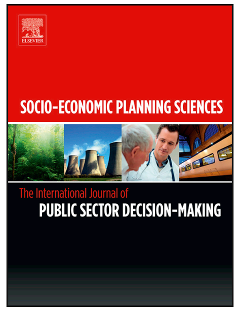
Public support for performing arts efficiency and productivity gains in eleven European countries

Journal Pre-proof



Public support for performing arts efficiency and productivity gains in eleven European countries

Concetta Castiglione, Davide Infantea, Marta Zieba

PII: S0038-0121(22)00245-2

DOI: https://doi.org/10.1016/j.seps.2022.101444

Reference: SEPS 101444

To appear in: *Socio-Economic Planning Sciences*

Received Date: 15 November 2020

Revised Date: 1 July 2022

Accepted Date: 21 September 2022

Please cite this article as: Castiglione C, Infantea D, Zieba M, Public support for performing arts efficiency and productivity gains in eleven European countries, *Socio-Economic Planning Sciences* (2022), doi: https://doi.org/10.1016/j.seps.2022.101444.

Public support for performing arts. Efficiency and productivity gains in eleven European countries

Concetta Castiglione[a], Davide Infante[b,*] and Marta Zieba[c]

[a]*Department of Economics Statistics and Finance, University of Calabria, Italy,* concetta.castiglione@unical.it

[b]*Department of Economics Statistics and Finance, University of Calabria, Italy,* davide.infante@unical.it

[c]*Department of Economics, University of Limerick, Ireland,* marta.zieba@ul.ie

**Corresponding Author*

Abstract

This paper investigates the importance of public cultural expenditure for the efficiency and productivity of the performing arts (PA) firms. To this aim, we estimate a translog production function using the stochastic frontier approach (SFA), and we obtain the estimates of both technical efficiency and its determinants for the PA firms in EU-11 countries over the period 2009-2017. The large panel data set enables the application of robust true random-effects SFA techniques, which control for noise, unobserved firms' heterogeneity and endogeneity of the inputs. Moreover, by estimating a production function, the characteristics of the production technology in the PA sector is also derived. The empirical results demonstrate that PA firms are technically inefficient, implying that the investigated firms could increase their artistic output between 32 and 42 percent and that decreasing returns to scale are prevalent, due to the presence of too many micro and large-scale firms in the European PA sectors. In contrast to the seminal Baumol and Bowen's (1965) paper, we also demonstrate that the total factor productivity (TFP) increased in the EU PA firms over the examined period. Technical efficiency, although relatively low, was the main driver of this productivity growth, as opposed to scale efficiency change or technological change, which display very small or no increases. We also find that, contrary to the common wisdom on its negative effects on firm efficiency, public spending on culture increases the efficiency of PA firms. Within this context some policy implications are discussed.

Keywords: Cultural public expenditure; SFA production function; performing arts; technical efficiency; TFP change

JEL: D24, L82, L88, O52, Z10, Z18

1. Introduction

The rationale of cultural policy is a topic that re-emerges as an issue from time to time with the aim to discuss the costs and benefits of providing public financial support to different cultural institutions (Throsby, 2010; Bertacchini and Dalla Nogare, 2014; Fernandez-Blanco et al., 2019).

This work is posited within this literature and presents several novelties. Firstly, we measure the impact of cultural expenditure on firm performance and in particular on technical efficiency in the performing arts (PA) sector in several European countries that are characterised by different cultural traditions. The European PA sector is a valuable case study for many reasons. The economic and public budget crises, that followed the global 2007-08 financial crisis, have reduced the subsidies that the sector has received in the past years in many countries as evidenced, for example, for Italy (Castiglione et al., 2018), Germany (Last and Wetzel, 2011; Zieba and Newman, 2013), Austria and Switzerland (Zieba, 2011), and Poland (Fernandez-Blanco et al., 2019). In the absence of a clear European cultural policy, the differences registered in cultural public expenditure in EU countries are mainly due to individual country government choices to support cultural policies. The need to receive public funding arises from the fact that, as argued by Baumol and Bowen (1965), the PA sector is usually characterised by limited technological change which leads to a decrease in total factor productivity of the sector over time. An argument that might still hold today for the European PA firms. For example, the recent technological advances in telecommunication, broadband, and IT are important productivity-enhancing factors for the whole economy, but they might not contribute to an adequate output increase and hence higher productivity gains in the PA sector. However, we extend the argument presented by Baumol and Bowen debating that technological change is not the only driver of the total factor productivity. We hypothesise and demonstrate that other sources of productivity changes, such as technical efficiency and scale efficiency may also have an important impact on total factor productivity (TFP) of PA sector. Consequently, the identification of the main sources of productivity changes is an important issue for the EU performing arts companies and policies. In addition, since the comparative analysis between countries in terms of demand and supply in the PA sector was not very common due to the lack of reliable and comparable data (O'Hagan, 2016), the availability of new comparable firm data justifies the effort of a new study.

Secondly, the contribution of this paper relates to the innovative application of efficiency measurement methods to the PA sector. In the current literature, the most used approach in evaluating the performance of different organisations and institutions in cultural sectors is based on Data Envelopment Analysis (DEA) non-parametric methods (e.g. D'Inverno et al., 2018; Ni Luasa et al., 2018; Guccio et al., 2020). In this research, we take a different parametric stochastic frontier approach (SFA) that is commonly applied to evaluate firms and organisations in the rest of the economy. The robust novel panel data SFA techniques applied in this research allow us to control not only for noise but also for the unobserved heterogeneity of the PA firms and endogeneity of the inputs, and they also account for both persistent and time-invariant inefficiency.

Thirdly, the previous works on the efficiency in the PA sector has usually been narrowed down specifically to the theatre, and not to other PA forms[1]. This came about as a result of Baumol and Bowen's work on cost disease, which focused primarily on the various forms of theatrical activity that best represent this paradox. Our analysis adds significantly to the extant literature by taking a holistic approach, since it includes all the PA firms (theatrical and non-theatrical) in the 11 European countries, that comply with the relevant mandatory financial statements.

This study also investigates the determinants of efficiency and the productivity changes of the EU PA firms. In order to compare their total factor productivity changes through time, the Malmquist total factor productivity (TFP) index is calculated. This index is decomposed into three components: technical efficiency change, scale efficiency change, and technological change (Coelli et al., 2005). To this purpose, a novel and very rich panel data set of 6479 PA firms over a 9–year period from 2009 until 2017, and for 11 European countries is applied. Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden and the UK are included in the analysis (see Table 1). To our knowledge, this is the first study which applies such a large database on the EU PA firms, thus enabling a robust evaluation of their efficiency and productivity.

We estimate technical efficiency by applying a flexible translog production function, which accounts for the non-standard features of production technology associated with the PA sector. The stochastic frontier approach proposed by Aigner et al. (1977) and the modern panel data extensions of this model are applied, such as the true random-effects (TRE) SFA

[1] According to Towse (2020 p. 415), "the term performing arts is a broad grouping of live art forms, only some of which have been researched in cultural economics. While orchestras, opera, ballet and spoken theatre have all featured in the subject, circus, puppetry, mime among other live performance have not."

model of Greene (2004, 2005) and the generalised true random-effects model (GTRE) of Colombi (2010) and Colombi et al. (2011, 2014). The SFA production function model recognises that both the technical inefficiency component and random shocks beyond producers' control may affect the production outputs and inputs. Both TRE and GTRE are panel data SFA models that allow for individual unobserved heterogeneity of the examined firms. While the TRE model controls for the transient inefficiency, the GTRE model allows estimation of both persistent and transient inefficiency. Moreover, we also include the Mundlak's adjustment in the TRE production function model which allows for a correlation of the random parameter and hence of the inputs with the error term.

Finally, we also examine the impact of various efficiency determining variables on technical efficiency (TE), by directly parametrising the variance of inefficiency in the SFA production function model. In line with previous studies (Zieba, 2011; Zieba and Newman, 2013; Castiglione et al., 2018), we model technical efficiency as the function of different firm-level characteristics (i.e. firm size and age) and environmental factors (i.e. expenditures on cultural services) in the country where the PA firm is located, using a consolidated data set for EU-11 countries.

The results demonstrate that PA firms are technically inefficient, implying that EU PA firms could increase their artistic output between 32 and 42 percent by the given level of inputs used. We also find that decreasing returns to scale are prevalent in the European PA sector which is due to the presence of too many micro and large-scale firms. We show how much the changes in the technical efficiency and other sources (i.e. scale efficiency and technical change) contributed to the total factor productivity changes. We find that technological progress, as defined by technological change, is not the main driving productivity factor of the PA firms in the EU-11 countries. However, in contrast to previous research and to the seminal Baumol and Bowen's (1965) paper, this work demonstrates that the total factor productivity was increasing in the EU PA sector over the 2009–2017 period. This result is mainly due to the positive technical efficiency change as opposed to the technological change or scale efficiency change. Finally, contrary to the common wisdom that public expenditure on culture negatively affects firm efficiency, because of rent-seeking behaviours, we find that public expenditure increases the efficiency of PA firms.

The paper is structured as follows. The next section reviews the productivity and efficiency literature in the cultural sector, and provides the theoretical background for this research. Section 3 presents the SFA production function and the methods to estimate both firms' productivity and efficiency in the PA sector. Whilst section 4 presents the data sample, the variables used and the summary statistics; section 5 discusses the empirical results and presents robustness checks to validate the main findings. Section 6 concludes the paper with some policy implications.

2. Literature review and background

Firms' performance has been studied in different countries and regions from various perspectives, such as: labour and total factor productivity, technical efficiency, allocative and cost efficiency. However, scholars have usually concentrated on studying sectors such as manufacturing (Pieri and Zaninotto, 2013; Raymond et al., 2015), health (Colombi et al. 2017; Ni Luasa et al. 2018), or education (Guarini et al., 2020), whilst very little attention has been paid to the cultural sector. In what follows, the studies which evaluate efficiency in the cultural sector are outlined.

2.1. Evaluation of efficiency in the PA sector

Throsby (1977) and Gapinski (1980, 1984) were the pioneering scholars whose work assessed the production in the PA sector and they used theatre attendance as a measure of artistic output to estimate either the Cobb-Douglas or translog production function for non-profit PA organisations in Australia, the US and the UK, respectively. Gapinski's studies found that PA firms operate under a decreasing returns to scale technology but with positive marginal products of all inputs. In a more recent study, Zieba and Newman (2007) using panel data for 153 German public theatres over 40 years confirmed the findings of Gapinski (1980) founding that although the marginal product for all inputs is positive, it is of a small magnitude, thereby suggesting that the possibilities for increasing output in the PA sector are limited. On the other hand, Taalas (1997) estimated the cost functions for Finnish theatres and found evidence for scale economies. She also suggests that in managing Finnish theatre, inputs are not combined in optimal proportions in light of prevailing market prices. Similarly, Fazioli and Filippini (1997) estimated the translog cost function of 28 public theatres in Italy and confirmed the evidence of economies of scale; meaning that the majority of the Italian theatre companies operate at an inappropriately low-scale level.

The more recent econometric techniques and better data availability have allowed researchers to examine the Baumol and Bowen's productivity gap in greater detail by estimating the technical efficiency of PA organisations, or by directly estimating the total factor productivity. Technical efficiency is just one of the components of total factor productivity. Previously, some studies used the output-oriented TE concept and defined the

TE index as the ability to obtain the maximum output from the given input vector (Marco-Serrano, 2006; Zieba, 2011; Zieba and Newman, 2013; Castiglione et al., 2018). Other studies applied an input-oriented TE index which they defined as the ability to use minimum inputs for the same level of output (Last and Wetzel, 2010; Fernández-Blanco et al., 2019). All the previous efficiency studies focused on the estimation of technical efficiency as opposed to cost efficiency because the assumption of cost-minimising behaviour for PA firms is difficult to validate. In fact, Last and Wetzel (2010), using data on German public theatres, empirically proved that the assumption of cost-minimising behaviour cannot be maintained for public theatres.

Numerous studies applied the non-parametric Data Envelopment Analysis (DEA) to assess efficiency of public services (e.g. museums, education, public libraries). For the PA sector, only Marco-Serrano (2006) estimated managerial efficiency using DEA, while other already mentioned studies (Last and Wetzel, 2010, 2011; Zieba, 2011; Zieba and Newman, 2013, Castiglione et al. 2018; Fernandez-Blanco et al., 2019) used the parametric SFA approach. The parametric SFA recognises not only the technical inefficiency component (deviations below the optimal output level or above the minimum input level), but also the random shocks (or noise) that are beyond producers' control. Applying SFA to panel data also allows for the controlling for the heterogeneity of the examined PA firms. Subsequently, and similarly to this study, Last and Wetzel (2011) applied the Malmquist total factor productivity index observing, in line with the cost-disease hypothesis, that there is a decrease in total productivity and this was caused by a combination of increasing labour costs and no (or very limited) opportunities to benefit from both technological and technical efficiency improvements.

The estimated average TE scores for the PA sector from previous research are all below one, thus demonstrating that PA firms are technically inefficient. Castiglione et al. (2018) found a TE score of about 0.66, indicating that Italian PA firms could increase their revenues by 34 per cent by using the same level of inputs. Zieba (2011) found TE scores of 0.87 for Austrian and 0.73 for Swiss theatres, respectively. The scores were higher in Zieba and Newman (2013) for German public theatres, which were about 0.85 on average for the period 1972–2004. The studies that used an input-oriented model provided higher average TE scores, whereby German public theatres were found to be 96 per cent efficient in Last and Wetzel (2010) for the period 1991–2005. Fernández-Blanco et al. (2019) found that Polish public municipality theatres in Warsaw were 93 per cent efficient. The lowest scores, however, were found by Marco-Serrano (2006) and they ranged between 24 and 54 per cent but these results were obtained using a non-parametric DEA, and so they are not directly comparable with the other findings. The differences in the obtained TE scores in the previous studies may also arise due to the differences in the applied definition of TE and the definition and measurement of artistic output. In particular, if the variable returns technology is assumed, then the input-orientation versus output orientation is important to consider as the obtained TE scores will also differ. According to Coelli et al. (2005), this orientation will depend on what the objectives of the firms' managers are and what they are trying to optimise. In this research, we assume that the European PA sector firstly experiences varying returns to scale and, secondly, that firm' managers aim to increase the attendance at their performances. Hence, this research chooses an output-oriented TE approach and uses total earned revenue as the maximisation (output) variable, which is also a consistent approach with other studies and sectors (see Pieri and Zaninotto, 2013).

2.2. Public funding as determinant of efficiency in the PA sector

Another important research aspect of the efficiency analysis in any sector is the evaluation of the determinants of TE scores. Castiglione et al. (2018) used a range spectrum of variables such as size, quality (artistic wages) and the crime index to define the determinants of efficiency of PA organisations in Italy. They found that the examined firms present either economies or diseconomies of scale and could increase their efficiency by revising their scale of activity.

Moreover, understanding how efficiency outcomes are influenced by the level of funding is particularly important where substantial public resources are devoted to providing services that, arguably, could be provided by the private sector. In the economic literature, public intervention in the PA sector is theoretically based on two seminal works focused on supply and demand side perspectives. On the one side, Baumol and Bowen's (1966) book started the economic analysis of live professional performance to explain financial problems of performing companies. They suggest that the trends in income gap between total earned income and total expenditure were the results of different forces, mainly rising costs versus low productivity gains in the presence of a fixed production technology in live performing arts. It is an increasing gap that cannot be covered by an increasing rate in ticket prices. They also justify the public support for performing arts on the basis of positive externalities in production and consumption that performing arts give to the economy and national cultural endowment; a market failure that gives justification to subsidies in the PA sector.

On the other side, Peacock (1969) in his seminal paper on ‘Welfare Economics and Public Subsidies to the Arts’ has posited his attention on the demand side for PA, arguing that, instead of production sets, consumer’s preferences about how they consume arts should be taken into account. Peacock (1969) disputed the idea that public subsidies find rational justification because of the existence of market failure due to externalities that arise in production and consumption of arts. Even if these externalities exist, it cannot be assumed that public subsidies in the arts have a greater marginal benefit than other activities would have, such as sports or education (Towse, 2005).

However, the theoretical questioning of public subsidies to PA does not stop Peacock from saying that in the presence of public subsidies those who receive public funds should present ‘some form of accountability if only as a protection to the taxpayer who is footing the bill' (Peacock, 1993). In fact, in the case of public subsidies, rent-seeking behaviours can arise from those companies who apply and receive them. Their managers can use subsidies either to adjust the combination of factors used, thus augmenting the efficiency of the company, or to remunerate the staff and personnel above market prices, thus diminishing company’s efficiency. In this case, the role of subsidies can be detrimental for taxpayers and the economy. As noted by Grampp (1989), the economic structure of the arts is more prone to rent-seeking, since the arts, in the name of artistic freedom, try to resist any control of the way their resources are used. In public PA expenditures there are also various political aspects. Tepe and Vanhuysse (2014) show that the use of government public expenditure in highbrow culture (in their case, the German public theatres and orchestras) is targeted for voting manipulation. Guccio and Mazza (2014) find that the allocation of funds for cultural heritage conservation in Sicily is directed to those districts that present loyal voting behaviours towards the ruling party.

An economic way to evaluate the role that public expenditure for culture has on PA companies is to estimate its impact on firm performance, such as technical efficiency. Werck et al. (2008) found that theatres’ subsidies have an impact not only on the number of plays they perform but also on their nature, providing the first systematic empirical evidence that theatres make qualitative changes to output due to cost pressures. In a study on English theatres, O’Hagan and Neligan (2005) found a negative relationship between subsidy as a proportion of total income and the conventionality of theatre programmes. Neligan (2006) provides a similar evidence for German public theatres confirming that financial factors (public subsidy and subscription income) do play an important role in repertoire decisions. The findings of Zieba (2011) and Fernández-Blanco et al. (2019) indicate that public funding increases the TE of theatres. Hence, public subsidies not only affect the repertoire conventionality (O'Hagan and Neligan, 2005) but also result in theatre managers being more efficient. The legal or organisational form of a theatre which defines the way in which a theatre company is organised, financed and controlled, might also affect the productive or economic performance of theatres.[2] While Castiglione et al. (2018) found that the legal form has no effect on the efficiency of Italian PA firms, Zieba and Newman (2013) examined the effect of institutional setting on efficiency of German public theatres. Using the natural experiment of the reunification of East and West Germany in 1990, their results provide evidence to support the hypothesis that theatres organised in public legal forms, where theatre management is subject to strict monitoring and reporting requirements, are more technically efficient than those organised in private legal forms where monitoring and reporting is less stringent.

3. Model and methods

3.1. TRE SFA production function model

To estimate TE for the EU PA firms, we use a one output and two inputs production function model. To account for the non-standard features of production associated with the performing arts, a flexible functional form is preferred and a translog (logarithmic transcendental) function by Christensen et al. (1973) is applied.[3] Expressing output and inputs in natural log values, the translog true random-effects (TRE) SFA production function model can be written as:

$$\ln Y_{it} = \alpha + w_i + d_c + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \frac{1}{2}\left[\beta_{KK}(\ln K_{it})^2 + \beta_{LL}(\ln L_{it})^2\right] + \beta_{KL} \ln K_{it} \ln L_{it} + $$
$$+\beta_{tK} t \ln K_{it} + \beta_{tL} t \ln L_{it} + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + v_{it} - u_{it} \quad (1a)$$

$$\alpha_i = \alpha + w_i, \; w_i \sim N\left(0, \sigma_w^2\right) \quad (1b)$$

$$\varepsilon_{it} = v_{it} - u_{it}, \; v_{it} \sim N\left(0, \sigma_v^2\right), \; u_{it} \sim N^+(0, \sigma_u^2) \quad (1c)$$

where Y_{it} is the real output (total revenues) of the i^{th} PA firm in year t ($i=1,2,\ldots,N$ and $t=1,2,\ldots T$), K_{it} and L_{it} are the capital (total assets) and labour (number of employees) inputs

[2] The legal form could not be included in this study for the European PA firms due to the limited information in the Orbis/Amadeus database. Moreover, the legal forms differ between the examined European countries and therefore such variable would be difficult to define at the European level.

[3] The simplest and the most common functional form used in many SFA applications is the Cobb-Douglas production function. However, this functional form imposes certain restrictions on the production structure, such as non-varying returns to scale and unitary elasticity of substitution.

used, respectively. Furthermore, t is the time trend and t^2 is the time trend squared which allows the technological change effect to increase or decrease with time, depending on whether β_{tt} is positive or negative. To account for non-neutral technological change in line with Coelli et al. (2005), the time trend also interacts with both inputs. The statistical noise term is denoted by v_{it} and $u_{it} \geq 0$ is a non-negative one-sided inefficiency term, while w_i represents a time-invariant, firm-specific random intercept which captures the unobserved individual firm's heterogeneity in line with Greene (2005), Colombi et al. (2017) and Castiglione et al. (2018). Finally, d_c are the 11 dummy variables for each EU country controlling for country fixed-effects in the production technology.

Both v_{it} and u_{it} can be expressed as a two-part composite error according to Eq. (1c). Ignoring the heterogeneity term, w_i, the model in Eq. (1a) becomes the pooled SFA model of Aigner et al. (1977), where the inefficiency term, u_{it}, is computed in line of Jondrow et al. (1982). For the TRE model, the inefficiency term, u_{it}, is computed as the simulated conditional expectation of inefficiency which is $E[-u_{it} \mid w_i + \varepsilon_{it}]$ whereas w_i is integrated out of u_{it} using simulations presented in Greene (2005). Consequently, the term u_{it} is the log-difference between the maximum output defined by the frontier function and the actual observed output, and the TE index for firm i in year t, is predicted as:

$$TE_{it} = \exp(-u_{it}) \,. \tag{2}$$

The TE score is bounded by zero and one. A score of one means full TE, whilst a score less than one means that the firm is inefficient for the given technology, and it could increase its output level without increasing the level of inputs.

Due to the inclusion of unobserved heterogeneity term, w_i, the TRE model presented in Eq. (1a) has important advantages over the original model of Aigner et al. (1977) as it differentiates between unobserved time-varying efficiency and exogenous heterogeneity of PA firms through random-effects. As highlighted by Castiglione et al. (2018), PA firms are very heterogeneous with regard to localisation, size, quality and institutional setting of the firm. Thus, they may operate in different regions with various environmental factors and characteristics that are only partially observed. Moreover, in this research we use dummy variables to control for different technological endowments for each European country. The inefficiency of firms is also time-varying which is an appropriate assumption given the fact it is a dynamic phenomenon (Farsi and Filippini, 2006). This holds especially for our analysis as the number of time periods in the panel is large, and, thus, it is difficult to assume a time-invariant efficiency only. Furthermore, the TRE SFA model, in contrast to the time-invariant efficiency panel data models (e.g. Pit and Lee, 1981), controls for omitted variable biases in the production function coefficients and in the estimates of technical (in)efficiency.

3.2. TREM SFA model

Furthermore, in line with Farsi et al. (2005), Pieri and Zaninotto (2013), Last and Wetzel (2010), the TRE SFA production function model presented in Eqs. (1a)–(1c) is extended to account for a possible correlation between firm-specific random component (w_i) and the inputs, by using the adjustment of Mundlak (1978). The Mundak's specification involves inserting the within-group means of inputs in the TRE production frontier as follows:

$$w_i = \lambda' \cdot \overline{X_i} + \eta_i \qquad (3)$$

where $\overline{X_i} = (1/T_i)\sum_{t=1}^{T} X_{it}$ are the firm specific means, T_i is the number of time periods for firm i, λ' is the corresponding vector of coefficients to be estimated, and $\eta_i \sim N(0, \sigma_\eta^2)$. Eq. (3) divides the firm-specific stochastic term into two components: the first one explains the relationship between the inputs and the firm-specific effect (with the auxiliary coefficients λ_i) and the second component, η_i, is orthogonal to the explanatory variables. In this way, we control for any correlation between the inputs and the heterogeneity component, also eliminating a possible endogeneity bias in the inputs. Hence, we assume a weak exogeneity of inputs in line with the standard within (fixed-effects) panel data estimator as discussed in Ackenberg et al. (2015).[4]

3.3. GTRE SFA model

Following Colombi et al. (2017), in this research we also employ a further extension of the TRE model presented in Eqs. (1a)–(1c) which takes into account all the above-mentioned factors (i.e. time-varying inefficiency, time-invariant inefficiency and heterogeneity). This is achieved by adding to the TRE model a time persistent inefficiency counterpart which is denoted here as h_i. The extension of the model adds to the TRE model a time persistent counterpart to u_{it} in the time-varying stochastic frontier. The model has been proposed by

[4] We do not apply the alternative semi-parametric productivity models outlined in Ackenberg at al. (2015) that control for a strict exogeneity of inputs due to a number of reasons. Firstly, we do not have valid variables as instruments in our dataset to run these models. Secondly, these models require the assumption of Cobb-Douglas production technology whereas this research uses the more preferred flexible translog production function with the first-order approximation of the input coefficients (see Ackenberg et al., p. 1415). Finally, these methods also do not allow for estimation of the (in)efficiency determining variables in one step estimation as it can be achieved in the SFA framework.

Colombi (2010) and Colombi et al. (2011, 2014, 2017) and Tsionas and Kumbhakar (2014) referred to it as the 'Generalized True Random- Effects' (GTRE) model, which in the case of stochastic production function takes the following form:

$$\ln y_{it} = \alpha + (w_i - h_i) + \beta' x_{it} + (v_{it} - u_{it}) \quad (4)$$

where $\ln y_{it}$ is the log of observed output, and x_{it} is the vector of inputs (in logs); β' is a J × 1 vector of the corresponding production function parameters which are defined as before. The random components v_{it}, u_{it} and w_i are as defined earlier, while $h_i = |H_i|$ denotes a time-invariant persistent inefficiency that has a half normal distribution with underlying variance σ_h^2. Hence, this model is called a two-level model with two types of inefficiency: time-varying inefficiency following Eq. (1a) above and persistent inefficiency as per Eq. (4). The persistent TE is then derived in line with Eq. (2) as:

$$TE_i^p = \exp(-h_i) \quad (5)$$

3.4. TFP index and its components

With the consideration of estimating the change in the productivity of firms over time, the Malmquist TFP Index is applied to measure the total factor productivity (TFP) change from one year to another. We apply the TFP index in a SFA framework according to Orea (2002) and derivations presented in Coelli et al. (2005). The estimated parameters of the SFA model presented in Eqs. (1a)–(1c) and the TE estimates presented in Eq. (2) are used to construct a generalised Malmquist productivity index. The index is based on the approach outlined by Coelli et al. (2005) where TFP change from year *s* to *t* is the product of the technical efficiency change (TEC) as presented in Eq. (5), the scale efficiency change (SEC) as presented in Eq. (6) and the technical change (TC) as presented in Eq. (7) below:

Technical Efficiency Change (TEC): $$TEC_{s,t} = \frac{TE_{it}}{TE_{is}} \quad (5)$$

Scale Efficiency Change (SEC): $$SEC_{s,t} = \exp\{0.5\sum_{n=1}^{N}[\varepsilon_{nis}SF_{is} + \varepsilon_{nit}SF]\ln(x_{nit} / x_{nis})\}$$

Where $SF_{it} = (\varepsilon_{is} - 1)/\varepsilon_{is}$, $\varepsilon_{is} = \sum_{n=1}^{N}\varepsilon_{nis}$ (returns to scale) and $\varepsilon_{nis} = \frac{\delta \ln Y_{it}}{\delta \ln x_{nit}}$ (output elasticities for each input) (6)

Technological change (TC): $$TC_{s,t} = \exp\left\{0.5\left[\frac{\delta \ln Y_{is}}{\delta s} + \frac{\delta \ln Y_{it}}{\delta t}\right]\right\} \quad (7)$$

All the indexes and the product of all of them, which is the TFP MPI index, are ratio values with the scores above one indicating positive change and a score below one indicating a negative change from one period to another.

3.5 Efficiency determinants in the TRE and TREM models

To integrate the effects of efficiency determinants as explanatory variables in estimating the true unbiased technical efficiencies, we can incorporate them either in the estimated distribution of inefficiency or directly in the production function. Following Caudill et al. (1995), Hadri (1999), Wang (2002), Hadri et al. (2003), and Greene (2007), we include the efficiency determinants Z_k as heteroscedastic variables in the inefficiency function, directly parameterising the variance of the inefficiency as follows:

$$\sigma^2_{u_{it}} = \exp(\gamma' z_{it}) \quad (8)$$

where z_{it} is the vector of three potential TE determinants which we consider: the age of the firm in years (age_{it}); the firm's size and the state expenditure per capita on cultural services at country level. With regard to the size, we divide the examined PA firms into *micro* firms, if the firm has 0–9 employees, *small* firms, if the firm has 10–49 employees, *middle-sized* firms if the firm has 50–249 employees, and *large* if it has at least 250 employees. We include the state expenditures on culture per capita at country level as we assume, in line with previous discussion and with Contreras and Lozano (2020), that public funding might be linked with the performance of those institutions.

As already discussed in section 2, the economists have reached different points of view on the overall influence of public subsidies on technical efficiency. We concluded that, in line with the previous literature, the standard argument could firstly apply that public funding might have an adverse effect on the incentives of management and the employees to be efficient, as found for museums by Bishop and Brand (2003), and in this scenario *higher* cultural expenditure would *increase* inefficiency, and hence *decrease* TE of PA firms. However, in section 2, we also discussed that increased cultural expenditure may create incentives for PA firms' managers to innovate and experiment, or to increase quality, and hence it could lead to higher efficiency of the firm. We assume that the public funding also differs from the own earned revenues of PA firms in the sense that the additional resources can be used by the managers to invest into production enhancing activities (e.g. innovation or quality), which in turn would improve the productive performance of PA companies. As already noted, Fernández-Blanco et al. (2019) and Zieba (2011) found that public funding might increase technical efficiency of PA firms. Therefore, we test the alternative hypothesis that *higher* cultural expenditure would *decrease* inefficiency and hence *increase* TE of PA firms.

In the economic literature, firm performance also depends on firm size, which may affect its efficiency. However, this relationship is not well supported since empirical evidence suggests mixed results with regard to the link between efficiency and firm size in either direction. Diaz and Sanchez (2008) assert that whilst a positive effect may be expected due to the economies of scale, the firm size may be negatively linked to efficiency if large firms experience management and supervision problems. On the other side, Jha et al. (1998) find that large firm size is associated with higher TE. These mixed results may be influenced by technology and sector characteristics. However, since we are analysing a sector where the technological progress is scarce and the EU PA sector is largely composed of small firms (see next section for details), we need further investigation to explore the relationship between firm' size and TE in the PA sector in the European countries.

We also test whether older firms are more efficient than younger ones. Whilst a positive relationship between age and TE can be expected due to the 'learning by doing' process; older firms often delay the adoption of new technologies as it may be too costly to substitute old methods, thus implying that efficiency may decrease with age. This contrasting view may depend on sector's characteristics. In fact, at the Italian level, Castiglione and Infante (2014) find a positive effect of age on firm efficiency for the manufacturing sector whilst Castiglione et al. (2018) do not find a significant effect of age on the TE scores of Italian PA firms.

4. Data set

4.1. Data sample

The panel data set on output, inputs and other firm-level characteristics for European PA firms comes from the Amadeus/Orbis database provided by Moody's Analytics/Bureau van Dijk which contains data on firms' financial and productive activities from balance sheets and income statements for over 130 million companies across the world. From this database, we choose the sector *9001 - Performing arts,* which displays comparable financial balance sheet information over the period 2009-2017. We originally restricted our data base to the old EU 15 states as this is a sample of rather homogeneous countries, in terms of economic living standards in per capita terms. These member countries also share almost similar cultural and social values. In addition, they share a long history as market economies, as opposed to other EU countries that had fifty years of planned economies experience". After examining the data, the number of countries was further reduced to 11, since Austria had only 5 firms with non-missing observations in the sample and therefore it was excluded from the estimation, while those of the remaining EU 15 countries (Greece, Ireland and Luxembourg) were not available in the database and hence are also not examined in this study.

The Amadeus/Orbis data set had data entries for approximately 150 thousand PA firms in the EU-11 countries, however the majority of these data entries did not contain any financial information except for the names of the firms. Following this, we excluded those firms and observations from the initial dataset.[5] Furthermore, the number of observations with missing values for output and inputs and non-zero turnover had also to be dropped from the sample. As a result, the *effective sample* used in this study consists of 6479 firms which gives a total of 25,928 observations and which forms an unbalanced panel (see Table 1). [6]

Moreover, 4950 firms had been in the data sample for at least two years (24,399 observations or 91% of all observations), indicating that 1889 firms were available only for one year in the sample. As one of our main aims in this research is to estimate the changes in TE and total factor productivity over time, we focused mostly on the models in which we exclude the one-year observations. Furthermore, according to Baltagi and Song (2006), we can still use the standard panel data methods for consistent estimation of unbalanced panel if the selection rules leading to the attrition in the panel are ignorable for the parameters of interest. Therefore, we test empirically if the attrition in the panel is for random rather than systematic reasons and also provide the results for balanced panel data model in the Appendix A.

It should also be noted that the dataset used for the SFA estimations includes various types of PA firms. However, it was not possible to differentiate between those types of PA firms in our sample in any meaningful way.[7] Even if such information was available, the various sub-categories of PA firms (orchestras, operas, theatres etc.) would vary from country

[5] The main reason for the missing financial information is that the historical data of the companies can be reported only for the last 10 recent years in Amadeus, and for the last 5 recent years in Orbis database. Moreover, whilst Amadeus will also delete the company from the database, if the firm did not report anything in the last 5 years, the Orbis will keep this company as long as the company is active in the business register (see discussion in Kalemli-Özcan et al., 2015)

[6] The unbalanced panel data implies that certain individual firms are not observed for some time periods.

[7] We use the 9001 category since there is no possibility of using a more detailed sub-code than 9001 in this database.

to country. This is because, for example, the 'opera' companies in one country (e.g. Germany) will still differ in their production or repertoire structure from 'opera' companies in another country (i.e. UK). As noted by O'Hagan (1998), the main differences between European PA firms arise from a varying emphasis on the different PA firms, for example, with Germany placing emphasis on orchestral music and theatre, Italy on opera, France on opera and ballet, while UK has moved closer to the American model of the PA firms with strong pro-market orientation being the dominant force. Following this, we assume that the country differences are important in this context and these are being appropriately captured by the country-fixed effects in our SFA models. Another alternative to differentiate between various firm types would be the application of the SFA latent class model (LCM) suggested in Greene (2005) and applied in Castiglione et al. (2018) for the Italian PA firms. The LCM classifies the sample into several classes (groups), and it assigns each PA firm to a particular group using the estimated probabilities of the class membership. This model was also initially considered for this study. However, since it could be obtained only for two classes, it could not be tested against more than two classes due to the convergence issues. The available LCM results imply that although the LCM controls for different technologies between the classes, it does not control for the heterogeneity within each class of the PA firms. Hence, this model was not considered in the further analysis.[8]

4.2. Variables used

In the PA sector, factors used as inputs (e.g. labour and capital, etc.) are transformed into a product which can be observed and measured only indirectly. Previous efficiency studies in the PA sector measured artistic output using the number of visitors (Zieba 2011; Zieba and Newman 2013), the revenue from tickets sales (Castiglione et al. 2018) in an output-oriented TE model, or they used the number of supplied tickets (Last and Wetzel 2010), or both the number of productions and the number of performances (Fernández-Blanco et al. 2019) in an input-oriented efficiency model. The novelty of our research is that we utilise financial accounting data, which are mainly used in efficiency studies for other sectors (e.g. Pieri and Zaninotto, 2013). Following Castiglione et al. (2018), artistic output is measured by total deflated annual earned revenues coming from different company activities (shows, renting, and others). Hence, we assume that this financial measure is highly correlated with the real

[8] The production function coefficients and returns to scale from the SFA LCM were very similar to those obtained in the pooled SFA model (see Section 5 for more details), and the TE scores resembled binomial distribution, with one class resembling distribution of the pooled SFA and another one having a similar distribution to the TRE SFA models. However, these results are available on request.

artistic production (i.e. the number of visitors, tickets sold or the number of performances and productions). As people attend performing arts for aesthetic or artistic reasons, we also assume that quality will increase artistic consumption, and hence the tickets sales and revenue of the PA firms. Castiglione et al. (2018) controlled for quality of performances using the proxy variable of quality such as artistic wages and found that quality increase efficiency of the Italian PA firms. Unfortunately, we do not have data to control for quality of performances for PA firms in all 11 European countries which provides an important scope for future research.

Labour input is measured as the total number of employees at the end of the year and capital stock in a given year is proxied by the nominal value of tangible and intangible assets after depreciation. To transform the financial data measured in local currency into real values, the output (the earned revenues) was deflated using the 2-digit harmonised consumer price index (CPI) obtained in the Eurostat database for each EU country, whilst for the capital stock the 2-digit World Bank GDP deflators, also at the country level, were applied. Moreover, to allow for comparison of output and inputs between the countries, the real values in local currency were converted for each EU country into constant 2011 dollars by applying the Purchasing Parity Power (PPP) conversion factors which are available in the World Bank database.

As for the efficiency determining variables, the size and age are obtained on firm-individual level using the Orbis/Amadeus database. The data on subsidies, as measured by public expenditures for cultural services, are collected from the Eurostat at the country level and are divided by the population size of each country and the relevant GDP deflators.[9] As already noted earlier, in order to allow for comparability between the countries, we use the same data sources for the financial deflators and for the public cultural expenditures variable that is included as the efficiency determinants. The advantage of our data set applied in this study is that we examine the efficiency and productivity of the PA firms, and we apply, at the same time, consolidated and comparable financial data for the examined PA firms in 11 EU countries.

Table 2 presents the description of the data used in the analysis, whilst the summary statistics of the variables used as output, inputs in the production function, and of the

[9] A subsidy variable at the more granular (i.e. PA firm) level was not available in our database. However, using the public expenditure per capita at the country level is an important approach in our context. This type of multilevel analysis or 'mixing' the country-level data with the 'firm-level' data is not uncommon in the applied research when one simply wants to examine the overall effect of the aggregated variable (i.e. subsidies) on the dependent variable. Such type of analysis has also recently been conducted within the SFA framework in other studies (see e.g. Guarini et al. 2020; Castiglione et al. 2018).

efficiency determining variables, are presented in Table 3. The statistics present the mean and standard deviations for both the reduced sample and the full (original) sample of observations that includes one-year observations of the PA firms. The summary statistics of the reduced sample (excluding one-year observations) differ very little from the original sample. There is a large variation in the output and inputs (labour and capital) about their means. The efficiency determinants, which are continuous variables and affect the variability and hence the mean of the inefficiency (u_{it}), are also presented in Table 3. As regards the size, the vast majority of the observations presented in Table 3 belongs to the micro-sized firms with less than 10 employees (86% of observations), and the smallest proportion of PA firms belong to the large category (only 0.46% of all observations in Table 3). The EU PA firms are also 12 years old on average, and 180 PPP US dollars per capita are spent on average on cultural services. Table 3 also shows the percentage distribution of the observations for each EU country. Since there is discrepancy in the number of observations between each EU country, the country fixed-effects are included in the production function to also control for these differences.

4.3. Cultural public expenditure structure in the EU-11 countries

Figures 1 and 2 also show the distribution of the government expenditures per capita for each country on average (Figure 1) and through time (Figure 2). From Figure 1 we can see that Denmark, France, the Netherlands and Sweden have a greater spending per capita on cultural services and they are above the EU-11 average, while Belgium's and Finland's expenditures on culture are close to the EU-11 average. There is also some variation in cultural expenditure over time and from Figure 2 it is worth noting that on average there has been a decline in cultural expenditure for the EU-11 countries. This trend can be explained by the global financial and economic crisis in 2009 which contributed to lower GDP and to lower government expenditures. Only Denmark, Belgium and Germany experienced a slight increase in cultural expenditures per capita, while Italy and Portugal experienced even a decline and their average cultural expenditures are also well below the EU-11 average. It is, however, noteworthy to mention that although the expenditure increased for some countries between 2009 and 2017, they had returned to lower or pre-crisis levels by the year 2017.

The EU-11 countries' variability in per capita cultural expenditure is not surprising since in the European Union the formal recognition of cultural action was first introduced in the Treaty of European Union in 1992 and was not meant to establish the grounds for a European-wide cultural policy (article 128) but to only supplement member state policy

(Barnett, 2001). In the 2000 Treaty of Lisbon, whose aim was to make the EU by 2010 "the most competitive and dynamic knowledge-based economy in the world", the role of the cultural sector was almost ignored. Only in 2007 did the European Commission explicitly adopt the European Agenda for Culture. In 2013 the Creative Europe Programme (2014 to 2020) was introduced, which aims to enhance European cultural and linguistic diversity (Europe's cultural heritage), thus strengthening the competitiveness of the European cultural and creative sectors. Even in 2018, the New Agenda for Culture was intended to take into account the evolution of the cultural sector, stressing that individual EU Member States are responsible for their own culture sector policies, and the role of the European Commission is to address common challenges (COM/2018/267).

Therefore, in the years of analysis in absence of a clear European cultural policy, the registered differences in per capita cultural expenditure are mainly due to individual country government choices to support cultural activities and to the level of per capita income held by each of the countries.

In addition, the 11-EU countries have different systems to allocate public funds to PA sector that follow the different institutional context operating in each country. For example, in Belgium, Finland, France, Germany, Italy, the Netherlands, three or four levels of government – state, regions, provinces and municipalities – share responsibilities in the cultural field. Whilst in other countries such as Denmark, Portugal, Spain, and the United Kingdom the central government is responsible for the allocation of resources among different cultural sectors. Although, in Denmark and the United Kingdom the allocation of funds is managed by national autonomous cultural agencies or arts councils. In the UK, alongside the arts councils, the National Lottery Heritage Fund also operates.

However, to better focus on the differences of European countries in cultural expenditures we can have a look at Table 4 that shows the percentages of per capita income that is dedicated to cultural expenditure across the eleven European countries. The data in the table confirm that the economic crisis and the budget cuts that followed in 2009 hit the public expenditure in culture in all the reported European countries. The percentage of per capita income expenditure in cultural services decreased from 0.70 to 0.66 in Denmark, the highest investor country in cultural services of the country sample, and from 0.39 to 0.25 in Portugal, which remains the lowest investor country in cultural services. In the other nine countries, there are some, like Belgium, Germany, Finland, France, and Sweden, that remained more or less with same percentage of income per capita invested in cultural services, whilst the remaining countries, Italy, the Netherland, Spain and the UK, registered big decreases in the percentage on income per capita invested in cultural services. Severe cuts in the sector were realised in Italy and the UK, accompanied by additional reductions later due to cutbacks in local authorities' expenditure. To this purpose, as justification of the cuts in the public cultural sector expenditure, we can refer to the words of a former Italian conservative Finance minister who said: "You can't live on culture, I go to the buffet to make myself a culture sandwich, and I start with the Divine Comedy" (La Repubblica, 14 October 2010). As far as the UK is concerned, after a decade of austerity following the 2008 world financial crisis, the situation has been the same but in a different context. This country has always registered lower per capita cultural expenditure in comparison with those of the other European countries for two main reasons: the frequent complaints about public support to cultural activities (see Peacock 1969, 1993), and the private funding supports for cultural activities that in the UK were always rather higher than in any other European country (Fisher, 2020). In 2009, the starting year of our period of study, the percentage of income per capita invested in cultural services was about 39 per cent, whilst in 2017 this percentage collapsed to 25 per cent, due to both the austerity in UK government spending policy and the decreasing private contribution funding.

5. Results

The SFA production function estimates are presented in Table 5. The results are presented for the standard pooled SFA model, the true random-effects (TRE) model, the extended true random-effects model with Mundlak's terms (TREM) and the generalised true random-effects (GTRE) model.[10] The results are presented for PA firms in 11 European countries and the country fixed-effects are included by using the country dummy variables in all models. Accordingly, we assume that the production function intercepts will differ between the EU-11 countries due to the country-specific technological endowments as per Eq. (1a).

All estimations were performed for the reduced sample, by excluding PA firms with one-year observations from the sample, except the GTRE model which is estimated for the full sample (i.e. including firms with one-year observations).[11] Furthermore, as the results in Table 5 refer to an unbalanced panel, we also present in Appendix A (Table A.3) the robustness check results for the balanced panel, by using only 707 firms over the full number

[10] All models were estimated using LIMDEP version 11.0 (Greene 2007).

[11] We prefer to exclude the PA firms with one-year observations as we want to focus on the panel nature of the data set. However, the GTRE model with the reduced sample became highly unstable and led to problems with convergence when applying simulated MLE estimations. Nevertheless, the results for the full sample of other SFA models (pooled, TRE and GTRE) were very similar to the results obtained for the reduced sample and they are available on request.

of nine years and excluding three countries. All further robustness and specification tests are also presented and discussed in Appendix A.

5.1. Estimated SFA production function coefficients

For all four models presented in Table 5 (pooled SFA, TRE, TREM and the GTRE), all inputs and output variables are normalised at their sample mean prior to the estimation of the translog production function. Thus, the presented first-order coefficients (β_K and β_L) are directly interpreted as output elasticities with respect to labour and capital, respectively. These elasticities are positive and significant at the 1% level for all the models presented in Table 5. The total share of the statistically significant translog production function coefficients is also very high.[12] The output elasticity of capital is much higher than that of labour, suggesting that the largest contribution to the production in the PA sector in the EU countries is due to capital input. This result can be explained by the fact that the output per man-hour cannot be easily raised in the PA sector and the productivity improvements may arise from increases in capital rather than in labour, such as capacity of venues, organisation, directing, rehearsing, scenes and costumes. The results in Table 5 also indicate a slight upward bias in the labour elasticity coefficient in the pooled SFA model which does not control for unobserved heterogeneity but also in the TRE model without the Mundlak's terms, indicating a possible correlation of inputs with the error term and validating using the TREM specification.

Furthermore, the total elasticity of scale is defined here as a local measure of returns to scale, and it equals 1.028 for the pooled model, demonstrating the evidence of constant returns to scale, but it ranges between 0.76 and 0.89 for the TRE and TREM models, and 0.84 for the GTRE model. We base our findings on the TRE, TREM and GTRE models as they take into account the heterogeneity of PA firms. We can also see that once controlling for the correlation of inputs using the TREM model, the total elasticity of scale is also less than one implying decreasing returns to scale (DRS) for the European PA firms at the sample mean. These results indicate that increasing all inputs by 1%, would increase output by 0.76 to 0.90%. The evidence of decreasing returns to scale was also found in Castiglione et al. (2018) for PA firms in Italy. A similar result was found in the previous studies on production functions for PA firms, such as Zieba and Newman (2013) for German theatres, and Zieba (2011) for Austrian and Swiss theatres, and Gapinski (1980; 1984) for the PA firms in the

[12] The LR test confirms that the translog function (unrestricted model) fits our data better than the alternative Cobb-Douglas function (restrictive model).

UK and the US. None of those PA studies, however, applied the GTRE SFA model which controls for both transient and persistent (in)efficiency or used such an extensive data set as applied in this study.

The time trend in the production function in Table 5 is significantly smaller than zero, while the time squared is positive and significant as expected. The time trend is also interacted with both inputs (labour and capital) to control for non-neutral technological change, similarly to Last and Wetzel (2011). This result suggests that the technological change was not influencing the EU PA sector during the examined period. However, the technological change is examined more closely using the estimated SFA production function coefficients and calculating the MPI TFP index, and it is discussed in detail in section 5.3 below.

All country-specific dummies are mostly always significant, indicating that there are important country fixed-effects. The individual country indicator variables control for differences in the technological endowments between the eleven European countries. We find that the PA firms located in Germany, France and Belgium (the reference category) show a higher production frontier than the PA firms in the other eight countries. Hence, there are important differences across the examined countries with regard to the available production technology. However, the country fixed-effects denote solely the differences in the production technology between the countries at the same point in time, and not within the individual PA firms or over time. The productivity differences between the individual firms are captured by the MPI index presented in Tables 6 and 7 which are discussed below. It should be noted that it is difficult to explain the differences in technological endowment between the European countries "as each country has pursued an independent cultural policy, and even in the European Union, culture is one of the areas where each country's independence is guarded and protected, with minimal with any, harmonisation of cultural policy between the member states" (O'Hagan, 1998, p. 201).

5.2 Estimated TE scores

The means and standard deviations of TE scores are also presented in Table 5 for the respective models. While the pooled SFA model in column (1) does not control for firm's unobserved heterogeneity, it also displays the lowest TE score, which is 0.44 on average, indicating that not including the firm-specific component in the SFA model largely underestimates the obtained TE scores (see also Colombi et al. 2017). However, the TE scores of the TRE, TREM and GTRE models which additionally control for the unobserved heterogeneity of the PA firms, are higher and range on average between 0.579 and 0.596. The differences between the TRE and TREM models are also very small. While the TRE and GTRE models control for the unobserved heterogeneity of the PA firms, the Mundlak's adjustment in the TREM model additionally allows for the correlation of inputs with the error term similarly to the standard fixed-effects estimator. We can also see in line with Van Biesebroeck (2008) that the TE scores and hence the productivity levels of PA firms, are not affected by the possible correlation of inputs with the error term. These TE results are similar to those obtained by Castiglione et al. (2018) and Zieba (2011) but differ from Marco-Serrano (2006) who found much lower TE scores in the DEA model, and from Last and Wetzel (2010), and Fernández-Blanco et al. (2019) who found much higher TE scores in an input-oriented TE model. However, as already discussed in subsection 2.1, the previous studies used different methods and various data samples and consequently the results are not directly comparable.

Furthermore, the generalised true random-effects (GTRE) model of Table 5 extends the basic TRE model by adding the persistent inefficiency component (h_i), and hence the persistent TE scores are obtained besides the transient TE scores. As already mentioned, estimating this model proved to be quite unstable for the reduced sample (excluding one-year observations), and so the results for the full sample of all firms are only presented.[13] Nevertheless, it should be noted that the transient TE is almost identical to that obtained in the TRE model and equals 0.58 on average, while the persistent TE is low and equal to only 0.39 on average. This indicates that the persistent or structural efficiencies in the European PA sector are lower than the time-varying efficiencies.

The kernel density functions of the estimated TE scores presented in Figure 3 indicate that the TRE and TREM models display very similar variances of the TE scores. The simple pooled model has a similar distribution to the TRE models, albeit with a lower mean value of TE, as expected, as this model does not control for the unobserved heterogeneity of the PA firms and hence it underestimates the TE scores. The variance of the short-run time-varying TE estimated within the GTRE model is very close to the traditional TRE TE scores, again confirming the robustness of our results. For this reason, and assuming that the technical efficiency is mainly time-varying, the TRE and TREM models are the favoured model specifications in our further analysis.

[13] Whereas the results for the GTRE model could not be estimated by including the Mundlak's terms for the unbalanced panel, Table A.3 in Appendix A presents the GTRE model with Mundlak's adjustment for the fully balanced panel.

5.3 Estimated MPI index

Consequently, following the TRE and TREM estimates, the Malmquist productivity index (MPI) is obtained using both the values of the TE scores and the estimated parameters of the SFA production function (output elasticities) and the coefficients related to the technological change which are the time trend, the time trend squared and the time-trend interaction variable. Table 6 presents the average changes in total factor productivity (TFP) for each country from the base period 2009 to 2017. Based on the TRE model results, the average change for the EU PA sector is positive indicating that the total factor productivity improved by 6.9% from 2009 until 2017, while the technical efficiency improved by 15.5%, as indicated by TE change (TEC). On the other hand, there was a decline in the scale efficiency change (SEC) by 0.3 % and a decline in the technological change (TC) by 7.2%, as both SEC and TC indexes are below one on average. A very similar pattern can be observed in Table 6 for the indexes which were derived from the results using the TREM model, validating the robustness of the obtained results.

There are clear differences in the average change of the productivity index from 2009 until 2017 for each European country. Most of the countries experienced an increase in the productivity as the MPI index is greater than unity except for PA firms in Belgium, Denmark and the UK for the TRE model. From Table 6, it also follows that the main driver of the increase in the total factor productivity for most of the countries is the technical efficiency change. The TEC index is always greater than unity for all countries except Denmark. On the other hand, the SEC is either close to unity or slightly below one for most of the countries, indicating that if there is an increase in the scale efficiency, this increase is very small.

In Table 7, the MPI average values for all PA firms indicate that EU PA sector productivity increased over time. The values are more than unity for all time periods on average for the overall TFP MPI index and the pattern of productivity becomes similar when we analyse the MPI index over time for each EU country separately (see Table B.1 in Appendix B). Furthermore, Figure 3 presents the cumulative percentage change of the MPI index and its sources over time and on average for all the EU countries (based on the TREM model).[14] We can see that, while there were large fluctuations in the TEC change, there is little or almost no change in SEC and in the TC. The fluctuations in the MPI index are due to technical efficiency change which, except 2011, was always positive, but then the TEC increased at a steady rate as shown in Figure 3. Therefore, the change in MPI index is driven

[14] The MPI results for the TRE model without the Mundlak's term were almost identical with the MPI results obtained for the TREM model, and they are available on request.

mainly by the technical efficiency change and not by technological progress. This finding does not necessarily mean that the technological progress was absent in the European PA sector, as in certain years, and for some firms or countries (see Table B.1) the index is above one. However, on average a trend emerges that the index is only very slightly above or below 1, or very close to one, indicating that the positive TFP in European PA firms has been largely driven by TE change rather than the technological change.

Overall, these findings suggest that the productivity increases in the PA sector can arise from technical efficiency change, scale efficiency change or technological change. An example of technological change in PA sector could be increasing the capacity of venues or streaming the performances to wider audiences which could increase the productivity over time. At the same time, the technical efficiency could contribute to higher productivity by better exploiting the current capacity of their venues, and through the means of increasing the number of performances and their quality. Therefore, following Cowen (1996) we argue that innovation, digitalisation, an increase in the quality and hence consumption in the PA sector might have played an important role in increasing the technical efficiency of the PA firms and their total factor productivity. For example, even in the pandemic crisis, there is anecdotal evidence that the productivity in the PA sector might increase due to investments in the digitalisation (OECD, 2020).

5.4 Estimated TE determinants

Table 8 presents the SFA production function estimations using the TRE and TREM models which report the estimated coefficients of the efficiency determining factors (Z_k) which were included as heteroscedastic variables in the inefficiency function in Eq. (7). The coefficients show their direct effect on inefficiency (u_{it}) which is the opposite effect on TE. The presented TRE and TREM models with heteroscedastic inefficiency terms are an important extension of our analysis.

The size variable *size_2*, which denotes 10–49 employees, has always a significant and negative effect on inefficiency (u_{it}). This implies that the small-sized firms are more technically efficient than the micro firms with less than 10 employees, our reference category (*size_1*). Thus, the small-sized firms (*size_2*) and the medium-sized firms (*size_3*) could be considered as those with the most-efficient size for the EU PA market, whilst large firms (*size_4*) do not present any statistical difference from *size_1* firms. This result demonstrates that the European PA companies could significantly increase their technical efficiency by moving to the small or medium scale, represented by firms that operate with 10–49 employees or 50–249 employees, thereby removing the scale inefficiency.

Our results also confirm that the age_{it} of the firm contributes significantly to changes in inefficiency for EU PA companies. The age coefficient is significant and negative, implying that it has a positive effect on technical efficiency, and that learning by doing and accumulate experience matters in the PA sector. Therefore, efforts should be made that PA firms do not exit the market as that could lead to greater inefficiencies and lower productivity in the PA sector over time.

The level of public cultural expenditures, has also a significant and negative effect on inefficiency, indicating a positive effect on TE of government cultural expenditures. The coefficient is significant at the 1% level. The positive effect of EU-11 public cultural expenditures on technical efficiency is in line with the findings of Zieba (2011) and Fernández-Blanco et al. (2019) that, using public subsidies, show a positive effect on efficiency for Austrian and Swiss theatres and for municipal Polish theatres in Warsaw, respectively. One explanation for these results might be the fact that public funding increases the incentives of company managers to spend more on intangible inputs in order to improve quality which in turn increases the artistic production of the firm. Public funding may be correlated, for example, with higher expenditures on more qualified or more talented labour, renovation and innovation which would in turn increase quality and hence the output of the firm given the level of inputs. On the contrary, Bishop and Brand (2003) found that subsidies decrease TE of public museums in South West England, albeit the authors applied a pooled SFA model which does not control for the unobserved heterogeneity of the output and inputs variables used.

Figure 4 presents TE scores for single EU countries together with per capita public expenditure on culture and compares them against the mean values at the EU level. A star besides the country name indicates that the difference between the mean TE score for a country and the EU-11 average is statistically significant at the 5% level. According to our results Belgium, France, the UK have TE scores above the EU-11 average and the difference is statistically significant, while Spain and Portugal have TE scores significantly below the EU-11 average. The latter case also applies for the Netherlands but the difference is not statistically significant, while Finland, Germany and Italy are close to the EU-11 average. In Figure 4, we can also find the confirmed result that higher expenditures on culture per capita in PPS $ correspond with higher TE scores: the only exception is the UK that presents a lower cultural expenditure per capita and a higher TE score in comparison with the EU-11 countries. A result that seems to contradict our main finding (high public cultural expenditure increases firm efficiency). However, private funding support (business, individuals, and trusts and foundations) largely contribute to this result and in the UK this is about 25–27 per cent of the total UK expenditure in cultural services, whilst in the other European countries this contribution is less relevant (Fisher, 2020).

To summarise, the technical efficiency is influenced positively by government cultural expenditures and age, but it is negatively affected by the size of PA firms. As our findings from section 5.3 indicate, the technical efficiency change has also been the largest driver of productivity change in the 11 European countries over the examined period. Hence, the obtained results with regard to TE determinants are very important in terms of policy implications which will be discussed in the next section.

6. Conclusions

In this study, using the true random-effects SFA approaches and applying a large panel data set of EU-11 countries, a production function, a technical efficiency and its determinants of the performing arts firms were estimated. The results were obtained controlling for both the unobserved heterogeneity using TRE and TREM models, and the endogeneity of the inputs using the Mundlak's adjustment. We also control for technological endowment using the country fixed-effects methodology. The results indicate that the examined PA firms belonging to the EU-11 countries are technically inefficient. The PA firms are barely 58 to 60 percent efficient when based on the most preferred TRE and TREM models and they are 68 percent efficient when we consider the efficiency determinants as heteroscedastic variables directly in the inefficiency function. This implies that the EU PA firms could increase their artistic output, and hence their total earned revenue between 32 and 42 percent. This study also finds that the persistent or structural inefficiency is higher than the transient inefficiency.

The country fixed-effects are strongly significant and indicate that there are important differences in the technological endowments at the country level. There is little information available in the literature to explain these differences between the countries and as such this research indicates further need to explore the European PA sector. Moreover, we find that the decreasing returns to scale are prevalent for the European PA sector and the output elasticity of capital is greater than that for the labour input. This implies that increasing the investment in capital by, for example, introducing technological innovations, could further increase the productivity of EU PA firms.

In this research, we also compared if and how much the changes in the technical efficiency and other sources of productivity growth (i.e. scale efficiency change and technological change) contributed to the total factor productivity (TFP) of the European PA firms between 2009 and 2017. One of the important findings of this study is that the technological progress is not the main driver of the productivity growth for the PA firms, providing to some degree support for the presence of Baumol and Bowen's (1966) economic dilemma in the sector. However, in contrast to previous research, we found that the total factor productivity was increasing in the EU PA sector over the examined period, and the driving force for this is mainly due to the positive technical efficiency change as opposed to the scale efficiency and technological change. Although TE is low with 58 to 68 percent on average, it has been increasing over time. Therefore, we confirm that for the PA firms there is still room for further improvements in technical efficiency.

There are also certain differences in technical efficiency and total factor productivity between the EU-11 countries. In Table B.1, only three countries (Belgium, Denmark and the UK) have registered an average increase of MPI TFP index below unity, whilst the other eight had rather impressive changes above the unity and these changes were again driven by positive technical efficiency changes.

This work also explored the factors which could ameliorate technical efficiency and hence productivity of EU PA firms. Firstly, contrary to the common wisdom that public cultural expenditures to the sector could produce rent-seeking behaviours, turning into a government failure, we have demonstrated that per capita public expenditure for culture has a positive and significant effect on technical efficiency of the EU PA firms. As the technical efficiency increases over time and is the main driver of productivity growth, these results also highlight that public support for the PA sector might increase the total factor productivity of PA firms over time. Secondly, the age of the firm has a significant and positive effect on TE scores, meaning that learning by doing and accumulated experience in the art sector play an important role. Thirdly, we have also demonstrated that firm size matters. The small PA firms (10-49 employees) and the middle-sized PA firms (50-249 employees) are more technically efficient than the micro or the large firms. This finding is partly in line with Castiglione et al. (2018) which found that the small firms are the most efficient in the Italian PA sector.

As for common policy research, we arrived at some conclusions. If European countries believe that the cultural sector should be sustained using public funds, to increase the productivity of PA firms and avoid rent-reeking behaviours at the same time, they have to put some strings to the concession of public funds using some indicators based on technical efficiency improvement. Finding the possibility to increase both the technical efficiency and the technological progress for the PA firms through innovation and quality improvements by using IT technologies is another important policy implication coming from this research. This aspect might in particular prove important in the current pandemic crisis as discussed in OECD (2020) report, although the data for this research does not cover this period.

Furthermore, as the PA companies display decreasing returns to scale and a decrease in scale efficiency over time, there is scope for improvement to readjust the firm scale of operation. In particular, since the majority of the PA firms in the sample (86 percent) are micro firms with less than 10 employees, they could receive incentives to perform and cooperate better. To this aim the provisions or support for cultural services for artists and technicians to enlarge employment opportunities and networking could be a solution to increase both technical and scale efficiencies. Moreover, since age is important for the PA sector indicating that older firms are more technically efficient, financial support might increase the chances for the younger and smaller PA firms to survive in the market and to become more productive over time, incentivising those young companies that merge together to become more efficient, thus increasing their survival probability. This is an important policy issue, as it is younger companies that experiment with new forms of expression and introduce technical and visual innovations there should be an appeal to the Commission and national governments for policies that should incentivise both innovation in, and cooperation between, younger PA companies.

Finally, it should be noted that this research evaluated efficiency and productivity of performing arts sector from a more holistic perspective and at the European level. At the same time, we acknowledge that certain differences with regard to the art forms can exist between the examined PA companies in various European countries, and which could not be captured by the applied models. Therefore, future research could explore these issues at a more granular level, providing that more detailed data on the European PA sector are available.

Acknowledgements

The authors would like to thank the Editors of the journal, and three anonymous referees for their valuable comments and suggestions, which helped to improve the quality of the paper substantially. Earlier versions of this paper were presented at the 9th European Workshop on Applied Cultural Economics (EWACE) in Copenhagen, at the 60th Annual Conference of the Italian Economic Association in Palermo, and at the 35th Irish Economic Association Conference (IEA) in Dublin. We are grateful to the participants of these conferences for their insightful comments and discussion.

References

Ackenberg, D. A., Caves, K., Frazer, G. (2015). Identification Properties of Recent Production Function Estimators, *Econometrica*, 83 (6), 2411-2451.

Aigner, D., Lovell, C., Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics*, 6(1), 21–37.

Baltagi, B., Song, S. (2006). Unbalanced Panel Data: A Survey. *Statistical Papers*, 47(4), 493–523.

Barnett, C. (2001). Culture, policy and subsidiarity in the European Union: From symbolic identity to the governmentalisation of culture. *Political Geography*, 20(4), 405–426.

Baumol, W.J., Bowen, W.G. (1965). On the Performing Arts: The Anatomy of Their Economic Problems. *The American Economic Review*, 55(1/2), 495–502.

Baumol, W.J., Bowen, W.G. (1966). Performing - The Economic Dilemma. The MIT Press, Boston.

Bertacchini, E., Dalla Nogare, C. (2014). Public provision vs. outsourcing of cultural services: Evidence from Italian cities. *European Journal of Political Economy*, 35, 168–182.

Bishop, P., Brand, S. (2003). The Efficiency of Museums: A Stochastic Frontier Production Function Approach. *Applied Economics*, 35(17), 1853–1858.

Bureau van Dijk (various years). Amadeus/Orbis Database, Brussels.

Castiglione, C., Infante, D. (2014). ICTs and time-span in technical efficiency gains. A stochastic frontier approach over a panel of Italian manufacturing firms. *Economic Modelling*, 41(1), 55–65.

Castiglione, C., Infante, D., Zieba, M. (2018). Technical efficiency in the Italian performing arts companies. *Small Business Economics*, 51(3), 609–638.

Caudill, S.B., Ford, J.M., Gropper, D.M. (1995). Frontier Estimation and Firm-Specific Inefficiency Measures in the Presence of Heteroscedasticity. *Journal of Business and Economic Statistics*, 13(1), 105–111.

Coelli, T., Rao, D., O' Donnell, C., Battese, G. (2005). An Introduction to Efficiency and Productivity Analysis, 2nd edition, Springer.

Colombi, R. (2010). A skew normal stochastic frontier model for panel data. *Proceedings of 45th Sci Meeting of the Italian Statistical Society*.

Colombi, R., Kumbhakar, S.C., Martini, G., Vittadini, G. (2014). Closed-skew normality in stochastic frontiers with individual effects and long/short-run efficiency. *Journal of Productivity Analysis*, 42(2), 123–136.

Colombi, R., Martini, G., Vittadini, G. (2011). A stochastic frontier model with short-run and long-run inefficiency random effects. Working Paper no 01-2011. Department of Economics and Technological Management, University of Bergamo, Italy.

Colombi, R., Martini, G., Vittadini, G. (2017). Determinants of transient and persistent hospital efficiency: The case of Italy, *Health Economics*, 26 (S2), 5-22.

Contreras, I. and Lozano, S. (2020). Allocating additional resources to public universities. A DEA bargaining approach, *Socio-Economic Planning Sciences*, 71, 1-14.

Cowen, T. (1996). Why I do not believe in the cost-disease, *Journal of Cultural Economics*, 20(3): 207-214.

Czarnizki, D. (2006). Research and development in small and medium-sized enterprises: the role of financial constraints and public funding, *Scottish Journal of Political Economy*, 53(3), 335-357.

Diaz, M.A., Sanchez, R. (2008). Firm size and productivity in Spain: a stochastic frontier analysis. *Small Business Economics*, 30(3), 315–323.

D'Inverno, G., Carosi, L., Ravagli, L. (2018). Global public spending efficiency in Tuscan municipalities, *Socio-Economic Planning Sciences*, 61, 102-113.

Eurostat (various years). Online dataset. https://ec.europa.eu/eurostat/data/database, accessed the 1st June 2020

Farsi, M., Filippini, M. (2006). An Analysis of Efficiency and Productivity in Swiss Hospitals. *Swiss Journal of Economics and Statistics*, 142(1), 1–37.

Farsi, M., Filippini, M., Kuenzle, M. (2005). Unobserved heterogeneity in stochastic cost frontier models: an application to Swiss nursing homes, *Applied Economics*, 2005, 37, 2127–2141.

Fazioli, R., Filippini, M. (1997). Cost Structure and Product Mix of Local Public Theatres. *Journal of Cultural Economics*, 21(1), 77–86.

Fernández-Blanco, V., Rodríguez-Álvarez, A., Wiśniewska, A. (2019). Measuring Technical Efficiency and Marginal Costs in the Performing Arts: The Case of the Municipal Theatres of Warsaw. *Journal of Cultural Economics*, 43(1), 97–119.

Fisher, R. (2020) Country profile United Kingdom: England and Wales, Association of the Compendium of Cultural Policies and Trends, "Compendium of Cultural Policies and Trends," 20th edition 2020. Available under: <http:// www.culturalpolicies.net>. ISSN: 2222-7334.

Gapinski, J. H. (1980). The production of culture. *Review of Economics and Statistics*, 62(4), 578–586.

Gapinski, J.H. (1984). The Economics of Performing Shakespeare. *American Economic Review*, 74(3), 458–466.

Grampp, W.D. (1989). Rent-seeking in arts policy. *Public Choice*, 60(2), 113–121.

Greene, W. (2004). Distinguishing between heterogeneity and inefficiency: stochastic frontier analysis of the World Health Organization's panel data on national health care systems. *Health Economics*, 13(10), 959–980.

Greene, W. (2005). Reconsidering heterogeneity in panel data estimators of the stochastic frontier model. *Journal of Econometrics*, 126(2), 269–303.

Greene, W. (2016). LIMDEP Version 11 Reference Guide, Vol. 2, Econometric Software Inc: New York.

Griffith, R., Huergo, E., Mairesse, J. & Peters, B. (2006). Innovation and Productivity across four European Countries, *Oxford Review of Economic Policy*, 22(4), 483-498.

Guarini, G., Laureti, T., Garofalo, G. (2020). Socio-institutional determinants of educational resource efficiency according to the capability approach: An endogenous stochastic frontier analysis, *Socio-Economic Planning Sciences*, 71, 1-15.

Guccio, C., Mazza, I. (2014). On the Political Determinants of the Allocation of funds to Heritage authorities. *European Journal of Political Economy*, 34, 18–38.

Guccio, C., Martorana, M., Mazza, I., Pignataro, G., Rizzo, I. (2020). An analysis of the managerial performance of Italian museums using a generalised conditional efficiency model, *Socio-Economic Planning Sciences*, Online first.

Guccio, C., Pignataro, G., Mazza, I., Rizzo, I. (2014). Evaluation of the efficiency of public historical archives. Available at SSRN:http://ssrn.com/abstract=2476423.

Hadri, K. (1999). Estimation of Doubly Heteroscedastic Stochastic Frontier Cost Function. *Journal of Business and Economic Statistics*, 17(3), 359–363.

Hadri, K., Guermat, C., Whittaker, J. (2003). Estimation of Technical Inefficiency Effects Using Panel Data and Doubly Heteroscedastic Stochastic Production Frontiers. *Empirical Economics*, 28(1), 203–222.

Jha, R., Chitkara, P., Gupta, S. (1998). Productivity, technical and allocative efficiency and farm size in wheat farming in India: a DEA approach. *Applied Economics Letters*, 7(1), 1–5.

Jondrow, J., Lovell, K., Materov, L., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. Journal of Econometrics, 19(2–3), 233–238.

Kalemli-Özcan, S., Sorensen, B., Villegas-Sanchez, C., Volosovych, V., Yesiltas, S. (2015). How to Construct Nationally Representative Firm Level Data from the ORBIS Global Database. *NBER Working Paper No. 21558*.

La Repubblica (2010). Il Consiglio dei ministri dà ok unanime e già pensa a chiedere la fiducia. La Repubblica online, 14 October 2010. Available at: https://www.repubblica.it/economia/2010/10/14/news/finanziaria_cdm-8045850.

Last, A.K., Wetzel, H. (2010). The efficiency of Geman public theaters: a stochastic frontier analysis approach. *Journal of Cultural Economics*, 34(2), 89–110.

Last, A.K., Wetzel, H. (2011). Baumol’s cost disease, efficiency, and productivity in the performing arts: an analysis of German public theaters. *Journal of Cultural Economics*, 35(3), 185–201.

Marco-Serrano, F. (2006). Monitoring managerial efficiency in the performing arts: A regional theatres network perspective. *Annals of Operations Research*, 145(1), 167–181.

Mundlak, Y. (1978). On the pooling of times series and cross section data. *Econometrica* 46(1), 69–85.

Neligan, A. (2006). Public funding and repertoire conventionality in the German public theatre sector: an econometric analysis. *Applied Economics*, 38(10), 1111–1121.

Ni Luasa, S., Dineen, D., Zieba, M. (2018). Technical and scale efficiency in public and private Irish nursing homes – a bootstrap DEA approach, *Health Care Management Science*, 21, 326-347.

O’Hagan, J. (1998). *The State and the Arts. An Analysis of Key Economic Policy Issues in Europe and the United States*. Cheltenham, Edward Elgar.

O’Hagan, J.W. (2016). European Statistics on cultural participation and their international comparability, *International Journal of Cultural Policy*, 22 (2), 291–303.

O’Hagan, J.W., Neligan, A. (2005). State Subsidies and Repertoire Conventionality in the Non-Profit English Theatre Sector: An Economic Analysis. *Journal of Cultural Economics*, 29(1), 35–57.

OECD (2020). Culture shock: Covid-19 and the cultural and creative sectors. Available at: https://www.oecd.org/coronavirus/policy-responses/culture-shock-covid-19-and-the-cultural-and-creative-sectors-08da9e0e/

Orea, L. (2002). Parametric decomposition of a generalized Malmquist productivity index. *Journal of Productivity Analysis*, 18(1), 5–22.

Peacock, A. (1969). Welfare economics and public subsidies to the arts. *The Manchester School of Economics and Social Studies*, 37(4), 323–335.

Peacock, A. (1993). *Paying the Piper. Culture, Music and Money*. Edinburg. Edinburg University Press.

Pieri, F., Zaninotto, E. (2013). Vertical integration and efficiency: an application to the Italian machine tool industry. *Small Business Economics*, 40(2), 397–416.

Pit, M., Lee, L.F. (1981). The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry. *Journal of Development Economics*, 9(1), 43–64.

Raymond, W., Mairesse, J., Mohnenc, P., Palmd, F. (2015). Dynamic models of R & D, innovation and productivity: Panel data evidence for Dutch and French manufacturing. *European Economic Review*, 78, 285–306.

Taalas, M. (1997). Generalised Cost Functions for Producers of Performing Arts – Allocative Inefficiencies and Scale Economies in Theatres. *Journal of Cultural Economics*, 21(4), 335–353.

Tepe, M., Vanhuysse, P. (2014). A vote at the opera? The political economy of public theatres and orchestras in the German states. *European Journal of Political Economy*, 36, 254–273.

Throsby, D. (1977). Production and Cost Relationships in the Supply of the Performing Arts Services. In: K. Tucker (ed.), *The Economics of the Australian Service Sector*, London, pp. 414–432.

Throsby, D. (2010). The Economics of Cultural Policy. Cambridge, Cambridge University Press.

Towse, R. (2005). Alan Peacock and Cultural Economics. *The Economic Journal*, 115(504), F262–F276.

Towse, R. (2020). Performing arts, in Towse, R. & Navarrete Hernandez, T. (eds): *Handbook of Cultural Economics*, Cheltenham, Edward Elgar.

Tsionas E., Kumbhakar S. (2014). Firm heterogeneity, persistent and transient technical inefficiency: A generalized true random-effects model. *Journal of Applied Econometrics*, 29(1), 110–132.

Van Biesebroeck, J. (2008). The sensitivity of productivity estimates: Revisiting three important debates. *Journal of Business and Economics Statistics*, 26(3), 311-328.

Wang, H.J. (2002). Heteroscedasticity and Non-Monotonic Efficiency Effects of a Stochastic Frontier Model. *Journal of Productivity Analysis*, 18(3), 241–253.

Werck, K, Grinwis Plaat Stultjes, M., Heyndels, B. (2008). Budgetary constraints and programmatic choices by Flemish subsidized theatres. *Applied Economics*, 40(18), 2369–2379.

Wooldridge, J. (2002). Econometric analysis of cross section and panel data. London: The MIT Press.

Zieba, M. (2011). An Analysis of Technical Efficiency and Efficiency Factors for Austrian and Swiss Non-Profit Theatres. *Swiss Journal of Economics and Statistics*, 147(2), 233–274.

Zieba, M., Newman, C. (2007). Understanding Production in the Performing Arts: a Production Function for German Public Theatre. *TEP Working Paper 07/07*, Trinity College Dublin.

Zieba, M., Newman, C. (2013). Organisational Structure and Managerial Efficiency: A quasi-experimental analysis of German public theatres. *Homo Oeconomicus*, 29(4), 497–534.

Appendices

APPENDIX A. Robustness checks on the results

We apply a number of robustness checks to corroborate our empirical results. We firstly carried out general likelihood ratio (LR) tests to differentiate between the main SFA models applied (Table A.1). The first test rejects the null hypothesis of no one-sided time-varying inefficiency term, for both the pooled SFA and TRE SFA models, confirming that the average response function with just the error term, v_{it}, is not adequate to our data and that the SFA production function model is more appropriate. The pooled SFA model was also tested against the TRE model which includes the random error term (w_i) and the null hypothesis is also strongly rejected implying that controlling for the heterogeneity is an important extension of the pooled SFA specification. The TRE model was further tested against the unrestricted GTRE model and the null hypothesis of no persistent (time-invariant) inefficiency was rejected at the 5% level. These findings indicate that GTRE model is an important extension of the TRE model and that persistent efficiency is lower than the time-varying efficiency. Importantly, the LR tests in Table A.1 validate that the Mundlak's terms which control for the endogeneity of inputs in the SFA production function are jointly significant.

Table A.1. Generalised LR tests on SFA models

Null hypothesis	Restricted vs. unrestricted model	Critical value	Test statistics
H_0: $\sigma_{uit}=0$ (no time-varying inefficiency)	OLS vs. Pooled SFA	2.71	3293*
	OLS vs TRE	2.71	17537*
H_0: $w_i=0$ (no heterogeneity term)	Pooled SFA vs. TRE	2.71	14663*
H_0: $\sigma_{hi}=0$ (no time invariant inefficiency)	TR E vs GTRE [a)]	2.71	806.92*
H_0: $\lambda_1=\lambda_2=\lambda_3=\lambda_4=\lambda_5=0$ (no Mundlak terms)	TRE vs TREM (*Table 4*)	10.37	141.96*
	TRE vs TREM (*Table 7*)	10.37	609.1*
H_0: $\delta_0=\delta_1=\ldots=\delta_5=0$ (no efficiency determinants)	TRE vs. TRE with determinants	10.37	3307*
	TREM vs. TREM with determinants	10.37	3774.4*

* An asterisk on the value of the test statistics indicates that it exceeds the 95th percentile for the corresponding distribution and so the null hypothesis is rejected. The critical value comes from Kodde and Palm (1986).

The importance of the Mundlak's terms is also confirmed in Table A.2 where the individual Mundlak's terms for each of the input and input interaction terms are statistically significant at the 1% level. Finally, we test the restriction that the effects of efficiency determinants included as Z_k variables affecting inefficiency are jointly zero. The null hypothesis that the variance of inefficiency is not a function of those factors is rejected at the 1% level of significance for both the TRE and TREM specifications. This implies that the TRE models presented in Table 8 which include the heteroscedastic (in)efficiency determinants provide a better fit to the sample data and are important extensions of our analysis. These models not only incorporate both the observed and unobserved heterogeneity of PA companies but they also explain possible sources of (in)efficiency.

Table A.2. The estimated Mundlak's terms in the TREM models.

Mundlak's Terms	$\overline{\ln Capital}$ (λ_1)	$\overline{\ln Labour}$ (λ_2)	$\overline{0.5 \ln Capital2}$ (λ_3)	$\overline{0.5 \ln Labour2}$ (λ_4)	$\overline{\ln Capital_l nLabour}$ (λ_5)
Table 4	-0.032*** (0.008)	0.242*** (0.008)	-0.042*** (0.003)	-0.072*** (0.009)	0.037*** (0.004)
Table 7	0.097*** (0.006)	0.307*** (0.006)	-0.018*** (0.003)	-0.058*** (0.006)	0.061*** (0.003)

Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

As noted already earlier, the dataset in this study forms an unbalanced panel and the estimator consistency requires that the sample selection process does not lead to errors being correlated with the regressors. Therefore, in the next step we applied a test for panel data to check if the attrition in the panel is random. For the observations which are missing for unexplained reasons, a test for the significance of a sample selection indicator, s_{it}, according to Wooldridge (2002), is conducted, suggesting no sample selection bias due to missing observations.[1]

Furthermore, we estimated all the models (pooled, TRE, TREM and GTRE) using the balanced panel data for only 707 firms (using 6363 observations) and these results are shown in Table A.3. The results with regard to the estimated production function coefficients and the estimated TE scores are very similar to those presented as the main results (Table 5). Although the balanced panel TE scores are on average slightly higher than those presented in Table 5. This might be due the seven-fold smaller sample size of the balanced panel and also due to the fact that not the 11 European countries were included in the balanced panel since PA firms in Denmark, Germany and the Netherlands had to be excluded.[2] Following these specification checks, we assume that the unbalanced panel which is based on the sample of all 11 European countries, does not suffer from any sample selection bias as the attrition in the panel is random. Consequently, we preferred to use the unbalanced panel as this sample resembles the overall effective population of the PA firms in the eleven countries, since all empirical checks confirm the main results illustrated and described in the in the main sections of this study.

[1] The indicator equals 1 if a PA firm *i* is observed in particular year *t* and 0 otherwise. The lagged selection indicator $s_{i,t-1}$ is then estimated in both TRE and TREM models, together with other parameters of the production function given in Eq. (1a). The lagged indicator is insignificant and these results are available on request.

[2] Moreover, we estimated additional results for the balanced panel for the TRE model with efficiency determinants and the results did not change again.

Table A.3. Balanced panel SFA model estimations.

Dependent variable: $\ln Y_{it}$	Pooled SFA	TRE	TREM	GTRE
lnCapital (β_1)	0.510***	0.530***	0.444***	0.415***
	(0.019)	(0.007)	(0.012)	(0.036)
lnLabour (β_2)	0.503***	0.253***	0.139***	0.153***
	(0.023)	(0.008)	(0.012)	(0.036)
0.5lnCapital^2 (β_{11})	-0.032***	0.013***	0.022***	0.019
	(0.008)	(0.000)	(0.004)	(0.013)
0.5lnLabour^2 (β_{22})	-0.140***	-0.004	0.002	-0.0005
	(0.016)	(0.006)	(0.011)	(0.027)
lnCapital_lnLabour (β_{12})	0.037	-0.020***	-0.064***	-0.058***
	(0.009)	(0.003)	(0.006)	(0.016)
lncapital_time (β_{1t})	0.003	-0.002***	-0.002***	0.003
	(0.003)	(0.0009)	(0.001)	(0.003)
lnlabour_time (β_{t2})	-0.003	0.004***	0.004***	-0.0003
	(0.003)	(0.001)	(0.001)	(0.004)
t (β_t)	-0.062***	-0.109***	-0.100***	-0.063***
	(0.016)	(0.007)	(0.008)	(0.017)
t^2 (β_{tt})	0.004***	0.008***	0.008***	0.005***
	(0.001)	(0.0007)	(0.0006)	(0.001)
Country fixed-effects[a]	yes	yes	yes	yes
Random parameter (w_i)	no	yes	yes	yes
Mundlak's terms	no	no	yes	yes
Returns to scale	1.013	0.783	0.583	0.568
Mean (TE)	0.497	0.648	0.647	0.597/0.375
Standard Deviation (TE)	0.176	0.169	0.162	0.111/0.0001
λ-parameter	2.058***	3.637***	3.338***	2.186***
Log-likelihood	-7324	-4559	-4454	-7195
No. Years	9	9	9	9
No. Firms	707	707	707	707
No. Observations	6363	6363	6363	6363

[a)] The balanced panel excludes *Denmark, Germany* and *Netherlands*. The GTRE includes also the Mundlak's terms. Standard errors are in parentheses. * significant at 10%; **significant at 5%; *** significant at 1%. Belgium is the reference category for the country dummies.

APPENDIX B. MPI Total Factor Productivity index – Country-level analysis

Table B.1. The MPI TFP index and its components – analysis for each EU country.

Time	MPI	TEC	SEC	TC	MPI	TEC	SEC	TC	MPI	TEC	SEC	TC
	Belgium				**Denmark**				**Finland**			
2009-2010	0.98	1.09	0.99	0.89	-	-	-	-	0.94	1.04	1.00	0.90
2010-2011	1.02	1.11	1.01	0.91	-	-	-	-	0.94	1.03	1.00	0.90
2011-2012	1.03	1.12	1.01	0.91	-	-	-	-	1.07	1.16	1.00	0.91
2012-2013	1.05	1.13	1.00	0.92	-	-	-	-	1.33	1.45	0.99	0.92
2013-2014	0.94	1.02	0.99	0.93	0.75	0.83	0.98	0.93	0.96	1.03	1.00	0.93
2014-2015	0.84	0.91	0.99	0.94	0.90	0.97	0.98	0.94	1.02	1.08	1.00	0.94
2015-2016	0.94	0.99	1.00	0.95	0.91	0.96	0.99	0.95	1.09	1.15	1.00	0.95
2016-2017	0.98	1.02	1.00	0.96	1.01	1.06	0.99	0.95	0.94	0.98	0.99	0.96
Average	**0.97**	**1.05**	**1.00**	**0.93**	**0.93**	**0.99**	**0.99**	**0.95**	**1.04**	**1.12**	**1.00**	**0.93**
	France				**Germany**				**Italy**			
2009-2010	1.17	1.17	1.17	1.17	0.95	1.07	0.99	0.91	1.27	1.43	0.99	0.90
2010-2011	1.11	1.11	1.11	1.11	0.95	1.01	1.02	0.91	1.13	1.22	1.00	0.91
2011-2012	1.02	1.02	1.02	1.02	1.63	1.78	1.01	0.92	1.01	1.11	1.00	0.92
2012-2013	1.07	1.07	1.07	1.07	1.00	1.09	0.99	0.93	0.97	1.06	1.00	0.92
2013-2014	1.04	1.04	1.04	1.04	0.93	0.99	1.00	0.94	1.07	1.14	1.00	0.93
2014-2015	0.98	0.98	0.98	0.98	1.24	1.29	1.01	0.94	1.04	1.11	0.99	0.94
2015-2016	1.00	1.00	1.00	1.00	0.95	0.98	1.01	0.95	0.96	1.03	0.98	0.95
2016-2017	1.02	1.02	1.02	1.02	0.83	0.87	0.98	0.96	1.22	1.29	0.99	0.96
Average	**1.06**	**1.06**	**1.06**	**1.06**	**1.06**	**1.13**	**1.00**	**0.93**	**1.06**	**1.14**	**0.99**	**0.93**
	Netherlands				**Portugal**				**Spain**			
2009-2010	6.64	7.96	0.99	0.89	1.27	1.43	0.99	0.89	1.06	1.18	1.00	0.89
2010-2011	1.21	1.31	1.03	0.90	1.06	1.17	0.99	0.90	1.06	1.18	1.00	0.90
2011-2012	0.99	1.09	1.00	0.91	1.05	1.15	0.99	0.91	1.00	1.09	1.00	0.91
2012-2013	0.93	1.01	1.00	0.92	1.25	1.33	0.99	0.92	0.99	1.07	1.00	0.92
2013-2014	0.90	0.93	1.03	0.93	1.15	1.25	0.99	0.93	1.19	1.28	0.99	0.93
2014-2015	0.93	0.99	1.00	0.94	1.20	1.31	0.99	0.94	1.15	1.22	1.00	0.94
2015-2016	0.63	0.67	0.99	0.95	1.13	1.20	0.99	0.95	1.14	1.21	0.99	0.95
2016-2017	0.93	0.97	0.99	0.96	1.21	1.28	0.99	0.96	1.00	1.06	0.99	0.96
Average	**1.82**	**2.08**	**1.01**	**0.92**	**1.16**	**1.26**	**0.99**	**0.93**	**1.07**	**1.16**	**0.99**	**0.93**
	Sweden				**UK**							
2009-2010	1.02	1.14	1.00	0.89	1.21	1.33	0.99	0.90				
2010-2011	1.15	1.28	0.99	0.91	0.93	1.02	0.99	0.91				
2011-2012	1.03	1.14	0.99	0.91	1.04	1.13	0.99	0.92				
2012-2013	1.08	1.18	0.99	0.92	0.99	1.07	0.99	0.92				
2013-2014	1.02	1.09	1.00	0.93	0.97	1.03	1.00	0.93				
2014-2015	1.01	1.08	0.99	0.94	0.94	0.99	0.99	0.94				
2015-2016	1.05	1.12	1.00	0.95	0.96	1.00	0.99	0.95				
2016-2017	1.04	1.10	0.99	0.96	0.98	1.03	0.99	0.96				
Average	**1.05**	**1.13**	**0.99**	**0.93**	**0.99**	**1.06**	**0.99**	**0.93**				

The results are obtained from the TRE SFA model presented in Table 4.

Tables

Table 1. Effective data sample used for the PA firms in 11 EU countries.

	Full sample		Excluding one-year observations		Balanced panel	
Country	No. firms	No. obs.	No. firms	No. obs.	No. firms	No. obs.
1. Belgium	86	349	67	330	10	90
2. Denmark	21	41	9	29	..	..
3. Finland	271	937	198	864	9	81
4. France	1,290	3,415	803	2928	12	108
5. Germany	42	115	32	105	..	..
6. Italy	268	1,060	202	994	14	126
7. Netherlands	29	61	14	46	..	..
8. Portugal	1,040	4,253	807	4020	121	1089
9. Spain	1,424	6,213	1192	5981	190	1710
10. Sweden	1,352	6,557	1149	6354	251	2259
11. UK	656	2,927	477	2748	100	900
Total	**6479**	**25,928**	**4950**	**24,399**	**707**	**6363**

Table 2. Description of the variables

Output/Input variables	Description
Output (Y_{it})	Total revenues earned from different company activities (i.e. shows, renting) in constant PPP dollars for 2011 and adjusted for inflation using HCPI index.
Capital (C_{it})	Total assets of the PA firms in constant PPP dollars. Total assets include tangible and intangible assets. They are adjusted for inflation using World Bank GDP deflators at country level.
Labour (L_{it})	The number of full-time and permanent employees of the performing arts firms.
Public expenditure for cultural services	The public expenditure for cultural services from Eurostat (COFOG99) divided by the population size in each country in constant PPP dollars and deflated using the World Bank GDP deflators.
Size	Size categories: Size_1 (micro firms) = 0 - 9 employees; Size_2 (small firms) = 10 - 49 employees; Size_3 (medium firms) = 50 - 249 employees; Size_4 (large firms) >= 250 employees. The variable was dichotomized in the final analysis.
Age	The age of the firm in years.
Country dummy	Individual country dummy variables included directly in the production function specification.

Table 3. Descriptive statistics

Variable and Description	Full sample	Reduced sample
	Mean value	Mean value
	Continuous variables	
Y (Output in thousand US dollars)	1392 [9244]	1433.8 [9497.9]
K (Capital stock in thousand US dollars)	1341 [14,459.4]	1396 [14,892]
L (Labour as the number of employees)	10.14 [67.21]	10.46 [69.09]
Public expenditures per capita on culture (in US dollars)	181.81 [69.76]	180.8 [69.11]
Age (Age of the firm in years)	12.20 [11.71]	12.47 [11.81]
	Categorical variables - Count in %	
size_1[a] (micro firms: 0 - 9 employees)	86.2	85.8
size_2 (small firms: 10 - 49 employees)	9.87	10.08
size_3 (medium firms: 50 - 249 employees)	3.47	3.58
size_4 (large firms: ≥ 250 employees)	0.44	0.46
Belgium[a] (DC1)	1.34	1.35
Denmark (DC3)	0.16	0.12
Finland (DC5)	3.61	3.54
France (DC6)	13.17	12.00
Germany (DC2)	0.44	0.43
Italy (DC8)	4.10	4.07
Netherlands (DC9)	2.35	0.19
Portugal (DC10)	16.40	16.47
Spain (DC4)	23.96	24.51
Sweden (DC11)	25.29	26.04
United Kingdom (DC7)	11.29	11.26
No. Firms	6212	4950
No. Observations	25,928	24,399

Standard deviation for continuous variables is presented in the squared parentheses. [a] Reference Category.

Table 4. Percentage of real expenditures on cultural services per capita over GDP per capita

	2009	2010	2011	2012	2013	2014	2015	2016	2017
Belgium	0.51	0.49	0.51	0.52	0.49	0.49	0.47	0.50	0.51
Denmark	0.70	0.66	0.67	0.68	0.67	0.65	0.67	0.66	0.66
Finland	0.54	0.54	0.54	0.54	0.53	0.52	0.52	0.51	0.52
Germany	0.39	0.38	0.40	0.38	0.38	0.38	0.38	0.38	0.38
France	0.75	0.76	0.75	0.77	0.79	0.77	0.71	0.69	0.67
Italy	0.44	0.36	0.34	0.33	0.34	0.33	0.37	0.30	0.30
Netherlands	0.55	0.54	0.50	0.49	0.47	0.45	0.40	0.43	0.41
Portugal	0.39	0.43	0.38	0.29	0.32	0.25	0.19	0.25	0.25
Spain	0.65	0.65	0.58	0.47	0.44	0.46	0.46	0.44	0.43
Sweden	0.59	0.56	0.54	0.55	0.56	0.53	0.51	0.52	0.50
United Kingdom	0.36	0.36	0.33	0.31	0.30	0.28	0.28	0.26	0.25

Table 5. SFA translog production function estimates for PA firms in 11 EU countries.

Dependent variable: lnY_{it}	Pooled SFA	TRE	TREM	GTRE
		Production Function Coefficients		
lnCapital (β_1)	0.596***	0.661***	0.665***	0.599***
	(0.011)	(0.004)	(0.008)	(0.004)
lnLabour (β_2)	0.4248***	0.231***	0.097***	0.264***
	(0.014)	(0.006)	(0.009)	(0.006)
0.5lnCapital^2 (β_{11})	0.007**	0.043***	0.038***	0.026***
	(0.003)	(0.001)	(0.002)	(0.0009)
0.5lnLabour^2 (β_{22})	-0.109***	-0.051***	-0.073***	-0.066***
	(0.008)	(0.004)	(0.008)	(0004)
lnCapital_lnLabour (β_{12})	0.020***	-0.0002	-0.017***	-0.001
	(0.004)	(0.001)	(0.003)	(0.001)
lncapital_time (β_{1t})	0.004**	-0.004***	-0.009***	-0.119***
	(0.001)	(0.0006)	(0.0006)	(0.005)
lnlabour_time (β_{t2})	-0.006**	0.006***	0.0102***	0.009***
	(0.002)	(0.001)	(0.001)	(0.001)
t (β_t)	-0.055***	-0.123***	-0.128***	-0.004***
	(0.010)	(0.005)	(0.006)	(0.0006)
t^2 (β_{tt})	0.004***	0.009***	0.009***	0.003***
	(0.001)	(0.001)	(0.0006)	(0.001)
		Country fixed-effects		
Denmark (DC3)	-0.327***	0.009	-0.197**	-1.020***
	(0.165)	(0.085)	(0.091)	(0.064)
Finland (DC5)	-0.243***	-0.310***	-0.091***	-0.751***
	(0.054)	(0.002)	(0.030)	(0.027)
France (DC6)	0.196***	0.0305	0.359***	-0.171***
	(0.048)	(0.025)	(0.027)	(0.024)
Germany (DC2)	0.543***	0.159***	0.339***	-0.145***
	(0.094)	(0.044)	(0.046)	(0.039)
Italy (DC8)	-0.394***	-0.675***	-0.269***	-0.916***
	(0.053)	(0.027)	(0.029)	(0.026)
Netherlands (DC9)	-0.481***	-0.790***	-0.275***	-0.762***
	(0.128)	(0.062)	(0.065)	(0.051)
Portugal (DC10)	-0.421***	-0.674***	-0.307***	-0.915***
	(0.048)	(0.0247)	(0.027)	(0.024)
Spain (DC4)	-0.409***	-0.599***	-0.269***	-0.777***
	(0.047)	(0.024)	(0.027)	(0.024)
Sweden (DC11)	-0.453***	-0.754***	-0.247***	-0.881***
	(0.048)	(0.025)	(0.027)	(0.024)
United Kingdom (DC7)	-0.170***	-0.166***	-0.0013	-0.537***
	(0.048)	(0.025)	(0.027)	(0.024)
Random parameter (w_i)	no	yes	yes	yes
Mundlak's terms	no	no	yes [a)]	no
Returns to scale	1.021	0.892	0.762	0.841
		Persistent technical efficiency (TE_i^p)		
Mean (TE^p)	n/a	n/a	n/a	0.391
Standard Deviation (TE^p)				0.030
		Transient technical efficiency (TE_{it})		
Mean (TE)	0.442	0.579	0.596	0.583
Standard Deviation (TE)	0.187	0.185	0.165	0.119
No. Firms	4950	4950	4950	6479
No. Observations	24,399	24,399	24,399	25,928
λ-parameter	2.486***	5.093***	1.374***	4.656***
Log-likelihood	-31587.6	-24256.1	-24185.1	-27720.3

Standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. Belgium is the reference category for the country dummies. [a)] The Mundlak's terms are presented in Table A.2.

Table 6. Technical Efficiency, MPI TFP index and its components (2009-2017 average)

Country	TRE Model					TRE with Mundlak (TREM) Model				
	TE	MPI and components				TE	MPI and components			
		TFPC	TEC	SEC	TC		TFPC	TEC	SEC	TC
1. Belgium	0.612	0.971	1.047	1.001	0.927	0.628	0.964	1.037	1.004	0.925
2. Denmark	0.598	0.926	0.986	0.992	0.946	0.638	0.921	0.994	0.981	0.942
3. Finland	0.580	1.042	1.118	1.001	0.934	0.601	1.034	1.106	1.004	0.937
4. France	0.589	1.061	1.157	0.996	0.921	0.604	1.072	1.192	0.993	0.919
5. Germany	0.578	1.056	1.135	1.000	0.931	0.595	1.029	1.106	1.000	0.932
6. Italy	0.576	1.062	1.141	0.994	0.934	0.598	1.052	1.142	0.989	0.933
7. Netherlands	0.545	1.816	2.076	1.005	0.922	0.569	4.328	5.364	1.016	0.917
8. Portugal	0.561	1.165	1.265	0.995	0.928	0.582	1.197	1.320	0.991	0.927
9. Spain	0.574	1.075	1.163	0.998	0.925	0.591	1.088	1.181	0.997	0.923
10. Sweden	0.583	1.046	1.130	0.999	0.931	0.596	1.054	1.140	1.000	0.932
11. UK	0.599	0.992	1.062	0.997	0.932	0.612	0.992	1.055	0.996	0.932
All EU-11	**0.579**	**1.069**	**1.155**	**0.997**	**0.928**	**0.596**	**1.083**	**1.179**	**0.996**	**1.055**

TE- technical efficiency, MPI – Malmquist productivity index, TFPC – Total factor productivity change; TEC- TE change, SEC – scale efficiency change, TC (technological change).

Table 7. MPI TFP index and its components – yearly change

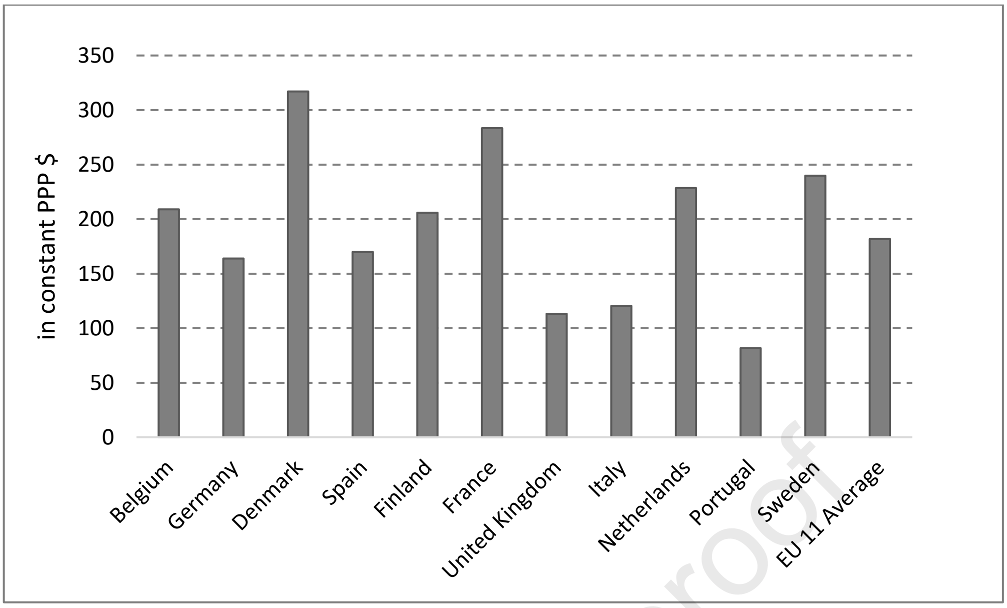
Time	TRE Model				TRE with Mundlak (TREM) Model			
	TFPC	TEC	SEC	TC	TFPC	TEC	SEC	TC
2009-2010	1.128	1.262	1.000	0.897	1.182	1.346	1.001	0.896
2010-2011	1.067	1.179	0.999	0.905	1.050	1.159	0.999	0.904
2011-2012	1.030	1.125	1.000	0.913	1.064	1.154	1.002	0.912
2012-2013	1.077	1.167	0.998	0.922	1.058	1.143	0.998	0.921
2013-2014	1.075	1.158	0.997	0.930	1.068	1.152	0.996	0.929
2014-2015	1.062	1.136	0.998	0.939	1.099	1.186	0.997	0.938
2015-2016	1.065	1.130	0.995	0.947	1.078	1.155	0.992	0.947
2016-2017	1.058	1.117	0.994	0.956	1.080	1.164	0.987	0.956
Average	**1.069**	**1.155**	**0.997**	**0.928**	**1.083**	**1.179**	**0.996**	**0.927**

Table 8. Estimates of TE determinants

Dependent variable: $\ln Y_{it}$	TRE	TRE with Mundlak (TREM)
	Production function coefficients	
lnCapital (β_1)	0.605***	0.526***
	(0.004)	(0.006)
lnLabour (β_2)	0.1547***	0.053***
	(0.005)	(0.007)
0.5lnCapital^2 (β_{11})	0.023***	0.024***
	(0.001)	(0.002)
0.5lnLabour^2 (β_{22})	-0.085***	-0.072***
	(0.003)	(0.005)
lnCapital_lnLabour (β_{12})	0.003*	-0.021***
	(0.001)	(0.002)
lncapital_time (β_{1t})	-0.0009	-0.001**
	(0.0005)	(0.0005)
lnlabour_time (β_{t2})	0.005***	0.005***
	(0.0007)	(0.0007)
t (β_t)	-0.091***	-0.103***
	(0.004)	(0.004)
t^2 (β_{tt})	0.007***	0.007***
	(0.0004)	(0.0004)
Country-fixed effects	yes	yes
Random parameter (w_i)	yes	yes
Mundlak's terms (within-group means)	no	yes [a)]
Returns to scale	0.760	0.579
	Determinants of technical (in)efficiency	
Age (γ_1)	-0.002***	-0.002***
	(0.0002)	(0.0002)
Size2 (γ_2)	-0.316***	-0.331***
	(0.003)	(0.003)
Size3 (γ_3)	-0.589***	-0.627***
	(0.011)	(0.009)
Size4 (γ_4)	-82.02	-0.846***
	(37.30*10^2)	(0.028)
Public cultural expenditures (γ_5)	-0.401***	-0.392***
	(0.004)	(0.004)
	Time-varying technical efficiency (TE_{it})	
Mean (TE)	0.683	0.681
Standard Deviation (TE)	0.184	0.181
λ-parameter	4.681***	5.314***
Log-likelihood	-22,602.5	22,297.9
No. Firms	4950	4950
No. Observations	24,399	24,399

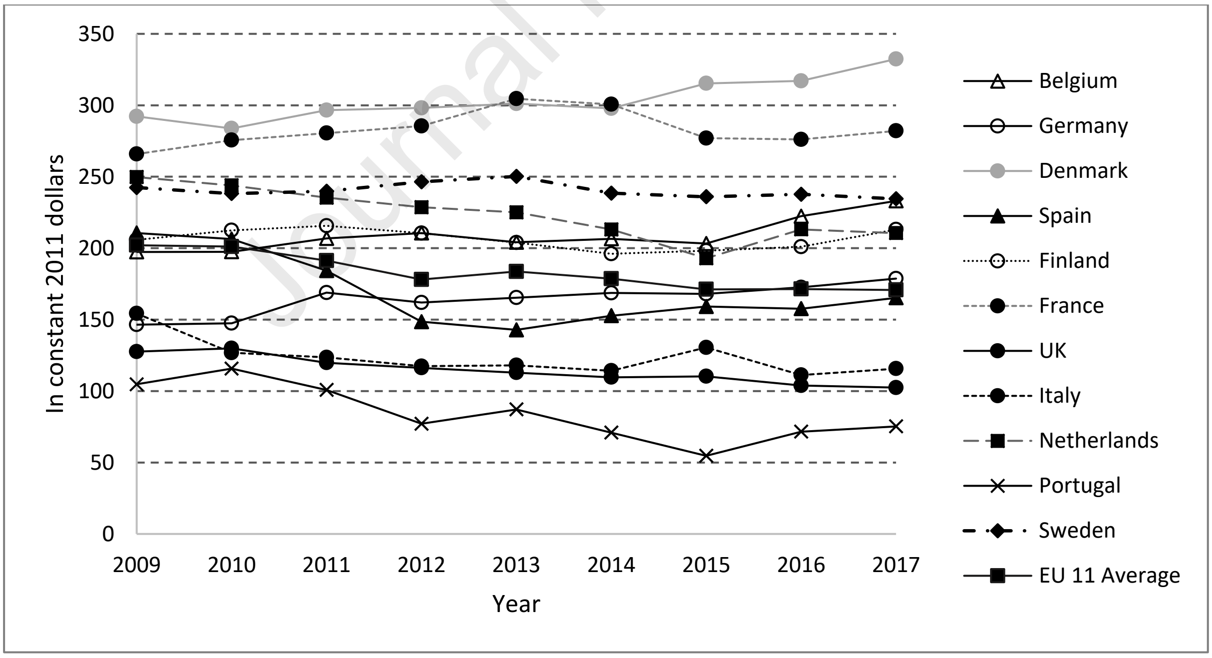
Standard errors are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. Belgium is the reference category for the country dummies. [a)] The Mundlak's terms are presented in Table A.2.

Fig. 1. Public expenditure per capita on cultural services, average value by country.



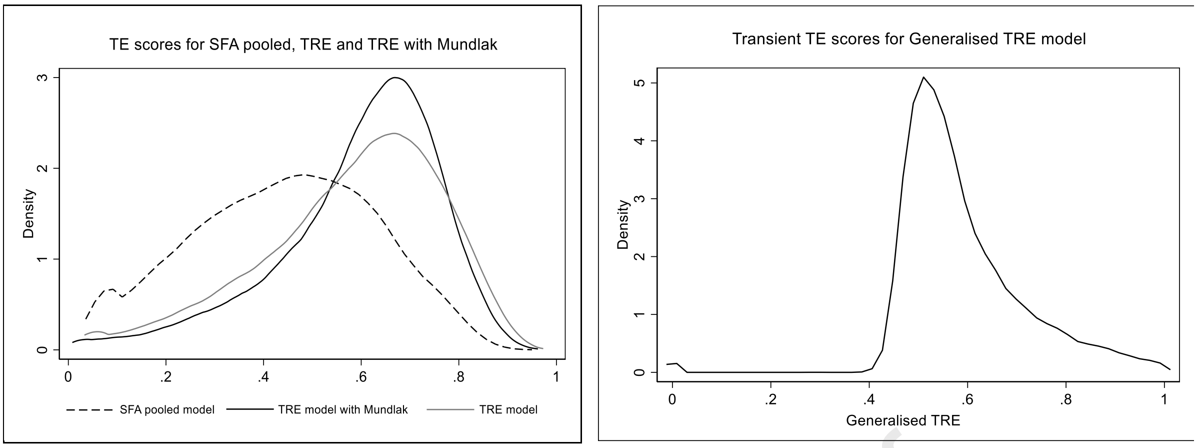
Source: Own elaboration based on the Eurostat database.

Fig. 2. Public expenditure per capita on cultural services, 2009-2017.



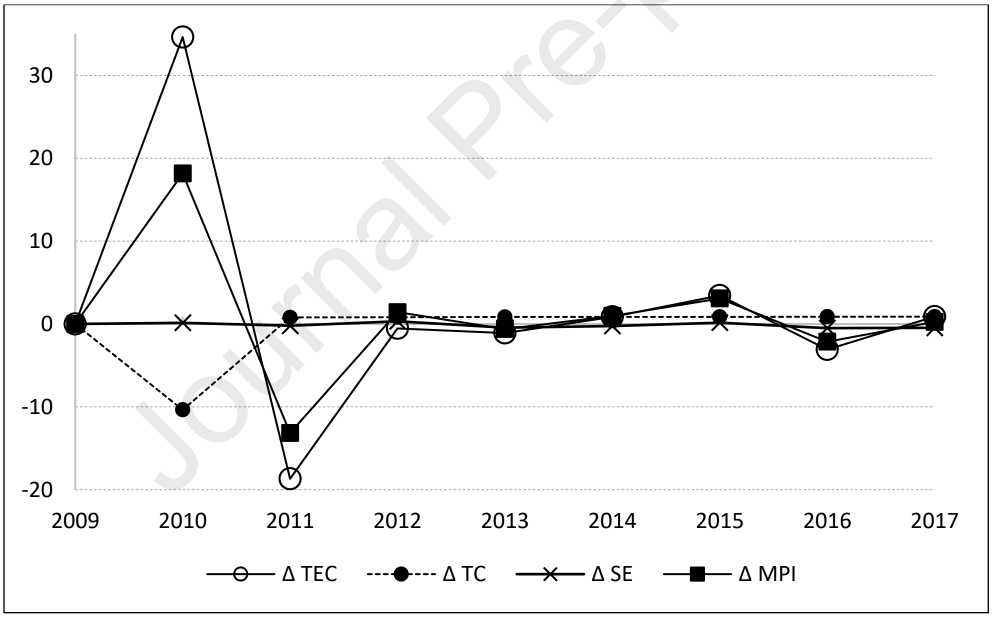
Source: Own elaboration based on the Eurostat database.

Fig. 3. Kernel density functions for TE scores of European PA firms.



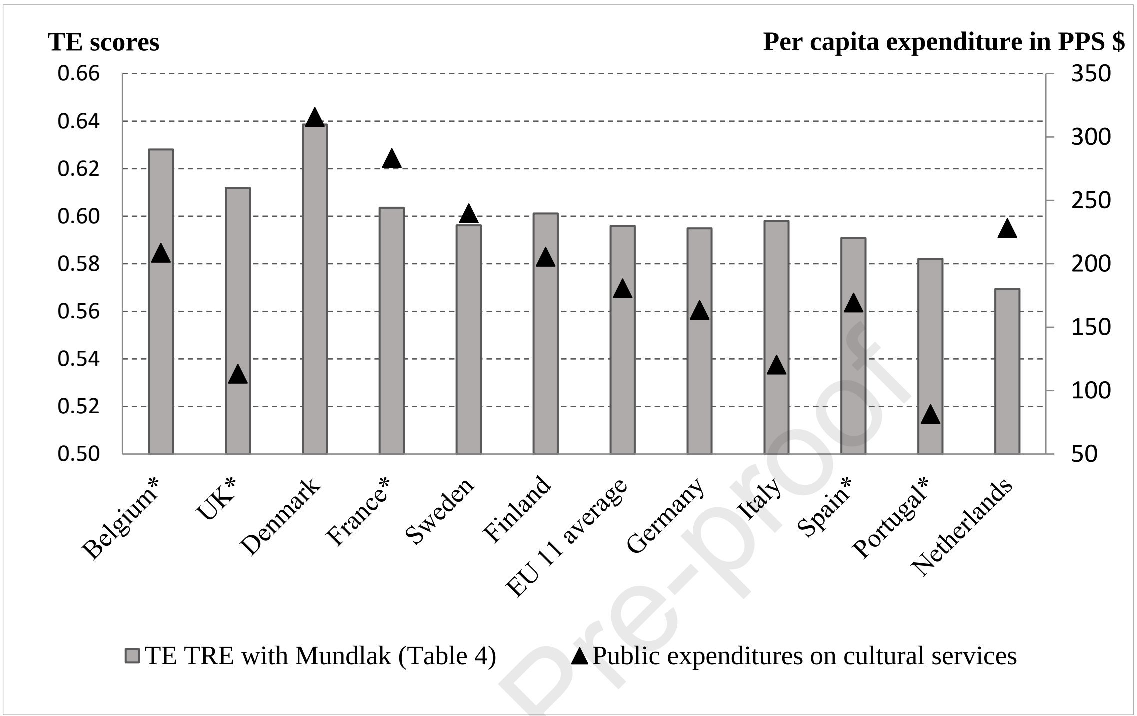
Source: Own elaboration based on the Amadeus/Orbis database.

Fig. 4. Cumulative % change in the MPI, TEC, SEC and TC indexes.



Source: Own elaboration based on the Amadeus/Orbis database (TRE model with Mundlak).

Fig. 5. The comparison of estimated TE scores and per capita public subsidies for the Eleven EU countries.



Source: Own elaboration based on the Amadeus/Orbis database. *Notes*: * A star besides the country name indicates that the difference between the mean TE score for the country and for the EU-11 average is statistically significant at the 5% level.

Highlights

- True random-effects SFA production function models are estimated for EU PA firms
- Firms' technical efficiency (TE) is low although increasing over time
- Drivers of productivity growth are more related to TE than technological
- Public expenditure has a positive effect on EU PA firms' technical efficiency
- Accumulated experience and small and medium-sized firms positively influence TE

Concetta Castiglione is Associate Professor in the Department of Economics Statistics and Finance at University of Calabria, Italy. She has been for three years Assistant Professor in the same Department and for other three years post-doc research fellow in the Department of Statistical Sciences at University of Bologna, Italy. She holds a PhD in Economics from the Trinity College Dublin, Ireland, and a Doctoral degree in Applied Economics from the University of Calabria, Italy. Her research interests are in the area of cultural participation, consumer' demand, productivity and efficiency analysis, ICT investments and environment policies. Her list of publications includes a number of papers in referred academic journals. In addition, she acts as a reviewer for numerous international journals.

Davide Infante is Adjunct Professor of Political Economy at the University of Calabria, Department of Economics Statistics and Finance, and qualified as Full Professor of Economic Policy. He graduated at the University of Rome La Sapienza. He has also taught at the University of Palermo, and, as visiting professor, in other European countries (Russia included). His scientific interests mainly embrace economic growth, firm productivity and efficiency, cultural economics, institutions, and environmental policy. He has published more than 100 publications among international referred journals, books, book chapters and conference proceedings. In addition, he acts as a reviewer for numerous international journals.

Marta Zieba is a lecturer in Economics and a leading member of the Efficiency and Productivity Analysis (EPA) Research Cluster at the Kemmy Business School, University of Limerick, Ireland. She holds her PhD in Economics from Trinity College Dublin, Ireland. Her main research areas of interest are cultural economics with the emphasis on demand and efficiency for performing arts institutions, and the economics of health sector. She has published in several journals including Journal of Cultural Economics, Swiss Journal of Economics and Statistics, Health Care Management Science, Small Business Economics and Regional Studies, Regional Science.

Declarations of interest: none

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.