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Abstract

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Key Words: efficiency, production function, museums, new public management
JEL classification numbers: H72, D24, H83

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1 Introduction

In order to reconstruct the budget positions of local governments, the Koizumi government advocated a policy of "small" government and cuts in the costs of public cultural facilities. In order to try to reduce or eliminate inefficiencies in the management of public facilities, some local governments introduced the New Public Management (NPM). The NPM is a system to apply private management methods to the public sector and is based on the idea that the introduction of private sector management methods can improve efficiencies in the public sector. One example of a NPM introduced into public facilities in Japan was the Designated Manager System (DMS), which was enacted in 2006 and enabled private managers to manage public facilities. Regardless of whether or not the DMS was introduced, many public facilities introduced some form of the NPM.

This paper focuses on prefectural museums, and aims to determine how the small government policy has changed the efficiency of Japanese prefectural museums since 2006, using econometric methods. Generally speaking, a prefectural museum is a museum which has been established by a prefectural government. For the purpose of this paper, museums that have been established by prefectural governments and that are members of the Council of Deputy Director Generals and others of Prefectural Art Museums (*Todoufukenritsu Fukukanchoutou Sekininsyakaigi*) are defined to be Japanese prefectural museums. According to this definition, the total number of the Japanese prefectural museums in 2015 is 65. In all 47 prefectures except Tokyo, the fiscal deficits of prefectural governments have been increasing and prefectural cultural facilities have been a heavy burden on public finances. Some museums introduced NPM by introducing the DMS in order improve the prefectural budget situation. Other museums introduced NPM without introducing the DMS. Therefore, this paper measures the impact of the DMS on the productive efficiencies of museums.

Since the activities of a museum has a variation, a performance of a museum should be evaluated from various viewpoints. For example, Sasaki (2008) argues that Japanese public museums should be evaluated to examine the following four; (1) whether or not the work to hold exhibitions is proceeding efficiently; (2) whether or not projects are planned to maximize potential value of a museums, considering available materials, human resources, budget, and geographical conditions; (3) whether or not the museums can check its account system and its organization to realize a solid and stable management; and (4) whether or not the museum has established as cultural capital to spread the external economy effect to its location.

Especially, this study focuses on the evaluation of productive efficiency in holding exhibitions from an economic view viewpoint.

Assuming that holding exhibitions is the main activity of a museum, the existing literature measures the technical or cost efficiencies of museums using frontier analysis. In most of the existing econometric studies, the "output" of museums is defined to be the total number of visitors to exhibitions. Mairesse and Echkanut (2002) measure the technical efficiency of 64 Belgian museums using window data envelop analysis (DEA). Based on a new paradigm which appeared toward the end of the 1980s, Mairesse and Echkanut (2002) consider three tasks of museums to be the outputs of museums: (1) the collection and preservation of art works; (2) research and communication, that is, the interpretation of artworks in exhibitions, and (3) outcomes including the number of visitors and economic aspects. Using data from a postal survey of the members or associate members of the South West Museums Council in 1998, Bishop and Brand (2003) measure the technical efficiency of 110 British museums by estimating a Cobb-Douglas production function using the stochastic frontier approach (SFA). Their results indicate that public funding and voluntary activity decrease technical efficiencies. Basso and Funari (2003) analyse the performance of museums using classical DEA and free disposal hull data envelop analysis (FDH DEA). Basso and Funari (2004) measure the technical efficiency of 15 public Italian museums in 1998 using DEA. They also propose both quantitative and qualitative factors that should be considered when the efficiencies of museums are measured. Barrio et al. (2009) measure the technical efficiency of Spanish museums using DEA. They define one of the outputs of museums as the number of visitors to museums. Haruna at al. (2011) measure the inefficiencies of Japanese prefectural museums from 1998 to 2006 using micro data from the "Prefectural Art Museums Survey" conducted by the Council of Deputy Director Generals and others of Prefectural Art Museums. They use network DEA for their analysis, and take into account the local characteristics of the location of the museums, for example, any monetary support, the number of volunteers, and the prefectural population. However, they did not analyze the factors causing these inefficiencies. Suhara (2011) measures the technical efficiency of Japanese prefectural museums from 1998 to 2008 using SFA. She estimates a Cobb-Douglas production function using micro data from the "Prefectural Art Museums Survey" and her results indicate that prefectural educational events and the introduction of the DMS did not affect technical efficiency of museums. Only the distance from the central city in the prefecture to the museum improves technical efficiency. In his analysis, Suhara (2011) does not consider whether the designated manager engaged in planning exhibitions and whether the designated manager was selected through a competitive process. To examine whether public museums did not make an effort to avoid deficits in Japan when they can cover deficits with any public financial support, Kuwahara and Siozu (2013) estimate a Cobb-Douglas cost frontier function for Japanese prefectural museums over the period from 1998 to 2007 using SFA. However, their estimated cost function is not based on economic theory because the inefficient factors are treated as input factors in their estimated cost function. The estimation results also do not satisfy the standard assumption of a cost function that all the coefficients of input variables should be positive. Kuwahara and Siozu (2013) conclude that exhibitions financed mainly by prefectural governments are not cost inefficient compared with co-hosted exhibitions financed by private companies because the co-hosts have less incentive to minimize costs in Japan. Carvalho et al. (2014) measure the technical efficiency of 285 Portuguese museums using DEA, and then identify the determinants of inefficiency using a Tobit model. They define the output of a museum to be the number of visitors.

SFA and DEA are two main methods to measure the efficiency of museums to evaluate the performance of museums. Given their respective advantages and disadvantages, SFA and DEA can be viewed as being complementary. For instance, one of the key disadvantages of DEA is that it does not allow for hypothesis testing whereas SFA does. One of the disadvantages of SFA is the need to assume a specific form for the productive function and a specific distribution for the inefficiency component, while DEA does not require these assumptions. In this study, SFA is employed to determine the inefficient factors of management in museums.

The main contribution of this paper is consider the impact of the introduction of the New Public Management into Japanese public museums around 2006 based on statistical data. The econometric analysis is conducted in two steps. First, a translog production frontier function, which relaxes some of the assumptions of the Cobb-Douglas production frontier functions estimated in Suhara (2011), is estimated to measure the inefficiency of production. Second, the factors influencing museum inefficiency are analyzed, and the impacts of both the NPM and the DMS are examined using the estimated inefficiencies.

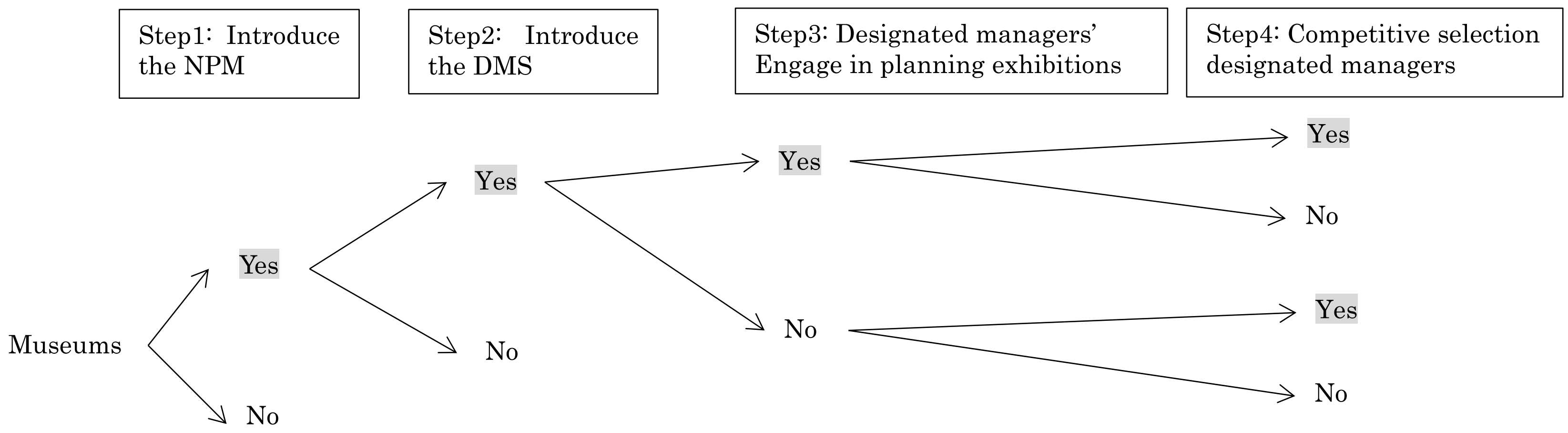
2 The Management of Japanese Prefectural Museums

The New Public Management (NPM) was introduced into Japanese public museums around the time the Designated Manager System (DMS) was enacted in

September, 2006 and as a result the management of the Japanese public museums has diversified. Before August 2006, prefectural museums were either managed by prefectural governments or by the external organizations of the prefectural governments. Private managers had not been allowed to manage the prefectural museums. After September 2006, private managers have been allowed to manage prefectural museums. In some museums, the managers changed to private managers. In the other museums, the managers did not change, so that either the prefectural government continued to manage the prefectural museums or an external organization of the prefectural government continued to manage the prefectural museums as the designated manager.

Each prefectural government decides on the managers of the prefectural museums located in each prefecture. To organize the decision making process relating to the management of prefectural museums, this paper assumes that the prefectural governments decides how to manage each museum in four steps. Figure 1 shows the decision making process relating to the management of the prefectural museums after 2006. In the first step, the prefectural government decides whether or not introduce the NPM into prefectural museums. In the second step, the prefectural government decides whether or not to introduce the DMS into the prefectural museums. In the third step, the prefectural government decides whether or not the designated managers will engage in planning exhibitions in the prefectural museums. Finally, the prefectural government decides how to select the designated managers. The prefectural government choose between a competitive system and direct designations. In econometric analysis in this paper, these four impacts on product

Figure 1: Desicion making prosess relating to the management of Japanese prefectural museums



3 Model

3.1 A translog stochastic production function

The number of inputs and the number of outputs of the Japanese prefectural museums are defined following Suhara (2011), that is, there are assumed to be three inputs and one output in the production of exhibitions. The three inputs are assumed to be: the premises to exhibit art works (K_1); the expenses for advertisements and leasing art works (K_2); and labor (L_1). Output (Y) is defined as the total number of visitors to exhibitions. While Suhara (2011) assumes a Cobb-Douglas production function for museums, this study assumes a translog production function, which requires weaker assumption than a Cobb-Douglas production function. The inputs and outputs are assumed to be related by the following translog production function:

$$\begin{aligned} ln\,Y_{it} = \alpha + \beta_1\, ln\,K_{1it} + \beta_2\, ln\,K_{2it} + \beta_3\, ln\,L_{1it} \\ +\beta_4 \tfrac{1}{2}(ln\,K_{1it})^2 + \beta_5 \tfrac{1}{2}(ln\,K_{2it})^2 + \beta_6 \tfrac{1}{2}(ln\,L_{1it})^2 \\ +\beta_7\, ln\,K_{1it}\, ln\,K_{2it} + \beta_8\, ln\,K_{1it}\, ln\,L_{1it} + \beta_9\, ln\,K_{2it}\, ln\,L_{1it} + v_{it}, \end{aligned} \tag{1}$$

$$lnY_{it} = f(\cdot) - u_{it} + v_{it}, \tag{2}$$

where Y_{it} is the total number of visitors to exhibitions at the i-th museum in year t, K_{1it} is the premises to exhibit art works at the i-th museum in year t, K_{2it} is the expenses for advertisements and leasing art works at the i-th museum in year t, L_{1it} is the number of employees employed by the i-th museum in year t, α, β_1, ···, β_9 are coefficients to be estimated, u_{it} is the inefficiency term for the i-th museum in year t, and v_{it} is a standard disturbance.

3.2 Stochastic Frontier Models

Equation (1) with u_{it}=0 for all i and t gives rise to a simple pooling model. In addition to this simple pooling model, six kinds of stochastic frontier models are estimated in this study to allow for the possible existence of stochastic inefficiencies. These six models are: the pooling stochastic frontier (pooling SF) model; the time invariant stochastic frontier (TI-SF) model (the random-effects stocastic frontier model); the time varying decay stochastic frontier (TVD-SF) model; the fixed-effects stochastic frontier (FE-SF) model; the true fixed-effects stochastic frontier (true FE-SF) model; and the true random-effects stochastic frontier (true RE-SF) model. The specification of these models are as follows:

Pooling Stochastic Frontier (Pooling-SF) Model

$$lnY_{it} = f(\cdot) - u_{it} + v_{it}, \quad u_{it} \sim N^{+}(\mu, \sigma_{\mu}^{2}), \quad v_{it} \sim N(0, \sigma_{v}^{2}), \tag{3}$$

Time Invariant Stochastic Frontier (TI-SF) Model,

$$lnY_{it} = f(\cdot) - u_{i} + v_{it}, \quad u_{i} \sim N^{+}(\mu, \sigma_{\mu}^{2}), \quad v_{it} \sim N(0, \sigma_{v}^{2}), \tag{4}$$

Time Varying Decay Stochastic Frontier (TVD-SF) Model

$$lnY_{it} = f(\cdot) - u_{it} + v_{it}, \quad u_{it} = exp\{-\eta(t - T_i)\}u_i, \quad u_{i} \sim N^{+}(\mu, \sigma_{\mu}^{2}), \quad v_{it} \sim N(0, \sigma_{v}^{2}), \tag{5}$$

Fixed-Effects Stochastic Frontier (FE-SF) Model

$$lnY_{it} = f(\cdot) + \zeta_i - u_{i} + v_{it}, \quad u_{i} \sim HN(0, \sigma_{\mu}^{2}), \quad v_{it} \sim N(0, \sigma_{v}^{2}), \tag{6}$$

True Fixed-Effects Stochastic Frontier (True FE-SF) Model

$$lnY_{it} = f(\cdot) - u_{it} + v_{it}, \quad u_{it} \sim |N(0, \sigma_{\mu it}^{2})|, \quad \sigma_{u_{it}}^{2} = \sigma_{u}^{2} \times exp(\alpha_i + \delta' z_{it}), \; v_{it} \sim N(0, \sigma_{v}^{2}), \tag{7}$$

True Random-Effects Stochastic Frontier (True RE-SF) Model

$$lnY_{it} = f(\cdot) + w_i - u_{i} + v_{it}, \quad w_i \sim N(0, \sigma_{w}^{2}), \quad u_{i} \sim N(0, \sigma_{u}^{2}), \quad v_{it} \sim N(0, \sigma_{v}^{2}), \tag{8}$$

where u_i, and u_{it} are measures of technical inefficiency, v_{it} is standard disturbance, ζ_i is an individual museum fixed effect, T_i is the number of observations on the i-th museum in the panel data set, and N and HN denote a nornal distribution and a half normal distribution, respectively. The difference between models (3), (4), (5), (6), (7) and (8) lies in the specification of the inefficiency term. Models (3), (4), and (7) take no account of the panel nature of the data, while model (6) does. It should be noted that models (3) and (4) are non-nested models, while equation (4) can be obtained as a special case of equation (5) by imposing the restriction $\eta = 0$, and as a special case of equation (6) by imposing the restriction $\zeta_i = 0$ for all i. The pooling model can be obtained as a special case of equations (3) and (4) by imposing the restriction $\sigma_{\mu}^{2} = 0$.

3.3 Examination of the impacts management changes on the productive efficiencies in museums

Following the discussion of Figure 1, four hypotheses are examined. The first hypothesis is that the political trend which introduced the New Public Management (NPM) into Japanese prefectural museums around 2006 contributed to improving the productive efficiencies of exhibitions rather than the introduction of the Designated

Manager System (DMS). The second hypothesis is that the introduction of the DMS into Japanese prefectural museums contributed to improving the productive efficiencies of exhibitions. The third hypothesis is that exhibitions which the designated managers are involved in planning are more efficient in increase the visitors than exhibitions. The fourth hypothesis is that designated managers which are selected through a competitive process contributed to improve the productive efficiencies of exhibitions. These four hypotheses correspond to the four decision-making steps of the prefectural governments in Figure 1. In order to test these hypotheses, we postulate the following model to explain the variations in technical inefficiency as measured by u_{it} determine the impact of these various;

$$u_{it} = a + b_1 NPM_t + b_2 DMS_{it} + b_3 TRE_{DMS_{it}} + b_4 DMS\_EXH_{it} + b_5 TRE_{DMS\_EXH_{it}} + b_6 DMS\_COM_{it} + b_7 TRE_{DMS\_COM_{it}} + \sum_{s=8}^{n} b_s J_{sit} + e_{it}. \quad (9)$$

where u_{it} is the efficiency term for the i-th museum in year t which is obtained from the results of estimating a stochastic frontier production function, NPM_t is a 0-1 dummy variables taking the value 1 in 2006 – 2014 and 0 for 1998-2005, DMS_{it} is a 0-1 dummy variables taking the value 1 if the i-th museum is managed by a designated manager in year t and 0 otherwise, $TRE_{DMS_{it}}$ is a 0-1 dummy variables taking the value 1 if the i-th museum has been managed by the designated manager sometime during the sample period and zero otherwise, $DMS_{EXH}\ _{it}$ is a 0-1 dummy variable taking the value 1 if the designated manager of the i-th museum is involved in the planning of exhibitions in year t, $TRE_{DMS_{EXH}\text{it}}$ is a 0-1 dummy variables taking the value 1 if the designated managers of the i-th museum has engaged in planning exhibitions sometime during the sample period, $DMS_{COM_{it}}$ is a 0-1 dummy variable taking the value 1 if the i-th museum is managed by a designated manager selected through a competitive process in year t and 0 otherwise, $TRE_{DMS_{COM_{it}}}$ is a 0-1 dummy variable which takes the value 1 if the i-th museum has been managed by a designated manager selected through a competitive process during the sample period, J_{sit} denotes other factors that influence the technical efficiency of the i-th museum in year t, a, b_1, ⋯, b_7, and $\mathrm{b_s}$ are coefficients to be estimated, e_{it} is a standard disturbance. $TRE_{DMS_{it}}$, $TRE_{DMS\_EXH}{}_{\text{it}}$, and $TRE_{DMS\_COM_{it}}$ is used to control each group effects of which management changes. Equation (9) is estimated by ordinary least squares (OLS), Since a larger positive value of u_{it} indicate greater inefficiency, if the introduction of NPM, the introduction of the DMS, allowing the designated manager to be involved in the planning of exhibitions or the use of a competitive process to choose the designated manager leads to greater efficiency, then the coefficients b_1, b_2, b_4 and b_6 should have negative signs.

4 Data

Data on inputs and output used in estimation of the production functions of exhibitions are taken from the "Prefectural Art Museum Survey" (*Todoufukenritsu Bijutsukan Kihon-chosahyou*) from 1998 to 2014. This survey is conducted by the Council of Deputy Director Generals and others of Prefectural Art Museums (T*odoufukenritsu Bijutsukan Fukukanchotou-jimusekininsya-kaigi*). Data on whether or the designated manager engaged in planning an exhibition and whether or not the designated manager were selected through a competitive process were obtained by conducting a telephone survey of all prefectural museums. Data on the population of the prefecture where the museum is located were taken from the "Population Estimates" (*Jinkou-suikei*) which are based on the national census conducted by Statistics Bureau in the Ministry of Internal Affairs and Communications (*Soumu-shou, Toukei-kyoku*).

The "Prefectural Art Museum Survey" includes microdata on all the prefectural museums in Japan, and this analysis uses all the available microdata available as of December 2015. The prefectural museums in Yamagata, Tokyo, Kyoto[1], Osaka, Tokushima, Oita, and Kagoshima are excluded from this analysis because the data needed to estimate the production function cannot be available. For the same reason, some observations on other museums are also excluded from our analysis. As a result, we have an unbalanced panel data set of 54 museums from 1998 to 2014 is used[2] which gives a total sample size of 698. Table 1 provides information on the number of museums by their management type, while Table 2 provides desciptive statistics for all the relevant variables. The variables LNY, LNK1, LNK2, and LNL1 in Table 2 refer to the natural logs of Y_{it}, K_{1it}, K_{2it}, L_{1it}, respectively.

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1 One prefectural museum in Kyoto, the Kyoto Prefectural Museum of Kyoto Culture (*Kyoto-fu Kyoto-bunka-hakubutsukan*), is excluded from our analysis even though data is available from the "Prefectural Art Museum Survey." The reason for excluding this museum is that despite its name the museum was established and has been managed by a private organization.

2 In 2006, there were a total of 65 Japanese prefectural museums.

Table 1: The number of prefectural museums by management type

	The number of museums (percentage)
Museums managed by designated managers	18 (33%)
Museums managed by designated managers which engage in planning exhibitions	6 (11%)
Museums managed by designated managers which were selected through a competitive process	8(15%)
All museums	54 (100%)

Table 2: Descriptive Statistics

Variable	Definition	Mean	Std.Dev.	Minimum	Maximum
LNY	log (total number of paying visitors)	10.690	0.901	6.887	13.210
LNK1	log (total floor space of exhibition rooms)	7.724	0.549	5.954	9.330
LNK2	log (expenses to hold exhibitions)	10.859	0.752	7.386	13.361
LNL1	log {(full-time employees)+(part-time employees)×0.5}	2.807	0.430	1.253	3.980

[1] The sample size is 698.
[2] Following Suhara (2011), the total number of part-time employees is converted into an equivalent number of full-time employees.
[3] Since the labor costs to employ the tempory staff cannot be derived from the total costs for holding exhibitions, the total number of temporary staff is not included in the labor input, LNL1.

Table 2: Descriptive Statistics (Cont.)

Variable	Definition	Mean	Std.Dev.	Min.	Max.
NPM_t	A 0-1 dummy variable taking the value 1 in 2006 – 2014, and 0 in 1998-2005.	0.56	0.50	0	1
DMS_{it}	A 0-1 dummy variable which takes the value1 if the i-th museum is managed by a designated manager in year t, and 0 otherwise.	0.14	0.35	0	1
TRE_DMS_i	A 0-1 dummy variables which takes the value 1 if the i-th museum was managed by a designated manager for some time during the sample period, and 0 otherwise.	0.31	0.46	0	1
DMS_EXH_{it}	A 0-1 dummy variable which takes the value 1 if the designated manager of the i-th museum engages in planning exhibitions in year t, and 0 otherwise.	0.06	0.24	0	1
$TRE\_DMS\_EXH_i$	A 0-1 dummy variable which takes the value 1 if the designated manager of the i-th museum has engaged in planning exhibitions some time during the sample period, and 0 otherwise.	0.10	0.29	0	1
DMS_COM_{it}	A 0-1 dummy variable which takes the value 1 if the i-th museum is managed by a designated manager selected through a competitive process in year t, and 0 otherwise.	0.08	0.27	0	1
$TRE\_DMS\_COM_i$	A 0-1 dummy variable which takes the value 1 if the i-th museum has been managed by a designated manager selected through a competitive process some time during the sample period, and 0 otherwise.	0.14	0.35	0	1
$VOLUNTEER_{it}$	A 0-1 dummy variable which takes the value 1 if volunteer activities exist in the i-th museum in year t, and 0 otherwise.	0.73	0.45	0	1
$EDUCATION_{it}$	Expenses to hold educational events.	6919.35	18308.51	0.00	420223.00
$POPULATION_{it}$	The population in year t in the prefecture where the i-th museum is located.	0.73	0.45	574.000	8792.000
$OPEN_{it}$	The number of days the i-th museum is open in year t.	289.28	36.36	128.00	359.00
$RATE\_CUR_{it}$	$\{(\text{total number of curators})/L1\}$	0.47	0.14	0.06	1.00
EXH_VAR_{it}	Total number of temporary exhibitions	5.70	2.79	0.00	23.00
$RATE\_EXH\_CO_{it}$	$\{(total\ number\ of\ cosponsored\ temporary\ exhibitions)/\text{EXH\_VAR}\}$	0.32	0.32	0.00	1.00

5 Results and Discussions

5.1 Estimated results of a production function

LIMDEP 10 (Greene (2005)) is used to obtain all the estimates presented in Tables 3, 4, 5, and 6. Table 3 presents results of estimating the production frontier function. In choosing between the non-frontier model (Models (3-1)) and the frontier models (Models (3-2), (3-3), (3-4), (3-5), (3-6) and (3-7)), all the frontier models except Model (3-4) are supported because estimates of λ and σ (or σ_u) are positive and significant. The time varying decay model (Model (3-4)) is not supported because the estimates of σ and η are not significant. As a result, the pooling stochastic frontier model, the time invariant stochastic frontier model, the true fixed-effects model, and the true random-effects model are the candidate models for the production function. In choosing the most appropriate model among the candidates, the true random effects model (Models (3-7)) is chosen because it has the largest log likelihood value and the smallest *Akaike* Information Criteria (AIC) value. Thus, estimates of the true random effects model are used to compute the estimates of inefficiencies that are used to examine the four hypotheses discussed in Section 3.3.

Table 3: Production function estimates

		Stochastic Frontier (SF) model					
	Pooling	Pooling-SF	TI-SF	TVD-SF	FE-SF	true FE-SF	true RE-SF
	(3-1)	(3-2)	(3-3)	(3-4)	(3-5)	(3-6)	(3-7)
LNK1	-1.222	-1.342	5.742*	5.963*	6.353***	-1.496**	3.088***
	(1.266)	(1.229)	(3.325)	(3.288)	(0.511)	(0.587)	(0.807)
LNK2	0.279	0.227	-0.538	-0.511	0.003	-3.219***	-0.764**
	(0.633)	(0.624)	(0.481)	(0.473)	(0.316)	(0.376)	(0.346)
LNL1	-2.147	-1.784	-2.742**	-2.816**	-3.524***	-2.114***	-2.762***
	(1.404)	(1.372)	(1.377)	(1.345)	(0.765)	(0.677)	(0.837)
LNK1_2	-0.004	-0.016	-0.829*	-0.845*	-0.877***	1.115***	-0.669***
	(0.195)	(0.189)	(0.451)	(0.446)	(0.103)	(0.161)	(0.135)
LNK2_2	-0.021	-0.031	0.153**	0.158**	0.118***	-0.682***	0.114***
	(0.069)	(0.069)	(0.062)	(0.062)	(0.045)	(0.011)	(0.043)
LNL1_2	0.546*	0.698**	-0.875***	-0.894***	-0.818***	0.177***	-1.088***
	(0.299)	(0.299)	(0.279)	(0.267)	(0.165)	(0.041)	(0.190)
LNK1K2	0.106	0.139*	-0.087	-0.099	-0.118***	0.288***	0.015
	(0.078)	(0.076)	(0.094)	(0.095)	(0.043)	(0.054)	(0.049)
LNK1L1	0.193	0.153	0.684**	0.694***	0.727***	-0.094	0.816***
	(0.217)	(0.211)	(0.267)	(0.260)	(0.123)	(0.089)	(0.142)
LNK2L1	-0.081	-0.122	0.018	0.023	0.043	2.042***	-0.025
	(0.114)	(0.113)	(0.127)	(0.130)	(0.080)	(0.038)	(0.075)
Constant	11.663**	12.366***	-7.911	-8.848			
	(4.672)	(4.568)	(12.526)	(12.425)			
Constant means for random parameters							
							2.893
Constant Scale parameters for dists. of random parameters							
							0.018
σ_u		0.599	1.226	1.208***	1.553	2.409	0.343
σ_v		0.580	0.452	0.452	0.492	0.672	0.401
$\sigma = \sqrt{\sigma_v^2/\sigma_u^2}$		0.834***	1.226***	1.290	1.629***	2.501***	0.528***
		(0.001)	(0.252)	------	(0.042)	(0.007)	(0.019)
$\lambda = \sigma_u/\sigma_v$		1.032***	2.709***	2.671***	3.154***	3.583***	0.853***
		(0.104)	(0.922)	(0.067)	(0.146)	(0.007)	(0.142)
η				0.003			
				(0.003)			
Log likelihood	-725.079	-723.130	-524.328	-524.050	-704.469	-3134.160	-515.279
AIC	-0.73163	1470.300	1072.700	1074.100	1538.900	6398.300	1056.600

[1] For each explanatory variable and λ, the first line reports the estimated coefficient, and the second line reports the estimated standard error.
[2] *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively.

5.2 First derivatives of the production function

The first derivatives of the production function are as follows:

$$\frac{\partial\, ln\, Y_{it}}{\partial\, ln\, K_{1it}} = \beta_1 + \beta_4\, ln\, K_{1it} + \beta_7\, ln\, K_{2it} + \beta_8\, ln\, L_{1it} > 0, \tag{10}$$

$$\frac{\partial\, ln\, Y_{it}}{\partial\, \ln K_{2it}} = \beta_2 + \beta_5\, ln\, K_{2it} + \beta_7\, ln\, K_{1it} + \beta_9\, ln\, L_{1it} > 0, \tag{11}$$

$$\frac{\partial\, ln\, Y_{it}}{\partial\, \ln L_{1it}} = \beta_3 + \beta_6\, ln\, L_{1it} + \beta_8\, ln\, K_{1it} + \beta_9\, ln\, L_{1it} > 0, \tag{12}$$

Table 4 provides descriptive statistics for estimates of these first derivatives of the production function computed using estimates obtained from the true random-effects models (Model (3-7)). Since each of the averages of of first derivatives are positive, it can be said that Model (3-7) satifies this condition on average.

Table 4: Checking the first derivatives

Variable	Mean	Std.Dev.	Minimum	Maximum
$\frac{\partial\, ln\, Y_{it}}{\partial\, \ln K_{2it}}$	0.380	0.325	-0.790	1.231
$\frac{\partial\, ln\, Y_{it}}{\partial\, ln\, K_{1it}}$	0.524	0.086	0.121	0.803
$\frac{\partial\, ln\, Y_{it}}{\partial\, \ln L_{1it}}$	0.218	0.415	-0.933	1.662

[1] Estimates of the first derivatives are computed using estimates of the true random-effects model.

5.3 Estimated inefficiencies

The technical efficiencies are calculated as $\exp(-u_{it})$, using the estimates of the inefficiency terms of Model (3-7) (the true RE-SF model). Technical Efficiency (TE) (Farrel (1957)) is caluculated as follows, using the estimated inefficiency term:

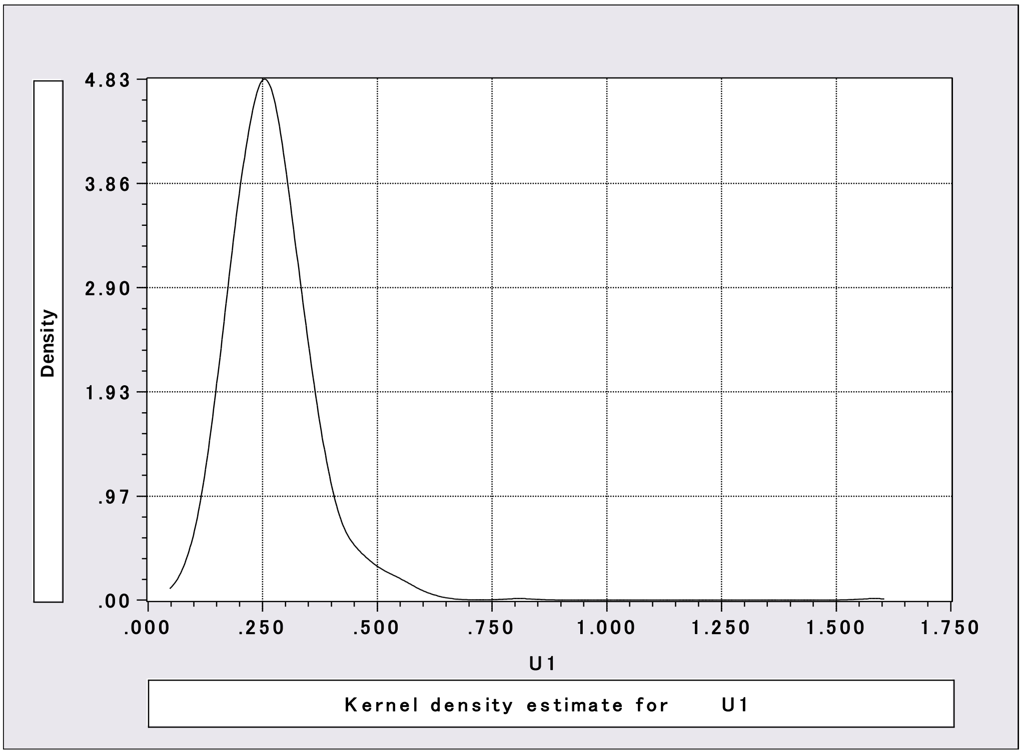
$$TE_{it} = exp(-u_{it}), \tag{12}$$

where TE_{it} is the estimated technical efficiency of the i-th museum in year t, and u_{it} is the inefficiency term of the i-th museum in year t which is obtained from estimates of production function. These technical efficiencies range from 0 to 1, with larger values of technical efficiency indicating a firm is more efficient. Table 5 presents the descriptive statistics for estimates of u_{it} and TE_{it} obtained from Model (3-7). The most efficienct museum takes the value 0.931, while the least efficient museume takes the value 0.205, and the average of TE_{it} is 0.766. This suggests the existence of many museums whose management efficiencies are far worse than the sample average. Figure 2 estimates the distribution of the estimated inefficiencies $u_{it}\mathrm{E}(u_{it}|v_{it} - u_{it})\sigma_u$.

Table 5: Estimated Results of Technical Efficiencies: Descriptive Statistic

Variable	Mean	Std.Dev.	Minimum	Maximum
u_{it}	0.271	0.099	0.071	1.583
TE_{it}	0.766	0.066	0.205	0.931

Figure 2: Estimated Inefficiencies



5.4 Results of examining hypotheses

In order to examine the four hypotheses presented in Section 3.3, equation (9) is estimated by ordinary least squares (OLS) and the results are reported in Table 6. First, we examine whether or not the political trend which introduced the New Public Management (NPM) into Japanese prefectural museums around 2006 has contributed to improving the productive efficiencies of exhibitions. Since the estimated coefficient of NPM_t is negative but insignificant in Model (9-1), and are positive in Models (9-2), (9-3), and (9-4), it is found that the introduction of the NPM around 2006 did not contribute to improving the productive efficiencies of Japanese prefectural museums. Rather, since 2006, it appears that the productive efficiencies of museums have decreased. Second, we examine whether or not the introduction of the DMS into Japanese prefectural museums contributed to improving the productive efficiencies of exhibitions. Since the estimated coefficient of DMS_{it} is negative but insignificant in Model (9-1), but are positive and significant in Models (9-3) and (9-4), it is found that the DMS itself does not contribute to improving productive efficiencies. This result is consistent with Suhara (2011). One possible reason for this result is that some designated managers have not engaged in planning exhibitions. In this case, the prefectural governments have engaged in planning exhibitions and the designated manager has only engaged in the maintenance of museum buildings. Third, we examine whether or not the designated managers which engaged in planning exhibitions have contributed to improving productive efficiencies. In Models (9-2), (9-3), and (9-4), the estimated coefficients of $\mathrm{DMS\_EXH}_{it}$ are negative and significant which suggests that the presence of designated managers which engaged in planning exhibitions decreases inefficiencies significantly. Finally, we examine whether or not designated managers which are selected through a competitive process contribute to improving productive efficiencies. In Models (9-2), (9-3), and (9-4), the estimated coefficients of $\mathrm{DMS\_COM}_{it}$ are negative and significant which suggests that the designated managers selected by competitive processes decrease inefficiencies significantly. Therefore, the results of examining the four hypotheses show that the productive efficiencies of museums have improved when designated managers are engaged in planning exhibitions and when the designated managers are selected through a competitive process.

In addition to these four hypotheses, some other factors which could possibly improve productive efficiencies are examined. In all models, the estimated coefficients of $\mathrm{VOLUNTEER}_{it}$ are negative and significant which suggests the presence of volunteer activities which is expected to work as a kind of supervision that prevents paid employees from being lazy contributed to improving efficiency. The estimated coefficients of $\mathrm{EDUCATION}_{it}$ are positive and insignificant in all models except Model (9-2). It might be expected that educational events in museums possibly have the effect of increasing the participation in exhibitions efficiently, but this effect cannot be observed except Model (9-2). The estimated coefficients of $\mathrm{POPULATION}_{it}$ are negative and significant, so that a larger population increased the productive efficiencies of exhibitions. The estimated coefficients of OPEN_{it} are positive and insignificant which suggests that opening a museum for more days does not necessarily improve the efficiencies. In Model (9-4), the estimated coefficient of $\mathrm{RATE\_CUR}_{it}$ is positive and insignificant which suggests that a higher percentage of curators does not improve the efficiencies. One possible reason for this is that curators' aims are different from maximizing profit or productive efficiency. In Model (9-4), the estimated coefficients of $\mathrm{EXH\_VAR}_{it}$ and $\mathrm{RATE\_EXH\_CO}_{it}$ are positive and insignificant which suggests that more temporary exhibitions and a higher percentage of cosponsored temporary exhibitions did not contribute to improving the efficiencies.

Table 6: Estimates of equation (9)

	OLS			
	(9-1)	(9-2)	(9-3)	(9-4)
Constant	0.413***	0.395***	0.394***	0.387***
	(0.032)	(0.032)	(0.032)	(0.038)
NPM_t	-0.004	0.003	0.000	0.000
	(0.008)	(0.008)	(0.008)	(0.008)
DMS_{it}	-0.015		0.049*	0.048*
	(0.015)		(0.026)	(0.026)
TRE_DMS_i	0.010		-0.024*	-0.025*
	(0.011)		(0.014)	(0.015)
DMS_EXH_{it}		-0.058**	-0.096***	-0.095***
		(0.026)	(0.033)	(0.033)
$TRE\_DMS\_EXH_i$		0.055***	0.072***	0.074***
		(0.021)	(0.023)	(0.024)
DMS_COM_{it}		-0.049**	-0.090***	-0.091***
		(0.020)	(0.030)	(0.030)
$TRE\_DMS\_COM_i$		0.029*	0.048**	0.048**
		(0.015)	(0.019)	(0.019)
$VOLUNTEER_{it}$	-0.015*	-0.018**	-0.019**	-0.018**
	(0.008)	(0.008)	(0.008)	(0.009)
$EDUCATION_{it}$	0.000	0.000*	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
$POPULATION_{it}$	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
$OPEN_{it}$	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
$RATE\_CUR_{it}$				0.013
				(0.032)
EXH_VAR_{it}				0.000
				(0.001)
$RATE\_EXH\_CO_{it}$				0.000
				(0.001)
R^2	0.037	0.054	0.060	0.061
log likelihood	640.808	647.043	649.179	649.646

[1] *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively.
[2] All equations are estimated by ordinary least squares (OLS).

5 Concluding Remarks

In order to improve the management of public museums, the Designated Manager System (DMS) was enacted in 2006, which was a kind of the New Public Management (NPM) and enabled private managers to manage public museums. Whether the Designated Manager System is introduced or not, many Japanese prefectural museums introduced the NPM around 2006. The aim of this paper is to determine how the limited government policy has improved the management of the Japanese prefectural museums since 2006, using econometric methods. In this study, exhibitions are forced as the main activities of the Japanese prefectural museums. In a production of exhibitions, output is defined as the participation in exhibitions of residents.

Four hypotheses are examined; they are; (A) the political trend which introduced the NPM into the Japanese prefectural museums around 2006 contributed to improve the productive efficiencies of exhibitions rather than the introduction of the Designated Manager System (DMS); (B) the introduction of the DMS into the Japanese prefectural museums contributed to improve the productive efficiencies of exhibitions; (C) the designated managers contributed to improve the productive efficiencies of exhibitions only when they engage in planning exhibitions; and (D) the designated managers which selected through the competitive public offering contributed to improve the productive efficiencies of exhibitions. The estimation results support hypotheses (C) and (D). As a result, it can be said that the productive efficiencies of museums have improved when the designated managers engaged in planning exhibitions. Especially, the designated managers selected through a competitive process shows more efficient performances.

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