Stage1 L	Stage2 L
Pearson (pw)	Overall M	1					
	Stage1 M	0.3752	1				
	Stage2 M	0.5034**	−0.4395*	1			
	Overall L	0.3497	0.2162	0.3384	1		
	Stage1 L	0.1051	0.1027	0.2891	0.7399***	1	
	Stage2 L	0.3330	0.1974	0.0102	0.1814	−0.3030	1
Spearman (rho)	Overall M	1					
	Stage1 M	0.2421	1				
	Stage2 M	0.4491*	−0.4474*	1			
	Overall L	0.0982	0.2842	0.2842	1		
	Stage1 L	−0.1088	0.1246	0.3035	0.7719***	1	
	Stage2 L	0.5070**	0.2579	0.0035	0.0474	−0.3263	1
Kendal (tau)	Overall M	1					
	Stage1 M	0.1813	1				
	Stage2 M	0.2982*	−0.3333*	1			
	Overall L	0.0526	0.1930	0.1696	1		
	Stage1 L	−0.0526	0.0877	0.2047	0.6374***	1	
	Stage2 L	0.3450**	0.1813	0.0175	0.0058	−0.2632	1

M: Museums; L: Libraries; *p-value <0.1; ** p-value <0.05; *** p-value <0.01.
Source: authors' own

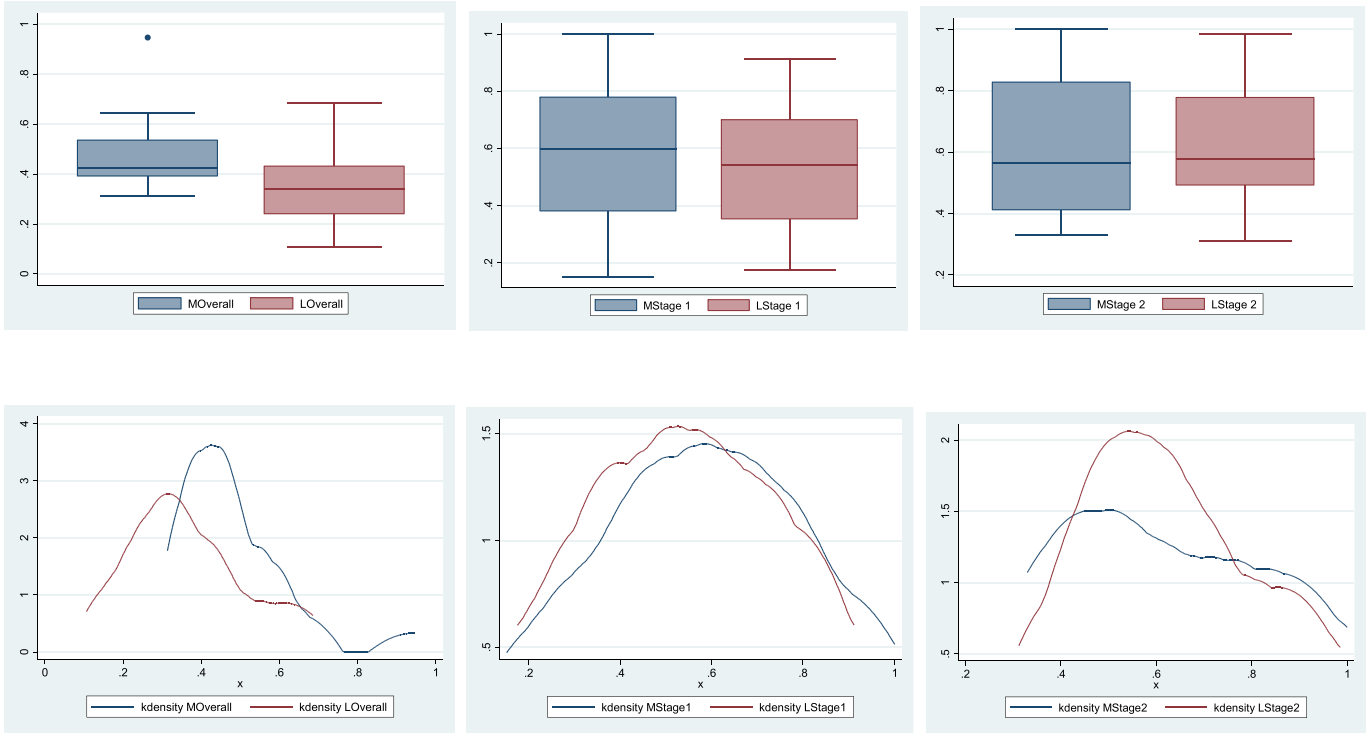


Fig. 6. Regional efficiency ratio distribution: boxplot analysis and density functions by overall and production stages.
Source: authors' own

provision and impact of museum-related goods– we find a significant and positive relation of overall efficiency in the whole period with the level of training at a regional scale. This is logical, given the positive relation of cultural consumption and level of training. We also find a positive correlation with the amount of regional public spending in culture, thereby highlighting the importance of public investment in these institutions. However, there is an inverse relation with income and senior population, which means that visitors might be younger. With regard to tourism indicators, there is a positive relationship with the total number of tourists, which includes foreign and domestic tourism. As noted in previous paragraphs, these results reveal the importance of the most accredited areas and major tourist icons with international repercussion, and which feeds back into the impact and attraction of museums. With regard to the institutional variables, there is a positive relationship with locally owned museums (municipal and provincial administration) and Church museums, while the relationship with national and regional museums is not significant.

If we look at the external variables that affect the museum's network efficiency of each of the two phases of provision already distinguished –cultural production and public impact– we find that, in the former, level of education and public expenditure in culture, again, and the size of the regional cultural sector in terms of historical heritage endowments have a positive effect, while the relationship is negative with regional income per capita. Inland regions appear to be the most

Table 5
Factors determining regional cultural efficiency in the provision and management of museums: regression analysis.

Variables	Overall score			Score stage 1			Score stage 2		
	SW	Tobit	FLR - Logit	SW	Tobit	FLR - Logit	SW	Tobit	FLR - Logit
Wealth	−0.001* (0.004)	−0.001 (0.000)	−0.003 (0.002)	−0.002*** (0.000)	−0.002*** (0.001)	−0.01*** (0.002)	0.003*** (0.001)	0.001 (0.001)	0.006* (0.003)
Human capital	0.009*** (0.003)	0.011*** (0.003)	0.046*** (0.013)	0.005* (0.003)	0.013*** (0.004)	0.067*** (0.019)	0.007 (0.005)	0.002 (0.004)	0.008 (0.025)
Senior	−0.013** (0.005)	−0.001 (0.006)	−0.039 (0.027)	0.005 (0.006)	−0.005 (0.007)	−0.024 (0.034)	−0.026*** (0.009)	−0.006 (0.008)	−0.031 (0.038)
Cultural public spending	0.002*** (0.001)	0.003*** (0.001)	0.015*** (0.003)	0.007 (0.008)	0.006*** (0.001)	0.031*** (0.006)	−0.001 (0.001)	0.000 (0.001)	0.000 (0.006)
Cultural consumption							0.001** (0.000)	0.001*** (0.000)	0.000 (0.006)
Heritage	0.000 (0.001)	0.000 (0.000)	0.000* (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	−0.000 (0.000)	−0.000 (0.000)	0.005*** (0.002)
Total tourism	0.009 (0.0006)	0.001* (0.006)	0.005* (0.002)	0.009 (0.006)	0.004 (0.008)	0.002 (0.004)	0.007 (0.001)	0.001 (0.009)	0.001** (0.003)
State museums	−0.000 (0.001)	0.001 (0.002)	0.006 (0.008)	0.001 (0.001)	−0.002 (0.002)	0.014 (0.011)	−0.001 (0.003)	0.002 (0.002)	0.000 (0.013)
Regional museums	−0.000 (0.001)	−0.000 (0.001)	−0.001 (0.005)	−0.006*** (0.001)	−0.004** (0.002)	−0.017* (0.008)	0.001 (0.002)	0.007*** (0.002)	0.037*** (0.011)
Local museums	0.004*** (0.001)	0.005*** (0.001)	0.021*** (0.006)	0.003* (0.001)	0.007*** (0.002)	0.037*** (0.015)	−0.001 (0.002)	0.000 (0.002)	0.002 (0.01)
Church museums	0.004** (0.002)	0.004* (0.002)	0.019** (0.009)	−0.003 (0.002)	0.003 (0.003)	0.021 (0.015)	0.008** (0.003)	−0.002 (0.003)	−0.004 (0.015)
Constant	0.203 (0.01)	0.036 (0.164)	−2.07*** (0.0689)	0.251 (0.173)	−0.118 (0.214)	−3.306*** (1.075)	0.314 (0.258)	0.083*** (0.008)	−1.675 (1.105)
Sigma	0.172*** (0.01)	0.041*** (0.004)		0.145*** (0.009)	0.071*** (0.007)		0.214*** (0.019)	0.083 (0.008)	
Wald chi2	40.53***	49.92***	59.85***	71.24***	55.22***	62.63***	38.08***	54.43***	63.17***
Pseudo r2		−3.523	0.038		0.596	0.08		0.448	0.103
Mean VIF	2.82	2.82	2.82	2.82	2.82	2.82	2.85	2.85	2.85

Note:* p-value <0.1; ** p-value <0.05; *** p-value <0.01. Standard errors are shown in parentheses. Regression models: SW, Simar-Wilson model (5000 bootstrap replicas); Tobit regression model; FLR, Fractional logic regression model.
Source: authors' own

Table 6
Factors determining regional cultural efficiency in the provision and management of libraries: regression analysis.

Variables	Overall score			Score stage 1			Score stage 2		
	SW	Tobit	FLR - Logit	SW	Tobit	FLR - Logit	SW	Tobit	FLR - Logit
Wealth	0.002** (0.001)	0.001* (0.009)	0.006** (0.003)	0.001 (0.002)	0.004*** (0.001)	0.019*** (0.005)	−0.002*** (0.000)	−0.003*** (0.001)	−0.013*** (0.003)
Human capital	0.003 (0.051)	0.005 (0.004)	0.021 (0.016)	0.004 (0.008)	−0.001 (0.006)	−0.007 (0.025)	0.012** (0.003)	0.012*** (0.004)	0.053*** (0.018)
Young	0.037*** (0.014)	0.028** (0.011)	0.116** (0.049)	0.044** (0.022)	0.025 (0.016)	0.101 (0.067)	0.015* (0.01)	0.006 (0.012)	0.025 (0.051)
Senior	0.031** (0.012)	0.021** (0.011)	0.088** (0.043)	0.047** (0.02)	0.02 (0.014)	0.084 (0.057)	−0.004 (0.008)	−0.02** (0.01)	−0.093** (0.044)
Cultural public spending	−0.000 (0.001)	−0.000 (0.001)	−0.001 (0.004)	0.003* (0.001)	0.001 (0.001)	0.006 (0.005)	−0.003*** (0.001)	−0.002** (0.001)	−0.009** (0.004)
Heritage	0.000* (0.000)	0.000*** (0.000)	0.00** (0.001)	0.001*** (0.000)	0.001*** (0.000)	0.00*** (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Domestic tourism	0.008*** (0.001)	0.007*** (0.002)	−0.002*** (0.009)	0.001** (0.004)	0.001*** (0.003)	0.006*** (0.001)	0.006*** (0.001)	0.006*** (0.002)	0.003*** (0.001)
Regional libraries	0.007* (0.003)	0.006*** (0.002)	0.025** (0.01)	0.007* (0.004)	0.003 (0.345)	0.012 (0.012)	0.007*** (0.002)	0.007*** (0.002)	0.032** (0.015)
Local libraries	0.002 (0.001)	0.001 (0.001)	0.005 (0.004)	0.002 (0.002)	−0.000 (0.001)	−0.000 (0.007)	0.004*** (0.001)	0.003*** (0.001)	0.015*** (0.004)
Constant	−1.321** (0.651)	−0.875 (0.555)	−5.629** (2.25)	−2.043* (1.1)	−0.507 (0.748)	−4.094 (3.1)	−0.271 (0.430)	0.388 (0.549)	−0.416 (2.366)
Sigma	0.222*** (0.017)	0.053*** (0.005)		0.267*** (0.031)	0.096*** (0.01)		0.15*** (0.001)	0.051*** (0.005)	
Wald chi2	20.50	23.06***	25.10***	16.94**	33.58***	45.56***	78.96***	36.27***	40.92**
Pseudo r2		3.506	0.022		0.2826	0.063		2.305	0.041
Mean VIF	4.71	4.71	4.71	4.71	4.71	4.71	4.71	4.71	4.71

Note:* p-value <0.1; ** p-value <0.05; *** p-value <0.01. Standard errors are shown in parentheses. Regression models: SW, Simar-Wilson model (5000 bootstrap replicas); Tobit regression model; FLR, Fractional logic regression model.
Source: authors' own

efficient in cultural production of museums. These display a high density of cultural heritage and are relatively less developed. We also found a negative relationship with regional museums, while the relationship was positive with local ones. In the visitor impact function, there is now a positive correlation with regional wealth and private expenditure on cultural consumption, revealing the nature of museums as leisure goods, which is also associated with total tourism flows. There is a negative relationship with the senior population strata, such that it can be assumed that this is young tourism. Finally, at the institutional level, Church museums appear as determinants of efficiency, as in the overall ratio. This hints at the importance of museums associated with cathedrals –one of the main attractions of urban tourism– and overall tourism, especially in some of the most emblematic cathedrals (Toledo, Seville, Burgos, etc.) and other basilicas (Sagrada Familia in Barcelona) and monasteries.

With regard to the efficiency of Spanish regions in the management and provision of library services, the first determinants of overall efficiency for the whole period are regional wealth per capita and the young and senior population strata, without explicitly discriminating between population groups, but rather giving priority to generic participation. Efficiency is also associated with the size of the cultural sector in terms of heritage endowments and with domestic tourism. It can therefore be assumed that the most efficient regional networks of libraries are located in inland regions. There is also a positive and significant relationship with the group of libraries owned and managed by the regional administration. The first phase of the regional production function –which refers explicitly to the capacity for cultural programming with existing resources– has the same structure of relationships as overall efficiency, reinforced by the positive contribution of public expenditure in culture. Finally, in the consumption impact phase (circulation activities and other visitors to libraries) –and contrary to the previous efficiency rates– clear positive relationships emerge with the level of human capital but negative with the level of regional income per capita and public cultural expenditure. In addition, there is a positive correlation with young people (inversely, as regards seniors) and domestic tourism flows. This shows how the use of libraries is envisaged mainly for local visitors, who are well-educated and mostly young, and who are assumed to be principally motivated by self-knowledge growth. This argument is reinforced when confirming a positive relationship with regional and local libraries –which are closer to local residents– rather than national ones.

5. Discussion and conclusions

There is abundant and growing literature on the efficiency evaluation of cultural institutions, although there are still few studies that address it from a spatial perspective, i.e., under the approach of a production function specified for spatial units, such as regions, and on the basis that regions are endowed with a number of cultural resources of capital and labour, with which to optimize certain outcomes, defined in terms of cultural production and impact on consumption. Based on these premises, it is also assumed that those responsible for cultural policy have the capacity to specify purposes, allocate funding and to define action strategies in accordance with these general objectives, with the ultimate aim of ensuring the quality and efficiency of cultural institutions, which in turn reinforces the conditions for economic development.

Our work responds to this perspective. The main aim is therefore to evaluate the efficiency of Spanish regions in the provision and management of two groups of emblematic cultural heritage institutions; the regional museum and library systems. A complex methodological approach is established, since we define regional production functions divided into stages with interrelated inputs, which correspond to the phases of cultural production and visitor impact; and time lapses connected by carry-overs, a type of immanent cultural capital, which does not run out in time. All the research dealt with a broad time period –between 2002 and 2020– for the Spanish administrative division, with 17 regions and two autonomous cities that have wide-ranging powers in cultural matters. A second phase of analysis is also proposed in order to estimate the influence of external factors on the efficiency ratios, considering for this purpose socioeconomic indicators, the size of the cultural and tourist sector and institutional variables.

The results first indicate that the average regional efficiency ratios for the whole period are relatively low, which shows the important margin that regions have for improving their level of efficiency in the use of resources and for managing cultural institutions, even considering that the results of the DN-DEA model are quite restrictive. The evolution of efficiency is stable, revealing a slight decline in the years of economic crisis, probably due to budgetary restrictions at that time. Productivity gains are very weak, and even negative in the case of regional museum systems. This may be indicative of their lower permeability to technical change and innovation, in comparison with libraries.

The regional distribution of efficiency ratios does not respond to a common pattern of ranges in the two sectors, nor in the stages of cultural production and impact on the use of services. Rather, a trade-off is observed between the two functions, i.e., regions that are more efficient in the first phase are less efficient in the visitor impact objectives. The overall efficiency of museum systems seems to be linked to the impact phase, while the efficiency of library systems is more determined by the cultural production phase. These results suggest the existence of external factors that determine the efficiency and behaviour of regional institutions; hence the relevance of the second phase of analysis in the research.

Indeed, human capital appears to be a common determinant of all the efficiency ratios: the higher the regional population's level of education, the more efficient the cultural heritage institutions are, especially as far as museums are concerned, both at the global level and in the phases of cultural production and visitor impact. In contrast, for libraries this effect is mainly determined in the impact stage, then followed by library consumption. This result is consistent with the usual norm in the consumption of cultural goods –which is positively related to human capital– but also strengthens the argument of becoming a condition for the quality of institutions and, consequently, of economic development. In contrast, per capita income, i.e. regional wealth, does not seem to play a positive role –rather the opposite in the case of museums and softer in the case of libraries. Nevertheless, this research does show that public spending on culture by regional governments is a determinant in cultural heritage institutions' efficiency, particularly when they are programming (cultural production stage), while the level of private spending, i.e., cultural consumption positively affects museum efficiency in terms of impact, which endorses their being seen as elements in leisure consumption.

The size of the cultural sector limits its impact in terms of the extent of cultural heritage endowments, which seems to feed back into regions' efficiency in cultural programming functions and to show that the most culturally accredited regions also display efficiency in cultural programming. The age of the regional population does not discriminate in the efficiency of libraries, although the adult population group does have a negative impact on museum performance, which reflects the fact that visitors might be mostly young. However, the major determinant of regions' efficiency in the management of cultural institutions –especially in the museum sector– is tourism. Indeed, total tourism flows (including foreign tourism) have a determining effect on museum efficiency, while domestic tourism impacts all the efficiency rates in libraries. This is an external factor that is unrelated to the quality and management strategy of the institutions, as it seems to demonstrate the importance of reputable tourist sites and major cultural icons in the performance of museums, while –at most– libraries receive the impact of domestic visitors. Finally, among the institutional indicators of management and ownership of these entities, no significant determinants seem to be found, except for the singularity of ecclesiastical museums, which positively affect efficiency. This leads us to highlight the

importance of certain celebrated icons, such as cathedrals and cathedral museums. In the regional library systems, regional and local ownership determine efficiency at the impact stage, i.e. when providing services to the public, where this kind of institution is closer to the public, rather than libraries at a national scale.

Our research constitutes a sophisticated contribution, for the first time applied in the cultural field, in three methodological dimensions: it contains a spatial approach to the production function of cultural goods and services, which is divided into productive and temporal stages and where the effects of wide-ranging external variables are contrasted. Moreover, the estimation strategy of external variables is implemented on all efficiency ratios and not only those of the last impact stage [64,74,75], on the assumption that there may be factors that determine both the possibilities of cultural production and the overall efficiency of the cultural heritage institution regional complex. A meticulous analysis of the selection of significant variables has also been carried out and a triple regression exercise has been performed to check the robustness of the results. The most important limitations of the research are the absence of variables representative of the quality of cultural institutions, indices of corruption and the political cycle, as well as indicators of accessibility. The difficulty of capturing such variables leaves room for analytical challenge in the future.

The findings of this research could be useful for policy implications regarding resource allocation vis-à-vis defining and accomplishing cultural goals at a regional scale. They are also valuable for revealing causes of inefficiency in order to improve quality in cultural institutions or to remove barriers that prevent stimulating this atmosphere, which ultimately drives economic development. Finally, whether or not greater cultural institution independence in a context of policy decentralization and the various new forms of public-private partnerships have really affected the performance of cultural institutions also remains an open question. In this vein, we can say that the principal-agent problem will always persist because decentralization might give rise to gains in visibility and might impact institutions (agents), as has been proven for the case of museums in Italy [7,8]. Nevertheless, cultural policy makers may wish to maintain a balance between the functions of cultural production (quality) and impact in terms of audience. The results of this research may shed light in this regard.

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Declaration of competing interest

The authors declare that they have no conflict of interest.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.seps.2023.101593.

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