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MUNICIPAL SPENDING AND URBAN QUALITY OF LIFE: A STOCHASTIC FRONTIER ANALYSIS

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Municipal Spending and Urban Quality of Life: a Stochastic Frontier Analysis

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Abstract

This paper evaluates the efficiency of 100 Italian chief towns of Province in providing urban environmental quality in the period between 1998 and 2007 and investigates the determinants of urban environmental quality. Using stochastic frontier models, we estimate different production function specifications exploiting the Legambiente Index as qualitative measure of the output and the current per capita environmental expenditure as input measure. Moreover, we verify the role played by socio-economic, fiscal and political variables in explaining different environmental municipalities' performance. We found that besides the socio-economic variables, those which explain different municipalities' performance are the fiscal and political ones.

JEL classification: C33, D72, H71, H72
Keywords: Local Government Efficiency, Stochastic Frontier Models, Environmental Quality

1 Introduction

A broad academic literature on urban systems has underlined that the functioning of urban areas should be aimed at maximizing the quality of life and well-being of the people that live and work in such areas (Riseborough *et al.*, 2000; Berce-Bratko, 2001). Many authors have highlighted the link existing between quality of urban environment and the health and well-being of citizens. Certainly, quality of life is a multi-faceted concept (Yuan *et al.*, 1999). In an urban environment, in fact, there are several different determinants of well-being: among those is surely the satisfaction of primary needs, such as being employed, having adequate income, feeling safe and immaterial needs, as, for example, the quality of public services, leisure and community participation, but the overall quality of life depends also on the healthiness of the urban environment.

On this issue, institutions, such as the European Union and WHO (E.U., Thematic Strategy on the Urban Environment; WHO, Healthy Cities programme), have underlined the crucial role played by cities and by their local policy-makers in deciding what environmental policies are to be implemented, since actions taken from that level of government can be more effective. Indeed, it is true that upper levels of government can impose standards and objectives on this matter, but is also true that, given the peculiarities that each city presents, only the local government can effectively act to implement those policies. Moreover, the improvement of quality of life put in place by a local government could be seen as an indicator of goodness and responsiveness of the local government to citizens' needs (List and Sturm, 2006).

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In this regard, the present work aims at evaluating the efficiency of Italian municipal governments in providing urban environmental quality by exploiting the Legambiente environmental index as a measure of policy outcome, and at verifying to what extent the observed gross environmental performance is determined by external circumstances over which local governments have not control. In particular, our aim is both to estimate the degree of efficiency of the 100 Italian chief towns of Province[1] in providing environmental urban services in the period between 1998 and 2007 and to explore the determinants of local governments' environmental performance. In our analysis, besides verifying the role played by exogenous and structural variables (e.g., the municipality population composition) in determining differences in efficiency, our aim is also verifying if political and fiscal variables, such as government ideology and size, explain those differences.

A large and growing literature has attempted at evaluating the efficiency of local governments in providing local services using the methods and techniques developed by the literature on productive efficiency[2]. One of the most common features in that literature is the focus on the efficiency of the production process of local governments in transforming inputs, typically the local government's expenditure, into outputs.

Furthermore, the application of such a literature on local government efficiency is twofold: some studies have evaluated the global efficiency of local governments (as, for instance, De Borger and Kerstens (1996) for the case of Belgium; Balaguer-Coll, Prior and Vela-Bargues (2002), Balaguer-Coll, Prior and Tortosa Ausina (2007) in Spain; Loikkanen and Susiluoto (2005) in Finnish municipalities); other works have focused on the evaluation of a specific local service, such as waste collection (Bosch *et al.*, 2000), police protection (Davis and Hayes, 1993), libraries (Vitaliano, 1997), public illumination (Lorenzo and Sánchez, 2007).

In this respect, the present work is somewhere in the middle: the urban environmental services provided by local governments in fact represent a multidimensional output/outcome, increasing the range of the focus with respect to a single specific service, but we consider only some of the policies implemented by local governments and not the whole spectrum.

The "middle range" focus we adopt gives us the chance to overcome some of the most problematic issues of the just mentioned literature. In fact, as underlined by Dollery and Worthington (2000), most of that literature suffers from the well-known lack of adequate measures of local government output and performance, and it uses a number of "crude proxies" for the service output delivered by municipalities. As an example of the latter, such proxies are typically related to the number of service users or to the size of municipalities which should be considered input measures rather than output measures (Dollery and Worthington, 2000).

In the present work, one of the advantages of using the Legambiente index as the output measure is that this index takes also into account the quality of urban environmental services provided by local governments since it is built, as explained more in detail below, as a weighted average of three wide categories of indicators selected according to standards and objectives of sustainability identified by the European Union and the OECD.

Another point that remains in part unsolved in such a literature is the choice of the "best" reference technology for evaluating the efficiency of local governments. In the aforementioned works two main kinds of methods have been applied typically to cross sectional data: parametric

[1] We do not consider in the analysis neither the three autonomus chief towns of Province (Aosta, Trento and Bolzano) given their different competences and local peculiarities nor the chief towns of Province recently created for which there are no data on Legambiente Index.

[2] The techniques commonly used for the analysis of productive efficiency are presented below, but for an introduction on the matter refer to Coelli, Rao and Battese (2005).

(Stochastic Frontier Approach) and non parametric ones (Data Envelopment Analysis, Free Disposal Hull). As highlighted by some authors (Geys and Moesen, 2009; De Borger and Kerstens, 1996) the methodological choices for evaluating the efficiency are not neutral: different approaches lead to different efficiency results. Therefore, aiming the present work at checking for the robustness of results, different stochastic models are used, and the panel dimension of our data set should allow us to disentangle heterogeneity across jurisdictions from inefficiency, overcoming one of the most common problem outlined in the literature.

2 How to Define and Measure Local Government Efficiency

Starting from the seminal paper of Farrel (1957), a large theoretical and empirical literature on efficiency and productivity analysis has developed a broad variety of econometric and mathematical frontier techniques for measuring the performance of firms and industries. Those approaches have later been applied also to evaluate the efficiency of local governments in providing local services.

In such a literature, local government efficiency is usually seen from two alternative perspectives: given the inputs, a government is efficient if it is able to obtain the maximum level of output, in the output-oriented case; or, in the input-oriented case, the government is efficient if it is able to use the minimum level of inputs given the level of output[3] (Koopmans, 1951). Both are definitions of technical efficiency, but evaluating the overall economic efficiency requires also measuring the allocative efficiency, which deals with assessing if the mix of used inputs is optimally chosen.

Following the literature on local government efficiency (for a review of the literature see Dolllery and Worthington, 2000), the present work analyses only the technical efficiency of municipalities and the reason is that evaluating the allocative efficiency presents two critical issues: the availability of information on quantities and prices of inputs, and the choice of behavioural assumptions about the municipality (e.g., cost minimization, profit maximization, etc.)

In that literature the relevant empirical issues for evaluating the degree of technical efficiency of local governments are three, which will be further detailed in the following sections: how to measure the outputs, that is to say the local services provided by municipalities, how to measure the inputs used in the production of those services and what is the method more appropriate for estimating the frontier and the degree of efficiency of municipalities.

We measure inputs as the per capita current environmental expenditure, the output as the value of the Legambiente index, and we use the stochastic frontier techniques for efficiency evaluation.

2.1 The Methodologies

The most exploited techniques for evaluating if a local government operates on the frontier of its production set are two: the non-parametric approaches (i.e. Data Envelopment Analysis – DEA, Free Disposal Hull – FDH) and the parametric ones (i.e. Stochastic Frontier Approach – SFA).

The DEA solves a linear programming problem applied to observed data, in which each jurisdiction is compared with the 'best' jurisdiction. If there is not a best jurisdiction that uses the same given inputs, a virtual best solution is computed that approximates values of available best local governments which are most similar in the composition of inputs.

[3] The choice of the output or input orientation depends on what is assumed to be more exogenous; it is more exogenous the input in the output-oriented case and viceversa. In the first case, it is estimated a production function, in the other case it is a cost function.

Technically, DEA identifies the best practice frontier as the envelop of the observed production possibilities. The FDH technique simply relaxes the assumption of convexity of the DEA approach.

The DEA and the FDH are deterministic methods, there is no accommodation for noise. The efficiency score is calculated and not estimated, therefore each deviation from the frontier is interpreted as inefficiency, even if the inefficiency may be determined by variables that are beyond the control of local governments.

The SFA is an econometric technique, dealing with noise, and in particular it is assumed that the error term has two components: one represents inefficiency and the other one represents statistical noise, such as measurement errors and variables not accounted in the estimation. In the output-oriented case, i.e. the production function, the output is expressed as function of inputs and it is possible to estimate the degree of efficiency of local governments after making some assumptions both on the functional form structure describing the relationship between inputs and the output[4] and on the error term distribution. In particular, a general formulation of the stochastic production frontier model, proposed by Aigner, Lovell and Schmidt (1977), is the following:

$$\begin{aligned} y_i &= x_i'\beta + v_i - u_i \\ v_i &\backsim N(0, \sigma_v^2) \\ u_i &\backsim N^+(0, \sigma_u^2) \end{aligned} \tag{1}$$

With respect to the classical linear regression model, there is u_i (in this model half-normal distributed)[5], that is a non-negative random variable associated with technical inefficiency, i.e. it represents the distance of the observation from the production function. Moreover, parameters are estimated with maximum likelihood, rather than least squares[6]. Then the jurisdiction-specific inefficiency is estimated as the expected value of the inefficiency error component conditional on the measured overall error $E(u_i|\ v_i - u_i)$ (Jondrow *et al.*, 1982) and the measure of technical efficiency is given by:

$$TE_i = \frac{E(y_i|u_i, x_i)}{E(y_i|u_i = 0, x_i)} \approx \exp(-u_i) \tag{2}$$

that is the ratio of observed output to the corresponding stochastic frontier output (the optimal output), and it takes a value between 0 and 1.

The parametric and non-parametric techniques present some advantages and some shortcomings. One of the advantages of using non-parametric techniques is that they do not require any functional assumption, which is instead necessary in the SFA. Furthermore, the non-parametric methods allow for multiple inputs and outputs setting. The higher flexibility of non-parametric approaches with respect to the parametric ones explains why they have predominantly been used in such a

[4] In the literature the more often used functional forms are the Cobb-Douglas and the TransLog function specification.

[5] The literature on efficiency has developed a broad variety of different stochastic models that principally differ for the assumptions on the error distribution (e.g. half-normal, truncated normal, exponential or gamma distribution), the estimation of the inefficiency score and the cross or panel dimension of data. For a survey on these models refer to Kumbhakar and Knox Lovell (2000)

[6] With OLS we obtain consistent slope coefficients, but the intercept is biased downward.

literature. Nevertheless the main shortcoming of the non-parametric approaches is represented by their deterministic nature (Murillo-Zamorano, 2004).

On the other hand, the non-deterministic nature of the stochastic frontier models requires, in order to estimate the degree of efficiency of local governments, restrictive assumptions both on the functional form of the production process and on the distribution of error components. Such requirements are even more restrictive for cross-sectional models with respect to panel stochastic frontier ones (Gong and Sickles, 1992).

In the literature on local government efficiency, stochastic frontier models are estimated with cross-sectional data. In such a literature also those which exploit non parametric techniques prevalently use cross-sectional data. The only exceptions are represented by the works of Loikkanen and Susiluoto (2005) and Balaguer-Coll, Prior and Vela-Bargues (2002). Moreover, the non parametric methods ignore the panel dimension of data. In fact, the efficiency score is computed for each single year as just in a cross-sectional framework. In this regard, the innovation introduced by this work is that it applies stochastic panel models to evaluate the efficiency of municipalities. The possibility of exploiting the cross and longitudinal dimension of the data gives us additional information: it is in fact possible to take into account the unobserved heterogeneity across jurisdictions, which could play a crucial role in explaining different performance of cities especially for environmental outcomes[7].

In conclusion, the choice of using only parametric techniques is also supported by the fact that stochastic frontier models give us the possibility of directly including in a single stage the variables that play a role in explaining the efficiency results of cities. On the contrary, in the non-parametric techniques the role played by those variables is analyzed in a two-stage procedure. More in detail, in a first stage it is computed the efficiency score of local governments considering only inputs and outputs, while in a second stage this efficiency result is regressed on variables beyond municipalities' control, typically with a Tobit regression. This two-stage procedure has been object of critique by Simar and Wilson (2007), who demonstrate inconsistency of those estimations given that the data generating process depends on the first stage.

3 How to Measure Output

Compared with the output produced by private firms, the output of local governments is characterized by two main critical issues, as already underlined in the literature (Hatry and Fishm 1992; Wolf, 1989). The first one is the multidimensionality of the goods produced by the public sector: it is not an easy task to tackle such a multidimensionality by defining an output measure that takes into account the quantity and the quality of the many services delivered by local governments.

The second critical point is the measurement of local goods and public services: being produced and exchanged outside the market mechanism, a price for them does not emerge.

Referring to the literature on the issue, output measures are often weak measures that use a number of "crude proxies" for the service output delivered by the municipalities. In fact, a further obstacle in overcoming inadequacy of output measures is the low level of accounting in public administrations and the consequent lack of data. For instance, De Borger and Kersten (1996), with the aim of evaluating the global performance of Belgium municipalities, use as output measures

[7] For example, a city that has more favourable climate conditions or citizens more concerned to environmental issues, takes the advantage of a higher environmental quality, which is not directly linked with the effort put in place by the local government.

the total population for proxying the administrative tasks of local governments, the number of beneficiaries of minimal subsistence grants, the number of students enlisted in local primary schools, the surface of public recreational facilities and finally the fraction of the population older than 65 for proxying the supply of social services to the elderly. Similar output measures are also used in the aforementioned works on local government efficiency. However, as noted by different authors (Dollery and Worthington, 2000; De Borger and Kersten, 1996), such proxies related to the number of service users and to the size of municipalities are input measures and determinants of local government expenditures rather than output measures. In other words, those indicators appear to be not capable explaining the quantity and quality of services delivered by local governments.

To this regard, the choice we made for measuring the environmental quality in the Italian chief towns of Province is represented by the Legambiente Index, and it depends upon some attractive features that this index presents. The main advantages of adopting such a measure are as follows: multidimensional environmental aspects are synthesized in a single measure of environmental quality; it is available yearly for all the main cities; it has a cardinal nature and it is comparable over years. The section that follows helps in understanding better the characteristics of the index and the reasons for choosing it.

3.1 Legambiente Index

Since 1994, Legambiente, an Italian independent association with the mission of preserving and promoting the environment, has published an annual report, “Ecosistema Urbano”, on the environmental quality observed in the 103 Italian chief towns of Province.

The choice of observing these cities depends, firstly, on the fact that those are urban areas where a lot of people live (i.e. one out of three Italian citizens) and where there is a great concentration of economic activities. They certainly have also a crucial role as economic, social and cultural drivers for the neighbouring areas. Therefore, even if they represent only one seventeenth of the Italian territory, it is in these areas that it is registered a core set of environmental problems such as poor air quality, high level of traffic and congestion, noise, poor-quality built environment, derelict land, greenhouse gas emission, urban sprawl, generation of waste and waste-water.

The purpose of Legambiente study is therefore to evaluate, on the basis of some parameters on which we focus later, the quality and the sustainability of the urban environment in order to disseminate knowledge to citizens and policymakers on relevant environmental matters, to stimulate local governments implementing concrete strategies and also to evaluate the effectiveness of the implemented environmental policies.

More in detail, Legambiente ranks 103 cities on the basis of a set of three wide categories of indicators reported in Table 1, which are selected according to the standards and objectives of sustainability identified by the European Union and the OECD.

The first category of indicators refers to the quality of the physical environment registered in the cities, such as air pollution, noise pollution, drinking water quality and rate of mortality for breathing apparatus diseases.

The second category concerns the pressure exercised by human activities on the environment, as, for example, consumption of fuel, electricity, water, motorization rate, waste production and population density.

The third category refers to the policies implemented by municipalities. This set of indicators, in which we find, for example, the level of separate waste collection, the intensity of use of public transports and the urban green space available to citizens, are a proxy of the environmental management ability demonstrated by local policymakers.

Moreover, in this last category it is also considered the monitoring activity of harmful polluters by municipalities: the bottom line is that if a local government cares in monitoring activities it should be able to implement adequate policies since it knows the source of environmental problems.

More in general, the third category represents a measure of the quality of the local government response to environmental challenges and to the citizens' needs, therefore, it is considered particularly important in order to assess what has been done by cities authorities. In fact, the goal of these policies should be to encourage changes in citizens' behavior and consequently they have also a positive impact on the other two types of indicator categories. This last issue is also reflected, as we will see later, in the higher weight given to these indicators in the final ranking.

Table 1: Principal indicators of Legambiente Index for category

Categories of indicators	Most important indicators
Physical environmental quality	Air pollution Noise pollution Drinking water quality Rate of mortality for breathing apparatus diseases
Pressure on environment	Consumption of fuel, electricity and water Motorization rate Waste production Population density
Environmental policies implemented by municipalities	Level of separate waste collection Public transportation services Urban green space Bicycle paths Monitoring activity

3.1.1 The Legambiente Data Sources

In the Italian context, Legambiente report is the first that analyzes and compares the environmental cities' performance.

For some components of the index the data sources are the statistics provided by public and private agencies. For some indicators, however, data is not available, therefore the data, is directly asked to municipalities, which certify the information to be correct. Legambiente has constructed a specific survey with a set of questions for each parameter, but the lack of public data is indicative of the low attention given by local governments to environmental issues and it also represents a problem for the quality of the data. For some indicators, in fact, there is a comparability problem because of different interpretations given by different administrators. In these situations, Legambiente has decided either to give low weight to these indicators or to take them not in consideration. Moreover, sometimes Legambiente has not been able to evaluate some cities because of lack of information given by the cities themselves. Furthermore the quality and availability of data have been improved during the years considered in the present analysis.

3.1.2 The Construction of the Ranking

During the years, the ranking construction has been modified because of learning by doing processes taking place and also because of the availability of more data.

Starting from the index evaluated in 1998[8], that is the initial year we consider in our analysis, three relevant innovations in the ranking construction have been introduced. First of all, the construction of the ranking is oriented to the achievement of a sustainability objective. Namely, the higher score for each indicator is not given, as for the years before 1998, to the city with the best value, but to the city or cities that achieve a value established ex-ante. A threshold is also established ex–ante for the worst value. For each parameter, the sustainability objective is selected either according to national and international standards or following other criteria such as the best value registered in other European cities. Unlike the years before, with the adoption of those thresholds, it is possible that no city is able to achieve the maximum value and consequently to obtain the maximum score assigned for each indicator (i.e. the value of 100), and obviously it is also possible that no city obtains 0. The choice of introducing these thresholds has been due to the aim of reducing the distortions arisen from some anomalous values registered[9].

Secondly, it is introduced a new different weight for each indicator. The weight given to each parameter is now between 0.2 and 1.6. This new system of weights has been defined in a panel with the participation of 20 local governments and resorting also to the Legambiente expertise. More in detail, the indicators considered more relevant in the final ranking are always those referring to the policies implemented by municipalities such as the urban green spaces, the public transport service, the level of separate waste collection and the efficiency of the water purification system implemented.

Finally, for two indicators, the monitoring of polluters and the public transport, it is introduced a different evaluation between big and small cities in order not to penalize the latter. Therefore, the final ranking is now computed as a sum of the single weighted score on the total of the theoretical score, and so is defined between 100 and 0.

After the introduction of this new ranking construction there have been some little adjustments in the number of indicators, that vary during the time between 18 and 26 (see Table 2) and consequently some little adjustments in the indicators weight. However, the major number of parameters depends substantially on a more detailed analysis of the same phenomena. For example, for public transport, starting from the 2003, not only the intensity of use is observed, but also the supply and its environmental impact. As before, the parameters that have major weight on the final ranking are those that represent the municipality response to the environmental challenges. The latter are, in fact, more frequent with respect to the others and are also those with a major weight. It is important to underline in a comparative perspective, that the framework based on the three indicator categories remains always the same for all the years of the analysis. It is possible therefore to use this index, albeit with some caution, to make some comparisons in the cities performance during the years.

Looking at the trend of Legambiente Index between 1998 and 2007, as shown in Figure 1 (referred

[8]Between the year 1994 and the 1997, the ranking construction was based on the weighted average of the score each city obtained for every single parameter. More in detail, the single indicator score was assigned giving 100 points to the city or cities with the best value, and 0 to the worst one. The other cities scores were re-proportioned to these extreme values. The final ranking score was then computed given a different weight to the three categories of indicators.

[9]For example, the high number of passengers that use public transports in Venice is clearly connected with the high number of tourists and not with an incisive local policy on public transport.

to all the cities) and in Figure 2 (referred only to cities included in our sample, which as will be explained in the next paragraph is an unbalanced panel), we observe that mean values remain quite stable over years about 50 points, while the minimum and maximum values are about 30 and 70, respectively. Moreover, it is interesting to notice that the trend of Legambiente Index presents spatial differences. As depicted in Figures 3 and 4, cities placed in the North and Centre of Italy have a Legambiente Index always higher than those of South Italy and Islands.

Table 2: Number of indicators for each category over years

	Legambiente Index									
Categories	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Physical environmental quality	4	5	5	5	5	7	7	5	6	6
Pressure exercised on environment	5	5	6	5	5	5	5	5	5	5
Environmental policies implemented	9	8	9	10	10	14	14	14	15	15
Tot.	18	18	20	20	20	26	26	24	26	26

Figure 1: Legambiente Index between 1998 and 2007, mean, maximum and minimum values

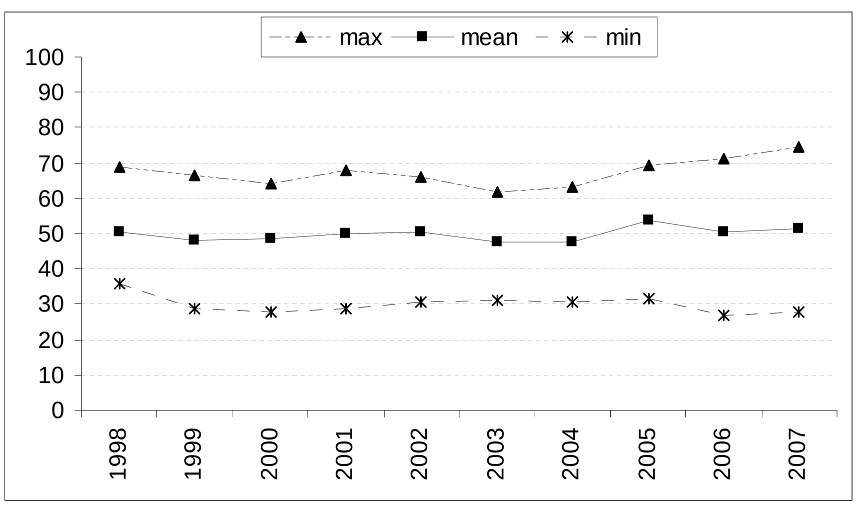


Figure 2: Legambiente Index between 1998 and 2007 referred to our sample of cities

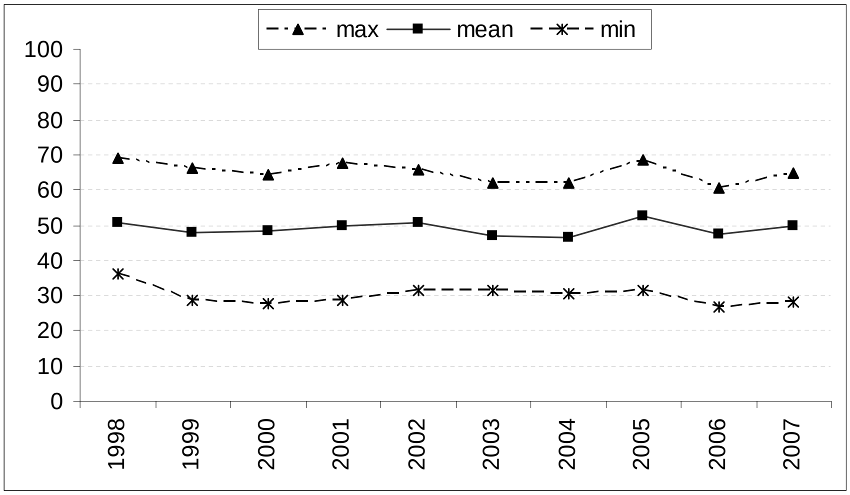


Figure 3: Legambiente Index average values between 1998 and 2007

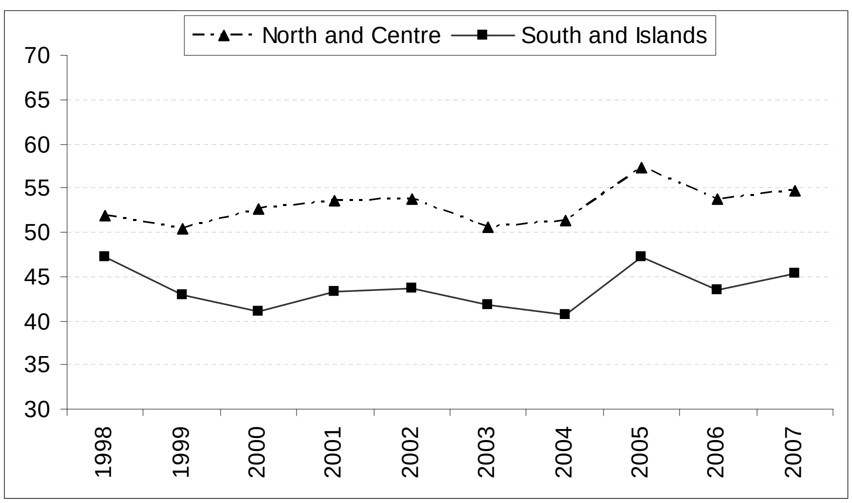
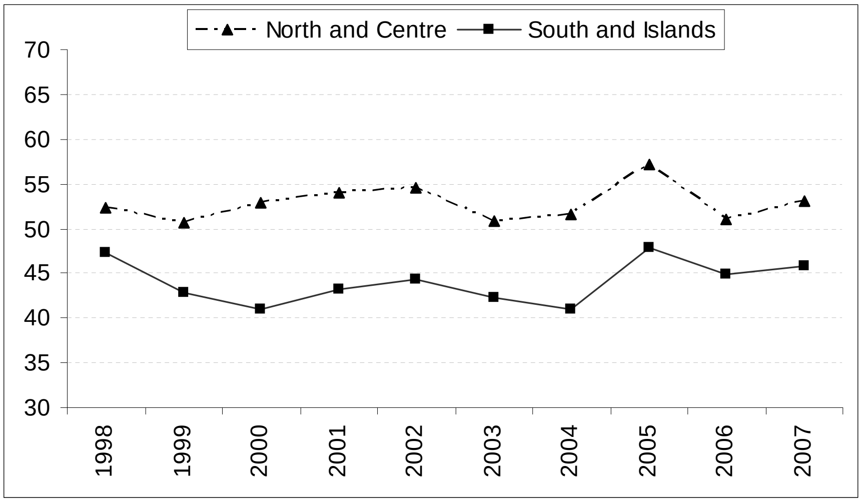


Figure 4: Legambiente Index average values between 1998 and 2007 referred to our sample of cities



4 How to Measure Inputs

The Italian system of local and regional government is based on three tiers: the regions, the provinces and the municipalities. The municipalities do not have a properly own legislative power, since the standard setting instruments adopted by those authorities are subject to regional and state legislation. Though, as the level of government closest to citizens, municipalities are responsible for the organization and provision of a number of specifically local public services. In particular, cities have responsibilities within the environment, social care, local planning, urban renewal, construction, roads and transport, the police, and also for cleaning and maintenance of roads, drains, recreational areas, drinking water, waste water and waste management and disposal.

In order to analyze the efficiency of municipal governments in providing this kind of public services, we have to build a production function based upon productive factors. In De Borger and Kerstens (1996) as well as in the large majority of contributions to the issue[10], the input is measured as the total expenditure of local governments. The reason for choosing such a data is the will to analyze whether such a spending is done efficiently, avoiding to disentangle the amounts of different factors because of the lack of significant data on the components of the total spending.

Further elements supporting the choice of governmental expenditure as input measure in our panel analysis are the fact that municipalities have access to the same capital market where there is a unique price, and the fact that labour force employed by municipalities is under the same collective bargain and thus wages are homogeneous over the considered sample (De-Borger and Kerstens, 1996).

Getting to the specific problem on focus here, we have chosen to consider the per capita expenditure related to environmental services: that is due to our interest in evaluating the efficiency in

[10]For a brief review of input measeruments see Afonso and Fernandes (2008).

providing environmental services, that is to say to analyze the relationship between what has been spent for producing environmental services (i.e., the input) and the resulting environmental quality (i.e., the output).

Furthermore, we consider current expenditure. The reason for not considering capital expenditure is the high volatility of such an expenditure for Italian municipalities: the volatility is typical of the investment choice and it is also due to the relevant impact on investment opportunities of upper level governments which set the political agenda and drive investments of municipalities[11]. Moreover, the current expenditure, which represents on average about the 70% of the total expenditure referring to our sample, is the way through which municipalities provide local services to their citizens.

4.1 Environmental Expenditure

The data on environmental expenditure of Italian municipalities comes from municipal balance sheets collected and certified by the Italian Ministry of Internal Affairs and it is available for the period 1998-2007.

Municipal balance sheets are made of several parts, the one here considered is obviously the one related to the current expenditure for the reasons aforementioned. Nevertheless, even the part related to current expenditure is composed by several categories, spanning from education to local police.

For our purpose, we aggregate the expenditure concerning environmental services. In detail, we consider the category related to traffic and public transportation and the one related to land use and environment management, subtracting to the latter the expenditure for public housing. In other words, we consider the expenditure for services such as the management of waste water, the provision of drinking water, the waste management and disposal, roads and public transportation and urban green space.

Passing to the availability of data for each single municipality of the considered kind, it is worth adding that some of them have been removed from the sample due to such an issue. To be more specific, on a year it can happen that the data of some municipalities is missing. Furthermore, there has been a change in the way by which expenditures for waste management are computed. In particular, a growing number of municipalities has started to apply a tariff scheme rather than a tax. Such a change, shown in Table 3, implies that the expenditure for waste management is not anymore reported in the balance sheet for those cities adopting the tariff scheme. Thus, we remove from the sample the data referred to the municipalities switching to the tariff starting from the moment in which the switch happened, obtaining an unbalanced panel which counts for 779 observations and that for the last year considers just 49 municipalities.

On aggregate, and considering data referred to the sample we use, the new category of expenditure for services of environment and transportation, which as mentioned before are the main responsibility of Italian municipalities, represents the main voice of current expenditure (see Figure 5). Inside the category, expenditure for waste management and disposal weights for about 50%.

[11] Just as an example of the impact of upper level governments on investment choices, consider the European funds available for regions of Southern Italy (Area Objective 1) for upgrading the infrastructure for public transportation.

Table 3: Number of indicators for each category over years

Year	Cities Switch to Tariff	Available Data (over 100)
1998	0	94
1999	2	96
2000	6	93
2001	8	90
2002	12	85
2003	22	76
2004	25	74
2005	32	66
2006	43	56
2007	42	49
Total	192	779

Figure 6 presents spatial differences in the category of expenditure on focus here. Considering that the average per capita expenditure on environment and transportation is about 245 Euro, it seems clear that there is a change about 2005 when municipalities of Southern Italy and Islands have started to spend more than Northern and Central ones.

Besides the recent dynamics in Southern Italy and Islands, the expenditure in the rest of Italy shows a continuously decreasing dynamics since 2001 and that could be due to the outsourcing of some services which has been implemented more on those regions. However, as explained before, the panel we consider copes with such a critical issue by considering only records coming from municipalities where the expenditure for waste management and disposal is still fully recorded in the published balance sheet.

Figure 5: Average current expenditure among categories referred to our sample of cities

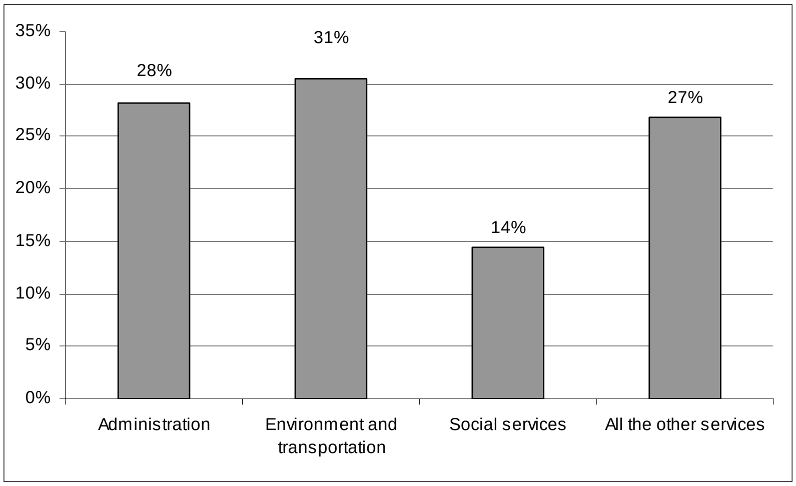
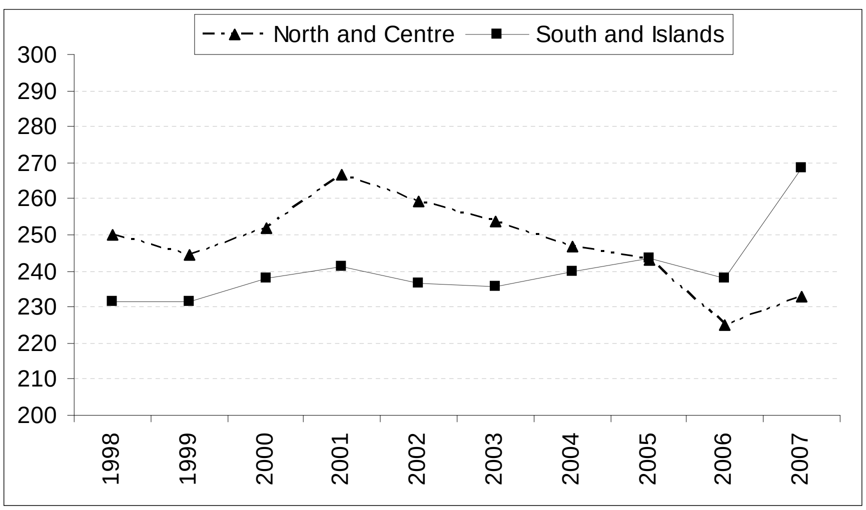


Figure 6: Per capita current environmental expenditure in cities of North and Centre of Italy and in South and Islands ones, between 1998 and 2007. (Euro, base year:1998)



5 Determinants of Environmental Quality

As mentioned before, the aim of this research is not only analysing whether Italian chief towns of Province are efficient in transforming environmental expenditure into environmental quality but also exploring what are the other determinants of environmental quality. Therefore, we also explore what is the role played by socioeconomic variables - typically beyond the control of municipal governments - in explaining different efficiency results. Moreover, we also include some fiscal and political variables in order to verify some hypotheses developed by the literature, that will be explained in more detail below. The descriptive statistics of those variables are reported in Tables 5 and 6.

Among the socioeconomic variables we are interested in, there are those referring to the population composition, i.e. the share of population less than 15 years old and the share of population over 65 years old. The population composition is considered in order to account for a hypothetical different impact on urban environment of those categories of citizens. The underlying idea is that those citizens may have more "virtuous" habits, for instance using more intensively public transportation.

Secondly, it is considered the ratio of graduates over population, and in this case the reason is twofold. In the local government literature this variable is included in order to proxy the political participation of citizens, since the monitoring activity of voters may enhance the performance of a municipality (Hayes, Razzolini and Ross, 1998). The positive impact of this kind of variable on local government efficiency is verified in several works (Vanden Eeckaut, Tulkens and Jamar, 1993; De Borger and Kerstens, 1996; Loikkanen and Susiluoto, 2005; Afonso and Fernandes, 2008). Though, in our case, the educational attainment of citizens may also have an impact on urban quality, for instance, if those "types" of citizens are those more concerned on environmental issues.

With the aim of proxying the monitoring activity of voters it is also included the average per capita income. In fact, in such a literature (De Borger and Kerstens, 1996) the explanation is that citizens with high-income may be less motivated in monitoring municipal expenditures, given the higher opportunity costs, and consequently politicians have more resources to waste. In previous studies (Vanden Eeckaut, Tulkens and Jamar, 1993; De Borger and Kerstens, 1996; Loikkanen and Susiluoto, 2005) the empirical evidence confirms that income negatively impact on local government efficiency, with the only exception of Afonso and Fernandes (2008), which instead show a positive impact. However, in our analysis the negative impact of income on environmental quality may be also explained by the higher level of consumption and consequently by the impact of this latter on urban environmental quality.

Finally, among the socioeconomic variables we also control for different population size, including a set of dummy variables. In fact, our sample of cities varying from nearly 20,000 citizens of Isernia to more than 2.5 millions inhabitants of Rome. With respect to small cities, the large ones are characterized by high rates of commuting, they thus may face congestion problem in the provision of public local services facing higher costs.

Passing to analyze fiscal determinants, we consider two variables: the local property tax rates and the proportion of central grants on municipal total revenue. The reason for considering those variables is because how local services are financed may matter on efficiency. In fact, if the local services are principally provided using citizens' resources this may increase the voters' awareness in controlling local public expenditure (Davis and Hayes, 1993). Therefore we expect that a higher tax rate will have a positive impact on municipal efficiency. In particular, we consider the ICI tax

(Imposta Comunale sugli Immobili) rates[12]: those applied to residential and the other ones applied to business properties. The ICI is an important source of revenue for Italian cities: it represents, on average, nearly 50% of total tax revenues of local governments, and more than 25% of total local government spending. Moreover the local property tax has a higher visibility[13] than other local taxes and it is generally considered by the literature on optimal taxation a good local tax, since it should provide a visible and accurate signal to the electorate of the cost of public services (Oates, 1999).

On the other hand, if instead the local services are financed using grants given by upper level governments, the incentive of voters to monitor municipal efficiency is lower, since the cost of an inefficient expenditure is shared by a broader constituency (Silkman and Young, 1982). Therefore the prediction of the literature is that central government grants should have a negative impact on efficiency. It is particularly interesting verifying this prediction in our sample of cities. For them in fact the central grants represent an important source of revenue, nearly 16% on average with an important spatial difference between cities of the North and Centre of Italy (14%), and South and Islands (21%).

Finally, following the principal-agent literature a less fragmented government should be able to exercise more control on public administration getting a more efficient expenditure (Mueller, 2003; Bartel and Schneider, 1991). Therefore, among the political variables, we consider a dummy variable that is equal to 1 if the mayor gets elected with more than 50% of votes. In the Italian electoral system if no one mayor candidate gets more than 50% of votes at the first stage, the two most voted ones run again at the second ballot to determine the final winner, and between the two rounds of voting, the parties supporting candidates which did not arrive at the second round could make an explicit agreement with one of the two surviving candidates[14]. Therefore, if a mayor is elected at the second stage it is more likely that a political bargaining process takes place with a hypothetical negative impact on efficiency. Then, in order to verify if also the political affiliation of the mayor matters on efficiency we also include a political dummy that is equal to 1 if a center-left mayor is in power.

Furthermore, with respect to other studies on the determinants of local government efficiency, since we can exploit the panel dimension of our data, we also test if the environmental quality follows an electoral cycle, that is if the year before the election politicians put in place a greater effort in the attempt of getting re-elected. Finally, we also have the possibility of verifying the effect of a binding term on efficiency. In Italy, in fact, a mayor cannot run for office more than two terms in a row. The effect of the term limit on the accountability of governors and consequently on voters' welfare has been principally studied by the political agency literature (Besley and Case, 1995). Following this literature, politicians who care to run again for office have to construct a good reputation, that is they may act in the interest of voters to merit re-election. The main prediction of these reputation-building models is that a binding term limit should have implications for policy choices (Besley and Case, 1995). In this framework, the mayor facing a binding term limit has lower incentives in acting

[12] In 1993, it was introduced the ICI local property tax. The property tax base is uniformly defined by the national government, while municipalities have the power to set the property tax rates in a range between 0.4 and 0.7 percentage points (with some exceptions). Moreover cities could also set different tax rates: the domestic tax rate (Aliquota Principale) is applied on resident household owners and it is generally also accompanied by a lump sum deduction, while the business tax rate (Aliquota Ordinaria) is applied on all other kind of properties.

[13] This is especially true in the Italian case, where a high portion of the population is home-owner and where the high visibility of the ICI is also guaranteed by the fact that, yearly, the taxpayer receives the information about the whole amount that must be paid and makes an explicit payment.

[14] For an analysis of the consequences of a dual ballot system on the policies implemented by Italian municipalities see Bordignon and Tabellini (2009).

in the interest of voters, since she cannot be re-elected, and this will be translated into lower effort put in place in her last term[15]. If this prediction is true we should expect that a mayor facing a second term is less efficient. In the model of Smart and Sturm (2004), on the contrary, the presence of a binding term, under some circumstances, could increase the welfare of voters. More in details, the authors argue that the term limit, reducing the value of holding office, it may create an incentive for the politicians to implement their preferred policies just in their first term. The term limit has, in this sense, a so called "truthfulness effect". In this setting, therefore, the past policy choices become a better indicator of the true preferences of the incumbent, and consequently it is easier for the voters to punish rent-seeking incumbents. The authors refer to this as the "selection effect" of term limit. Therefore, if the selection effect mechanism of elections works we should expect a positive impact on efficiency.

Table 4: Descriptive statistics of output and input variables

		Output and Input variables				
Variables		Mean	Std. Dev.	Min	Max	Observations
Legambiente	overall	49.02	8.20	26.93	69.00	N = 779
Index	between		6.76	35.08	62.92	n = 99
	within		4.62	34.01	62.43	T-bar = 7.86
Environmental	overall	245.54	65.90	118.66	719.89	N = 779
expenditure	between		62.20	153.41	590.25	n = 99
per capita	within		30.74	125.81	394.12	T-bar = 7.86

Table 5: Descriptive statistics of socioeconomic variables

		Socio-economic variables				
Variables		Mean	Std. Dev.	Min	Max	Observations
% pop <15	overall	13.02	2.16	8.66	20.10	N = 779
	between		2.12	8.96	18.53	n = 99
	within		0.49	11.60	14.59	T-bar = 7.86
% pop >65	overall	20.31	3.63	11.28	28.80	N = 779
	between		3.41	12.86	27.96	n = 99
	within		0.88	17.79	22.90	T-bar = 7.86
%Graduates/pop	Census, 2001	11.28	2.60	5.77	18.04	n=99
Per capita income	Census, 2001	20,783	4,021	13,112	32,060	n=99

[15] Obviously, this result may be mitigated by some factors such as a strong party control, since this latter has a longer horizon with respect to the incumbent, or by the possibility for the incumbent to run for further political offices. These two elements are particularly important in the Italian context, where it is often the case that the chief towns of Province mayors have a longer political life.

Table 6: Descriptive statistics for fiscal and political variables

		Fiscal and political variables (source Ministry of Internal Affairs)				
		Mean	Std. Dev.	Min	Max	Observations
Local property tax rates:						
ICI domestic rate	overall	5.03	0.66	3.20	7.00	N = 779
	between		0.55	3.69	6.50	n = 99
	within		0.34	3.67	7.41	T-bar = 7.86
ICI business rate	overall	6.28	0.73	4.00	7.00	N = 779
	between		0.62	4.00	7.00	n = 99
	within		0.43	4.78	8.12	T-bar = 7.86
Election year	overall	0.25	0.43	0.00	1.00	N = 779
(the year before elections)	between		0.08	0.00	0.50	n = 99
	within		0.43	-0.25	1.12	T-bar = 7.86
Center-left dummy	overall	0.56	0.50	0.00	1.00	N = 779
	between		0.40	0.00	1.00	n = 99
	within		0.30	-0.34	1.46	T-bar = 7.86
Mayor facing	overall	0.39	0.49	0.00	1.00	N = 779
a binding term	between		0.28	0.00	1.00	n = 99
	within		0.42	-0.47	1.29	T-bar = 7.86
Mayor obtaining	overall	0.52	0.50	0.00	1.00	N = 779
more than 50% of votes	between		0.39	0.00	1.00	n = 99
	within		0.34	-0.38	1.42	T-bar = 7.86

6 Empirical Model

We now present the several models we use to estimate the production function and the efficiency results for our sample of cities. As mentioned before, we here refer only to the parametric approaches.

To summarize the empirical data, we recall to the reader that models are used to estimate a production function using the Legambiente index as the output measure and the per capita environmental expenditure as the input one. Moreover, besides our input measure, we also consider the role played by other socio-economic, political and fiscal variables (presented in the preceding paragraph) in explaining the environmental performance of different cities. In fact, the environmental quality registered in cities depends not only on the policies implemented by local governments but also on some other characteristics which are typical of each jurisdiction and that could vary over time. In order to make the point clearer an example could be helpful: the grade to which citizens care about environmental issues, and consequently their life habits, may be relevant in explaining urban quality. It is the same for the geographical location of a city or its weather conditions, etc.. It is worth adding that, in a stochastic frontier framework, the fact of not considering those variables implies assuming that all municipalities share the same production function and thus face similar environmental conditions.

Therefore, aiming in the present work at dealing with 'background' variables[16] and at checking

[16]In the efficiency literature the variables, which influence the level of production and could explain different

for the robustness of results, we consider different stochastic models (see Table 7), which principally differ because of the assumptions on the non negative term representing technical inefficiency.

In particular, we use a twofold strategy in order to consider the role played by those variables. We use a single stage procedure[17] in two variants: we incorporate the background variables as regressors directly into the non-stochastic component of the production frontier or indirectly in the stochastic component of the error term (Battese and Coelli, 1995). In the first case, when those variables are included as regressors, we assume that the 'environmental' variables directly influence the shape of the technology and consequently the level of production. On the contrary, in the other case we assume that those variables influence the degree of technical efficiency, and thus they are, in other words, drivers of inefficiency.

More in detail, the models which directly include the 'environmental' variables as regressor have the following production function specification:

$$y_{it} = \beta x_{it} + z'_{i(t)}\gamma + p'_{it}\theta + \lambda_t + R_j + \varepsilon_{it} \tag{3}$$

where y_{it} is the log of the Legambiente index and $x_{it}$is the log of the per capita environmental expenditure. Then, we include in the production function the socioeconomic variables, $z_{i(t)}$, and the fiscal and political variables, p_{it}, all in logs. The reason for using the log of such variables is the assumption of the simplest functional form available: the Cobb-Douglas one. Finally, we also include a time effect λ_t that allows for a uniform influence of shocks, a dummy variable that equals 1 if cities are in the North or Centre of Italy, and a set of Regional dummies with the aim of capturing the unobserved heterogeneity of cities placed in different areas[18].

The composite error term in Eq. (3) has the following structure:

$$\varepsilon_{it} = v_{it} - u_{i(t)} \tag{4}$$

v_{it} is the conventional random noise and $u_{i(t)}$ is a non-negative random variable representing technical inefficiency in production, e.g. the inability of a municipality to reach the maximum level of output given the input and the different environmental conditions.

The production function in Eq. (3) is estimated using three different stochastic frontier models (see Table 7 for the econometric specification of them). The frontier models here considered principally differ both for the assumptions on the distribution of $u_{i(t)}$ and for considering the inefficiency component time-invariant.

Referring to Table 7, more in detail, Model 1 (a) is a pooled frontier model estimated by the maximum likelihood method proposed by Aigner *et al.* (1977). In this specification, the panel nature of the data is ignored and the model relies on two tight assumptions: the u_{it}s and the v_{it}s are indipendently and identically distributed, and the non-negative random variable, u_{it}, follows a half-normal distribution with zero mean and variance σ_u^2. An important shortcoming due to the assumption of a half-normal ditribution is that the mode is at zero implying that most inefficiency

efficiency results, are typically called 'background' or 'environmental' variables

[17]In the efficiency literature, the other way followed to deal with observable "environmental" or exogenous variables is a two-stage approach. In the first stage only output and inputs are included in the production function, while in the second stage the obtained efficiency results are regressed on environmental variables. However, that metod leads to biased results if the variables considered in the second stage are not orthogonal with the explanatory variables included in the first one (Wang and Schimdt, 2002). In the literature on local government efficiency this latter approach is the one mainly exploited.

[18]In the Italian context each Region contains a few chief towns of Province. To be more specific, the considered 100 chief town of Province are grouped in 18 Regions.

effects are in the neighbourhood of zero and that the associated measure of technical efficiency would be in the neighbourhood of one (Coelli *et al.*, 2005). Therefore, model 1 (b) (Stevenson, 1980) extends the previous one to a truncated normal model by allowing the mean of u_{it} to be nonzero. Such a variation in the distribution of $u_{i(t)}$ is cloned also in Model 2 and 3

The other two models exploit the cross and longitudinal dimension of the data. Model 2 is a random effects frontier model estimated using the maximum likelihood technique. In Model 2 (b) the inefficiency component, u_i, is assumed to be time invariant and following a truncated normal distribution. Moreover, as in the classical linear random effects model, the composite error term has to be uncorrelated with the regressors. Considering the peculiarities of our sample the time-invarying assumption could be questionable either because we have a long panel (ten years) or because the mayors, of whom we are interested in measuring the performance, change over time. Nevertheless, it is interesting comparing its results with those of Model 3 (Battese and Coelli, 1992), which allows time-varying technical inefficiency. In particular, the inefficiency term, u_{it}, is modeled as a half normal (a) or truncated-normal random variable (b), multiplied by a specific function of time, which takes the form:

$$u_{it} = (u_i \exp(-\eta(t - T_i))) \tag{5}$$

where η is an unknown parameter to be estimated, t is the current year and T_i is the terminal year. Since $t = T_i$ in the last period, the last period for municipality i contains the base level of inefficiency for that municipality. Therefore, when η is greater than zero it means that the inefficiency is decreasing with time and viceversa. On the contrary, if η is not significantly different from zero the more appropriate specification is the time-invariant one. Clearly a limitation of this specification is that it imposes a time trend that is equal for all the municipalities, and consequently a city that is ranked n-th at the first time period keeps its ranking over time[19].

The other typology of stochastic frontier models useful in understanding what are the determinants of inefficiency has been proposed by Battese and Coelli (1995). Following those authors, we propose an alternative production function with the following specification:

$$\begin{aligned} y_{it} &= \beta x_{it} + z'_{i(t)}\gamma + \lambda_t + R_i + v_{it} - u_{it} \\ u_{it} &\backsim N^{+}(m_{it}, \sigma_u^2) \\ m_{it} &= p'_{it}\theta \end{aligned} \tag{6}$$

In this formulation we directly include as regressors only the socio-economic variables $z_{i(t)}$, and the difference from Eq. (3) is the inefficiency effect term, u_{it}, here defined as explicit function of some observable municipal-specific factors, the political and fiscal variables p_{it}, which vary over time. More in detail, in this panel data frontier model (Model 4 in Table 7) the non-negative technical inefficiency term, u_{it}, is assumed to follow a truncated normal distribution with different means for each municipality, depending on the observable variables included. Therefore the inefficiency effects, as before, are assumed to be independently but not identically distributed.

Modeled in this way the fiscal and political variables, p_{it}, are interpreted as determinants of inefficiency because they directly explain the inefficiency results of municipalities, e.g. the distance

[19] There are other models which allow more flexible time-varying structures. Among these Cornwell, Schmidt and Sickles (1990) and Cuesta (2000). The Battese and Coelli (1992) specification has been chosen because it is the most exploited and referred in the efficiency literature and because it can be used as a good benchmark.

from the frontier. On the contrary, in the other specification (Eq. (3)) the effects of those variables determine the position of the frontier. To be clearer, if for instance center-left mayors are able to get a better environmental quality, in the specification of Eq. (3) this means that the frontier for those municipalities is shifted above, while in the other specification (Eq. (6)) they remain exactly the same but their distance from the frontier is reduced.

In the next paragraph we estimate Eq. (6) in two variants. In one specification the logs of the ICI tax rates are directly included as regressors, while in the other one those variables are considered as determinants of inefficiency and consequently included in the mean of the distribution of the inefficiency error component. The reason for this choice is that the ICI tax rates could also be considered as input variables rather than determinants of inefficiency. In fact, the level of those two local tax rates are set every single year by the mayor. Therefore, it is disputable the exogeneity of those variables, given that the imposed rates relevantly impact on the level of resources at disposal of the municipality.

To conclude, it is worth underlying that the two production function specifications, those of Eq. (3) and Eq. (6), are two competitive and not nested formulations. Moreover, in the efficiency literature it remains an open issue how these 'background' variables enter the model. The selection criterion followed by some authors is to compare the results of different models (Greene, 2004; Coelli, Perelman and Romano, 1999). In the next section, for each of the aforementioned models we present and discuss coefficient results. Furthermore, we also estimate and compare technical efficiency values reached by municipalities. We remind the reader that the technical efficiency is computed as in Eq. (2), and it gives us a measure of how distant a municipality is from the optimal level of output, i.e. the frontier.

Table 7: Econometric specification of the included models

Models		Inefficiency component $u_{i(t)}$	Random error ε_{it}
Model 1 Pooled frontier	(a)	$u_{it} \backsim iid\ N^{+}(0, \sigma_u^2)$ Aigner et al. (1977)	$\varepsilon_{it} = v_{it} - u_{it}$ $v_{it} \backsim iid\ N(0, \sigma_v^2)$ $u_{it} \backsim iid\ N^{+}(0, \sigma_u^2)$
	(b)	$u_{it} \backsim iid\ N^{+}(\mu, \sigma_u^2)$ Stevenson (1980)	$\varepsilon_{it} = v_{it} - u_{it}$ $v_{it} \backsim iid\ N(0, \sigma_v^2)$ $u_{it} \backsim iid\ N^{+}(\mu, \sigma_u^2)$
Model 2 Random Effects Frontier Time Invariant	(a)	$u_i \backsim iid\ N^{+}(0, \sigma_u^2)$ Pitt and Lee (1981)	$\varepsilon_{it} = v_{it} - u_i$ $v_{it} \backsim iid\ N(0, \sigma_v^2)$ $u_i \backsim iid\ N^{+}(0, \sigma_u^2)$
	(b)	$u_i \backsim iid\ N^{+}(\mu, \sigma_u^2)$ Battese, et al. (1989)	$\varepsilon_{it} = v_{it} - u_i$ $v_{it} \backsim iid\ N(0, \sigma_v^2)$ $u_i \backsim iid\ N^{+}(\mu, \sigma_u^2)$
Model 3 Random Effects Frontier Time Varying	(a)	$u_{it} = (u_i \exp(-\eta(t-T)))$	$\varepsilon_{it} = v_{it} - u_{it}$ $v_{it} \backsim iid\ N(0, \sigma_v^2)$ $u_i \backsim iid\ N^{+}(0, \sigma_u^2)$
	(b)	$u_{it} = (u_i \exp(-\eta(t-T)))$ (Battese and Coelli, 1992)	$\varepsilon_{it} = v_{it} - u_{it}$ $v_{it} \backsim iid\ N(0, \sigma_v^2)$ $u_i \backsim iid\ N^{+}(\mu, \sigma_u^2)$
Model 4 Battese and Coelli (1995) Background variables in u_{it}		$u_{it} \backsim N^{+}(m_{it}, \sigma_u^2)$ $m_{it} = p'_{it}\delta$	$\varepsilon_{it} = v_{it} - u_{it}$ $v_{it} \backsim iid\ N(0, \sigma_v^2)$ $u_{it} \backsim N^{+}(m_{it}, \sigma_u^2)$

7 Results

7.1 Benchmark: Linear and Log-linear Models

Before presenting the results of the stochastic frontier models[20], in Tables 8 and 9 are reported, as an useful benchmark, the estimates obtained by regression models that ignore the inefficiency component and consequently assume a linear (or log-linear) relationship among variables. More in detail, column (a) contains the estimates of the pooled least squares model, and column (b) and (c) the random effects and the fixed effects models, respectively.

It is interesting to notice that the expenditure has a significant but very low impact on urban environmental quality, especially in the linear models. In fact, an increase, for instance, of 100 euro on the per capita environmental expenditure - reminding that the average per capita expenditure is about 250 euro - determines an increase on the Legambiente index of only 0.01 points. We observe, instead, that in log-linear models that impact is higher, since an increase by ten percentage points of per capita expenditure determines an improvement in Legambiente Index of one percentage point.

More interesting, the variables that explain the Legambiente Index are the political ones, e.g. the political affiliation of mayors, mayors subject to a binding term and mayors which get more than 50% of votes. For instance, in the linear models a mayor at his second term increases the

[20] All the stochastic frontier models are estimated by the maximum-likelihood method using FRONTIER 4.1 (Coelli 1996).

Legambiente Index of more than 1 point, and in the log-linear models that increase is about 3 percentage points. However, the fact that the expenditure is not the main determinant of local government performance it is not so surprising. It has just been verified by the empirical literature that higher public spending levels do not imply better performances. To this regard, Revelli (2010) found that British local governments with public expenditure in excess of centrally set standards get worst performance results. In other words, spending more could imply wasting resources.

7.2 Stochastic Models: Pooled Frontiers

The stochastic pooled frontier model, which estimates equation (3) is made by two variants: in (a) u_{it} is assumed with a half normal distribution, in (b) such a distribution is truncated normal. The estimated results are reported in Table 10.

Looking at the estimated values, and in particular at parameter μ, the hypothesis that the half normal model is the adequate one is not rejected, being in fact μ not significant. Further elements supporting the rejection of the variant based upon the truncated normal distribution of u_{it} , are that the Log likelihood values and the estimated coefficients. Log likelihood values are the same and all estimated coefficients are quite similar, keeping the same level of significance and the same value over the two variants. Being model (b) a nested one, model (a) is thus the one that should be preferred.

Among the included regressors, the significant ones are the per capita environmental expenditure, all the socio-economic variables, the Ici residential tax rate and among the political variables, mayors supported by a large majority, those affiliated to center-left coalition and finally those subject to a binding term. It is interesting to notice that the per capita environmental expenditure has a lower impact on Legambiente Index than in log-linear models and this result could be explained by the inefficient usage municipalities make of public spending.

Furthermore, the result of the likelihood ratio test of σ_u^2 equal to zero confirms the presence of technical inefficiency. Looking at the different levels of inefficiency, the γ parameter, that is the ratio between the variance of the inefficiency term, σ_u^2, and the sum of the total variance, $\sigma_v^2 + \sigma_u^2$, shows that about 95% of the variation of the output, among the sampled municipalities, is due to differences in their technical inefficiencies.

As shown in Table 14, the mean value of technical efficiency estimated by the model is 0.87.

7.3 Stochastic Models: Random Effects Time Invariant

As before also the stochastic random effects frontier model, reported in Table 11, is estimated assuming two different inefficiency distributions: the half-normal in column (a) and the truncated normal in column (b). Differently from the pooled model, in this one the μ parameter is significant, and this suggests that the preferred specification is the second one, even if the Loglikelihood of the two specifications is quite similar.

Analysing the estimated coefficients of specification (b) we observe that the significant variables are the per capita environmental expenditure, all the socio-economic variables, the Ici residential tax rate and, among the political variables, the center-left mayors and the dummy representing mayors facing a binding term.

Moreover, in this model the variation of output due to inefficiency is lower than in Model 1. The inefficiency explains about 76% of the output variations among municipalities, while the average technical efficiency estimated, that we remember in this model is time invariant, is higher, about 0.93.

7.4 Stochastic Models: Random Effects Time Varying

Getting to the time varying random effects models, that is Model 3 reported in Table 12, we have as before the two specifications, (a) and (b), for the distribution of the inefficiency term. We observe that also in this case the truncated normal distribution is the preferred one and more interesting the η parameter is negative and significant even if at a lower level**.** This means that the inefficiency, which in this model is assumed having a common path for all the sampled municipalities, is increasing over time.

Among the included regressors significant variables are the per capita environmental expenditure, all the socio-economic variables, dummies of mayors affiliated to center-left parties and those subject to a binding term. Moreover the estimated coefficient for the ICI (residential rate) is significant in specification (b) but not in the other one. The percentage of variation in the output due to inefficiency is 83%, and the average technical efficiency is identical to Model 2, and it is equal to 0.93.

7.5 Stochastic Models: Battese and Coelli (1995)

The last frontier technique here considered, the Battese and Coelli (1995) model, estimates equation (6). The estimate results are reported in Table 13. We present two variants of this model. In column (a) the logs of the ICI tax rates are directly included as regressors, while in column (b) those variables, non logged, are considered as determinants of inefficiency and consequently included in the mean of the inefficiency error component. Looking to Loglikelihood values, model (a) seems to be the preferred one.

Analysing the estimated results of specification (a), the included regressors which are significant are the per capita environmental expenditure, all the socio-economic variables and the residential Ici tax rate. Among the determinants of inefficiency we observe that all the political variables included but the election year dummy significantly reduce the mean of the inefficiency error term and consequently their sign is negative. It is important to stress that in this particular model a negative coefficient means an increase in efficiency.

Looking at Table 14, it is interesting to observe that the estimated technical efficiencies are equal to those of the pooled models.

8 Discussion

Considering the set of econometric models exploited throughout the paper we can point out the analytical results which are robust in all specifications.

Besides the environmental current expenditure - our input measure, which positively impacts on environmental quality -, it is interesting analysing the role played by the other variables included in the production function.

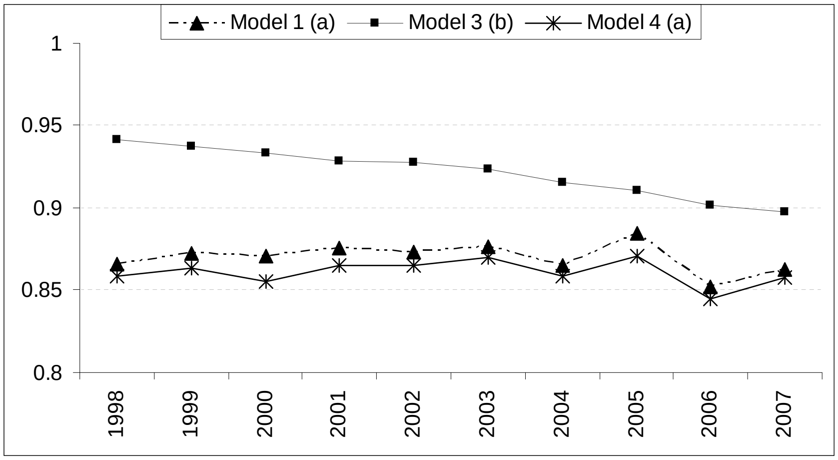
In particular, among the socioeconomic variables considered, the population composition (e.g. the share of population less than 15 years old and the share of population more than 65 years old) positively impacts the Legambiente index and, furthermore, that impact is quite similar in all frontier models. Then, as predicted by the literature and demonstrated in the aforementioned empirical works, the ratio of graduates over population has a positive effect while the average per capita income has a negative one. Nevertheless, it is worth underlining that we cannot discern if those effects are explained by citizens' habits rather than by their monitoring activity as voters. Finally, the population size of cities negatively affects the urban environmental quality: cities with more than 250,000 inhabitants present worse environmental performances than the others. One possible explanation of that result is that the advantages of exploiting scale economies are probably overcame by congestion problems.

Looking at the included fiscal variables, the only variable which in the majority of models positively affects the efficiency is the local property tax rate applied to residential properties. The fact that only this tax rate is significant it is consistent with the prediction of the literature (e.g. a high tax rate may increase the voters' awareness in controlling local public expenditure, Davis and Hayes, 1992). In chief towns of Province with respect to little towns, in fact, it is more likely that business owners are not voters in those municipalities. Moreover, the ratio of central grants on total municipal revenue has the sign which we expected, but it is not significant.

An interesting result is the positive impact on environmental quality of mayors facing a binding term. That result confirms the prediction of the model proposed by Smart and Sturm (2004), that is the term limit may have a "truthfulness" effect, and therefore at the second term it is more likely that "good" incumbents got re-elected. Moreover, also the political affiliation of mayor affects the efficiency: a center-left mayor gets a better environmental performance. The impact of the political affiliation on efficiency is also demonstrated by De Borger and Kerstens (1996), who find a positive effect of socialist parties. Furthermore, another remarkable result is the positive impact on performance of mayors elected with more than 50% of votes, which confirms that bargaining process negatively affect efficiency. Instead, evidence is not found in favour of electoral cycles of performance. In fact, the electoral year dummy we include has the expected sign, but it is not significant.

Finally, looking at results of inefficiency we notice that in all the models the variation of the output, among municipalities is due to differences in their technical inefficiencies. However the fourth models estimate different values of technical efficiency: as shown in the efficiency literature different models lead to different results (Geys and Moesen, 2009; De Borger and Kerstens, 1996). In particular, as reported in Table 14, we observe that pooled models and the Battese and Coelli (1995) ones present similar efficiency values as the two random effects models do. And more in detail, among the two couples of models obtaining similar results, the ones obtained in Random effects models are higher. Such issues are clearer looking at Table 15, where it is reported the technical efficiency correlation matrix. Furthermore, if we look at the dynamics of efficiency over time, presented in Figure 7, the similarity between the two models are clear and their resulting dynamics is oscillating around a stable mean, while the time varying random effects model shows a decreasing trend.

Figure 7: Technical efficiency over years



9 Concluding Remarks

In this work we have analyzed the extent to which Italian municipal governments are actually able to affect the environmental quality outcome, and to what extent the observed gross environmental performance is determined by external circumstances over which local governments have no control. Indeed, our aim has been exploring the determinants of municipalities' environmental performance in the period between 1998 and 2007, in order to estimate the degree of efficiency of the Italian chief towns of Province in providing environmental urban services.

To this regard, using stochastic frontier techniques, we have estimated different production function specifications exploiting the Legambiente Index as qualitative measure of the output and the current per capita environmental expenditure as input measure. The use of Legambiente Index to proxy environmental quality represents an innovation with respect to the other works studying municipal efficiency. In fact, most of that literature suffers from the well-known lack of adequate measures of local government output and performance, and uses a number of "crude proxies" for the service output delivered by the municipalities. Moreover it has been also considered the role played by other socio-economic, fiscal and political variables in explaining the environmental quality registered.

The interesting results to highlight are the following. Firstly, the expenditure has a significant but very low impact on urban environmental quality and that result confirms that public spending is not the main determinant of local government performance. Indeed, besides the socio-economic variables, the variables which explain different environmental municipalities' performance are the fiscal and political ones. The picture that emerges is that the electoral mechanism seems to work in the correct way. The term limit design is able to improve the selection mechanism. In fact, we found that mayors who got re-elected are those more efficient. Moreover, also mayors elected with more than 50% of votes are efficient too, and this result suggests that political bargaining processes have a negative impact on efficiency. Furthermore also the ideology of mayors seems to matter for efficiency. In fact, we found that center-left affiliated mayors are those able to get better environmental performance. To this regard our suggestion is that it would be extremely interesting to verify if political affiliation matters referring to other municipal policies, since the supply of environmental policies could be influenced by voters' preferences. Finally, more accountable and efficient municipalities are those which set higher local property tax rate, in particular the Ici tax rate on residential dwellings (*Aliquota Principale*), which has the advantage of having a higher visibility. Therefore, in this empirical analysis it is verified the link between fiscal autonomy of local governments and efficiency. To conclude that result suggests that giving an autonomous power to municipalities means gaining in accountability and consequently in efficiency of local governments.

Although this analysis has not shown a clear tendency of a decreasing level of efficiency of municipalities in providing urban environmental quality over time, such a problematic dynamics can be foreseen in the near future. That is not due to the more restrictive bounds imposed by central government on municipalities' expenditure on every year because of the high level of national public debt. As demonstrated in this work, public expenditure is not the main determinant of efficiency. The reason suggesting a likely decreasing tendency in efficiency is the abolition of the ICI on residential dwellings decided by the central government in the year 2008: in this work in fact ICI emerged as the most important fiscal instrument guaranteeing accountability of municipalities.

Table 8: Linear model estimates

Variables	(a) ols	(b) re	(c) fe
Per capita Current	0.0082*	0.0126***	0.0177***
Environmental Expenditure (100 Euro)	(0.005)	(0.005)	(0.006)
% pop>65 years old	1.1760***	0.8497**	-0.3830
	(0.314)	(0.345)	(0.948)
% pop<15 years old	0.9927**	0.6918	0.5344
	(0.432)	(0.475)	(0.583)
% Graduates/Population	0.5128***	0.5283***	
	(0.192)	(0.201)	
Log of per capita income	-9.6523**	-10.4514**	
	(4.243)	(4.070)	
ICI - Residential Rate	1.0561**	0.6891	0.3260
	(0.472)	(0.456)	(0.557)
ICI - Business Rate	0.5241	-0.0022	-0.4165
	(0.582)	(0.459)	(0.557)
% Central Grants/Total Revenue	-0.0005	0.0001	-0.0002
	(0.002)	(0.001)	(0.001)
Mayor elected with more than 50%	1.2222*	0.8671*	0.9741*
	(0.637)	(0.509)	(0.553)
Election Year Dummy	0.3852	0.4570	0.4542
	(0.348)	(0.329)	(0.324)
Center-Left Dummy	2.6786***	1.9244***	1.6230**
	(0.699)	(0.564)	(0.631)
Mayor Facing a Binding Term	1.5139***	1.3290***	1.0764**
	(0.518)	(0.478)	(0.483)
North-Centre of Italy Dummy	1.0260	1.7900	
	(2.537)	(2.617)	
Year effects	yes	yes	yes
Prob > F	0.0000	0.0000	
Regional dummies	yes	yes	no
Prob > F	0.0000	0.0000	0.0000
Population dummies	yes	yes	yes
Prob > F	0.1020	0.0583	0.0000
Constant	87.4878**	108.9171***	35.2745
	(42.794)	(40.306)	(22.910)
N	779	779	779
adj. R-sq	0.575		0.181

Standard errors robust to cross-section and time-series heteroskedasticity are in parenthesis, * p<0.10, ** p<0.05, ***p<0.01.

The included population dummies are four: Pop<60,000; Pop60,000-100,000; Pop 100,000-250,000; Pop>250,000. Those dummies are time-varying since over years some cities pass from one category to another.

Table 9: Log-linear model estimates

Variables	(a) ols	(b) re	(c) fe
Log of per capita Current	0.0434	0.0652**	0.0963**
Environmental Expenditure	(0.028)	(0.028)	(0.038)
Log of pop>65 years old	0.4516***	0.3498**	-0.0522
	(0.143)	(0.146)	(0.375)
Log of pop<15 years old/total population	0.2675*	0.2233	0.1522
	(0.145)	(0.149)	(0.206)
Log of Graduates/Population	0.1522***	0.1536***	
	(0.053)	(0.055)	
Log of per capita income	-0.2386**	-0.2475***	
	(0.094)	(0.092)	
Log of ICI - Residential Rate	0.1144**	0.0641	0.0122
	(0.047)	(0.049)	(0.061)
Log of ICI - Business Rate	0.0741	0.0134	-0.0415
	(0.070)	(0.056)	(0.069)
Log of Central Grants/Total Revenue	0.0103	0.0062	0.0062
	(0.010)	(0.008)	(0.008)
Mayor elected with more than 50%	0.0307**	0.0190*	0.0197*
	(0.015)	(0.011)	(0.011)
Election Year Dummy	0.0091	0.0104	0.0105
	(0.008)	(0.007)	(0.007)
Center-Left Dummy	0.0521***	0.0390***	0.0330**
	(0.016)	(0.013)	(0.014)
Mayor Facing a Binding Term	0.0310***	0.0271***	0.0220**
	(0.011)	(0.010)	(0.010)
North-Centre of Italy Dummy	0.0453	0.0524	
	(0.051)	(0.049)	
Year effects	yes	yes	yes
Prob > F	0.0000	0.0000	0.0000
Regional dummies	yes	yes	no
Prob > F	0.0000	0.0000	0.0000
Population dummies	yes	yes	yes
Prob > F	0.1219	0.1051	0.0000
Constant	2.6335**	2.5176**	-1.1887
	(1.205)	(1.220)	(0.988)
N	779	779	779
adj. R-sq	0.561		0.159

Standard errors robust to cross-section and time-series heteroskedasticity are in parenthesis, * p<0.10, ** p<0.05, ***p<0.01.

The included population dummies are four: Pop<60,000; Pop60,000-100,000; Pop 100,000-250,000; Pop>250,000. Those dummies are time-varying since over years some cities pass from one category to another.

Table 10: Pooled frontier estimates

	Model 1	
Variables:	(a)	(b)
Log of per capita Current	0.0278*	0.0282*
Environmental Expenditure	(0.017)	(0.017)
Log of pop>65 years old	0.4198***	0.4143***
	(0.07)	(0.07)
Log of pop<15 years old/total population	0.2095***	0.1996***
	(0.078)	(0.078)
Log of Graduates/Population	0.1196***	0.1214***
	(0.027)	(0.027)
Log of per capita income	-0.2042***	-0.2064***
	(0.047)	(0.047)
Dummy Pop <60,000	0.0656***	0.0668***
	(0.016)	(0.016)
Dummy Pop 60,000-100,000	0.0628***	0.0636***
	(0.014)	(0.015)
Dummy Pop 100,000-250,000	0.0642***	0.0646***
	(0.015)	(0.015)
Log of ICI - Residential Rate	0.1376***	0.1336***
	(0.033)	(0.034)
Log of ICI - Business Rate	0.0451	0.0424
	(0.039)	(0.039)
Log of Central Grants/Total Revenue	0.0082	0.0083
	(0.008)	(0.008)
Mayor elected with more than 50%	0.0179**	0.0175*
	(0.009)	(0.009)
Election Year Dummy	0.0109	0.0106
	(0.009)	(0.009)
Center-Left Dummy	0.0539***	0.0536***
	(0.009)	(0.009)
Mayor Facing a Binding Term	0.0331***	0.0333***
	(0.009)	(0.009)
North-Centre of Italy Dummy	0.0555*	0.0564*
	(0.031)	(0.031)
Year effect	yes	yes
Regional dummies	yes	yes
Constant	2.2525**	2.2455**
	(0.556)	(0.55)

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Table 10 – Continued

	Model 1	
Variables:	(a)	(b)
σ^2	0.0347***	0.0431***
	(0.003)	(0.016)
$\gamma = \frac{\sigma_u^2}{\sigma_v^2+\sigma_u^2}$	0.9509***	0.9485***
	(0.019)	(0.018)
μ		-0.0852
		(0.151)
η		
LR test of $\sigma_u^2 = 0$	72.68	73.18
Prob >= χ^2	0.000	0.000
Loglikelihood	620.63	620.88
N	799	799

Standard errors are in parenthesis, * p<0.10, ** p<0.05, ***p<0.01.

Table 11: Random effects time invariant model estimates

	Model 2	
Variables:	(a)	(b)
Log of per capita Current	0.0525**	0.0488**
Environmental Expenditure	(0.024)	(0.024)
Log of pop>65 years old	0.4118***	0.4303***
	(0.113)	(0.108)
Log of pop<15 years old/total population	0.2286**	0.2283**
	(0.104)	(0.101)
Log of Graduates/Population	0.1073**	0.0924**
	(0.048)	(0.045)
Log of per capita income	-0.1870**	-0.1732**
	(0.085)	(0.08)
Dummy Pop <60,000	0.0594**	0.0566**
	(0.026)	(0.026)
Dummy Pop 60,000-100,000	0.0617**	0.0546**
	(0.025)	(0.024)
Dummy Pop 100,000-250,000	0.0649***	0.0575**
	(0.025)	(0.024)
Log of ICI - Residential Rate	0.0769*	0.0798*
	(0.045)	(0.045)
Log of ICI - Business Rate	0.0030	-0.0056
	(0.054)	(0.054)
Log of Central Grants/Total Revenue	0.0045	0.0037
	(0.009)	(0.009)
Mayor elected with more than 50%	0.0181*	0.0173
	(0.011)	(0.011)
Election Year Dummy	0.0103	0.0102
	(0.009)	(0.009)
Center-Left Dummy	0.0405***	0.0405***
	(0.011)	(0.011)
Mayor Facing a Binding Term	0.0274***	0.0272***
	(0.009)	(0.009)
North-Centre of Italy Dummy	0.0679	0.0717
	(0.067)	(0.063)
Year effect	yes	yes
Regional dummies	yes	yes
Constant	2.0486**	1.9283**
	(0.987)	(0.919)

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Table 11 – Continued

	Model 2	
Variables:	(a)	(b)
σ^2	0.0193***	0.0412
	(0.003)	(0.012)
$\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$	0.5029***	0.7689***
	(0.057)	(0.074)
μ		-0.3561
		(0.166)**
η		
LR test of $\sigma_u^2 = 0$	118.84	121.30
Prob >= χ^2	0.000	0.000
Loglikelihood	643.71	644.94
N	799	799

Standard errors are in parenthesis, * p<0.10, ** p<0.05, ***p<0.01.

Table 12: Random effects time varying model estimates

	Model 3	
Variables:	(a)	(b)
Log of per capita Current	0.0540**	0.0509**
Environmental Expenditure	(0.024)	(0.024)
Log of pop>65 years old	0.3920***	0.4188***
	(0.111)	(0.11)
Log of pop<15 years old/total population	0.1810*	0.1989*
	(0.105)	(0.103)
Log of Graduates/Population	0.0930**	0.0814*
	(0.046)	(0.045)
Log of per capita income	-0.2320***	-0.2001**
	(0.086)	(0.079)
Dummy Pop <60,000	0.0470*	0.0499*
	(0.027)	(0.026)
Dummy Pop 60,000-100,000	0.0540**	0.0512**
	(0.025)	(0.025)
Dummy Pop 100,000-250,000	0.0600**	0.0542**
	(0.025)	(0.025)
Log of ICI - Residential Rate	0.0680	0.0740*
	(0.045)	(0.045)
Log of ICI - Business Rate	0.0060	-0.0059
	(0.053)	(0.053)
Log of Central Grants/Total Revenue	0.0040	0.0030
	(0.009)	(0.009)
Mayor elected with more than 50%	0.0180*	0.0169
	(0.011)	(0.011)
Election Year Dummy	0.0110	0.0104
	(0.009)	(0.009)
Center-Left Dummy	0.0420***	0.0414***
	(0.011)	(0.011)
Mayor Facing a Binding Term	0.0300***	0.0287***
	(0.009)	(0.009)
North-Centre of Italy Dummy	0.0340	0.0538
	(0.063)	(0.062)
Year effect	yes	yes
Regional dummies	yes	yes
Constant	2.3340**	2.0906**
	(0.984)	(0.924)

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Table 12 – Continued

	Model 3	
Variables:	(a)	(b)
σ^2	0.0280***	0.0563***
	(0.007)	(0.018)
$\gamma = \frac{\sigma_u^2}{\sigma_v^2+\sigma_u^2}$	0.6520***	0.8310***
	(0.09)	(0.058)
μ		-0.4328**
		(0.214)
η	-0.058*	-0.0372*
	(0.032)	(0.021)
LR test of $\sigma_u^2 = 0$	121.94	123.05
Prob >= χ^2	0.000	0.000
Loglikelihood	645.26	645.81
N	799	799

Standard errors are in parenthesis, * p<0.10, ** p<0.05, ***p<0.01.

Table 13: Battese and Coelli (1995) model estimates

	Model 4	
Variables:	(a)	(b)
Log of per capita Current	0.0313*	0.0297
Environmental Expenditure	(0.018)	(0.019)
Log of pop>65 years old	0.3652***	0.3602***
	(0.072)	(0.076)
Log of pop<15 years old/total population	0.1423*	0.1315
	(0.079)	(0.083)
Log of Graduates/Population	0.0897***	0.086***
	(0.027)	(0.028)
Log of per capita income	-0.2084***	-0.2115***
	(0.046)	(0.048)
Dummy Pop <60,000	0.0613***	0.0577***
	(0.016)	(0.017)
Dummy Pop 60,000-100,000	0.0570***	0.0541***
	(0.015)	(0.015)
Dummy Pop 100,000-250,000	0.0589***	0.0546
	(0.015)	(0.016)
Log of ICI - Residential Rate	0.1300***	
	(0.035)	
Log of ICI - Business Rate	0.0426	
	(0.041)	
North-Centre of Italy Dummy	0.0623**	0.0619**
	(0.031)	(0.031)
Year effect	yes	yes
Regional dummies	yes	yes
Constant	2.0548***	2.3487**
	(0.557)	(0.556)
% of Central Grants/Total Revenue	0.0001	0.0001
	(0.001)	(0.001)
ICI - Residential Rate		-0.0245
		(0.016)
ICI - Business Rate		-0.0279*
		(0.015)
Mayor elected with more than 50%	-0.0646**	-0.0568**
	(0.026)	(0.023)
Election Year Dummy	-0.0192	-0.0196
	(0.026)	(0.022)
Center-Left Dummy	-0.1155***	-0.1077***
	(0.029)	(0.027)
Mayor Facing a Binding Term	-0.0732***	-0.0744***
	(0.027)	(0.025)

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Table 13 – Continued

	Model 4	
Variables:	(a)	(b)
Constant	0.1802***	0.4782***
	(0.036)	(0.104)
σ^2	0.0289***	0.028***
	(0.006)	(0.006)
$\gamma = \frac{\sigma_u^2}{\sigma_v^2+\sigma_u^2}$	0.9379***	0.9293***
	(0.023)	(0.025)
LR test of $\sigma_u^2 = 0$	115.13	119.40
Prob >= χ^2	0.000	0.000
Loglikelihood	612.57	607.55
N	799	799

Standard errors are in parenthesis, * p<0.10, ** p<0.05, ***p<0.01.

Table 14: Summary statistics for technical efficiency

	Model 1 (a)	Model 1 (b)	Model 2 (a)	Model 2 (b)	Model 3 (a)	Model 3 (b)	Model 4 (a)	Model 4 (b)
Mean	0.870	0.879	0.927	0.937	0.925	0.936	0.861	0.860
Sd	0.085	0.082	0.050	0.051	0.053	0.052	0.088	0.088
Miin	0.544	0.553	0.777	0.774	0.706	0.728	0.515	0.527
Median	0.886	0.899	0.939	0.957	0.938	0.954	0.874	0.876
Max	0.983	0.982	0.984	0.987	0.987	0.988	0.986	0.985
N	779	779	779	99	99	779	779	779

Table 15: Technical efficiency correlation matrix

	Model 1 (a)	Model 1 (b)	Model 2 (a)	Model 2 (b)	Model 3 (a)	Model 3 (b)	Model 4 (a)	Model 4 (b)
Model 1 (a)	1.000							
Model 1 (b)	0.999	1.000						
Model 2 (a)	0.590	0.592	1.000					
Model 2 (b)	0.584	0.587	0.994	1.000				
Model 3 (a)	0.572	0.574	0.945	0.936	1.000			
Model 3 (b)	0.580	0.582	0.976	0.981	0.982	1.000		
Model 4 (a)	0.950	0.949	0.603	0.598	0.576	0.588	1.000	
Model 4 (b)	0.934	0.934	0.617	0.613	0.587	0.602	0.988	1.000

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