MEASURING EFFICIENCY IN CATALAN MUNICIPALITIES USING A DYNAMIC CONDITIONAL MODEL[*]

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The aim of this paper is to estimate efficiency measures for a sample of Catalan municipalities over an eight-year period (2005-2012) ranging from the years before the economic crisis to the start of recovery. To do this, we built a panel database for 154 municipalities with a population of from 5,000 to 50,000 inhabitants. The methodology used in the empirical analysis is a non-parametric dynamic conditional model that can be used to account for both the time dimension and a set of socioeconomic variables that might have an influence on the performance of the municipalities. The results show a remarkable decrease in efficiency levels during the years prior to the economic crisis, although this trend reversed as of 2010.

Key words: efficiency, municipalities, non-parametric models.

JEL classification: H20, H21, H24.

The economic crisis and strict restrictions on indebtedness have led to sizeable cutbacks in the resources that local authorities have at the disposal in order to properly perform the activities for which they are responsible. In face of this grim financial situation, the efficient management of available resources is now a priority for local governments. This has to do with the idea that municipalities "should do more with less", without, however, losing sight of the fact that their key objective is to improve the quality of life of their inhabitants. In fact, research focusing on local government efficiency assessment comes within the scope of new public management. New public management aims to set up an efficient and effective administration that meets the real needs of citizens at the least possible cost (Andrews, 2011; Andrews and Van de Walle, 2013).

This study refers to the particular case of municipalities in Catalonia. For this purpose, we selected a sample of 154 medium-sized municipalities (with a population of from 5,000 to 50,000 inhabitants) that have assumed similar competencies[1]. The stated aim is to measure and quantify their overall efficiency for an eight-year period (2005-2012) stretching from the years leading up to the economic crisis to the early years of recovery, accounting for the possible effect of the environment in which local governments operated, represented by a set of socioeconomic and geographical indicators. While these environmental variables are beyond the control of managers, they may sometimes deal a heavy blow to or else help municipalities achieve their goals. Therefore, their inclusion in the estimation of the efficiency scores is crucial in order to make sure that municipalities rated as inefficient really are poor performers or fail to achieve the targets that others manage to attain due to factors that are beyond their control.

Since the early papers on efficiency measurement at the municipal level in the mid-1990s [Van Den Eeckaut *et al*. (1993); De Borger *et al*. (1994); De Borger and Kerstens (1996a, 1996b)], empirical studies have been conducted in a host of countries attempting to evaluate the global efficiency of municipalities[2]. Most of these papers have opted to use non-parametric models like DEA or FDH [Worthington and Dollery (2000); Afonso and Fernandes (2006, 2008)], as this approach is more flexible and better adapted to the features of public services and the possibility of accounting for multiple inputs and outputs in the analysis [Ruggiero, (2007)][3]. Within this literature, which is quite notable in the Spanish context [Prieto and Zofio (2001); Balaguer-Coll, (2004); Balaguer *et al*. (2007; 2010; 2013); Giménez and Prior (2007); Balaguer-Coll and Prior (2009); Zafra and Muñiz (2010); Benito *et al*. (2014)], there has always been a lot of interest in finding out how environmental or contextual factors influence local government performance [Cruz and Marques (2014)]. Indeed, most of these studies explore the possible influence of variables representing the environment on the distribution of efficiency scores estimated by means of a second-stage analysis using conventional inference methods like Tobit [Sung (2007)] or ordinary least squares [Loikkanen and Susiluoto (2005)] models. In more recent studies, model parameters are estimated by applying truncated regression model based algorithms and bootstrapping methods developed by Simar and Wilson (2007), as they guarantee more consistent results [Bonisch *et al*. (2011); Bosch *et al*. (2012); Doumpos and Cohen (2014); Cruz and Marques (2014); Pérez-López *et al*. (2015)].

The main problem posed by the use of this methodological approach is that the validity of the results depends on whether the separability condition between the input-output space and exogenous variables holds. This relies on the assumption that the exogenous variables only affect the distribution of the inefficiencies and not the shape of

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(1) In fact, as indicated in the article 26 of Spanish Law 7/1985, regulating the bases of local government, this group of municipalities includes two levels of competencies powers divided as follows: local governments with a population of from 5,000 to 20,000 inhabitants and local governments with a population of from 20,000 to 50,000 inhabitants.

(2) A detailed analysis of this line of research is beyond the scope of this study. Two very recent papers [Narbón and De Witte (2017a, 2017b)] provide an up-to-date systematic literature review of this issue at the international level.

(3) However, the international literature also includes studies applying a parametric approach [e.g., Worthington (2000); Geys and Moesen (2009); Otsuka *et al*. (2014); Štastná and Gregor (2015)].

the estimated frontier [Badin *et al.* (2014)]. This hypothesis is very hard to accept with respect to the global efficiency measurement of municipalities because the economic and sociodemographic characteristics of the population can be presumed to largely determine the extent of service provision and resource consumption. Although a number of statistical tools can be applied to test this separability condition [Dariao *et al.* (2015)], none of the above empirical studies examined whether this constraint is met.

This study uses a non-parametric conditional efficiency model developed by Daraio and Simar (2005, 2007a, 2007b). This model is capable of directly accounting for the information regarding the heterogeneous context in which each of the municipalities may be operating into the estimation of the efficiency scores without having to assume the above separability condition. As far as we know, this methodological approach has not yet been applied to assess the efficiency of municipalities in Spain[4], on which ground this study is clearly innovative. Additionally, we have access to a longitudinal database. Therefore, we adapted this technique to a dynamic context by applying a recently developed extension by Mastromarco and Simar (2015), by means of which we can analyse how efficiency has evolved over the period under review. Thanks to this technique, we can also examine whether the contextual variables have a significant influence, and the sign (positive or negative) of their influence on the production frontier and the distribution of inefficiencies [Badin *et al.* (2012)].

The paper is structured as follows. Section 1 reports the methodology used, including the extensions regarding its application to both panel data and exogenous variables. Section 2 describes the main characteristics of the database used and the variables selected to conduct the proposed empirical analysis. Section 3 reports the results, and the main conclusions of the research are summarized in Section 4.

1. METHODOLOGY

The production technology used by local governments to convert inputs into local public services or to process outputs can be defined as

$$\psi = \{ \ (x,y) \in \Re_+^{p+q} \ | \ x \text{ can produce } y \ \} \tag{1}$$

In the context of this research, the production process is defined using a probabilistic formulation based on research by Cazals *et al.* (2002), according to which the joint probability measure of (*X, Y*) is completely characterized by the probability function defined as:

$$H_{XY}(x,y) = Pr(X \le x, Y \ge y). \tag{2}$$

The support of $H_{XY}(\cdot,\cdot)$ is ψ, and $H_{XY}(x,y)$ is interpreted as the probability of a unit operating at level (x,y) being dominated. This function can be decomposed as follows:

$$H_{XY}(x,y) = Pr(X \le x \ | \ Y \ge y) \ Pr(Y \ge y) = F_{X|Y}(x|y) \ S_Y(y), \tag{3}$$

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where $F_{X|Y}(x|y)$ stands for the conditional distribution function of X, and $S_Y(y)$ denotes the survival function of Y. Supposing that the above functions exist (that is, $S_Y(y) > 0$), the efficiency scores can be defined according to the above probabilities:

$$\theta(x,y) = \inf\left\{\theta \big| F_{X|Y}(\theta x|y) > 0\right\} = \inf\left\{\theta \big| H_{XY}(\theta x, y) > 0\right\} \quad [4]$$

Several non-parametric estimators, like FDH (free disposal hull) developed by Deprins *et al*. (1984) or DEA (data envelopment analysis) proposed by Charnes *et al*. (1978), can be used to estimate the full frontier $\hat{\theta}(x,y)$ The difference between the two approaches is that DEA accounts for the existence of convexity, whereas FDH does not. While the DEA technique is more popular among researchers, we will use FDH in this study, as it has better asymptotic properties [Park *et al*. (2000); Simar and Wilson (2000)] and assures that all the reference units are real[5].

When longitudinal data are available as is the case here, this model can be adapted to a dynamic context, making it possible to assess efficiency over a period. According to the development proposed by Mastromarco and Simar (2015), the model can be adapted by considering the time factor (*t*) as a discrete variable (with a different value for each year). This conditions Equation [2], which would be formulated as follows:

$$H_{X,Y}^{t}(x,y) = Pr(X \le x, Y \ge y \mid T = t). \quad [5]$$

Additionally, thanks to this probabilistic formulation of the production process, the efficiency scores can be calculated directly taking into account the effect of exogenous or contextual variables ($Z \in \Re^r$), where the efficiency scores are conditioned on certain values of the exogenous or contextual variables ($Z = z$). Accordingly, the above equations can be rewritten, this time taking into account the exogenous variables and the time effect:

$$H_{X,Y|Z}^{t}(x,y|z) = Pr(X \le x, Y \ge y \mid Z = z, T = t) \quad [6]$$

$$H_{X,Y|Z}^{t}(x,y|z) = F_{X|Y,Z}(x,y|z) S_{Y|Z}(y,z) \quad [7]$$

$$\theta_t(x,y|z) = \inf\{\theta \mid F_{X|Y,Z}^{t}(\theta x|y,z) > 0\}. \quad [8]$$

According to this definition of the methodology, time is regarded as an exogenous factor of the discrete model. Accordingly, if we treat the whole sample like cross-sectional data, we can capture information that is common across different but close periods by smoothing the temporal variable and choosing the appropriate bandwidth [Li and Racine (2007); Mastromarco and Simar (2015)]. In fact, it is thanks to this parameter that we can compare units belonging to one and the same year of the period within the space of all the observations. This is what distinguishes this from other dynamic analysis techniques.

$F_{X|Y,Z}^{t}(x|y,z)$ is harder to estimate in the conditional than in the unconditional case because it requires the use of smoothing techniques for Z variables (due to the equality constraint Z = z). These techniques are based on the use of a non-paramet-

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(5) When DEA is used, the reference units may be convex combinations of efficient units that do not really exist.

ric kernel function to select the units that will be used for reference purposes in the comparison. In this case, we will use the smoothing estimator:

$$\hat{F}^t_{X|Y,Z}(x|y,z) = \frac{\sum_{i=1}^{n} I(x_i \le x, y_i \ge y) K_{h_z}(z - z_i) K_{h_t}(v - t)}{\sum_{i=1}^{n} I(x_i \le x) K_{h_z}(z - z_i) K_{h_t}(v - t)} ,$$ [9]

where $K_h(\cdot)$ denotes the kernel and h_n is a bandwidth parameter of appropriate size for this kernel[6]. Bandwidth calculation is a key issue, as the estimation of the conditional frontier depends on this parameter. The best option for calculating this value if all Z variables are continuous is to use a data-driven method of selection [Badin *et al.* (2010)] based on a least squares cross validation (LSCV). This outputs a bandwidth that minimizes the weighted square error. Additionally, the procedure can separate influential from irrelevant Z factors that have large bandwidth parameter values h_n. The most common alternative is to smooth the continuous components and the discrete variables of the vector Z using continuous kernel functions and discrete kernel functions, respectively. However, if there is more than one possible value for these variables as is the case for the time period here, the most popular option is to smooth all the components of the vector Z using the continuous kernels proposed by Racine and Li (2004) and Li and Racine (2007)[7].

Another advantage of using this methodology is that it can analyse the possible effect of conditional variables on possible efficient frontier shifts by taking into account contextual variables. According to Badin *et al.* (2012), this effect can be investigated by calculating the ratio of conditional efficiency to unconditional efficiency:

$$Q(x, y|z, t) = \frac{\theta_t(x, y|z)}{\theta(x, y)}$$ [10]

In an input-oriented model, if the ratio tends to increase with the addition of conditional variables, this would denote an unfavourable effect (the conditional frontier moves away from the marginal frontier when the variables increase, which means that the variables act like an undesirable output), whereas a downward trend means that the effect of the variables is favourable (the conditional frontier moves towards the unconditional frontier when the variables increase, which means that the variables act like a fully available input).

The above ratio is useful only for identifying whether the conditional variables affect the production technology, that is, if there is a change in the shape of the efficient frontier. To obtain the effect of time and exogenous variables on the distribution of the inefficient units, we have to resort to applying robust partial order-α frontiers developed by Daouia and Simar (2007). These measures are based on the idea that, for each unit in the evaluated set, there is a quantile frontier for which the organization is efficient. For each possible value of α, this measure is defined by the following expressions for the unconditional and conditional cases, respectively:

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(6) See Badin *et al.* (2010) for a more detailed explanation of this issue.
(7) See Badin and Daraio (2011).

$$\theta_\alpha(x,y) = \inf\left\{\theta \middle| F_{X|Y}(\theta x | y) > 1 - \alpha\right\} \tag{11}$$

$$\theta_{\alpha,t}(x,y|z) = \inf\left\{\theta \middle| F^t_{X|Y,Z}(\theta x | y,z) > 1 - a\right\} \tag{12}$$

In this case, as recommended by Badin *et al.* (2012), we use the value of the median ($\alpha = 0.5$), which provides additional information about the effect of the exogenous variables on inefficiencies, as the frontier is built in the centre of the distribution of the efficiencies with approximately 50% of the units falling above and another 50% below the frontier. Therefore, the ratio to be analysed will be:

$$Q_\alpha(x,y|z,t) = \frac{\theta_{\alpha,t}(x,y|z)}{\theta_\alpha(x,y)} \tag{13}$$

As above, an upward trend in the ratio with respect to the conditional factors would signify an unfavourable effect, whereas a downward trend means that the conditional variables have a positive influence on the distribution of inefficiencies. If this and the effect of Equation [10] are similar, we can conclude that, when the values of time T and exogenous variables Z change, there is a shift in the frontier, whereas the distribution of efficiencies is unchanged. However, if there is a larger effect on the median, we can conclude that the effect on the distribution of efficiencies takes precedence.

Mastromarco and Simar (2015) refer to this effect as catch-up, using a notation like the one used to define the different components into which Malmquist productivity indexes can be decomposed [Fare *et al.* (1994)]. For Malmquist productivity indexes, a distinction is usually made between the change in technical efficiency and technical progress or technological change. However, instead of estimating efficiency scores for each period separately, our model smoothes discrete variables. As a result, we can use common information from other close periods depending on the selected bandwidth. Malmquist indexes do not account for this possibility, as they are calculated based on the differences between the efficiency scores for each evaluated year[8].

Finally, this methodological approach can also determine whether the effect of the conditional variables is significant by applying the non-parametric bootstrap test proposed by Racine (1997), as suggested by De Witte and Kortelainen (2013). This bootstrap procedure can be construed as the non-parametric equivalent of the t-statistic used in the linear regression model using ordinary least squares, where the p-value determines whether the variable has a significant impact. In this respect, Daraio and Simar (2014) suggest that it is not consistent to apply this procedure to the indexes estimated using a FDH estimator because it ignores the noise introduced into this estimation. They propose using measures based on partial order-α frontiers with values of α close to 1 instead of the FDH estimator, as they offer much more robust results in the presence of possible outliers. Following this recommendation, we applied the test proposed by Racine (1997) on scores estimated using an order-α frontier, where $\alpha = 0.99$.

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(8) In a recent paper, Kevork *et al.* (2017) report a breakdown of Malmquist productivity indexes based on the use of probabilistic directional distance functions.

2. DATA AND VARIABLES

The sample that we used is composed of 154 Catalan municipalities with a population of from 5,000 to 50,000 inhabitants. Although there are many more municipalities in Catalonia, the database has been confined to these municipalities in order to assure some level of homogeneity with respect to both local government organization and structure and their respective competencies. Besides, sampling was conditioned by the availability in the different consulted information sources of information on the variables accounted for in the empirical application for the entirety of the period under review, as discussed below.

The database has a panel structure, covering the eight-year period from 2005 to 2012, which can be clearly divided into two periods: one of economic prosperity and a term where the availability of local government resources shrank with the advent of the economic crisis. Note, in this respect, that the start of the crisis is usually dated in the year 2008. However, it did not immediately affect local authority budgets largely because the amount of resources provided to municipalities through the State tax revenue sharing system depends on the trend in the State tax revenue growth rate, and the definitive value of this indicator is calculated with a lag of two years[9]. We decided to apply a relatively simple model to rule out possible dimensionality problems that tend to occur in non-parametric models that have to account for too many linear programming variables [see Park *et al*. (2000); Dyson *et al*. (2001); Daraio and Simar (2007b)]. The model is in fact composed of three inputs and a composite indicator representing the output. Another five exogenous variables have been added, and are also taken into account to estimate the efficiency scores in the conditional model.

The inputs selected from the budget economic classification are personnel expenditure (Section 1), other current expenditure (Sections 2, 3 and 4 – current expenditure on goods and services, financial expenditure and current transfers) and capital expenditure (Sections 6 and 7 – real investment and capital transfers). These expenditures should approximate the cost of the municipal services offered. Additionally, the inclusion of capital expenditure accounts for the level of local investment in regular services, as well as the maintenance and new equipment available throughout the period. These inputs are typical of most previous empirical studies [Balaguer *et al*. (2007); Afonso and Fernandes (2008); Balaguer and Prior (2009); Zafra-Gómez *et al*. (2010); Bosch *et al*. (2012)]. The data are taken from the budget outturns of the municipalities compiled by the Virtual Office for Financial Coordination with Local Authorities, attached to the Ministry of Finance and Public Administration.

A more complex task is to select variables to represent the output, as local public services are troublesome to measure due to their intangibility and indivisibility, plus the non-existence of market prices serving as a reference [De Borger and Kerstens (1996a)]. Most studies use proxy variables related to services offered by local governments as a possible solution. In this case, we gathered information on six indicators representing the key local services, including the number of street lights, tonnes of collected waste, length of the water pipeline section, kilometres of surfaced main

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(9) See Cordero *et al*. (2013) for a detailed analysis of the effects of this index on local budgets.

roads and streets and square metres of built area of cemetery. The information regarding all these variables was sourced from the Infrastructure and Local Equipment Survey conducted by the Ministry of Finance and Public Administration[10]. On top of these indicators, there is the seasonal population of the municipality[11], a variable that is commonly used in the literature to approximate the wide range of general services for which there is no special-purpose measure [Narbón-Perpiñá and De Witte (2017a)].

It is not feasible to add all these variables to our model because of the above-mentioned dimensionality problems[12]. On this ground, we opted to build a composite indicator summarizing the original information provided by these variables[13]. To do this, we applied principal component analysis[14], according to which we identified a factor that explains 67.312% of the variance of the analysed outputs (Table 1). In this model, this component accounted for the output representing all the different services offered by local governments[15].

Table 1: RESULT OF PRINCIPAL COMPONENT ANALYSIS

	Initial eigenvalues			Squared sums of saturations		
Component	Total	Variance %	Aggregate %	Total	Variance %	Aggregate %
1	2.692	67.312	67.312	2.692	67.312	67.312
2	0.658	16.459	83.771			
3	0.454	11.355	95.126			
4	0.279	2.706	97.832			
5	0.028	1.736	99.568			
6	0.026	0.432	100.000			

Source: Own elaboration.

(10) The Infrastructure and Local Equipment Survey provides information for municipalities with a population of less than 50,000 inhabitants. Unfortunately, information on the Catalan municipalities for the years 2006, 2007 and 2012 is missing from this database. On this ground, we were obliged to impute the values for the above years based on the information from adjacent years. In fact, for 2006 and 2007, we calculated moving averages using information with respect to 2005, 2008 and 2009, whereas, for 2012, we projected the value according to the average annual growth rate for 2010 and 2011.

(11) The information on this variable was sourced from the Catalan Statistics Institute.

(12) We found that the efficiency scores estimated using the FDH model considering the three inputs and six outputs available for almost all the municipalities have values of one. Additionally, we found that problem persists if the number of outputs drops.

(13) Several emprical studies conducted at the local government level previously applied this procedure [Nijkamp and Suzuki (2009; Bosch *et al*. (2012); Nakazawa (2013, 2014); Yusfany (2015)].

(14) The weight allocated to each variable as a result of applying this method depends on the spread of its values rather than the assignment of an a priori weight.

(15) The component values were rescaled by adding the maximum negative value to all the values to assure that the variable values accounted for in the model are all positive.

Finally, we gathered information on several variables reflecting the socioeconomic context in which the municipalities operate that may have an influence on their efficiency levels, as inferred from the evidence reported in previous literature [Narbón-Perpiñá and De Witte, (2017b)]. They include per capita income, unemployment rate, consumption capacity[16], population density and per capita debt. The main source of information about these variables is the Economic Yearbook compiled by La Caixa. This is rounded out with municipal income indicators compiled by the Klein Institute and information on the levels of outstanding debt of local corporations compiled by the Ministry of Finance and Public Administration[17].

Table 2 shows the descriptive statistics of all the variables used to analyse each of the years under review. Clearly, the structure of most of the output indicators is similar, where there is widespread growth up to the maximum values about halfway through the study period, followed by a slight drop. The inputs evolve similarly, there being a sharp drop, as of the year 2009, in capital expenditure, which is often used as an adjustment entry at times of crisis. On the other hand, the socioeconomic indicators are much more constant, although the evolution of some, such as the rate of unemployment or consumption capacity, clearly mirrors the effects of the crisis. Besides, Table 3 reports information about the powers assumed by the different municipalities according to population size, as well as the variables used to roughly quantify those competencies.

3. RESULTS

This section reports the results of the unconditional model, where the efficiency scores are estimated using the information regarding the inputs and the composite output only, and the conditional model, which accounts for the effect of the exogenous variables. Economies of scale are assumed to be variable in all cases[18]. Consequently, it is assumed that each municipality is only comparable with others of a similar size, and we adopt an orientation of input minimization, as the output levels are construed to be fixed, whereas the municipalities do have more control over expenditure inputs or items.

We estimated three alternative conditional models accounting for the effect of exogenous variables. The exogenous variables were gradually added to each of these models in order to test the robustness of the results and build the final model. Thus, Model A only accounts for the three variables related to the socioeconomic environment of the municipality (per capita income, unemployment rate and employment), Model B also includes per capita debt and, finally, Model C adds a demographic variable, represented by population density. As the efficiency scores output by this alternative are highly correlated (0.8412, 0.8080 and 0.7377 for each combination), we report the results of Model C only, although all three estimates are taken into account to analyse the significance of the variables.

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(16) This index is calculated based on a set of variables representing the relative consumption capacity of the municipality, such as landlines, cars, lorries, bank branches and retail outlets.

(17) The variable used is outstanding local authority debt as of 31/12 of the current year according to the Public Finance and Debt System.

(18) Studies using a non-parametric dynamic conditional model commonly account for economies of scale [e.g., Tzeremes (2015); Matousek and Tzeremes (2016); Cordero *et al.* (2017)].

Table 2: DESCRIPTIVE STATISTICS OF THE VARIABLES (2005-2012)

		2005	2006	2007	2008	2009	2010	2011	2012
Seasonal population (inhabitants)	Mean	13,809	14,244	14,860	14,908	15,132	15,247	15,200	15,480
	S.D.	10,046	10,367	10,994	10,736	10,813	10,864	10,961	11,034
Street lights	Mean	2,636	3,854	3,854	2,906	2,907	2,914	2,974	2,864
	S.D.	2,337	8,259	8,259	3,652	2,665	2,669	3,129	2,404
Waste (tonnes)	Mean	9,992	9,944	9,947	10,263	9,199	8,179	7,591	7,838
	S.D.	10,246	9,633	9,632	12,819	9,341	8,619	7,677	7,951
Water (length in metres)	Mean	14,663	15,114	15,114	15,565	17,076	15,644	16,246	15,901
	S.D.	17,382	17,841	17,841	19,995	25,029	18,971	19,507	19,037
Main roads and streets (km)	Mean	53,308	54,020	54,020	54,731	57,202	57,138	56,549	56,944
	S.D.	36,465	36,025	36,025	38,806	42,079	42,075	42,395	42,169
Built area of cemetery (m^2)	Mean	12,573	12,785	12,923	12,996	13,062	13,059	13,065	13,062
	S.D.	47,557	47,534	47,527	47,547	47,532	47,533	47,532	47,532
Composite indicator	Mean	1.25	1.28	1.30	1.31	1.34	1.32	1.28	1.31
	S.D.	0.93	0.98	0.98	1.03	1.05	1.04	0.99	1.02

Outputs

Source: Own elaboration.

Table 2: DESCRIPTIVE STATISTICS OF THE VARIABLES (2005-2012) (continuation)

		2005	2006	2007	2008	2009	2010	2011	2012
Inputs									
Personnel expenditure (euros)	Mean	4,069,524	4,525,104	4,861,945	5,413,495	5,746,083	5,786,543	5,678,651	5,132,663
	S.D.	2,929,805	3,238,969	3,413,241	3,759,177	4,016,684	3,996,612	3,896,236	3,539,385
Current expenditure (euros)	Mean	5,400,360	6,175,236	7,007,991	7,623,797	7,672,987	7,422,577	7,338,642	7,371,398
	S.D.	4,227,028	4,862,012	5,463,351	6,013,976	6,132,659	5,909,017	5,716,280	5,767,001
Capital expenditure (euros)	Mean	2,730,953	3,945,966	4,924,731	4,534,084	6,136,431	4,962,174	3,165,297	1,486,436
	S.D.	2,266,032	3,338,553	3,821,738	3,674,354	5,346,296	4,340,435	2,912,134	1,652,129
Unemployment rate (%)	Mean	4.64	4.67	4.61	5.87	9.37	10.50	10.76	11.54
	S.D.	1.21	1.18	1.15	1.41	2.30	2.43	2.47	2.65
Consumption capacity (index)	Mean	30.31	30.56	30.89	31.08	31.13	30.95	30.69	30.58
	S.D.	21.34	21.30	21.39	21.59	21.45	21.21	21.06	21.03
Exogenous									
Income pc (euros)	Mean	15,416	16,411	17,143	17,875	17,941	16,619	16,661	16,674
	S.D.	2,732	3,223	3,181	3,274	3,608	2,346	2,236	3,441
Population density (inhabitants)	Mean	856	958	973	935	951	979	890	968
	D.S	1387	1434	1432	1418	1408	1475	984	1480
Debt pc (euros)	Mean	3.14	3.05	2.96	2.85	3.21	3.35	3.31	3.39
	S.D.	4.77	4.65	4.52	4.37	4.94	5.00	4.84	5.36

Source: Own elaboration.

Table 3: COMPETENCIES BY POPULATION SIZE AND SELECTED OUTPUTS

Population (inhabitants)	Powers	Variables used
Any population size	Street lighting	Number of street lights
	Cemetery	Built area of cemetery
	Waste collection	Tonnes of collected waste
	Road sweeping	Tonnes of collected waste
	Household drinking water supply	Length of water pipeline section
	Drains	Length of water pipeline section
	Road access and public road surfacing	Metres of surfaced main roads and streets
Greater than 5,000	Public park	Seasonal population
	Public library	Seasonal population
	Waste treatment	Tonnes of collected waste
Greater than 20,000	Civil defence	Seasonal population
	Assessment and reporting on situations of social necessity and immediate attention for people at risk of social exclusion	Seasonal population
	Fire prevention and extinguishing and public sports facilities	Seasonal population

Source: Article 26 of Spanish Law 7/1985, regulating the bases of local government and own elaboration.

Note: The competencies for each of the different population sizes include the specified competencies plus any listed higher up.

Table 4 shows the descriptive statistics of the unconditional model and the conditional Model C considering all the units evaluated in a dynamic context, that is, 154 municipalities over an eight-year period, totalling 1,232 different observations. Additionally, Figure 1 illustrates the distribution of the probability density of the efficiencies for both models. As expected, there are major differences between the two models, the mean efficiency being greater in the conditional model (around 15 points more) where each evaluated unit is compared exclusively against units operating in a similar environment. This increases the likelihood of a unit being placed on or close

to the frontier. In fact, the number of units that are classed as efficient is much greater in Model C (37% rather than 8% in the unconditional model). The value of the correlation coefficient (0.513) highlights that accounting for exogenous variables leads to major changes in the values of the efficiency scores. This illustrates the influence that these variables appear to have on estimated efficiency levels.

Table 4: DESCRIPTIVE STATISTICS OF ESTIMATED EFFICIENCY WITH THE TWO MODELS

	Mean efficiency	Standard deviation	Min	1st quartile	Median	3rd quartile	Max	Efficient units	Correlation coefficient
Unconditional model	0.7154	0.1686	0.2414	0.6037	0.7144	0.8294	1.0000	100 (8.1%)	
Conditional model	0.8684	0.1492	0.2896	0.7663	0.9173	1.000	1.0000	459 (37.3%)	0.513

Source: Own elaboration.

Figure 1: PROBABILITY DENSITY OF ESTIMATED EFFICIENCIES
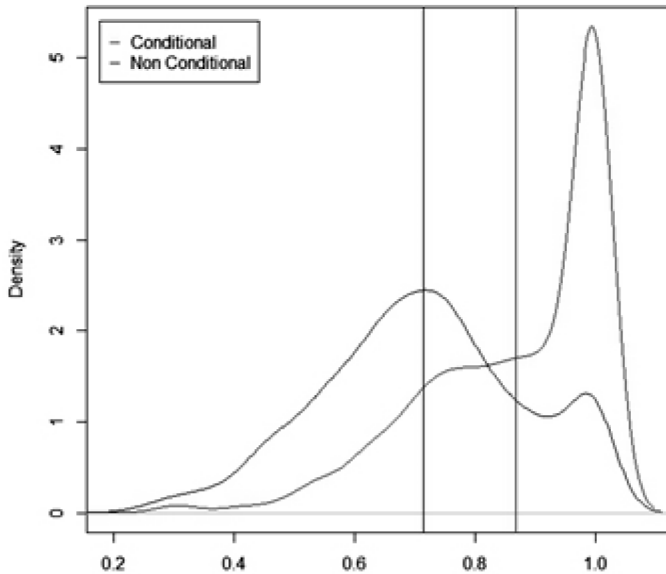
Source: Own elaboration.

Looking at specific municipalities, the unconditional model does not identify any of the municipalities as efficient in any of the years under review. On the other hand, the conditional model detects several cases that do satisfy this condition, some of which the unconditional model records as having very low efficiency values for all years. The explanation of this result is that some municipalities operate in a very unfavourable socioeconomic context, a point that is not taken into account when the efficiency levels are estimated considering the process inputs and outputs only. However, when the environment in which the municipalities operate is taken into account, their relative efficiency rating improves notably so much so that it may even be on the frontier.

As we took into account the dynamic structure provided by access to longitudinal data when estimating efficiency scores, we were able to examine how they have evolved over the period under review. Figure 2 shows that the efficiency scores evolved similarly for both models: the efficiency levels dropped gradually during the economic boom years and reached their minimum halfway through the period, as of when there was a slight recovery, although they failed to regain their original values. We found that the unconditional model recorded a much sharper decline and subsequent recovery after hitting rock bottom in 2009. On the other hand, the drop in the efficiency scores recorded by the conditional model, which includes several indicators representing the economic context, is much smoother during the worst years of the economic crisis, where average values are very similar from 2008 to 2011. This trend applies to all the municipalities taken together. Focusing on an analysis by individual municipalities, we find that there are local governments that have experienced a sizeable growth in efficiency throughout the period and others whose efficiency levels dropped continuously throughout the period.

Figure 2: EVOLUTION OF EFFICIENCY SCORES THROUGHOUT THE PERIOD
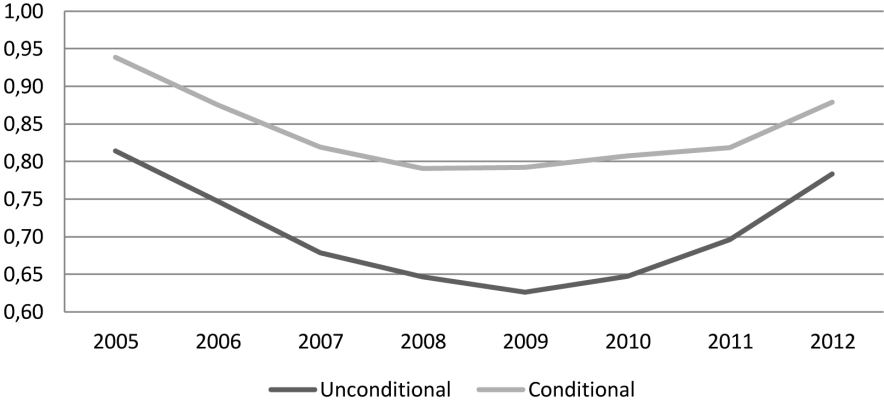
Source: Own elaboration.

Bearing in mind that there are major differences in municipality size within the evaluated sample, we believe that it is interesting to divide municipalities into three categories (from 5,000 to 10,000, from 10,000 to 20,000 and from 20,000 to 50,000 inhabitants) in order to compare the estimated efficiency scores for the conditional model. According to Figure 3, showing the evolution of the efficiency scores over the period for each of these categories, the larger municipalities have higher efficiency levels for all the analysed years, whereas the smaller municipalities have lower levels. The primary explanation for these results is that larger municipalities are better able to exploit economies of scale, as shown by several previous studies [for example, Revelli (2010) or Pérez-López *et al*. (2015). Additionally, we find that the efficiency levels of municipalities with a population of less than 20,000 inhabitants dropped continually until 2010, the year in which they started to grow again when local governments were hit belatedly by the crisis which forced them to offer the same services with fewer resources.

Figure 3: EVOLUTION OF MUNICIPALITIES BY POPULATION SIZE (CONDITIONAL MODEL)
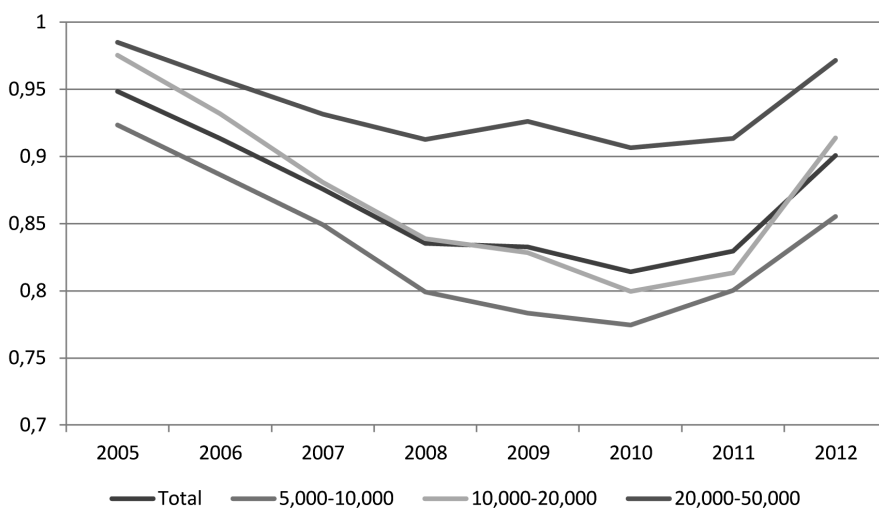
Source: Own elaboration.

Finally, we believe it is worth identifying contextual variables that have had a major influence on the local government efficiency estimation throughout this eight-year period. To do this, as described in Section 2, we calculate the ratio of the conditional to the unconditional scores and add the resulting value as a dependent variable to a non-parametric regression where the exogenous variables act as explanatory variables. This procedure was repeated for the three alternative estimated models (A, B and C) in order to guarantee that the results are robust. Table 5 shows the p-values of the significance test proposed by Racine (1997) output after bootstrapping with

1000 replications from which we inferred that the three socioeconomic variables have a significant effect on the efficiency of all models. On the other hand, while per capita debt is not significant in Model B, it is in Model C, which also includes the population density. This is the only variable that is not significant, a finding that matches other earlier studies [for example, Giménez and Prior (2007); Ashworth *et al*. (2015)].

Table 5: SIGNIFICANCE OF EXOGENOUS VARIABLES IN ALTERNATIVE MODELS

|	Model A	Model B	Model C
Significance (p-value)	Income pc (0.00***)	Income pc (0.00***)	Income pc (0.00***)
	Unemployment (0.00***)	Unemployment (0.00***)	Unemployment (0.00***)
	Employment rate (0.00***)	Employment rate (0.00***)	Employment rate (0.00***)
		Debt pc (0.25)	Debt (0.00***)
			Population density (0.31)

Source: Own elaboration.

Following Badin *et al*. (2012) and Mastromarco and Simar (2015), we use 3D plots in order to improve the visualization and interpretation of the significant effect of four variables. In fact, Figure 4 shows the estimated non-parametric regression plots for each of these four significant variables considering two alternative dependent variables: (i) the ratio of the conditional to the unconditional efficiency scores output by FDH, useful for exploring the effect of time and the exogenous variables on technological change; (ii) the ratio of the conditional to the unconditional efficiency scores estimated by means of robust partial order-α frontiers ($\alpha = 0.5$), useful for visualizing the influence of time and the exogenous variables on the distribution of inefficiencies (catch-up effect). As in both cases the model is input oriented, an upward trend suggests that the influence is unfavourable, whereas a downward trend means that the effect is favourable.

Looking at the plots regarding the unemployment rate (Figure 4a), we find that the effect on technological change is slightly unfavourable for the highest values. Some authors argue that the increased social cost caused by a rise in the number of unemployed in the municipality explains this effect [Revelli (2010); Kalb (2012)]. Consumption capacity has a clearly positive effect on the distribution of efficiencies (Figure 4b,ii), as a higher level of commercial activity tends to put more pressure on local governments. This leads to the need to improve efficiency levels. This result

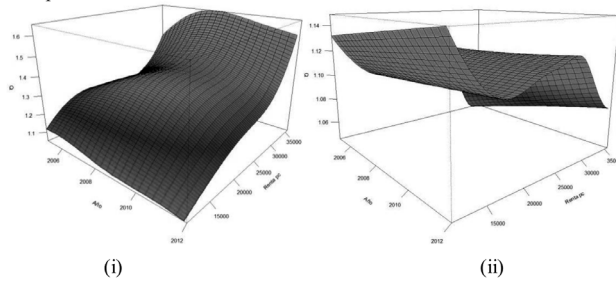Figure 4: EFFECTS OF TIME AND SIGNIFICANT EXOGENOUS VARIABLES
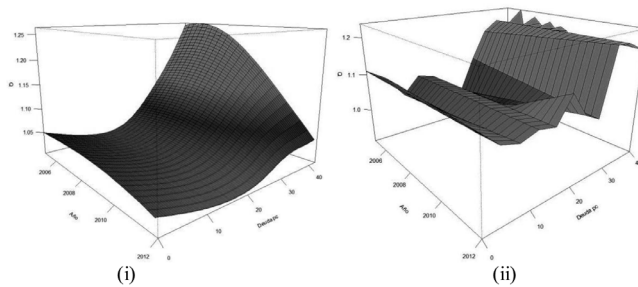
4.a. Unemployment rate

(i)   (ii)
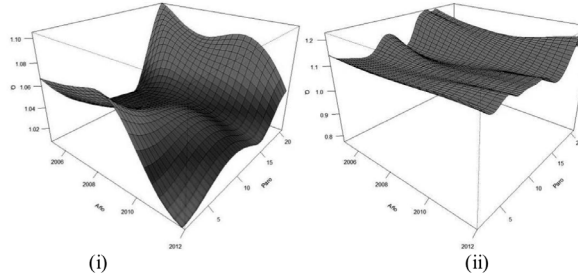
4.b. Consumption capacity

(i)   (ii)
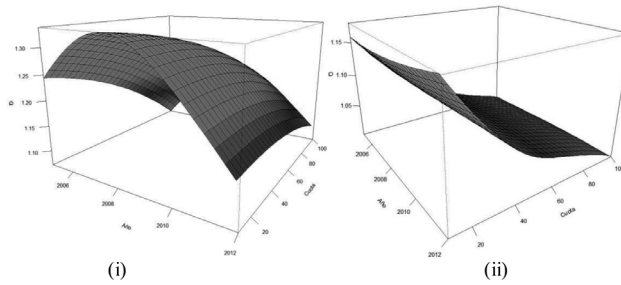
4.c. Per capita income

(i)   (ii)

4.d. Per capita debt

(i)   (ii)

Source: Own elaboration.

matches prior evidence available for samples of municipalities across Spain [Giménez and Prior (2007); Balaguer-Coll and Prior (2009)], as well as the particular case of municipalities located in Catalonia [Bosch *et al*. (2012)].

As far as per capita income is concerned, we find that it tends to slow down technological change (Figure 4c, i). This result corroborates evidence already reported in several previous papers, demonstrating that relatively richer municipalities exercise less control over municipal activities [De Borger and Kerstens (1996a,b); Bosch *et al*. (2012); Ashworth *et al*. (2014); Cruz and Marques (2014)]. However, this variable has a positive effect on the distribution of inefficiencies, especially for values greater than 25,000 euros. This suggests that there is greater pressure for efficient local services provision in municipalities located on the income distribution bound [Afonso and Fernandes (2008); Boetti *et al*. (2012); Asatryan and De Witte (2015)]. Finally, the effects of debt on technological change and the distribution of inefficiencies are unfavourable, albeit only for relatively high values, because fewer services will be offered if a large amount of resources are used for interest payment and debt repayment [Bonisch *et al*. (2011); Cruz and Marques (2014)].

4. CONCLUSIONS

In this study, we evaluated the global efficiency of a sample of medium-sized Catalan municipalities (with a population ranging from 5,000 to 50,000 inhabitants) for the period from 2005 to 2012. As a result, we can analyse the effects of the economic crisis on the performance of local authorities. To conduct this empirical analysis, we used an innovative methodology: the conditional non-parametric model adapted to a dynamic environment. This methodology provides the possibility of including the time factor and the effect of a number of contextual variables that may have an influence on the efficiency levels of local services provision by municipalities without having to assume the restrictive separability assumption between the input/output space and the exogenous variables required by traditional second-stage methods. This option is a remarkable improvement upon most of the empirical studies reported in the literature, which do not include the contextual variables that they analyse in the estimation of the efficiency measures. As a result, they overlook any heterogeneity between the evaluated units. Additionally, most previous studies use cross-sectional data, on which ground it is not possible to analyse the trend over a period of time.

The results show a downward efficiency trend for all municipalities during the economic boom phase which continued right up to the beginning of the economic crisis, which hit municipalities somewhat belatedly. As of then, there was a general recovery, which was not, however, big enough to regain the efficiency levels widespread at the start of the period under review. The consideration of the socioeconomic context in which the municipalities operate smoothes the observed global trend, providing for a more accurate estimation of the efficiency levels achieved by units operating in a more unfavourable environment. As a result, the average efficiency of all the units is greater when the analysis accounts for these contextual variables.

Of the contextual variables that we account for, the variables representing the socioeconomic context have a significant effect on efficiency, although there is some inconsistency with respect to the direction of their effect on technological change and

distribution of inefficiencies. The finding that these variables have a significant effect on efficiency leads to the conclusion that the estimation of measures indicative of local government performance that do not take into account these factors will be of very limited value.

The study also shows that the efficiency levels of municipalities with a population of from 20,000 to 50,000 inhabitants are much higher than for the others throughout the period under review. This leads to the conclusion that clustering into larger-sized municipalities may help to provide more efficient services. However, empirical evidence generated using quasi-experimental evaluation techniques is required to be able to draw conclusions in terms of causality, and their application in the municipal context is very scant.

Additionally, despite the fact that the empirical evidence gathered in this study offers a preliminary approximation of the effects that the economic crisis has had on the efficiency levels of Catalan municipalities, it would be worthwhile extending the analysis to include the latest years of economic recovery. This was not possible in this study because most of the socioeconomic indicators used sourced from the private institution (Fundación La Caixa) are not yet available. Likewise, we would be better able to fine tune the findings if we had access to qualitative data on which to make a better assessment of municipal services provision and round out the results of this study based solely on quantitative indicators.

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RESUMEN

El objeto de este trabajo consiste en la medición de la eficiencia de un conjunto de municipios catalanes desde los años previos a la crisis económica hasta los inicios de la recuperación (2005-2012). Para ello se ha construido una base de datos de tipo panel para un conjunto de 154 ayuntamientos con una población comprendida entre los 5.000 y 50.000 habitantes. La técnica empleada para llevar a cabo el análisis es un modelo no paramétrico condicional temporal con el que resulta posible incorporar al cálculo de los índices de eficiencia información relativa a un conjunto de variables socioeconómicas y la dimensión temporal. Los resultados obtenidos muestran que durante los años de bonanza económica estos municipios experimentaron un notable descenso en sus niveles de eficiencia aunque esta tendencia se invirtió a partir del año 2010.

Palabras clave: eficiencia, municipios, modelos no paramétricos.

Clasificación JEL: H20, H21, H24.