Evaluating local governments' performance in crisis times*

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Abstract

Besides the economic and financial crisis situation has had a huge impact on most Spanish local governments' incomes, they have also faced stricter budget limitations which set up more control on public debt and spending. In this context, the challenge of managing the available resources is more important, if possible. The aim of the study is to analyse whether the economic recession affects the Spanish local governments' performance, therefore we analyse the overall cost efficiency in local governments in Spain during the crisis period. For this, we measure efficiency, for which we consider not only the most popular method to evaluate local governments' efficiency, DEA (Data Envelopment Analysis), but also more recent proposals such as the order-m partial frontier as well as the non-parametric estimator proposed by Kneip, Simar and Wilson (2008), which share their non-parametric flavour. We carry out the analysis for a sample of 1,589 Spanish local governments for the period 2008-2012. Given how problematic it is to precisely define the bundle of services and facilities that municipalities must provide, we compare three different output specifications.

Keywords: efficiency, local government, non-parametric frontiers

JEL Classification: D24, H11, H70, R15

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1. Introduction

Over the last few years the improvement of public management efficiency has been a growing concern in many developed and developing countries, partly due to the new public finance scenarios brought about by the international economic crisis. However, in some specific contexts other mechanisms have also operated. This is the case of the European Union, where the Stability and Growth Pact (SGP) stipulates that all governments should put a particular emphasis on managing their resources efficiently in order to contribute to the viability of the European Economic and Monetary Union. Therefore, in a context in which the financial crisis has challenged the public finances in several Euro area and non-Euro area countries, leading to unprecedented increases in some particular countries, the efficient management of resources in all levels of government (central, regional and municipal) has become essential (Balaguer-Coll et al., 2013).

Focusing on the specific case of local government, it is responsible for a significant number of public powers (Devas and Delay, 2006; Da Cruz and Marques, 2014), although this ultimately depends on the country under evaluation. For instance, in Spain, since the approval of the 1978 Constitution, local governments have played an important role in the provision of public services, and form a sub-sector whose powers have increased over time—although modestly compared with higher (regional) levels of government. However, the international economic crisis in 2007 led Spain, and several of its Euro-area peers, into a deep recession, even becoming a prime priority for the Euro-zone in 2012. This situation has had a vast impact on most of Spanish local governments' revenues, provoking an increase on their deficits. Therefore, given the decline in municipal revenues, the challenge of managing the available resources is even more important. In addition, the budget constraints became stricter with the law on budgetary stability,[1], which set up more control on public debt and public spending. Under these circumstances, issues related to the efficiency of Spanish local governments for their contribution to public sector deficit is more relevant, if possible.

The economic crisis has emphasised the importance of improving efficiency and reducing costs of local public services as a prime area of concern. However, Spanish local governments have come under increasing pressure to improve their efficiency, while maintaining the quality, accountability and transparency. Therefore, in an attempt to cut back local public spending, local governments are looking for new ways of delivering quality services at lower cost (Andrews

[1] *Ley General Presupuestaria* (2007), or General Law on the Budget.

and Van de Walle, 2013). These organisational changes or reforms are implemented within the framework of New Public Management (NPM), which involves the application of private management techniques, such as cost reduction and improved effectiveness and efficiency, to the public sphere. Accordingly, local governments in Spain have introduced measures which seem to be viable when the economy runs into a downturn (Pérez-López et al., 2015).

Hence, theory suggests that the adoption of new managerial techniques may enhance the efficiency of public service delivery (Hood, 1995; Andrews and Van de Walle, 2013). Taking this premise together with the economic crisis situation as our starting point, one of the aims of this study is to analyse the overall cost efficiency in Spanish municipalities during the crisis economic period (2008–2012) which, up to now, has barely been examined.

Regardless of the context of analysis, the study of local government efficiency is a topic of high interest in the field of public administration. Over the last years there have been many empirical research studies that have focused on the evaluation of efficiency in local governments. In section 2, we provide a review of the existing literature on public sector efficiency from a global point of view. As we will see, this literature is fairly extensive and scattered in time, that is, there has not been a continuous flow of research. Otherwise, there exist two important problems shared by these studies that still remain unsolved. The first one is the complexity to define local governments' outputs and inputs which comes from the difficulty to collect data and the measurement of local services. Indeed, different studies use diverse measures of inputs and outputs, even those which analyse efficiency using data from the same country. The second problem is the lack of a clear and standard methodology to measure efficiency. Taking into account the problems in efficiency analysis in local governments exposed, the second aim of this study contributes to fill these gaps.

First, given how problematic is to define the bundle of services and facilities that municipalities must provide, we propose three different output specifications, relying on the legal framework: (i) model 1 includes the minimum services compulsory for all governments; (ii) model 2 extends model 1 to include additional services which must provide larger municipalities with population over 5,000 or 20,000; (iii) model 3 extends model 2 by adding quality variables. We compare how different outputs explain the differences between local governments and how the number of outputs can affect the efficiency scores. Moreover, the relevance of the study is also related to the sample under analysis since other Spanish studies focus on a specific region or year while our study examines a much larger sample, that is, 1,589 Spanish local governments between 1,000 and 50,000 inhabitants for the 2008-2012 period.

Second, we measure local government efficiency using three non-parametric methodologies, which are DEA (Data Envelopment Analysis), order-*m* frontier and the bias corrected DEA estimator proposed by Kneip et al. (2008) (hereafter, KSW), being the first one the most popular towards the non-parametric field and the last two the most recent proposals. We provide a comparative perspective because comparing the results between different methodologies allows checking the robustness of the efficiency results.

The paper is organised as follows: Section 2 presents a brief review of the existing literature on local governments efficiency. Section 3 establishes the institutional framework of Spanish local governments. Section 4 gives an overview of the methodologies used to determine the cost efficiency. Section 5 specifies the particularities of the data employed. Section 6 presents and comments the most relevant efficiency results. Finally, section 7 summarizes the main conclusions.

2. Literature review on efficiency in local governments

Over the last years there have been many empirical research studies that have focused on the evaluation of efficiency in local governments from multiple points of view and contexts. On the one hand, some studies concentrate on the evaluation of a particular service, such as refuse collection and street cleaning (Benito-López et al., 2015) or road maintenance (Kalb, 2012) among others. On the other hand, other studies evaluate local performance from a global point of view considering that local governments supply a wide variety of services.

From this global point of view, scholars have carried out a number of empirical investigations that cover several countries. For instance, the studies of Afonso and Fernandes (2008) and Da Cruz and Marques (2014) investigate cost efficiency of local governments in Portugal for data in 2001 and 2009 respectively, using DEA (Data Envelopment Analysis) approach. Similarly, other studies which use exclusively DEA methodology are Loikkanen et al. (2011) in Finland, Fogarty and Mugera (2013) in Australia and Doumpos and Cohen (2014) in Greece. In a different way, two German studies (Kalb et al., 2012; Geys et al., 2013) use only SFA (Stochastic Frontier Approach) to analyse more than 1,000 municipalities for 2001 and 2004 data. Also, the study of Štastná and Gregor (2015) in Czech Republic uses SFA to compare local governments efficiency in the transition period of 1995-1998 and the post transition period of 2005-2008.

Moreover, other studies compare efficiency estimates using different methodologies, like the study of Geys and Moesen (2008) in Belgium, which uses various approaches (Free Disposal Hull (FDH), DEA and SFA) to assess technical efficiency using a dataset of Flemish local governments in 2000, or the study of Balaguer-Coll et al. (2007) in Spain, which compares DEA and FDH methodologies to analyse 414 local governments in the Valencian Community region for data in 1995. Otherwise, Balaguer-Coll et al. (2013) assess a sample of 1,198 Spanish municipalities in 2000, splitting them into clusters according to various criteria (output mix, environmental condition and level of powers). Table 1 provides a review of some of the most important literature for the last few years assessing local government efficiency in different countries.

[Table 1]

3. Local governments in Spain: Institutional framework

The institutional context of the Spanish public sector was formally established in the 1978 Constitution. Accordingly, Spain is composed by three levels of government: central, regional and local, being one of the most decentralised countries in Europe (Bosch and Espasa, 2006; Balaguer-Coll et al., 2010). Specifically, Spain is organized into 17 Autonomous Communities or Regions (NUTS2), 50 Provinces (NUTS3) and 8114[2] Municipalities (NUTS5).

Since the approval of the 1978 Constitution, local governments play an important role in the provision of public services and form a sub-sector that has increased responsibilities over time. However, their share of total public spending has remained relatively stable over the years, at least compared to regional governments[3]. Table 2 shows the distribution of total public expenditures among central, regional and local levels.

[Table 2]

Spanish municipalities are heterogeneous concerning population and territorial distribution (almost the 83,74% of the municipalities had population lower than 5,000 inhabitants in 2011). They constitute the lowest level of government in Spain, but they have considerable autonomy regarding the management of their responsibilities. This autonomy is reflected in their revenues structure and the competences performed by local governments.

[2]Data from INE (*Instituto Nacional de Estadística*), January 2011.

[3]Regional governments have been gaining more powers at the expense of the central government than local governments (see, Balaguer-Coll et al., 2007, 2010).

On the one hand, local governments revenues come mainly from non financial incomes, being the most relevant the property taxes (*IBI, Impuesto de Bienes Inmuebles*), the transfers from the General government and fees paid for using public infrastructures or provision of public services. Note that, although municipalities are considered financially autonomous by law, only the 52.19% of their total revenues in 2008-2012 came from their own incomes. Table 3 shows the most important revenue categories of the municipalities and data for the years 2008-2012.

[Table 3]

On the other hand, the distribution of the municipal powers is established in the Spanish law which regulates the local system (*Ley 7/1985 Reguladora de Bases de Régimen Local*). Specifically, the article 26 of this law establishes the minimum services and facilities that each municipality must provide compulsorily depending on their size. Nevertheless, articles 25 and 27 consider that local competences also depend on the State or Autonomous Community, and may differ from a municipality to another. Therefore, the law only establishes the minimum services that each municipality must provide, not preventing from going beyond this minimum. Table 4 contains the different services and facilities provided by Spanish local governments considered by the law.

[Table 4]

4. Methodologies

In this study we measure cost efficiency[4] using different non-parametric techniques: Data Envelopment Analysis (DEA), order-*m* frontier and the bias corrected DEA estimator of Kneip et al. (2008) (KSW).

We focus on non-parametric methodologies as opposed to the parametric ones since they have less restrictive assumptions and they are more flexible, useful and easier to compute for our purpose. For a detailed review of the main differences between parametric and non-parametric frontier techniques, see Murillo-Zamorano (2004) and Bogetoft and Otto (2010). In addition, the evolution of parametric and non-parametric methodologies has not been equal, and some of the most recent proposals have leaned towards the non-parametric field, overcoming most of their limits (Daraio and Simar, 2007).

[4]See Coelli et al. (2005) and Fried et al. (2008) for an introduction to efficiency measurement.

4.1. Data Envelopment Analysis (DEA)

DEA (Charnes et al., 1978; Banker et al., 1984) is a non-parametric methodology which provides a mathematical linear programming to estimate and compare the relative efficiency of different entities, called decision-making units (DMUs). In this study, the DMUs are Spanish local governments.

DEA defines an empirical frontier which creates an "envelope" determined by the efficient DMUs. These units located at the frontier are considered the best practices and have an efficiency score equal to 1. On the contrary, units above the frontier are considered as inefficient and have a score less than 1. The distance between each DMU and the frontier shows the measure of its inefficiency. The most important assumptions of the model are: returns to scale, convexity and free disposability of inputs and outputs.

Similarly to previous studies on the efficiency of local governments, we employ the input-oriented DEA model (De Sousa and Stošić, 2005; Balaguer-Coll et al., 2007) because in public sector outputs are established externally (the minimum services that local governments must provide), so it is more appropriate to evaluate efficiency in terms of the minimization of inputs. Moreover, given that local governments differ considerably in size, we assume variable returns to scale (Balaguer-Coll and Prior, 2009; Bosch-Roca et al., 2012; Doumpos and Cohen, 2014; Da Cruz and Marques, 2014).

We introduce the mathematical formulation for the cost efficiency measurement (Färe et al., 1994). The minimal cost efficiency can be calculated by solving the following program for each local government and each sample year:

$$\begin{array}{lll} Min_{x^*_{ji}} & \sum_{j=1}^{q} \omega_{ji} x^*_{ji} & \\ s.t. & y_{ri} \leq \sum_{i=1}^{n} \lambda_i y_{ri}, & r = 1, \ldots, p \\ & x^*_{ji} \geq \sum_{i=1}^{n} \lambda_i x_{ji}, & j = 1, \ldots, q \\ & \lambda_i \geq 0, & i = 1, \ldots, n \\ & \sum_{i=1}^{n} \lambda_i = 1 & \end{array} \quad (1)$$

where for n observations there are q inputs producing p outputs. The $n \times p$ output matrix, r, and the $n \times q$ input matrix, j, represent data of all n local governments, while for each unit under evaluation i it is used an input vector x_{ji} available at prices w_{ji} for producing outputs y_{ri}. The last restriction ($\sum_{i=1}^{n} \lambda_i = 1$) implies variable returns to scale (VRS), which assures that each DMU is only compared to others of similar size.

A further extension of DEA model with variable returns to scale was proposed by Deprins et al. (1984), called Free Disposal Hull (FDH). The main difference with DEA is that it drops the convexity assumption. The FDH programming problem is similar to (1) but including the following constraint:

$$\lambda_i \in \{0,1\} \quad i = 1,\ldots,n \tag{2}$$

Finally, if we solve the problem (1), we find x_i^*, which is the minimal cost of producing y_r. Since there is no data about input prices and input quantities, all DMUs are supposed to deal with identical input prices, and we use input cost variables. Cost efficiency (CE_i) can be defined as the ratio between the minimal costs and the observed costs.

$$CE_i = \omega_i' x_i^* / \omega_i' x_i \tag{3}$$

The values of CE are the cost efficiency scores and they will be equal to 1 for efficient observations and less to 1 for inefficient observations.

4.2. Robust variants of DEA and FDH

The traditional non-parametric techniques DEA and FDH have been widely applied in efficiency analysis; however, they present some important limitations: efficient units by default, the influence of outliers and the "curse of dimensionality". First, since these techniques envelope all data, the lack of similar municipalities for comparison would turn a municipality into efficient by default (Balaguer-Coll et al., 2013), which implies that this efficiency does not result from any relative superiority. Second, due to the efficient frontier is determined by the observations which are extreme points (Simar and Wilson, 2008), the presence of outliers strongly influence the estimated frontier as well as the efficiency scores of all observations. Moreover, these estimators suffer from the "curse of dimensionality", which means that an increase in the number of inputs or outputs, or a decrease in the sample under analysis (that is, the number of units for comparison), implies higher efficiencies (Daraio and Simar, 2007). In addition, one of the main drawbacks of traditional non-parametric approaches is the difficulty of making statistical inference.

Here we present two alternatives to DEA and FDH estimators that overcomes most limitations of traditional non-parametric methods and allow for statistical inference, called order-m approach and the bias corrected DEA estimator of Kneip et al. (2008) (KSW).

4.2.1. Order-m

Order-m frontier (Cazals et al., 2002) is a robust alternative to DEA and FDH estimators which involves the concept of partial frontier, opposed to the traditional full frontier. As such, partial frontiers are less extreme because they do not envelope all the data, so they are more robust to extreme values and outliers (Simar and Wilson, 2008). In this way, order-m frontier is an estimator that for finite m units does not envelop all the observed data points. This method uses as benchmark the expected minimum input achievable among a fixed number of m units producing at least output level y. Hence, the order-m input efficiency score (Daraio and Simar, 2007) is given by:

$$\hat{\theta}_m(x,y) = E[(\hat{\theta}_m(x,y)|Y \geqslant y)] \tag{4}$$

The value m represents the number of potential units against we benchmark the analysed unit (that is, how efficient is a local government compared with m local governments.). If m goes to infinity, the order-m estimator becomes identical to FDH. Following the study of Daouia and Gijbels (2011), we define m as:

$$\alpha = \alpha(m) = (1/2)^{(1/m)} \tag{5}$$

Note that order-m scores are not restricted under 1. A value greater than 1 shows that the unit operating at the level (x,y) is more efficient than the average of m peers randomly drawn from the population of units producing more output than y.

4.2.2. Bias corrected DEA estimator of Kneip et al. (2008) (KSW)

KSW (Kneip et al., 2008) is a bias corrected DEA estimator which takes the standard DEA model and introduces asymptotics via bootstrapping techniques. DEA and FDH estimators are biased by construction (Simar and Wilson, 2008), which means that the true frontier would be located under the DEA-estimated frontier. The bootstrap procedure to correct this bias, based on sub-sampling, uses the idea that the known distribution of the difference between estimated and bootstrapped efficiency scores mimics the unknown distribution of the difference between the true and the estimated efficiency scores (Badunenko et al., 2012). It allows for estimation of the bias and performance of statistical inference based on DEA estimates.

Let $s = n^d$ for some $d \in (0,1)$, where n and s are the sample and sub-sample size, respectively. The optimal d depends on the dimensionality of the problem, so we set this value at 1. The bootstrap considers the following scheme:

1. First, a bootstrap sample $S_s^* = (X_i^*, Y_i^*)_{i=1}^s$ is generated by drawing (independently, uniformly and with replacement) s observations from the original sample, S_n.

2. DEA estimator is applied, where the technology set is constructed with the sub-sample drawn in step (1), to construct the bootstrap estimates $\hat{\theta}^*(x,y)$.

3. Steps (1) and (2) are repeated B times, using the resulting bootstrap values to approximate the conditional distribution of $s^{2/(p+q+1)}(\frac{\hat{\theta}^*(x,y)}{\theta^*(x,y)} - 1)$, which allows to approximate the unknown distribution of $n^{2/(p+q+1)}(\frac{\hat{\theta}^*(x,y)}{\theta^*(x,y)} - 1)$. The values p and q are the output and input quantities, respectively. The bias-corrected DEA efficiency score, which is adjusted by the s subsample size, is given by:

$$\theta_{bc}(x,y) = \theta^*(x,y) - Bias^* \tag{6}$$

   where the bias is adjusted by employing the s sub-sample size.

$$Bias^* = \left(\frac{s}{n}\right)^{2/(p+q+1)} \left[\frac{1}{B}\sum_{b=1}^{B} \hat{\theta}_b^*(x,y) - \theta^*(x,y)\right] \tag{7}$$

4. Finally, for a given $\alpha \in (0,1)$, the bootstrap values are used to find the quantiles $\delta_{\alpha/2,s}$, $\delta_{1-\alpha/2,s}$ in order to compute a symmetric $1-\alpha$ confidence interval for $\theta(x,y)$

$$\left[\frac{\hat{\theta}(x,y)}{1+n^{-2/(p+q+1)}\delta_{1-\alpha/2,s}}, \frac{\hat{\theta}(x,y)}{1+n^{-2/(p+q+1)}\delta_{\alpha/2,s}}\right] \tag{8}$$

5. Sample and variables specification

5.1. Sample

We carry out the analysis for a sample of Spanish local governments between 1,000 and 50,000 inhabitants for the period 2008-2012. The information of inputs and outputs comes from the

Spanish Ministry of the Treasury and Public Administrations (*Ministerio de Hacienda y Administraciones Públicas*). In particular, outputs were obtained from a survey on local infrastructures and facilities (*Encuesta de Infraestructuras y Equipamientos Locales*). In contrast to other studies for Spain, this survey enlarges our sample since data is available annually. Therefore, the relevance of the study is also related to the sample under analysis. While other studies based on Spanish data focus on a specific region or year, our study examines a sample of Spanish municipalities comprising various regions for several years. Information on inputs was obtained from local governments' budget expenditures. The final sample contains 1,589 municipalities for every year (it represents the 19.60%), after eliminating all the municipalities which do not have information available for data on inputs and outputs for the period 2008 to 2012. Particularly, there was no information for the Basque Country, Navarre, Catalonia and Madrid regions and the provinces of Burgos, Huesca, Guadalajara and Huelva. In table 5 we summarize the number of observations for each region in our sample.

[Table 5]

5.2. Outputs

Outputs are related to the specific services and facilities provided by each municipality. Most part of previous studies in different European countries include output variables such as road infrastructure, recreational facilities, waste collected, drinking water supplied, social services, primary and secondary education and healthcare (e.g., Afonso and Fernandes, 2008; Geys and Moesen, 2009; Kalb et al., 2012; Da Cruz and Marques, 2014; Štastná and Gregor, 2015). In the Spanish case, differences are basically confined to the area of education, care for elderly and health services since they are not responsibility of local governments in Spain.

Our selection of outputs is based on the article 26 of the Spanish law which regulates the local system (*Ley reguladora de Bases de Régimen Local*). It establishes the minimum services and facilities that each municipality must provide compulsorily depending on their size. Specifically, all governments must provide public street lighting, cemeteries, waste collection and street cleaning services, drinking water to households, sewage system, access to population centres, paving of public roads, and regulation of food and drink. In addition, larger municipalities with population of over 5,000, 20,000 or 50,000 (the limits that define the groups) must provide more services. The selection of outputs is consistent with the literature (e.g., Balaguer-Coll et al., 2007; Balaguer-Coll and Prior, 2009; Muñiz-Pérez and Zafra-Gómez, 2010;

Bosch-Roca et al., 2012). However, as the article 26 of this law was modified in 1996 and the service "abattoir" was removed, differently from previous studies in Spain we are not going to include it. In addition, we have added four new variables, including measures for sewage system (a compulsory service for all local governments which never is taken into account).

As a result, we have chosen 11 output variables to measure services and facilities that municipalities provide. Due to the difficulty of measuring public sector outputs, in some cases it is necessary to use proxy variables, an assumption which has been widely applied in the literature. Based on the study of De Borger and Kerstens (1996a,b), many of these output variables should be considered as crude proxies for the services delivered by municipalities because more direct outputs are not available.

Population size (*Y1*), has been used as a proxy for the services of cemetery, regulation of food and drink, civil protection and provision of social services. Moreover, street infrastructure surface area (*Y2*) is used as a proxy for street cleaning, access to population centres, paving of public roads and fire prevention and extinction. Additionally, there are services which have direct output measures such as public street lightning (calculated by the number of lighting points, *Y3*), waste collection and treatment of waste collected (calculated by the tons of waste collected, *Y4*), the supply of drinking water to households (measured by the length of the water distribution network, *Y5*), the sewage system (measured by the length of the sewerage networks, *Y6*), public parks (measured by the surface area of public parks, *Y7*), public library (measured by the surface area of public libraries, *Y8*), market (measured by the market surface area, *Y9*) and public sports facilities (measured by the sport facilities surface area, *Y10*).

Finally, following the previous studies of Balaguer-Coll et al. (2007), Balaguer-Coll and Prior (2009) and Muñiz-Pérez and Zafra-Gómez (2010), we include an output variable which measures the level of quality of the services (*Y11*). Since services and facilities are classified as "good", "fair" or "bad" according to their condition, we use this categorical variable weighted by the quantity of service provided.

Table 6 contains the minimum services that each local government must provide depending on their size for the period 2008-2012 and the different output indicators used to evaluate the services.

[Table 6]

As we have said above, in an attempt to generate a balanced set of outputs that matches all the services and facilities that municipalities must provide compulsorily by law, we have chosen 11 output variables.

Different to previous Spanish studies which consider exclusively the minimum services compulsory for all local governments (Giménez and Prior, 2007), the minimum services and a quality variable (Balaguer-Coll et al., 2007; Muñiz-Pérez and Zafra-Gómez, 2009, 2010) or the total amount of services provided by local governments (Balaguer-Coll et al., 2010, 2013), we compare how different output selections affect the efficiency scores.

Moreover, in relation to the number of outputs to be included in efficiency analysis, we must take into account the problem of dimensionality. A general guideline to establish the number of variables is that the number of observations (i.e., local governments) should be at least twice the number of inputs and outputs considered (Golany and Roll, 1989), so following this rule as the number of units increases it is possible to incorporate more variables in the analysis. However, the inclusion of a large number of variables can result in a large number of efficient units.

Thus, we propose three different output models in order to compare how different outputs explain the differences between local governments and determine how the number of outputs can affect the efficiency scores. These models are the following:

- Model 1 includes minimum services compulsory for all governments: Number of lighting points, total population, tons of waste collected, street infrastructure surface area (m^2), length water distribution networks (m) and length sewerage networks (m).

- Model 2 includes minimum services compulsory for all governments and additional services which must provide larger municipalities with population of over 5,000 or 20,000: Number of lighting points, total population, tons of waste collected, street infrastructure surface area (m^2), length water distribution networks (m), length sewerage networks (m), public parks surface area (m^2), public library surface area (m^2), market surface area (m^2) and sport facilities surface area (m^2).

- Model 3 introduces all the services provided by local governments and a quality variable: Number of lighting points, total population, tons of waste collected, street infrastructure surface area (m^2), length water distribution networks (m), length sewerage networks (m), public parks surface area (m^2), public library surface area (m^2), market surface area (m^2), sport facilities surface area (m^2) and quality.

5.3. Inputs

Inputs are derived from the local governments' budget expenditures and they are representative of the cost of the municipal services provided. Using budget expenditures as inputs is consistent with the literature (e.g., Balaguer-Coll et al., 2007, 2010; Muñiz-Pérez and Zafra-Gómez, 2010; Fogarty and Mugera, 2013; Da Cruz and Marques, 2014). The budget settlement is used instead of the forecast budget because it is well known that the last ones tend to underestimate expenditure and overestimate revenues. Expenditures of local budget are divided into two main groups: no financial transactions and financial transactions. On the one hand, within the non financial transactions there exist two categories: current or ordinary expenditures and capital expenditures. Likewise, the first category is divided into personnel expenses, current expenditures on goods and services, financial expenditures (interests and banking expenses) and current transfers (grants and assistances to other entities). Moreover, the second category is divided into real investments and capital transfers (grants or payments to entities for real investments). On the other hand, financial transactions are divided into financial assets and financial liability (they refer to get loans and deposits and their repayments).

Therefore, the inputs included in the study are personnel expenses $(X1)$, expenditures on goods and services $(X2)$, current transfers $(X3)$, capital investments $(X4)$ and capital transfers $(X5)$.

Table 7 shows the descriptive statistics for inputs and outputs for the period 2008 to 2012. We include the median instead of the mean with the intention of avoiding the outliers' distortion.

[Table 7]

6. Efficiency results

We estimate efficiency scores for 1,589 municipalities for the period 2008-2012. Table 8, Table 9 and Table 10 present overall cost-efficiency results averaged over all municipalities for each year in specification 1, 2 and 3, respectively. They show simple summary statistics such as mean and standard deviation and also additional statistics which provide further understanding into the distributions of efficiency scores. We report results for three output specifications, since we compare how different output selection explain the differences between local governments and how the number of variables considered can affect the efficiency scores.

[Tables 8 to 10]

The results indicate that the average cost efficiency has remained consistently above 63% throughout the period 2008-2012. In particular, in specification 1 the average efficiency scores range from 63% to 74%, suggesting that municipalities could achieve the same level of local output with about 26% to 37% fewer resources. Although the efficiency scores are similar when comparing DEA and order-*m* approaches, the difference between the percentage of cost-efficient local governments over the total number of observations is bigger, ranging from 9.88% in order-*m* to 18.82% in DEA approach. Otherwise, the number of efficient local governments in KSW is really low, being even 0 in 2010 and 2011. Similarly, in specification 2 and 3 the average cost efficiency scores vary from 63% to 80%.

When comparing values from one specification to another, in general we do not observe large differences in their efficiency scores. Obviously there are some differences among the three output specifications which can be partly explained by the different number of outputs included. However, when the quality of the services is included in the analysis (specification 3), the increase in the efficiency scores might be because local governments which are more cost efficient provide better quality services. We can test more formally, whether efficiency results differ significantly when the quality variable is included, using Li (1996) test. Since the test compares the closeness between two unknown density functions, we compare the efficiency scores from specification 2 and 3. Results are provided in Table 11.

[Table 11]

The test reveals significant differences in the efficiency scores when the variable "quality" is included at a significance level of 90%, that is, between specification 2 and 3. Therefore, we find statistical evidence that the quality of the services provided influence local government cost efficiency.

Tables 8, 9 and 10 also show the changes in the distribution of efficiency scores over the period 2008-2012. As we can see, there exist a general increase in the efficiency scores over time, except with order-*m* approach which shows a slightly decrease in 2011 and 2012. In order to analyse the evolution of the efficiency scores for the whole period from 2008 to 2012, we test whether significant differences in efficiency levels took place between the initial and the final period, using Wilcoxons' non-parametric test (Balaguer-Coll and Prior, 2009) and Li (1996) test. Results are provided in Table 12.

[Table 12]

Both tests present consistent results. The results reveal significant differences on the efficiency scores during the period 2008-2012. Therefore it confirms that local governments have improved their efficiency in crisis times. This growth could be explained by the law on budgetary stability enforcement *(Ley General de Estabilidad Presupuestaria)*, which set up more control on public debt and spending with the aim to achieve a balanced budget. In this context, Spanish local governments have improved efficiency since they have reduced costs while maintaining local public services.

Additionally, after a global analysis, we now concentrate on the distribution of the coefficients according to size of the municipalities. Table 13, Table 14 and Table 15 present overall cost-efficiency results by population sizes for each year in specification 1, 2 and 3, respectively.

[Tables 13 to 15]

Tables show that efficiency results vary according to local governments' size as conclude the studies of Balaguer-Coll et al. (2007, 2010) and Muñiz-Pérez and Zafra-Gómez (2010). Larger municipalities perform better, that is, mean efficiency scores are higher in municipalities with more than 20,000 inhabitants than in municipalities between 5,000 and 20,000 inhabitants, which in turn are more efficient than the municipalities with fewer than 5,000 inhabitants. This result holds for all the years for the three methodologies in all output specifications. Thus, we can conclude that the most inefficient municipalities are found amongst those municipalities with fewer than 5,000 inhabitants, that is, smaller municipalities are further from their efficient frontier, whereas most of larger municipalities are efficient and closer to the frontier. Of special note is that given our variable returns to scale assumption we only compare municipalities of similar sizes, so this inefficiency does not take problems of scale into account.

Finally, we also provide kernel smoothing density estimates and violin plots to show further interpretation of results. Both include all features of the distribution and provide a deeper insight into how the different methodologies behave. Kernel densities are particularly useful in order to show multi-modality in the distribution and the existence of outliers, which have an impact on mean efficiency. Specifically, the kernel smoothing density estimator is:

$$\bar{f}(x) = \frac{1}{nh} \sum_{i=1}^{n} k \frac{(x - x_i)}{h} \tag{9}$$

where n is the sample size, x_i represents the value of x for each local governments under evaluation i, h is the bandwidth parameter and k is the kernel function. Figures 1, 2 and 3 represent for the years 2008, 2010 and 2012 [5] the density and violin plots for DEA, order-m and KSW approaches, respectively.

[Figures 1 to 3]

Density plots present a bi-modal structure among all the methods and specifications, indicating that there are two tighter probability masses: at unity, which shows the cost-efficient units (in KSW case at 0.9), and those which are inefficient around 0.6. As can be observed, there do not seem to be large differences in the cost structures among the different output specifications. However, we note that the modes representing the efficient units are higher in specification 3 (that is, when quality is included), supporting the significant differences tested when the variable "quality" is included in the analysis.

7. Conclusion

Over the last few years, due to the international economic crisis scenario, the improvement of public management efficiency in local governments has been a growing concern. In most Euro-area countries, the economic and financial situation has had a huge impact on most of local governments' incomes, provoking an increase on their deficits. The interest is even higher in countries such as Spain, where municipalities have faced stricter budget limitations with the law on budgetary stability *(Ley General Presupuestaria)*, which set up more control on public debt and public spending. In addition, this country has experienced a deep economic recession since 2008, even becoming a prime priority for the Euro-zone in 2012. In these circumstances, issues related to the efficiency of Spanish local governments for their contribution to public sector deficit is more relevant, if possible. In this paper, we have analysed the overall cost efficiency in Spanish local governments during the period of the economic crisis (2008-2012) which, up to now, had barely been examined, and has strongly affected Spanish local governments.

Moreover, the current large body of literature that focuses on the evaluation of efficiency in local governments in several countries share two important problems that remain unsolved. The first one refers to the complexity to define local governments' outputs and inputs. The

[5] For visual simplicity, we have chosen to show only 2008, 2010 and 2012. The years 2009 and 2011 do not differ much and are available upon request.

second problem is the lack of a clear and standard methodology to measure efficiency. The present study contributes to fill these gaps.

First, given how problematic is to define the bundle of services and facilities that municipalities must provide, we propose three different output specifications, relying on the legal framework: (i) model 1 includes the minimum services compulsory for all governments; (ii) model 2 extends model 1 to include additional services which must provide larger municipalities with population over 5,000 or 20,000; (iii) model 3 extends model 2 by adding quality variables. In model 3 we include an unusual variable which measures the quality of the services provided. It is very interesting and informative for local governments to measure not only the quantity but also the quality of the services and facilities, since performance decisions may affect directly the quantity and not quality. We compare how different outputs explain the differences between local governments and how the number of outputs can affect the efficiency scores. Also, the relevance of the study is related to the sample under analysis. While other studies based on Spanish data focus on a specific region or year, our study examines a much larger sample of Spanish municipalities, that is, we have carried out the analysis for a sample of 1,589 Spanish local governments with population between 1,000 and 50,000 for the period 2008-2012. Note that we have excluded all the municipalities which do not have information available for all the years and also municipalities with population under 1,000 inhabitants.

Second, we measure efficiency comparing results from three different non-parametric methods. Specifically, we have considered the most popular method to evaluate local governments' efficiency, DEA (Data Envelopment Analysis), and also two more recent proposals, order-*m* partial frontier as well as the non-parametric estimator proposed by Kneip et al. (2008).

From the comparison of the three different output specifications, in general we do not observe very large differences in their efficiency scores. It obvious to find some differences, which can be partly explained by the number of outputs included in each model. However, these differences could be also explained by the importance of the outputs selected in the efficiency analysis, such as the quality of the services. Therefore, we have tested whether efficiency scores differ when the variable quality is included. The results show statistical evidence of the possible implications of the quality variable when measuring local government cost efficiency, as concluded Muñiz-Pérez and Zafra-Gómez (2010) for municipalities with fewer than 5,000 inhabitants. Our conclusion is that in our sample of Spanish local governments, an increase of the efficiency scores when the variable quality is included is important since local governments which provide better quality services are more efficient.

Considering the various non-parametric methodologies used, we found some differences in the mean and median efficiency scores. Since there is a lack of a clear and standard methodology to measure efficiency, the ability to assess accurately cost efficiency remains difficult. Therefore, it is reasonable to use different methodologies in order to check the robustness of the results. Broadly speaking, in our case study inefficiencies are not extremely high. More specifically, our main results indicate that the average cost efficiency has remained consistently above 63% for all methods, suggesting that municipalities could achieve the same level of local output with about 37% fewer resources.

Additionally, results also vary according to the size of the municipalities. The analysis shows that larger municipalities perform better, that is, smaller municipalities are further from their efficient frontier, whereas most of larger municipalities are efficient and closer to the frontier. Of special note is that given our variable returns to scale assumption we only compare municipalities of similar sizes.

Finally, we have investigated whether efficiency of Spanish municipalities has changed during the period 2008-2012, using Wilcoxons' non-parametric test and Li (1996) test. Results indicate significant differences on the efficiency scores between the years 2008 and 2012 are significant. Specifically, there is a general improvement in the efficiency scores over the years. Thus, local governments have improved their efficiency in crisis times. We conclude that Spanish local governments have improved efficiency since they have reduced costs while maintaining local public services.

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Table 1: Studies on efficiency in local governments in several countries

Country	Author(s)	Sample	Method	Outputs	Inputs	Main results
Portugal	Afonso and Fernandes (2008)	278 Portuguese municipalities in 2001	DEA	Local Government Output Indicator (LGOI)	Total per capita municipal spending	Mean efficiency differs from 0.23 to 0.65.
	Da Cruz and Marques (2014)	308 Portuguese municipalities in 2009	DEA	Population, Extension of municipal roads, Urban waste collected, Drinking water supplied, Wasted water treated, Infrastructures	Staff, Capital expenditures, Other operational expenditures	Mean efficiency is 0.73.
Finland	Loikkanen et al. (2011)	353 Finnish municipalities from 1994-1996	DEA	Children's day care and family day care, Institutional care of the elderly and the handicapped, Open basic health care and bed wards, Dental care, Hours of teaching in comprehensive schools and senior secondary schools, Total loans of municipal libraries	Net operating costs	Mean efficiency scores differs from 0.85 to 0.89.
Australia	Fogarty and Mugera (2013)	98 Western Australian local councils in 2009 and 2010	DEA	Population, No. of properties in the council area, Length of sealed and unsealed roads	Employee costs, Physical expenses, Financial expenses	Mean efficiency is 0.4 for CRS and 0.6 for VRS.
Greece	Doumpos and Cohen (2014)	2,017 Greek municipality-year observation from 2002-2009	DEA	Recreational facilities, Roads infrastructure, Pavements, Lighting infrastructure, Costs of goods and services	Fees and charges, Tax revenues, Subsidies from central government	Mean efficiency differs from 0.65 to 0.75.
Germany	Kalb et al. (2012)	1,015 German municipalities in 2004	SFA	Students in local public schools, Kindergarten places, Surface of public recreational facilities, Total population, Population older than 65, Employees paying social security contributions	Total (net) current primary expenditures	Local governments should reduce inputs by 17% to 20%.
	Geys et al. (2013)	1,021 German municipalities in 2001	SFA	No. of students in local public schools, No. of kindergarten places, Surface of public recreational facilities, Total population, Share of population older than 65, No. of employees paying social security contributions	Total (net) current primary expenditures	On average cost should be reduced by 12% to 14%.

Table 1 – continued from previous page

Country	Author(s)	Sample	Method	Outputs	Inputs	Main results
Czech Republic	Šťastná and Gregor (2015)	202 Czech municipalities in 1995-1998 and 2005-2008	SFA	Pupils, Cultural facilities, Sport facilities, Built-up area, Urban green area, Waste, Businesses, Roads, Bus stops, Elderly population	Total current expending	Comparison of public sector efficiency in and beyond transition. Mean efficiency score increase from 0.62 in 1995-1998 to 0.69 in 2005-2008.
Belgium	Geys and Moesen (2008)	304 Flemish municipalities in 2000	DEA, FDH and SFA	Subsistence grants beneficiaries, Students in local primary schools, Surface of public recreational facilities, Total length of municipal roads, Municipal waste collected through door-to-door collection	Total current expenditures	Mean efficiency differs from 0.50 to 0.64 for DEA, 0.95 for FDH and 0.86 for SFA.
Spain	Balaguer-Coll et al. (2007)	414 municipalities in Comunidad Valenciana in 1995	DEA and FDH	Population, No. of lighting points, Tons of waste, Street infrastructure surface area, Registered surface area of public parks, Quality	Wages and salaries, Expenditure on goods and services, Current transfers, Capital expenditure	Mean efficiency is 0.53. FDH analysis present higher efficiency scores for larger municipalities.
	Balaguer-Coll et al. (2013)	1,198 Spanish municipalities between 1,000 and 50,000 inhabitants in 2,000	FDH	Population, No. of lighting points, Tons of waste, Street infrastructure surface, Public buildings surface, Market surface, Public parks surface, Assistance centres surface	Wages and salaries, Expenditure on goods and services, Current transfers, Capital expenditure, Total cost	Mean efficiency is 0.91. They analyse efficiency after splinting municipalities into clusters according to various criteria (output mix, environmental conditions, level of powers).

Table 2: Distribution of total public expenditures among central, regional and local administrations

	1995	2000	2005	2010
Central	62.05%	53.81%	46.31%	45.68%
Regional	24.19%	30.91%	38.22%	38.60%
Local	13.76%	15.28%	15.48%	15.72%
Total	100.00%	100.00%	100.00%	100.00%

Source: IGAE, Ministry of the Treasury and Public Administrations.

Table 3: Structure of local revenues during the period 2008-2012

		% Revenues
CURRENT INCOMES:		**78.79%**
- Direct taxes:		**29.92%**
	Property tax [2]	19.41%
	Motor Vehicle tax[3]	4.40%
	Urban land tax[4]	2.45%
	Business Activities tax[5]	2.77%
	Other direct taxes 0.88%	
- Indirect taxes:		**2.56%**
	Construction, Installation and Works tax [6]	1.84%
	Other indirect taxes	0.72%
- Fees and other incomes:		**16.09%**
	Fees	10.18%
	Public prices	1.13%
	Other incomes	4.79%
- Current grants received:		**27.83%**
	From General government	16.58%
	From Regional government	7.29%
	From provincial government	3.18%
	Other grants	0.78%
- Property incomes:		**2.38%**
CAPITAL INCOMES:		**14.72%**
	Alienation of real investments	1.24%
	Capital transfers	13.48%
NON FINANCIAL INCOMES		**93.50%**
Financial incomes		6.50%
TOTAL INCOMES		**100.00%**

Sources:

Data from Spanish Ministry of Treasury and Public Administrations (*Ministerio de Hacienda y Administraciones Públicas*).

Notes:

[1]: Share of total incomes among the period 2008-2012.

[2]: IBI, Impuesto de Bienes Inmuebles.

[3]: IVTM, Impuesto sobre Vehículos de Tracción Mecánica.

[4]: IIVTNU, Impuesto sobre el Incremento de Valor de los Terrenos de Naturaleza Urbana.

[5]: IAE, Impuesto de Actividades Económicas.

[6]: ICIO, Impuesto sobre Construcciones, Instalaciones y Obras

Table 4: Municipal powers (*Ley 7/1985 Reguladora de Bases de Régimen Local, LRBRL)*

Article 26	**Articles 25, 27 and 28**
- Public street lighting	- Powers exercised in the conditions defined by State and Regional laws:
- Cemetery	Public safety
- Waste collection	Traffic management
- Street cleaning	Civil protection, fire prevention and extinction
- Drinking water to households	Management of parks and garden
- Sewage system	Urban policies
- Access to population centres	Cultural heritage
- Paving of public roads	Protection of the environment
- Regulation of food and drink	Fairs and related activities
- Public parks	Protection of public health
- Public library	Participation in the management of first healthcare
- Market	Cemeteries and funeral services
- Treatment of collected waste	Social services, promotion of social reinsertion
- Civil protection	Local public networks (waste and water supply, public lighting)
- Provision of social services	Public transport
- Fire prevention and extinction	Cultural or sport activities and facilities
- Public sports facilities	Tourism
- Urban passenger transport service	Participation in the design of education programmes and facilities
- Protection of the environment	- Any delegated competence
	- Complementary activities from other levels of government (related to education, culture, women promotion, housing, health and environment protection).

Table 5: Observations per Spanish Region in the sample

Region	**Number of municipalities**
Andalusia	380
Aragon	58
Asturias	43
Balearic Islands	48
Canary Islands	51
Cantabria	45
Castile la Mancha	172
Castile and Leon	140
Valencian Community	269
Extremadura	118
Galicia	213
Murcia	28
La Rioja	24
Total	**1589**

Table 6: Minimum services provided and output variables

	Minimum services	**Output indicators**
In all local authorities:	Public street lighting	Number of lighting points
	Cemetery	Total population
	Waste collection	Waste collected
	Street cleaning	Street infrastructure surface area
	Supply of drinking water to households	Length water distribution networks (m)
	Sewage system	Length sewerage networks (m)
	Access to population centres	Street infrastructure surface area
	Paving of public roads	Street infrastructure surface area
	Regulation of food and drink	Total population
In local authorities with populations of over 5,000, in addition:	Public parks	Surface area of public parks
	Public library	Surface area of public libraries
	Market	Surface area of markets
	Treatment of collected waste	Waste collected
In local authorities with populations of over 20,000, in addition:	Civil protection	Total population
	Provision of social services	Total population
	Fire prevention and extinction	Street infrastructure surface area
	Public sports facilities	Surface area of public sport facilities (m2)
In local authorities with populations of over 50,000, in addition:	Urban passenger transport service	Total population, Street infrastructure surface area
	Protection of the environment	Total surface area

Table 7: Descriptive statistics for data in inputs and outputs, period 2008-2012

	Median					s.d.				
	2008	**2009**	**2010**	**2011**	**2012**	**2008**	**2009**	**2010**	**2011**	**2012**
INPUTS[1]										
Personnel expenses (X1)	1,262,965.00	1,369,145.00	1,393,523.00	1,314,901.00	1,154,764.00	3,143,882.59	3,314,595.39	3,262,041.68	317,368.48	2,805,570.32
Expenditures on goods and services (X2)	1,079,986.00	1,142,665.00	1,096,437.00	1,070,415.00	1,098,097.00	2,886,955.07	2,926,583.89	2,841,105.88	2,756,006.25	2,957,502.50
Current transfers (X3)	172,760.00	181,554.00	164,600.00	151,038.00	146,595.00	811,689.97	847,422.51	782,531.48	750,255.31	772,985.05
Real investments (X4)	951,809.00	1,599,789.00	1,337,430.00	707,972.00	410,564.00	2,095,699.22	2,826,964.09	2,448,957.49	1,800,748.72	1,018,721.09
Capital transfers (X5)	2,484.00	999.00	0.00	0.00	0.00	325,567.98	351,276.98	265,937.91	214,925.94	158,977.53
OUTPUTS										
Total population (Y1)	4,049.00	4,078.00	4,108.00	4,121.00	4,121.00	8,245.01	8,384.05	8,459.59	8,503.73	8,551.14
Street infraestructure surface area [2](Y2)	198,947.00	208,411.00	216,407.00	223,737.00	239,581.00	309,260.45	319,917.50	324,877.55	338,766.74	347,196.84
Number of lighting points (Y3)	941.00	970.00	983.00	1,009.00	1,049.00	1,327.72	1,396.30	1,659.42	1,737.44	1,774.84
Tons of waste collected (Y4)	1,652.00	1,727.50	1,624.90	1,663.60	1,626.40	56,189.25	33,599.40	11,098.58	6,350.99	6,116.52
Length water distribution networks [2] (Y5)	26,939.00	27,500.00	28,448.00	29,286.00	30,767.00	111,988.69	104,145.69	103,523.37	79,946.84	118,364.74
Length sewerage networks [2] (Y6)	1,720.00	18,250.00	19,000.00	1,842.00	1,845.00	3,665.37	29,670.10	31,121.22	4,025.59	4,080.63
Public parks surface area [2] (Y7)	19,813.00	21,488.00	23,700.00	25,735.00	27,554.00	554,190.46	561,649.66	557,338.52	560,281.32	565,797.89
Public library surface area [2] (Y8)	0.00	0.00	0.00	0.00	0.00	1,460.95	2,181.34	2,075.48	1,965.38	1,329.26
Market surface area [2] (Y9)	180.00	187.00	200.00	208.00	208.00	10,027.60	10,323.33	10,569.08	10,915.70	11,166.88
Sport facilities surface area [2] (Y10)	31,597.00	33,363.00	33,381.00	34,166.00	34,614.00	384,283.88	385,861.66	606,533.43	606,320.29	509,772.18
Quality (Y11)	2.41	2.41	2.42	2.43	2.44	0.32	0.31	0.31	0.31	0.31

Notes:
[1]: In thousands of Euro.
[2]: In square meters.

Table 8: Summary statistics for efficiency results in specification 1

	DEA				
	Mean	**Median**	**S.d.**	**Skewness**	**% of eff. obs.**
2008	0.70	0.68	0.21	0.00	16.68
2009	0.72	0.71	0.19	0.00	15.48
2010	0.72	0.70	0.19	0.04	15.23
2011	0.73	0.72	0.18	-0.04	16.55
2012	0.74	0.74	0.19	-0.16	18.82

	Order-m				
	Mean	**Median**	**S.d.**	**Skewness**	**% of eff. obs.**
2008	0.71	0.71	0.22	0.01	11.83
2009	0.74	0.73	0.21	0.13	10.51
2010	0.74	0.73	0.21	0.11	9.88
2011	0.72	0.71	0.22	0.08	10.26
2012	0.72	0.72	0.22	-0.07	10.51

	KSW				
	Mean	**Median**	**S.d.**	**Skweness**	**% of eff. obs.**
2008	0.63	0.62	0.20	0.14	0.33
2009	0.66	0.65	0.17	0.11	0.07
2010	0.66	0.64	0.17	0.07	0
2011	0.67	0.65	0.17	0.06	0
2012	0.68	0.68	0.17	-0.12	0.20

Table 9: Summary statistics for efficiency results in specification 2

	DEA				
	Mean	**Median**	**S.d.**	**Skewness**	**% of eff. obs.**
2008	0.71	0.69	0.21	-0.08	19.38
2009	0.74	0.73	0.19	-0.08	18.50
2010	0.74	0.72	0.19	-0.05	18.88
2011	0.76	0.75	0.19	-0.17	20.70
2012	0.76	0.76	0.19	-0.26	22.40

	Order-m				
	Mean	**Median**	**S.d.**	**Skweness**	**% of eff. obs.**
2008	0.78	0.83	0.22	-0.52	24.29
2009	0.79	0.82	0.21	-0.50	23.41
2010	0.78	0.81	0.21	-0.46	22.03
2011	0.78	0.82	0.22	-0.56	24.80
2012	0.76	0.79	0.23	-0.47	21.65

	KSW				
	Mean	**Median**	**S.d.**	**Skweness**	**% of eff. obs.**
2008	0.63	0.61	0.20	0.01	0.00
2009	0.67	0.66	0.17	-0.01	0.00
2010	0.66	0.65	0.18	0.05	0.13
2011	0.68	0.67	0.17	0.03	0.20
2012	0.68	0.69	0.18	-0.20	0.13

Table 10: Summary statistics for efficiency results in specification 3

	DEA				
	Mean	**Median**	**S.d.**	**Skewness**	**% of eff. obs.**
2008	0.74	0.74	0.21	-0.22	23.79
2009	0.76	0.75	0.18	-0.20	22.53
2010	0.76	0.75	0.19	-0.20	23.98
2011	0.78	0.79	0.18	-0.33	25.80
2012	0.79	0.79	0.19	-0.41	27.82

	Order-m				
	Mean	**Median**	**S.d.**	**Skewness**	**% of eff. obs.**
2008	0.80	0.87	0.22	-0.64	29.07
2009	0.80	0.86	0.21	-0.63	28.45
2010	0.80	0.85	0.21	-0.58	26.81
2011	0.78	0.83	0.23	-0.55	26.49
2012	0.78	0.83	0.23	-0.59	26.81

	KSW				
	Mean	**Median**	**S.d.**	**Skweness**	**% of eff. obs.**
2008	0.65	0.64	0.20	-0.11	0.13
2009	0.68	0.67	0.18	-0.03	0.20
2010	0.68	0.67	0.18	-0.08	0.13
2011	0.70	0.69	0.18	-0.04	0.2
2012	0.70	0.71	0.18	-0.36	0.00

Table 11: Distribution hypothesis test (Li, 1996)

		Null hyphotesis (H_0)	f(S2)=g(S3)
DEA	**2008**	T -test statistic	8.151
		p-value	0.000
	2009	T -test statistic	4.987
		p-value	0.000*
	2010	T -test statistic	9.256
		p-value	0.000*
	2011	T -test statistic	9.678
		p-value	0.000*
	2012	T -test statistic	8.316
		p-value	0.000*
Order-m	**2008**	T -test statistic	5.161
		p-value	0.000*
	2009	T -test statistic	5.798
		p-value	0.000*
	2010	T -test statistic	7.147
		p-value	0.000*
	2011	T -test statistic	1.490
		p-value	0.068*
	2012	T -test statistic	7.992
		p-value	0.000*
KSW	**2008**	T -test statistic	2.344
		p-value	0.010*
	2009	T -test statistic	0.833
		p-value	0.202
	2010	T -test statistic	2.653
		p-value	0.004*
	2011	T -test statistic	2.692
		p-value	0.004*
	2012	T -test statistic	1.741
		p-value	0.041*

Notes:
*denote significant differences at 10%, 5% and 1%.

Table 12: Wilcoxon's and (Li, 1996) tests

Null hyphotesis (H_0)	f(2008)=g(2008)	Wilconxon's test		Li (1996) test	
		T -test statistic	**p-value**	**T -test statistic**	**p-value**
DEA	**Spe1**	1105072	0.000*	16.019	0.000*
	Spe2	1097524	0.000*	11.135	0.000*
	Spe3	1115977	0.000*	12.710	0.000*
Order-*m*	**Spe1**	1237397	0.332	0.924	0.178
	Spe2	1326583	0.013*	4.255	0.000*
	Spe3	1317249	0.032*	2.945	0.002*
KSW	**Spe1**	958070	0.000*	21.278	0.000*
	Spe2	952456	0.000*	22.958	0.000*
	Spe3	975233	0.000*	18.551	0.000*

Notes:
* denote significance differences at 1%, 5% or 10%.

Table 13: Summary statistics for efficiency results by population sizes in specification 1

DEA

Year	Size	Mean	Median	S.d.	Skweness	% of eff. obs.
	<=5000	0.653	0.618	0.212	0.251	13.16
2008	>5000 a <=20000	0.729	0.713	0.188	-0.078	16.42
	>20000	0.873	0.923	0.149	-1.033	43.06
	<=5000	0.681	0.653	0.188	0.214	11.67
2009	>5000 a <=20000	0.752	0.750	0.167	-0.057	15.91
	>20000	0.851	0.873	0.154	-0.560	37.09
	<=5000	0.688	0.665	0.190	0.195	12.42
2010	>5000 a <=20000	0.733	0.709	0.172	0.083	13.46
	>20000	0.866	0.960	0.145	-0.634	37.91
	<=5000	0.711	0.696	0.186	0.059	14.01
2011	>5000 a <=20000	0.729	0.707	0.171	0.037	12.57
	>20000	0.882	0.941	0.142	-0.871	44.52
	<=5000	0.707	0.692	0.192	0.027	14.79
2012	>5000 a <=20000	0.761	0.750	0.172	-0.188	18.27
	>20000	0.889	0.983	0.140	-0.967	46.45

Order-*m*

Year	Size	Mean	Median	S.d.	Skweness	% of eff. obs.
	<=5000	0.604	0.589	0.194	0.567	2.45
2008	>5000 a <=20000	0.822	0.825	0.166	-0.044	13.32
	>20000	0.993	1.000	0.044	1.065	64.58
	<=5000	0.638	0.625	0.193	0.752	2.81
2009	>5000 a <=20000	0.824	0.830	0.163	0.212	10.42
	>20000	0.996	1.000	0.055	3.467	56.29
	<=5000	0.640	0.633	0.186	0.530	2.26
2010	>5000 a <=20000	0.818	0.818	0.168	0.434	9.46
	>20000	0.991	1.000	0.037	-0.076	54.90
	<=5000	0.615	0.603	0.192	0.403	1.92
2011	>5000 a <=20000	0.797	0.794	0.178	0.031	9.29
	>20000	1.004	1.000	0.079	5.622	61.29
	<=5000	0.618	0.605	0.199	0.269	2.69
2012	>5000 a <=20000	0.812	0.818	0.175	-0.075	9.59
	>20000	1.000	1.000	0.070	2.922	58.71

KSW

Year	Size	Mean	Median	S.d.	Skweness	% of eff. obs.
	<=5000	0.588	0.559	0.201	0.458	0.58
2008	>5000 a <=20000	0.663	0.653	0.168	-0.032	0.00
	>20000	0.788	0.806	0.153	-0.596	0.00
	<=5000	0.625	0.604	0.175	0.370	0.12
2009	>5000 a <=20000	0.698	0.700	0.151	-0.086	0.00
	>20000	0.786	0.790	0.151	-0.157	0.00
	<=5000	0.625	0.611	0.175	0.225	0.00
2010	>5000 a <=20000	0.671	0.662	0.162	-0.005	0.00
	>20000	0.784	0.790	0.150	-0.303	0.00
	<=5000	0.650	0.633	0.168	0.112	0.00
2011	>5000 a <=20000	0.656	0.647	0.157	0.024	0.00
	>20000	0.800	0.811	0.151	-0.363	0.00
	<=5000	0.650	0.639	0.177	0.070	0.23
2012	>5000 a <=20000	0.696	0.698	0.159	-0.262	0.19
	>20000	0.793	0.805	0.161	-0.962	0.00

Table 14: Summary statistics for efficiency results by population sizes in specification 2

DEA

Year	Size	Mean	Median	S.d.	Skewness	% of eff. obs.
	<=5000	0.667	0.632	0.213	0.181	14.60
2008	>5000 a <=20000	0.745	0.732	0.189	-0.163	19.71
	>20000	0.881	0.964	0.147	-1.090	47.92
	<=5000	0.696	0.672	0.192	0.135	14.48
2009	>5000 a <=20000	0.769	0.766	0.167	-0.148	19.19
	>20000	0.860	0.907	0.152	-0.641	39.74
	<=5000	0.705	0.683	0.193	0.111	15.58
2010	>5000 a <=20000	0.750	0.726	0.172	-0.018	16.91
	>20000	0.878	0.967	0.143	-0.730	45.09
	<=5000	0.729	0.714	0.189	-0.032	17.40
2011	>5000 a <=20000	0.757	0.749	0.175	-0.119	17.85
	>20000	0.899	0.994	0.136	-1.139	49.68
	<=5000	0.724	0.718	0.195	-0.065	17.60
2012	>5000 a <=20000	0.781	0.773	0.173	-0.304	22.14
	>20000	0.899	1.000	0.135	-1.096	50.97

Order-*m*

Year	Size	Mean	Median	S.d.	Skewness	% of eff. obs.
	<=5000	0.656	0.638	0.201	0.180	5.57
2008	>5000 a <=20000	0.926	0.987	0.116	-1.441	36.68
	>20000	1.000	1.000	0.001	-10.660	93.75
	<=5000	0.668	0.646	0.192	0.166	4.83
2009	>5000 a <=20000	0.919	0.985	0.121	-1.334	34.19
	>20000	0.999	1.000	0.012	-11.741	94.04
	<=5000	0.667	0.657	0.192	0.248	4.52
2010	>5000 a <=20000	0.913	0.972	0.122	-1.244	30.91
	>20000	1.000	1.000	0.013	6.965	90.85
	<=5000	0.656	0.646	0.204	0.112	5.42
2011	>5000 a <=20000	0.920	0.985	0.123	-1.373	35.70
	>20000	1.000	1.000	0.004	11.376	96.13
	<=5000	0.633	0.613	0.203	0.094	4.26
2012	>5000 a <=20000	0.902	0.963	0.140	-1.153	30.26
	>20000	1.000	1.000	0.012	10.488	91.61

KSW

Year	Size	Mean	Median	S.d.	Skweness	% of eff. obs.
	<=5000	0.586	0.562	0.195	0.235	0.00
2008	>5000 a <=20000	0.665	0.655	0.173	-0.114	0.00
	>20000	0.794	0.804	0.167	-0.858	0.00
	<=5000	0.629	0.613	0.174	0.187	0.00
2009	>5000 a <=20000	0.705	0.707	0.151	-0.157	0.00
	>20000	0.794	0.801	0.157	-0.285	0.00
	<=5000	0.634	0.619	0.177	0.166	0.12
2010	>5000 a <=20000	0.679	0.673	0.162	0.033	0.19
	>20000	0.793	0.792	0.150	-0.197	0.00
	<=5000	0.658	0.641	0.173	0.100	0.12
2011	>5000 a <=20000	0.674	0.666	0.165	0.028	0.39
	>20000	0.815	0.847	0.153	-0.526	0.00
	<=5000	0.654	0.646	0.182	0.022	0.12
2012	>5000 a <=20000	0.699	0.703	0.163	-0.484	0.19
	>20000	0.796	0.810	0.164	-0.810	0.00

Table 15: Summary statistics for efficiency results by population sizes in specification 3

DEA

Year	Size	Mean	Median	S.d.	Skewness	% of eff. obs.
	<=5000	0.706	0.681	0.212	0.007	19.06
2008	>5000 a <=20000	0.766	0.775	0.190	-0.302	23.18
	>20000	0.903	1.000	0.138	-1.384	55.56
	<=5000	0.718	0.710	0.193	-0.002	17.17
2009	>5000 a <=20000	0.787	0.789	0.169	-0.271	23.22
	>20000	0.882	1.000	0.149	-0.843	51.66
	<=5000	0.737	0.717	0.195	-0.074	20.54
2010	>5000 a <=20000	0.771	0.758	0.175	-0.138	22.00
	>20000	0.890	1.000	0.139	-0.904	50.98
	<=5000	0.764	0.767	0.188	-0.251	22.26
2011	>5000 a <=20000	0.776	0.767	0.178	-0.216	23.13
	>20000	0.911	1.000	0.130	-1.339	55.48
	<=5000	0.759	0.758	0.194	-0.265	23.21
2012	>5000 a <=20000	0.795	0.791	0.174	-0.369	27.12
	>20000	0.915	1.000	0.125	-1.312	56.77

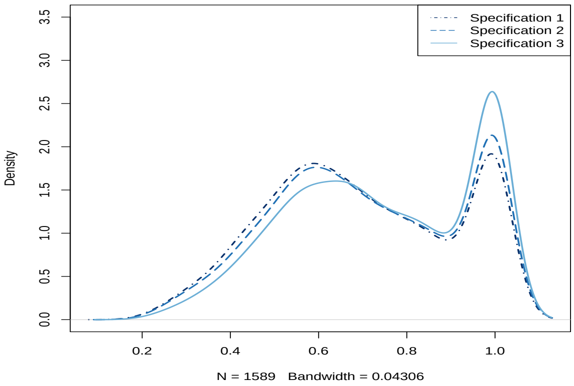
Order-*m*

Year	Size	Mean	Median	S.d.	Skewness	% of eff. obs.
	<=5000	0.675	0.651	0.211	0.099	8.25
2008	>5000 a <=20000	0.939	0.998	0.108	-1.685	45.44
	>20000	1.000	1.000	0.000	-10.032	96.53
	<=5000	0.686	0.661	0.201	0.076	7.63
2009	>5000 a <=20000	0.932	0.996	0.112	-1.628	43.69
	>20000	0.999	1.000	0.009	-11.895	96.03
	<=5000	0.683	0.665	0.200	0.130	6.77
2010	>5000 a <=20000	0.927	0.993	0.117	-1.457	39.82
	>20000	1.000	1.000	0.012	9.966	94.77
	<=5000	0.650	0.620	0.211	0.153	6.44
2011	>5000 a <=20000	0.917	0.990	0.127	-1.456	39.16
	>20000	1.000	1.000	0.001	-8.511	95.48
	<=5000	0.653	0.631	0.214	0.061	7.40
2012	>5000 a <=20000	0.918	0.989	0.132	-1.539	39.48
	>20000	1.001	1.000	0.011	12.249	94.19

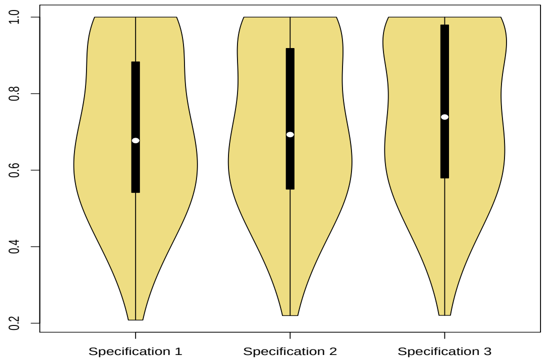
KSW

Year	Size	Mean	Median	S.d.	Skweness	% of eff. obs.
	<=5000	0.619	0.599	0.195	0.054	0.12
2008	>5000 a <=20000	0.668	0.663	0.181	-0.268	0.19
	>20000	0.812	0.822	0.176	-1.001	0.00
	<=5000	0.639	0.630	0.176	0.107	0.24
2009	>5000 a <=20000	0.703	0.705	0.156	-0.173	0.19
	>20000	0.809	0.839	0.171	-0.534	0.00
	<=5000	0.656	0.642	0.180	0.037	0.12
2010	>5000 a <=20000	0.684	0.682	0.167	-0.242	0.19
	>20000	0.801	0.819	0.166	-0.477	0.00
	<=5000	0.683	0.679	0.176	-0.012	0.12
2011	>5000 a <=20000	0.682	0.672	0.170	0.031	0.58
	>20000	0.834	0.874	0.160	-0.793	0.00
	<=5000	0.677	0.683	0.179	-0.222	0.00
2012	>5000 a <=20000	0.699	0.703	0.167	-0.457	0.00
	>20000	0.809	0.840	0.181	-1.385	0.00

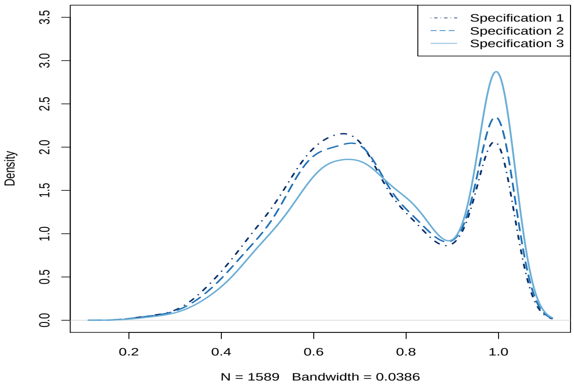
Figure 1: Densities and violin plots for DEA efficiency scores, the three specifications per year.



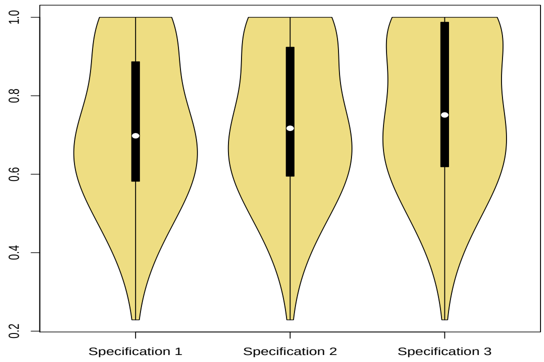
(a) DEA 2008



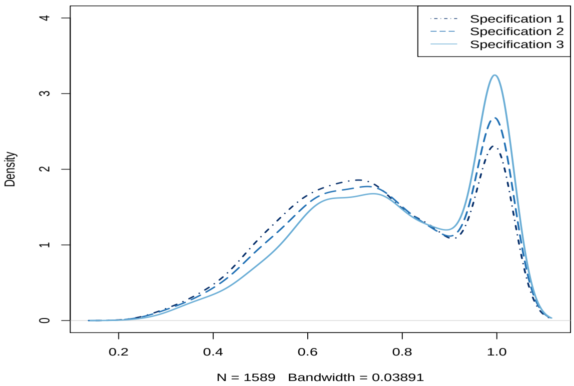
(b) DEA 2008



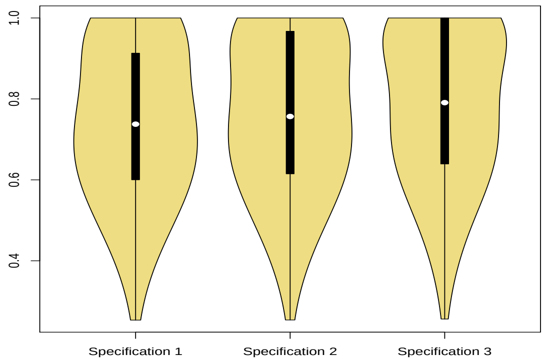
(c) DEA 2010



(d) DEA 2010

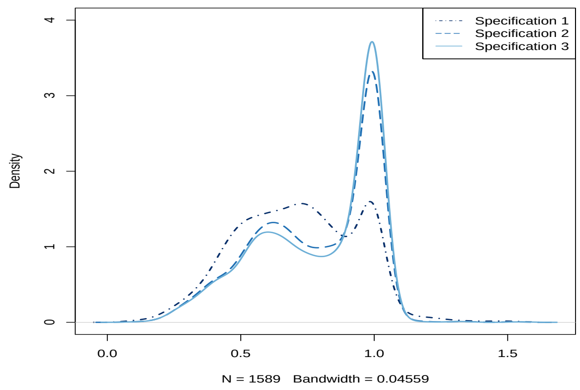


(e) DEA 2012

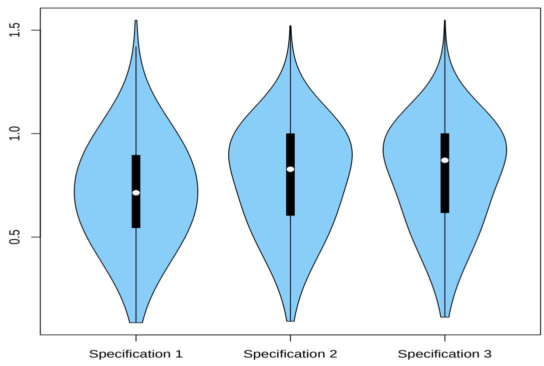


(f) DEA 2012

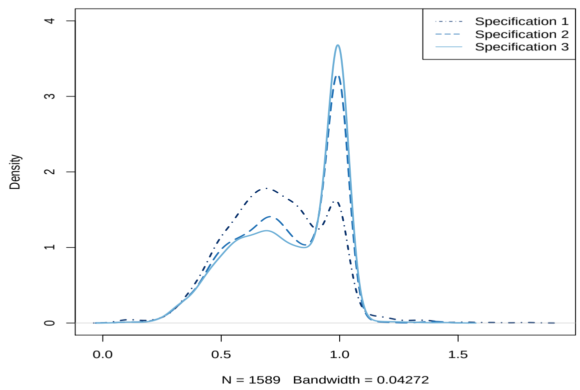
Figure 2: Densities and violin plots for order-m efficiency scores, the three specifications per year.



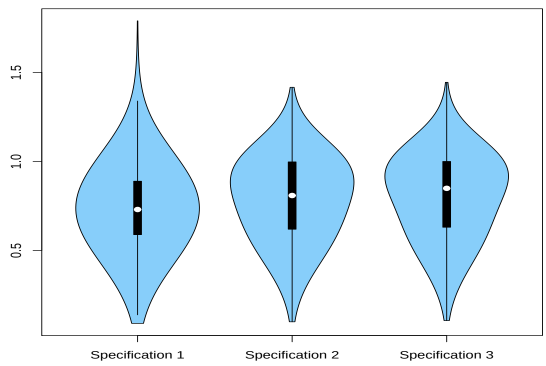
(a) Order-m 2008



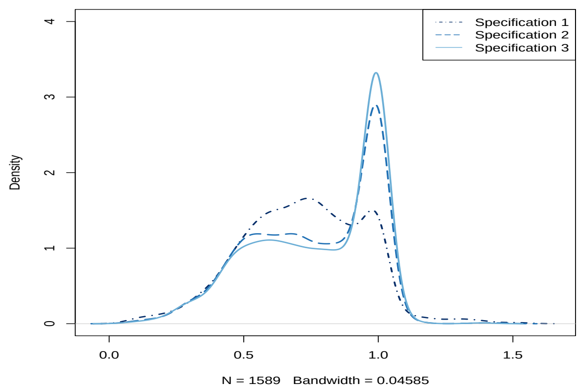
(b) Order-m 2008



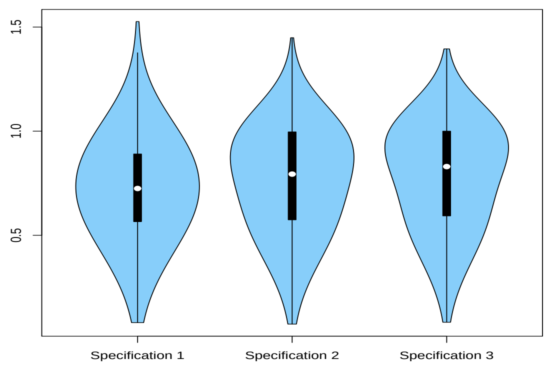
(c) Order-m 2010



(d) Order-m 2010

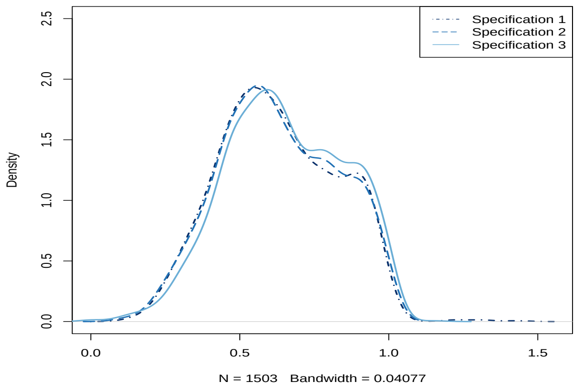


(e) Order-m 2012

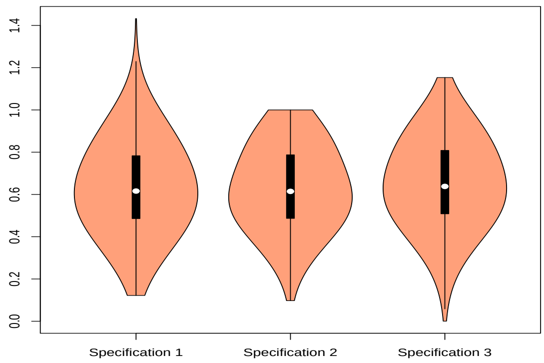


(f) Order-m 2012

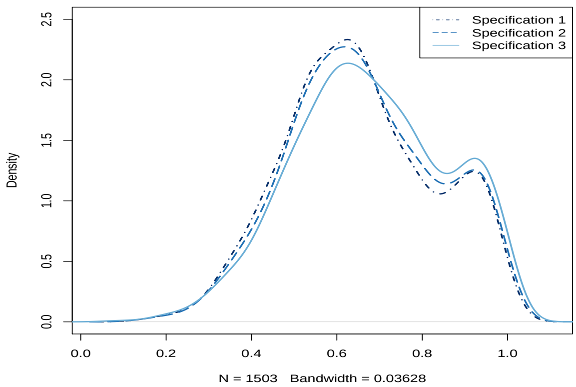
Figure 3: Densities and violin plots for KSW efficiency scores, the three specifications per year.



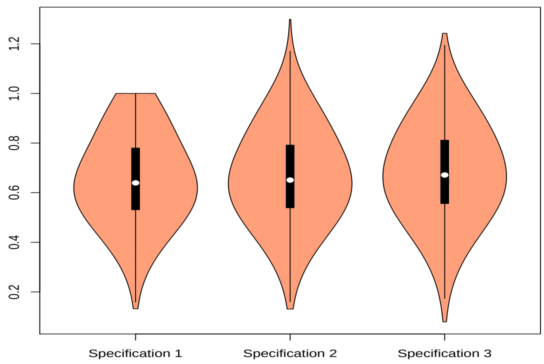
(a) KSW 2008



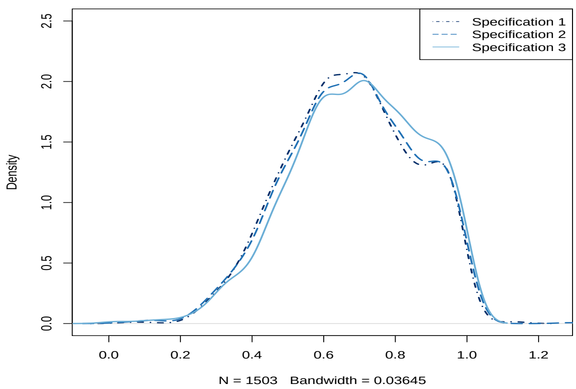
(b) KSW 2008



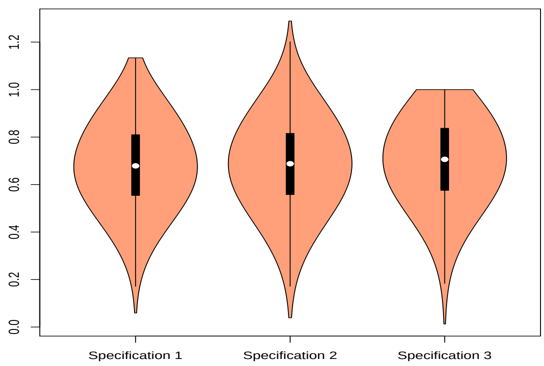
(c) KSW 2010



(d) KSW 2010



(e) KSW 2012



(f) KSW 2012