Decomposing museum performance using network DEA: Contrasting perspectives in quests for economic sustainability in museum performance

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Decomposing museum performance using network DEA: Contrasting perspectives in quests for economic sustainability in museum performance

The economic sustainability of a museum is reflected by its long-term capacity to perform educational, researching and collecting activities through efficiently using its resources. Since museums are challenged to compete for continuous funding, performance analysis that considers resource utilization becomes a decisive issue for museum managers such as funding allocators. Our study contrasts the significance of different perspectives in museum performance evaluation by using a network DEA approach. Accordingly, we are able to face the complexity of museum activities by decomposing museum performance in two stages of production. The first stage considers the museums' efficiency in service provision. Here we assess financial resource utilization related to cultural service supply. The subsequent stage faces efficiency in visitor attraction by service offer. Findings show substantially higher efficiency estimates related to service provision whereas the attraction of visitors by service offer turns out to be major source for inefficiency.

Keywords*: network DEA, museums, economic sustainability*

Track: *Public Sector and Non-Profit Marketing*

1. Introduction and Objectives

For many years, the tense competition for (public) funds forms a recurring issue in international literature on museum management (see e.g. Pop & Borza, 2016; Recuero Virto, Blasco López, and San-Martín, 2017). However, it is liable to expect that Covid-19 might even enhance the competitive pressure for museums in the allocation of grants (see International Council of Museums, 2020). Accordingly, discussing managerial ways to ensure continuous funding by appropriately addressing the non-profit character of museums appears more relevant than ever before.

A museum's ability to prove its economic sustainability is an important step in order to stay competitive and ensure persistence in financial support (Di Pietro, Guglielmetti Mugion, Renzi, and Toni, 2014). This can be argued since economic sustainability addresses the long-term capacity to enable or even improve activities serving a museum's educational, researching and preserving function (Hildebrand, Paetz, and Küblböck, 2022). Every museum activity is connected to a process of resource combination that in total form a museum's performance. When demonstrating substantiated financial viability, performance evaluation in general such as the ability to evidence efficient resource utilization is of particular importance (Basso, Casarin, and Funari, 2018). Consequently, the recent years have shown a growing interest of museums and funding allocators in performance evaluation methods such as Data Envelopment Analysis (DEA) (Basso & Funari, 2020a).

DEA is a non-parametric technique for evaluating performances of peers. It is used to analyse relative efficiency in production processes which are represented by multiple inputs and outputs (Cooper, Seiford, and Zhu, 2011). Hence, it is possible to include complex production processes such as it accounts for museums which perform multiple interrelated activities to serve their museum functions. Conventional DEA models treat the analysed units as black boxes by considering input usage for producing external output (Kao, 2017). In the case of museums, this could mean performance evaluation taking into account capital resources, e.g. a museum' s building area, and visitors as external production output (Del Barrio-Tellado & Herrero-Prieto, 2019). By contrast, network DEA includes internal processes that facilitate the creation of external output by applying efficiency estimation for production stages (Kao & Hwang, 2011). Thereby, it is possible to analyse sources of inefficiency within production processes (Kao, 2017). Several black box DEA applications for museums exposed the utility of managerial implications resulting from DEA. Merely, Del Barrio-Tellado and Herrero-Prieto (2019; 2022) introduced network DEA as methodical approach to locate potential sources of inefficiency in museums' production processes.

To take up this research demand, we conduct a network DEA for a set of German publicly funded museums. We suggest a research model that analyses museum performance throughout two production stages. The first stage considers the museums' usage of public funds for creating service ability. In the second production stage, we investigate the adequacy of provided services in the light of gained attendance.

By additionally computing corresponding black box model estimates, we aim to demonstrate the decisive role of considering different perspectives in museum performance evaluation. Moreover, few existing research on network DEA causes a lacking basis for discussing survey-overriding structures of occurring inefficiency in museums' production processes. Accordingly, our study contributes to a better understanding how (in)efficiency develops throughout museum performance.

This paper is organized as follows: In section 2, we provide theoretical foundations for our empirical study. Here, we offer a brief introduction in efficiency estimation for network DEA models and shortly review on existing DEA applications of museums. Section 3 reports on data of our empirical study and constitutes major research results. A conclusion and managerial implications are provided in section 4.

2. Theoretical Foundations

2.1 Efficiency Estimation for Basic Two-Stage Network DEA Systems

DEA is a technique for investigating relative efficiency of peers denoted as Decision Making Units (DMUs). It characterizes few data based restrictions and its capacity to assimilate multiple inputs and outputs of often unknown relations for oriented and non-oriented efficiency measures (Cooper, Seiford, and Tone, 2007). In our study, we establish oriented efficiency measures for a group of German museums that are considered as DMUs under investigation. Since the analysed museums do not operate in similar scale, we employ measures under the assumption of variable returns to scale (VRS). An optimization problem is to be solved for each DMU to compute efficiency scores that reflect ratio and input-oriented efficiency measures taking into account efficiency frontier estimation. The efficiency frontier is determined by fully efficient best practice units which serve as reference for efficiency score computation (Cooper, Seiford, and Zhu, 2011).

We consider n museums to be our DMUs for efficiency analysis. A DMU j (j=1, …, n) transforms m inputs in s external outputs. We denote X_{ij} as the amount of input i (i=1, …, m) that is used by DMU j to produce Y_{rj} assumed as amount of external output r (r=1, …, s). Input i and output r are related to weights considered as v_i and u_r, respectively. Starting with standard input-oriented BCC (Banker-Charnes-Cooper) model formulation, E_0 ($E_0 \in [0, 1]$) is supposed to be the efficiency score associated with a DMU indexed 0 and has the following form:

$$E_0 = max.\ \frac{\sum_{r=1}^{s} u_r Y_{r0} - u_0}{\sum_{i=1}^{m} v_i X_{i0}} \tag{1}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r Y_{rj} - u_0}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1,\ j = 1, \dots, n \tag{2}$$

$$u_r, v_i \geq \varepsilon,\ r = 1, \dots, s, \quad i = 1, \dots, m \tag{3}$$

u_0 unrestricted in sign.

An obtained efficiency score E_0 of 1 indicates a best practice unit that is fully efficient. Any value E_0 smaller than 1 characterises a non-efficient entity which does not show optimal frontier behaviours. Accordingly, non-efficient units require adjustments in performance criteria in order to reach 100% efficiency (see e.g. Cooper, Seiford, and Tone, 2007). By applying black box approach, results might serve as general information on DMU performance (Kao, 2017). However, when conducting network DEA it is considered how a DMU produces external output by including intermediate products in efficiency evaluation. Accordingly, we introduce Z_{gj} as amount of intermediate product g (g=1, …, h) produced by DMU j and suppose w_g to be the weighting related to intermediate product Z_{gj}. Referring to basic two-stage network DEA approach, Z_{gj} serves as linking output of production stage one. The second production stage fixes the intermediate products of stage one and considers them to be converted to final output (Kao & Hwang, 2008). With reference to Kao (2017), figure 1 illustrates a basic two-stage system structure.

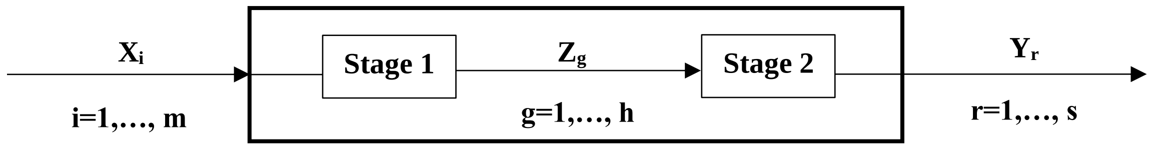

Figure 1. Illustration of a basic two-stage network DEA system structure

A straightforward way for stage efficiency estimation would be to establish independent ratio-form measures as introduced in (1)-(3). Certainly, if one seeks to model a system or DMU efficiency assimilating the connection of its production stages (intermediate measures) in the objective function, an efficiency decomposition model employing ratio-form measures might be of researcher's choice (Kao, 2017). As initially introduced in Koa and

Hwang (2008) by assuming constant returns to scale (CRS) the system or overall efficiency is supposed to be the product of stage efficiency estimates. However, when applying efficiency decomposition to the proposed multiplier form, yielded stage efficiencies might not be unique under VRS assumption (Chen, Cook, Kao, and Zhu, 2013). The implementation of game theoretic approach in DEA solving method, addresses this need for stage coordination (Liang, Cook, and Zhu, 2008; Cook, Liang, and Zhu, 2010; Lim & Kim, 2022). In our study, we chose a non-cooperative game approach for stage efficiency coordination. We propose the first production stage to be the leader which implies efficiency estimation of visitor attraction follows efficiency measures of service ability.

2.2 Literature Review

Conducting DEA for efficiency analysis of museums cannot be stated as recent appearance in museum performance research. Over the past decade researchers from Iran (Taheri & Ansari, 2013), Portugal (Carvalho, Costa, and Carvalho, 2014) and Korea (Kim & Chung, 2020) conducted DEA studies of diverse black box model facets. Besides Italian surveys of Basso and Funari and Spanish research of Del Barrio-Tellado and Herrero-Prieto form recurring contributions to efficiency research track of museums. While Basso and Funari (2018; 2020a; 2020b) recently concentrate on methodical development for a joint application of black box DEA and Balanced Scorecard, Del Barrio-Tellado and Herrero-Prieto (2019) initially demonstrate the applicability of network DEA. The survey of Del Barrio-Tellado and Herrero-Prieto (2019) underlies the assumption that museum performance is to be comprehended in two production stages of differing scope for potential managerial influence. During the first production stage, a museum transforms its resources (represented by staff, surface size, collection movements) to multiple cultural products (modelled by scheduled exhibitions, supplemental activities, publications). Del Barrio-Tellado and Herrero-Prieto (2019) conjecture this stage as expression of managerial efficiency. In contrast, the second production stage assesses gained visitor attendance by service provision which is not under absolute managerial control. The results of their non-oriented slack-based model show slightly higher efficiency estimates related to the first production stage. They demonstrate efficiency scores of both stages as independently distributed and conclude that managerial efficiency does not assure high visitor attendance. Del Barrio-Tellado and Herrero-Prieto (2022) recently focus on dynamic network efficiency analysis on a five-year database. They maintain major model assumptions but consider the museum’s surface and the provision of open museum rooms as constant over time. Findings show overall efficiency as certainly stable over time, though efficiency improvements in both production stages can be identified.

3. Empirical Study

3.1 Data

In our empirical study, we collected data for a set of German publicly funded museums. Therefore, the allocation of substantial state funding served as major selection criteria. This brings the advantage of mostly disclosed economic information in budgeting plans and accounts of the respective federal states. Since accessing comparable economic information for a larger set of museums forms a significant challenge in model building, budgeting plans and accounts served as valuable source for data collection. The present study grounds on data of the report year 2019 for which latest budgeting accounts were available for all federal states.

Table 1 provides information on all included performance criteria. As not all involved performance information could be gauged via budgeting plans and accounts, annual (financial) reporting and strategy papers, collection documents, program brochures and additional information from museum websites were used to select data on the proposed inputs and outputs. Finally, museum staff such as some finance ministries of the respective federal states were contacted for missing data. In total, we identified 165 museums matching with major data selection criteria. In order to determine our final data set, we performed two stages of museum exclusion. This is important because DEA is a data-sensitive method which requires comparability of its DMUs (see e.g. Bahari & Emrouznejad, 2014). Our first stage of museum deletion considered missing data and the second stage excluded museums of incomparable performance conditions. Upon others, for deletion stage one we identified a couple of museums of a state office affiliation to be not suitable for comparative analysis. For this type of organization, it is difficult to isolate economic museum information from remaining state office activities. Furthermore, museum organizations of more than one museum revealed as challenging since most of them use a shared finance and accounting system. Hence, it is to assume that these museums are managed as a whole. Therefore, we decided to compute fictive average museums for organizations holding more than one museum.

We identified a final set of 47 museums to be suitable DMUs for comparative analysis. Thereof, eleven DMUs make up fictive average museums. In contrast to existing DEA applications for museums as reviewed in 2.2, our study grounds on an extended data set.

Concerning the selection of assimilated inputs and outputs, our model takes up recurring model components of existing DEA applications for museums. Accordingly, we do justice to state of the art model building and concurrently, we initially introduce public funding as single model input which puts particular emphasis on efficiency analysis in using public funds.

	Description	Mean	Sd	Min	Max
Public funding (input)	Allocated funding in € from federal states, municipalities and the national government (project funding excluded)	4,133,855	3,426,100	81,700	16,554,000
Personnel expense (intermediate product)	Annual personnel expense in € monetarily representing extant and quality of museum staff	2,390,135	1,957,665	47,938	7,772,700
Weekly opening hours (intermediate product)	Annual average of regular weekly opening hours	45.16	8.51	15.75	56
Exhibition area (intermediate product)	Display area for permanent and special exhibitions in m^2	4,368	3,548	400	14,250
Facility level (intermediate product)	Average amount of supplement services aggregated in four facility categories (events, gastronomy, shop, library)	1.12	0.62	0.25	2.25
Special exhibitions (intermediate product)	No. of scheduled special exhibitions	4.92	3.45	0	16
Publications (intermediate product)	No. of research and educational publications	5.60	12.09	0	78
Visits (final output)	Total no. of annual visits	105,907	88,295	6,282	372,956

Table 1. Description and descriptive statistic of included performance criteria

3.2 Results and Discussion

By contrasting computation of black box and network model estimates, we are able to provide multiple perspectives for evaluating efficiency in using public funds. When applying black box approach for efficiency analysis as introduced in section 2.1, it is asked whether the analysed museums might be able to gauge a similar attendance by minimizing financial resource use. The results in table 2 imply small black box scores for the sets majority. Approximately 75% of the set gauge a score smaller than 0.3. Only four museums yield a black box efficiency score of 1.0 and therefore efficiently use their public funds from black box perspective.

By conducting network DEA, a corresponding system or overall score is yielded that considers constructed stage efficiency. Statistics in table 2 show that from overall network perspective, only three museums are said to be 100% efficient. However, the average network overall score is slightly higher than the corresponding black box value. Overall efficiency scores show a different distribution as already implied by a median value of 0.24. Since the overall efficiency is computed as the product of stage estimates, it is to assume that differences in black box and overall network distribution result from higher efficiency scores of the considered production stages. The investigation of the respective stage efficiency distribution offers an additional perspective for analysing efficiency in using public funds. The first production stage of our model considers efficiency in using funds to create cultural service ability. The results imply that the great majority of the set yield substantially higher efficiency scores when funding is evaluated not only in the light of gained attendance but also in the light of service provision. From this evaluation perspective, 17 museums are 100% efficient, though another three museums gauge a score greater than 0.99 but not equal to 1. Accordingly, 43% of the set (almost) show optimal frontier behaviour.

	Black box score	Overall score	Stage 1 score	Stage 2 score
Mean	0.28	0.36	0.69	0.46
Sd	0.31	0.29	0.32	0.27
Median	0.11	0.24	0.75	0.42
Min	0.03	0.01	0.05	0.05
Max	1	1	1	1
No. efficient units	4	3	17	3
No. observations	47	47	47	47

Table 2. Descriptive statistic of efficiency estimates

The following production stage finally measures efficiency in service provision against the background of visitor attendance. Due to input-orientation, stage two asks if a respective attendance level might be able gain by minimizing the included criteria of service provision. The results allow conjecturing that inefficiency rather occurs in the second production stage. This is in accordance with research results of Del Barrio-Tellado and Herrero-Prieto (2019; 2022). They derive managerial efficiency as reflected by efficiency in gaining service ability does not assure efficiency in visitor attraction through the provided service level. Our results support this assumption and show that it makes a difference if efficiency in using public funds is to be evaluated in the light of visitor attendance or in the light of service provision. Referring to the current set, greater potential for performance optimization is located in the ability to attract visitors by provided service offer. This underlines the importance of further investigations that consider what influences visitor attendance.

4. Conclusions

Even more because of the Covid-19 pandemic museums need to be able to prove their economic viability to compete for continuous funding. Operating economical sustainable is and will be an affecting challenge for museum managers. Thereby, it is not suffice to understand this as an exercise to finance museum activities. To ensure long-term competitiveness, quests for funding activities have to be accompanied by asking for efficiency in (financial) resource utilization. In our study we show that conducting network DEA in addition to standard black box approach can contribute to a better understanding of how (in)efficiency occurs in museum performance. We employed input-oriented and ratio based measures throughout two constructed production stages. The first production stage of our network model takes into account whether public funds are efficiently used to create cultural offer for receiving visitors. The following stage considers the adequacy of service provision criteria against the background of visitor attendance. The results show that museums of the analysed set tend to show higher efficiency scores related to the evaluation of resource use for creating service offer than in attracting visitors. A contrasting analysis of black box estimates reveals that it is crucial whether resource evaluation considers service provision or visitor attendance. Our study results imply when evaluating efficiency in using public funds, it would not be appropriate to exclusively consider finally gained attendance (black box perspective). However, network results induce the attraction of visitors by service offer as major source for inefficiency.

Against the background of our findings, we infer the following managerial implications: When discussing efficiency in using public funds it is important to emphasize that merely assessing visitor attendance is not a suitable approach to evaluate museum performance. When reflecting resource utilization, it might be decisive to argue for what kind of activity inputs are used for. Nevertheless, scrutinizing if provided services meet what is attracting visitors appears as equally important.

Since few studies considered network DEA as methodical approach to investigate museum performance by introducing analysis of production stages, the employment of network DEA of different model orientations, returns to scale assumptions and performance criteria are future research issues. This is of particular importance since DEA results are always limited to their underlying database.

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