Estimating Local Government Efficiency using a Panel Data Parametric Approach: The Case of Chilean Municipalities

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Abstract

Previous empirical evidence on municipal efficiency mostly uses cross-sectional data which makes it impossible to separate unobserved heterogeneity from inefficiency. Furthermore, they also typically use a two-stage approach which has been widely criticized as the assumptions in the first stage are violated in the second stage, generating biased results. We contribute to the literature by putting forward a one stage approach with parametric models and panel data to estimate municipal efficiency of 324 Chilean municipalities for the period 2008-2018. We take into account observed and unobserved heterogeneity, incorporating them both into the frontier and jointly estimating efficiency of all the municipalities in the sample. Our results suggest that Chilean municipalities have a relevant degree of inefficiency as they could achieve the same provision of services with 53% -61% less resources, depending on the specification, and that there is large heterogeneity in their level of efficiency. Finally, we also find that municipalities with a high dependency on the Municipal Common Fund are less efficient supporting the notion of *local governments fiscal laziness* present in the literature.

Keywords: Efficiency, Local governments, Panel Data, Parametric Estimation, Chile.

JEL Classification: H71, H72, H83, D24, O54

1 Introduction

Local governments (municipalities) are a crucial factor when politicians pursue a decentralized system of policy making. This is because they are the closest political level to the population and their needs. Due to this, they have their own budgets and are in general mandated to provide a number of services to their community.

Given their relevance, there have been a long series of studies which tried to measure the level of efficiency on municipal provision of public services. Traditionally, previous literature have used a two stages approach, a first stage to estimate inefficiency and a second stage to estimate the determinants that affect the previously estimated inefficiency. This two-stages approach has been widely criticized (Wang and Schmidt, 2002) because the assumptions in the second stage contradicts

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those made in the first stage, potentially biasing the results. In particular, in the first stage it is assumed that the inefficiency term is independent and identically distributed while in the second step inefficiency is deterministic. Thus, a one stage approach has been suggested to solve the drawbacks of the two stage approach.

Additionally, the vast majority of previous literature uses a cross-section approach. This has the drawback that it is not possible to separately identify inefficiency from municipal unobserved heterogeneity. In order to overcome this difficulty, models with panel data have been suggested. Recent literature have used panel data for municipal efficiency estimation. Unfortunately, the vast majority of recent previous literature have used non-parametric methods which uses a two stage approach to estimate inefficiency and their determinants (Greene, 2005c). Apart from this, they face other drawbacks. In particular, non-parametric methods uses linear programing techniques instead of econometric methods which implies that the error is calculated and not estimated. This in turn implies that non-parametric techniques have a deterministic nature. In this way, any deviation from the frontier is interpreted as inefficiency even though the source of these deviations may be due to variables that are not under the control of the municipality. Furthermore, with availability of panel data, non-parametric methods have an additional drawback. As non-parametric methods optimize period by period, efficiency score is computed for each single year as just in a cross-sectional framework, therefore they ignore the panel dimension of the data.

Moreover, most parametric evidence uses cross sectional data, which does not allow to disentangle municipal efficiency from municipal unobserved heterogeneity (see Greene 2005a, 2005b and 2005c). In addition, as municipalities can be very heterogeneous in kind, observed heterogeneity should also be taken into account in the analysis. If the issue of observed heterogeneity is not adequately considered in the analysis, which may be due to omitted variables, the model can be misspecified and therefore the estimates can be biased and inconsistent. Some authors have suggested a separate analysis based on the use of clusters of municipalities, to deal with this issue (Afonso and Fernandez, 2008). Unlike them, we propose an alternative methodology that allows us to control by heterogeneity incorporating it into the frontier and jointly estimate all the municipalities in the sample. In particular, we take observed heterogeneity into account by including those effects in the mean of the distribution of inefficiency as suggested by Kopsakangas-Savolainen and Svento (2011), who study the electricity distribution industry.

To our knowledge this is the first attempt to use a one stage approach with parametric models and panel data to estimate municipal efficiency, taking into account observed and unobserved heterogeneity in local governments stochastic frontier models. In particular, we present an efficiency analysis of **324** Chilean municipalities for the period **2008-2018**. For this task we use administrative data provided by the Chilean Government on the municipal provision of a series of services (SINIM). Our results suggest that Chilean municipalities present on average inefficiency levels of **61%** approximately for the period 2008-2018. In other words, Chilean municipalities could provide the same amount of services but with a **61%** less of resources. We also report the evolution of average efficiency for the period 2008-2018 showing that the levels of aggregated inefficiency have sharply risen during this period, from **37,5%** to **78,4%**. We also find that regional or provincial capitals are more efficient on average than the rest of municipalities of the same region. Furthermore, we also find evidence that municipalities with a high dependency on the Municipal Common Fund (as percentage to self-generated income) and with a high percentage of public investment with respect to total expenditure are, ceteris paribus, less efficient. Also, we find that local governments with higher self-generated revenues coming from higher territorial taxes collected or higher municipal commercial rights are more efficient. Finally, we find that current transfers from public institutions (namely, Ministries and other public services) to municipalities also increase efficiency.

This study is organized as follows: section 2 provides the institutional framework of municipal management. Section 3 presents the details of the methodology used in this work. Section 4 puts forward the data and the summary statistics. Section 5 and 6 present the results and the sensitivity analysis respectively. Finally, section 7 offers some concluding remarks and policy recommendations.

2 Institutional Framework

Chile is organized in 15 regions.[1] Each of them has provinces (54 in total) and each of the provinces has municipalities (345 in total). The Organic Law of Municipalities (Law N^{o}18,695) establishes how municipalities are constituted (i.e. the Major and the City Council), how their authorities are elected and their attributions. The major has two main attributions: (i) those related with municipal management and (ii) those attributed to the municipality as an institution. Among the former, the major has to be the legal responsible individual in judicial and extra-judicial cases and also he/she is the responsible for the municipal budget. On the other hand, the city council is in charge of fiscalization and enhancement of community participation.

2.1 Specific functions of the local government

The Organic Law of Municipalities (Law N^{o}18,695) establishes that the local government has 6 exclusive responsibilities and 13 shared with other institutions. Among the former are: the planning and management of the development communal plan (*PLADECO*), promotion of community development, public transport regulation, hygiene services, urbanism and construction norms. Among the shared responsibilities are those which attributes to municipalities the main responsibility for education and health at the local government area.

Regarding financial matters, article 13^o of the Organic Law of Municipalities (Law N^{o}18,695) establishes the main source of municipal assets, among which are:

- All real state goods they acquire
- Transfers from the regional government
- Resources from the municipal common fund (FCM).
- Benefits obtained from the services they deliver and for any concession (rights) or permits they give.
- Income received as a result of their activities and activities in related dependencies.
- Income collected from all the taxes the law allows local government to charge. Among these are: territorial tax, transport tax and commercial rights on alcoholic sells.
- Interests and penalties.

[1] Arica and Parinacota, Tarapacá, Antofagasta, Atacama, Coquimbo, Valparaíso, Región Metropolitana, del Libertador Bernardo O'Higgins, Maule, Bío-Bío, Araucanía, de Los Ríos, de Los Lagos, Aysén and Carlos Ibañez del Campo and Magallanes and Chilean Antartica.

Municipal income can be classified depending on the source of funding. There are two main funding sources: permanent self-generated revenues (Ingresos Propios Permanentes, *IPP*) and municipal common fund (Fondo Común Municipal, *FCM*). Other sources are transfers from regional government and the central government. Among the latter are transfers for education and health services. In this way, local government act as an intermediary between local education and health services and the respective ministry. Next, we present the detail of the income sources of the municipal budget coming from non-conditional transfers of the central government (education and health), i.e. municipal common fund (*FCM*) and permanent self-generated revenues (*IPP*).

2.1.1 Municipal Common Fund (FCM)

The Municipal common fund is a fund created by the local government reform in 1979. The objective is to redistribute communal income in order to guarantee the achievement of municipal functions and its adequate functioning. In this way, the sources of funding of the FCM come from municipal income and are defined by article 14^o of the Organic Law of Municipalities (Law N^o18,695) in the way presented in **Table 1**.

Regarding the mechanism of distribution of this fund, there is a defined structure which allocate the resources. The mechanism of distribution can be observed in **Table 2**. In this way, the first 25% corresponds to the amount transferred to be distributed in the same proportion in all the municipalities in the country. The next 10% is distributed depending on poverty levels (i.e. number of poor people relative to poor people in the country). The next 30% is distributed according to the number of assets exempt of territorial tax relative to the total of exempts asset (regarding territorial tax only) in the country. Finally, the last 35% is transferred to those municipalities which generate lower permanent self-generated revenue (*IPP*) per capita than the national average.

2.1.2 Permanent self-generated revenues (IPP)

Permanent self-generated revenues (*IPP*) is the source of funds a local government generates from municipal management. Income generated from this source has no restriction on where or in what to invest. From article 38 of the municipal rents law N^o3,063, *IPP* are composed by: municipal rights income, hygiene rights, concessions, municipal property rents, percentage of the income from territorial tax and transport tax, among others. From these sources most of the income of *IPP* comes from: territorial tax, commercial rights and transport tax. The first one is a tax imposed to agricultural and non-agricultural land.[2] From this source of income, only 40% remains in the municipality for its own funding and the other 60% is directed to the municipal common fund (*FCM*).[3]

Commercial rights are regulated mainly by the municipality as it chooses the tax rate to charge (subject to a range established by the law). Of the amount of income collected by commercial rights, only the richest four municipalities (Santiago, Providencia, Las Condes and Vitacura) transfer a proportion to the FCM: Santiago 55% and the other three 65%. Finally, regarding transport tax, from the amount collected the 37.5% goes for municipal benefit and the rest (64.5%) go to the *FCM*.

[2] This is regulated in the Law N^o17,235 about territorial tax.

[3] For the four richest municipalities, Santiago, Providencia, Las Condes and Vitacura percentage are: 35% and 65% respectively.

3 Literature Review[4]

3.1 Parametric versus Non-Parametric approaches

In order to measure efficiency two types of approaches have been used: non-parametric (such as Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH)) and parametric (such as Stochastic Frontier Analysis (SFA)). On the one hand, the non-parametric approach analyzes efficiency from the data available and not from imposed functional forms. Also, it uses linear programing techniques instead of econometric methods which makes that the error is calculated and not estimated implying that non-parametric techniques have a deterministic nature. In this way, any deviation from the frontier is interpreted as inefficiency even though the source of these deviations may be due to variables that are not under the control of the municipality. Also, non-parametric methods use two stages procedures, which have been criticized because of the contradictions between the assumptions made in the first stage versus to what is estimated in the second stage. Furthermore, with availability of panel data, non-parametric methods have an additional drawback. As non-parametric methods optimize period by period, efficiency score is computed for each single year as just in a cross-sectional framework, therefore they ignore the panel dimension of the data.

Parametric methods, such as the stochastic frontier analysis, originally developed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van Broeck (1977), come from an extension of Ordinary Least Squares (OLS) and Maximum Likelihood (ML). In this way, while OLS estimate the most appropriate function of medium cost, the stochastic frontier analysis estimates the maximum production or the minimum cost. Furthermore, it decomposes the deviation from the frontier in to a random component (the error term) and the inefficiency. In this way, this approach can accommodate exogenous shocks such as bad weather and separate it from inefficiency. An additional advantage of parametric methods is that, when there is panel data, they take into account the unobserved heterogeneity across municipalities, which could play a crucial role in explaining the performance of cities.[5] The drawback of parametric methods is the necessity of an assumption about the production (or cost) function. As, in this study, we use the parametric approach, we tackle its weakness by assuming different production (cost) functions in order to check if results are sensitive to them.

3.2 Empirical Evidence on Municipal Efficiency[6]

The analysis of municipal efficiency has been carried out mainly in two steps models: the first one as an efficiency analysis itself and the second as an evaluation of its determinants (see Ballaguer-Coll et al. (2002), Herrera and Francke (2009), Afonso and Fernandes (2006)).

In this way, in the first step the focus has been placed on the analysis of the productive process by which the local government utilize the available resources to generate goods and services; As such, municipal performance has been measured by the efficiency of municipal expenditure. The results obtained in previous literature, which focused in municipal efficiency, suggests that there are important inefficiencies on municipal expenditure. For example, the Afonso and Fernandez (2006) DEA study for Portugal concludes that on average municipalities of the Lisbon region could achieve the same performance with 39% less resources. Similarly, a second DEA evaluation applied to 278

[4] For a systematic literature review on the Local governments' efficiency see: Narbón-Perpiñá & De Witte (2018) and Aiello and Bonanno (2019).

[5] Parametric methods estimate the time profile of the scores endogenously in a single panel.

[6] For a systematic literature review on the Local governments' efficiency see Narbón-Perpiñá & De Witte (2018).

Portuguese municipalities showed similar inefficiency levels (Afonso and Fernandez 2008). For Peru, the parametric cross-section analysis of Herrera and Francke (2009) showed that municipalities could achieve the same provision of good and services with 58% less resources. In the same line, Pang, Liu, Peng and Wu (2010) find inefficiency levels of 41% for Taiwanese municipalities and Balaguer-Coll et al. (2007) with a DEA and a FDH find similar results for Spain.

Studies focused on the second stage, where the determinants of the inefficiency are estimated, showed that for Belgium, De Borger and Kerstens (1996a) the level of education has positive effects on municipal efficiency while average income and the amount of transfers relative to local income have negative effects on municipal efficiency. Also for Belgium, Van den Eckaut et al. (1993) find a positive relationship between municipal efficiency and political composition of the City Council (i.e. better results for municipalities with heterogeneous composition of the council versus those with a more homogeneous composition). For Peru, Herrera and Francke (2009) find that a higher participation in *FONCOMUN* (similar to the Chilean *FCM*) has negative effect on municipal efficiency while political participation affects positively municipal efficiency. The parametric and non-parametric evaluation of Greek municipalities by Anthanassopoulos and Triantis (1998) find a negative relationship between efficiency levels and the ratio of transfers over municipal total income, population density and political affiliation (measured as parties affiliated to the central government). For Finland, Loikkanen and Susiluoto (2005) find a positive relationship between municipal efficiency and certain age groups (mainly with individuals between 35-49 years old) and a negative relationship with peripheric geographic location, high income levels, high population, transfers of good and services from other municipalities and higher participation in municipal funds. For Taiwan, Pang, Liu, Peng and Wu (2010) concluded that environmental policies adopted by municipalities were crucial for municipal efficiency. Cordero et al (2017) apply time-dependent conditional frontier estimators to assess the performance of the 278 Portuguese mainland municipalities for the 2009–2014 period. Following Mastromarco and Simar (2015) conditional nonparametric frontier analysis, they found that the economic and demographic indicators included as contextual variables in their model play an important role as influencing the production set, although those effects do not seem to vary much over time. This evidence was corroborated after they conducted a second-stage nonparametric regression of the conditional efficiency measures over those variables.

In one of the very few parametric studies with panel data, Bianchini (2010) evaluates the efficiency of 100 Italian chief towns of Province in providing urban environmental quality during 1998-2007. She finds that, besides socioeconomic variables, those which explain different municipal performance are the fiscal and political ones. The other known parametric panel data study has been carried out for the Czech Republic by Stastna and Gregor (2011). They find that population size, distance to the regional center, share of university educated citizens, capital expenditure, subsidies per capita and the share of self-generated revenues increase inefficiency.

Previous results from the literature, as those mentioned above, are based on a variety of estimation methods. On the one hand, parametric methods have been used which assume a functional form to model the relationship between the variables of input and output and on the other hand non-parametric methods have been used, which assume that any deviation from the frontier are due to inefficiency. Under this general setup, the stochastic frontier analysis is the main parametric approach while the data envelopment analysis and the free disposal hull are the main approaches in non-parametric methods. Due to the variety of techniques for the estimation of municipal efficiency, there have been some studies which focuses on the analysis of the differences of the results given by the different techniques. As such, De Borger and Kerstens (1996a and 1996b) in Belgium and Worthington (2000) and Worthington and Dollery (2000) in Australia explore the differences of the results given for the same municipalities using parametric and non-parametric methods. Similarly, Van den Eckaut et al. (1993) focused in the comparison of the results of DEA and FDH. All these studies have shown that the result obtained about municipal efficiency is sensitive to the technique used. However, despite the magnitude of efficiency changes from method to method, the general results are very similar.

Furthermore, it is important to mention that all the parametric evidence uses cross sectional data (except Bianchini (2010) and Stastna and Gregor (2011)). This is crucial as, this kind of data, may be informative for efficiency measures but it has the drawback that it is not possible to disentangle municipal efficiency from municipal heterogeneity (see Greene 2005a, 2005b and 2005c). Bianchini (2010) and Stastna and Gregor (2011) have carried out an overall analysis. Some authors (Afonso and Fernandez 2008) have criticized this as municipalities are very heterogeneous, which may be due to omitted variables, generating in this way a misspecified model. Unlike them, who suggest a separate analysis based on the use of clusters of municipalities, we propose an alternative methodology that allows us to control by heterogeneity incorporating it into the frontier and jointly estimate all the municipalities in the sample. In particular, we take observed heterogeneity into account by including those effects in the mean of the distribution of inefficiency as suggested by Kopsakangas-Savolainen and Svento (2011), who study the electricity distribution industry.

For parametric models, the majority of the empirical evidence on technical efficiency mentioned above uses a two step approach, where the second step estimates the determinants of the inefficiency estimated in the first step. This is carried out regressing the estimated inefficiency on exogenous variables which may affect municipal performance. This two step method has been widely criticized in the literature because this method assumes that the exogenous variables included in the second step are not correlated with the variables used to estimate the inefficiency in the first step. The reason for this is that in the first step it is assumed that inefficiency is independent and identically distributed but in the second step the assumption is that inefficiency is explained by exogenous variables, which may be a contradiction. In other words, if the variables included in the second step are not orthogonal to those included in the first step, this method will obtain biased results (Wang and Schmidt 2002). In this way, to increase the number of input, output or exogenous variables will probably increase the probability of violating the assumption. This issue is particularly problematic for two stage studies that employ non-parametric methods (Simar and Wilson 2007)[7].

To solve this problem in the parametric case Khumbhakar, Gosh and McGuckin (1991) proposed a one step estimation method where determinants of inefficiency are estimated jointly with the frontier given the appropriate assumptions about the error terms. This method of estimation solves the inconsistency on the estimators due to the assumptions imposed on the inefficiency term. Exists two options for this one step estimation. The first one incorporates the exogenous determinants of the inefficiency directly in to the production function (Battese and Coelli, 1992) and the second one and more used in the literature, includes the exogenous determinants into the mean of the inefficiency term (Battese and Coelli, 1995). Interpretation of results differ in each option. In the former, the effect of the determinants of the inefficiency term determines the position of the production function whereas in the latter they are interpreted as the distance to the frontier. As our objective is to analyze the determinants of municipal inefficiency, we use the Battese and Coelli (1995) approach (i.e. we include the exogenous determinants into the mean of the inefficiency term), all this carried out in one step in order to avoid the problems described above. Furthermore, in

[7] In their own words:"*A more serious problem in all of the two-stage studies that we have found arises from the fact that DEA efficiency estimates are serially correlated. Consequently, standard approaches to inference are invalid*". Furthermore, the two stage approach is routine in the DEA literature (Greene 2005c).

order to take into account municipalities observed heterogeneity in our stochastic frontier model, we incorporate such specific effects in the estimated distribution of inefficiency, specifically in the mean of the distribution of inefficiency (see Kopsakangas-Savolainen and Svento, 2011).

4 Methodology

4.1 Stochastic Frontier Analysis

The Stochastic Frontier Analysis was developed by Aigner, et al. (1977) and Meeusen and Van Broeck (1977) as a model to estimate production and/or cost frontiers. In general, the approach followed in the literature, either production maximization or cost minimization, depends upon the exogeneity of output and inputs variables. In particular, when inputs are considered more exogenous than the product (i.e. that they do not fully depend on municipal management) product maximization is used and viceversa. In order to choose, the institutional framework is crucial, and given the Chilean institutional framework described above, where output is given by the law (i.e. exogenous) and inputs depend on municipal management, *a cost minimization approach is more adequate for our analysis.*

Greene (2005c) argues that cost inefficiency is a blend of the two sources technical and allocative. Despite this complexity, there are several studies which analyze cost inefficiency because they allow to include multiple inputs, which is not straightforward on the production side. It is important to notice that any deviation from cost efficiency may come from two sources: input-oriented technical inefficiency and allocative inefficiency. In order to estimate the latter, additional data should be available, for example: the vector of inputs prices. If the additional data is not available it is only possible to estimate the input-oriented technical inefficiency. *As in the Chilean case, we do not know all the inputs and their respective prices, we focus our attention in this study only on input-oriented technical inefficiency.* Throughout this study we will refer to the input-oriented technical efficiency as cost efficiency.

Hence, Aigner, et al. (1977) and Meeusen and Van Broeck (1977) input-oriented specification, define the minimum cost level for observation i needed to produce a good and services vector given inputs prices (w_i). In this way the model can be expressed as:

$$C_i = C(y_i, w_i, \beta)\ exp(v_i + u_i) \tag{1}$$

$$i = 1, ..., N \quad with \quad u_i \geq 0$$

where:

C_i	is the observed (actual) cost or expenditure of municipality i
$C(y_i, w_i, \beta)$	is the cost frontier of municipality i
y_i	is the output vector of municipality i
β	is a vector of parameters to be estimated.

v_i is an iid random variable[8].This variable represents exogenous factors which are not controlled by the municipality which affect the cost level (e.g. weather, luck , regulation, etc.). u_i is a random

[8] That is: this random variable is independent and identically distributed.

variable which correspond to the inefficiency level in costs and its distribution will depend on the assumptions made (explained below).

The parameters of this model are estimated by Maximum Likelihood, given suitable distributional assumptions for the error term. Aigner, et al. (1977) assumed that v_i has a normal distribution and u_i has either the half-normal or the exponential distribution. The main criticism is that there is no a priory justification for the selection of any particular distributional form for the u_i . Since then, started a literature which have proposed more general distributional forms, such as the truncated-normal (Stevenson 1980) and the two-parameter Gamma (Greene 1997).[9]

It is crucial to notice that deviations between the observed cost (C_i) and the frontier ($C(y_i, w_i, \beta)$) can come from two sources: technical inefficiency of the municipality (u_i) or random shocks which are not under the control of the municipality (v_i). Both components are assumed to be independent from each other. The stochastic frontier method consist on the estimation of the variation of (v_i) and (u_i) in order to obtain evidence of the relative effect of each of them on costs. Thus, given input prices w_i, and in order to reach certain output y_i, the cost efficiency level of a municipality (CE) will be given by:

$$CE_i = \frac{C(y_i, w_i, \beta)\ exp(v_i)}{C(y_i, w_i, \beta)\ exp(v_i + u_i)} = exp(-u_i) \tag{2}$$

when the value of equation (2) tends to 1, implies that municipality i is very efficient in terms of costs because actual costs will be similar to the cost efficient level. On the other hand, CE<1 provides a measure of the gap between the minimum possible cost and the one observed. The inefficiency term itself (u_i) is not observable, therefore $\varepsilon_i = v_i + u_i$ must be used for the estimation of equation (2). In order to do this, the estimation is carried out computing the expected value of the inefficiency term component (u_i) given the composite error term (ε_i). This is:

$$CE_i = E\left[exp\left(-u_i|\varepsilon_i\right)\right] = E\left[exp\left(-u_i|(v_i + u_i)\right)\right] \tag{3}$$

In order to find $E\left[-u_i|\varepsilon_i\right]$ the conditional density function must be known, and this function is defined by:

$$f\left(u_i|\varepsilon_i\right) = \frac{f(u_i, \varepsilon_i)}{f(\varepsilon_i)} = \frac{f(u_i, (v_i + u_i))}{f(\varepsilon_i)} \tag{4}$$

To estimate this, it is necessary to assume a probability distribution for both error components. As it was previously mentioned, in all the models the v_i is considered as independent and identically

[9] Truncated normal and the two-parameter Gamma were introduced because the Half-normal and exponential distributions both have a mode at zero. This causes conditional technical inefficiency scores, specially in the neighbourhood of zero that can involve artificially high technical efficiency levels. The Truncated Normal is more flexible since the modal efficiency value can also be away from one, and for this reason in most empirical works it is preferred relative to the Half Normal.

distributed following a normal distribution ($N\left(0, \sigma_v^2\right)$). Despite there are no consensus on which distribution to assume for u_i, the most used one in the empirical literature is the truncated-normal ($N^+\left(\mu, \sigma_u^2\right)$). The main reason for this is that this distribution allows us to estimate the determinants of the inefficiency in one step, avoiding the problems presented above when a two stage approach is carried out.

After both distributions are defined, their distributions functions should be obtained:

$$f\left(v_i\right) = \frac{1}{\sigma_v\sqrt{2\pi}} exp\left(\frac{-v^2}{2\sigma_v^2}\right) \tag{5}$$

$$f\left(u_i\right) = \frac{2}{\sigma_u\sqrt{2\pi}} exp\left(\frac{-u^2}{2\sigma_u^2}\right) \tag{6}$$

as the joint density function ($f(u_i, \varepsilon_i)$) is unknown, the joint density function of both error term components can be estimated ($f(u_i, v_i)$) and replaced it in the term $v_i = \varepsilon_i - u_i$. As u_i and v_i are independent to each other, the joint density function corresponds to the product of the individual density functions such as:

$$f(u_i.v_i) = f(u_i)\ f(v_i) = \frac{2}{2\pi\sigma_v\sigma_u} exp\left(\frac{-u^2}{2\sigma_u^2} - \frac{v^2}{2\sigma_v^2}\right) \tag{7}$$

by replacing $v = \varepsilon - u$ we obtain the joint density function of u_i and ε_i:

$$f(u_i.\varepsilon_i) = \frac{2}{2\pi\sigma_v\sigma_u} exp\left(\frac{-u^2}{2\sigma_u^2} - \frac{(\varepsilon - u)^2}{2\sigma_v^2}\right) \tag{8}$$

Now, to find the denominator of equation (4), we integrate equation (8) to get:

$$f(\varepsilon_i) = \int_0^\infty f(u_i.\varepsilon_i)du = \frac{2}{\sqrt{2\pi}\sigma}\left[1 - \Phi\left(-\frac{\varepsilon\lambda}{\sigma}\right)\right] exp\left(\frac{-\varepsilon^2}{2\sigma^2}\right) \tag{9}$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\lambda = \frac{\sigma_u}{\sigma_v}$ and $\Phi()$ is the cumulative distribution function of a standard normal. Using this parametrization, λ is the ratio of the variability coming from each of the variables that conform the composite error term. Therefore, if $\sigma_u^2 \rightarrow 0$ (and thus $\lambda \rightarrow 0$), it is the random effect the one that predominates relative to the inefficiency and thus the density function of the composite error term tends to a normal. On the other hand, if $\sigma_u^2 \rightarrow \infty$ (and thus $\lambda \rightarrow \infty$) the gap between the minimum cost and the actual cost will be mainly determined by the inefficiency (u_i).

Finally, replacing equation (9) in to equation (4) we obtain the density function of u given ε:

$$f\left(u_i|\varepsilon_i\right) = \frac{f(u_i, \varepsilon_i)}{f(\varepsilon_i)} = \frac{1}{\sqrt{2\pi}\sigma^*\left[1 - \Phi\left(-\frac{\mu^*}{\sigma^*}\right)\right]} exp\left(\frac{-(u-\mu^*)^2}{2\sigma^{*2}}\right) \tag{10}$$

where:

$$\mu^* = \frac{-\varepsilon\sigma_u^2}{\sigma^2} \tag{11}$$

$$\sigma^{*2} = \frac{\sigma_u^2\sigma_v^2}{\sigma^2} \tag{12}$$

From the above, we conclude that $f\left(u_i|\varepsilon_i\right)$ is the density function of a variable that distributes $N^+\left(\mu^*, \sigma^{*2}\right)$ .Once this distribution is known, and given that the value of cost inefficiency u_i is not observable, it is possible to use the expected value $E(u_i|\varepsilon_i)$ as the estimator of the cost inefficiency of each municipality.

$$E(u_i|\varepsilon_i) = \mu^* + \sigma^*\left[\frac{\phi\left(\frac{-\mu_i^*}{\sigma^*}\right)}{1-\Phi\left(\frac{-\mu_i^*}{\sigma^*}\right)}\right] \tag{13}$$

where $\phi()$ is the density function of a standard normal. Thus, the cost efficiency function for a municipality is:

$$CE_i = E\left[exp\left(-u_i|\varepsilon_i\right)\right] = \frac{1-\Phi\left(\sigma^* - \frac{\mu_i^*}{\sigma^*}\right)}{1-\Phi\left(-\frac{\mu_i^*}{\sigma^*}\right)} exp\left\{-\mu_i^* + \frac{\sigma^{*2}}{2}\right\} \tag{14}$$

4.2 Determinants of Inefficiency

As it was previously mentioned, a branch of the stochastic frontier literature has incorporated a second stage where the determinants of the inefficiency found in the first stage are estimated. This approach has been criticized by more recent literature (Wang and Schmidt, 2002) and a one stage approach has been suggested which solves the drawbacks of the two stage approach.

In order to carry out this one stage approach, there are two alternatives: the first one incorporates the determinants directly as regressors in the non-stochastic component of the cost frontier. The second one, incorporates indirectly the determinants in the stochastic component, in particular on the variable u_i. Thus, in the first approach, it is assumed that determinants affect directly the cost frontier by moving it. On the other hand, the second approach assumes that determinants affects the costs inefficiency levels. This latter approach was introduced in the literature by Battese and Coelli (1995) and it allows to find which are the determinants of the estimated inefficiency.

Therefore, the interpretation of the results corresponds to the distance between the effective costs and the cost frontier.

There is no consensus in the literature on which of the previous alternatives is preferred (Greene 2005c). Due to this and given our objective of finding the determinants of the inefficiency, we use the Battese and Coelli (1995) approach.

4.3 Estimation Method

When panel data is available, there are two main approaches for the estimation of frontier functions: fixed and random effects. In order to choose the more appropriate method it is important to consider the assumptions about the inefficiency term and the linearity of the production function. If the production function is not linear, then the within estimator will be inconsistent as the difference with respect to the mean may not eliminate the unobserved heterogeneity, furthermore, in short panels (as in our case) fixed effects suffer of what is known as incidental parameter problem and random effects should be used. If the production function is linear, then in principle both methods may be appropriate depending on the assumptions made on the inefficiency term.

When inefficiency term is time invariant the Fixed Effect and the Random Effect present problems as in both approaches u_i carries both the inefficiency and, in addition, any time invariant municipal specific heterogeneity. Additionally, for both approaches, the time invariance assumption in long time series of data, is likely to be a particularly strong assumption.

For these reasons, recent literature have promoted models with a time varying inefficiency term. Even in this context, fixed effects do not take into account time invariant covariates (which is our ultimate interest in this study). Due to this, a random effects model is preferred (see more details in **Appendix A**, available upon request). This model can be expressed as:

$$ln(C(y_{it},\beta)) = \beta_0 + \sum_{r=1}^{R}\beta_r ln(y_{rit}) + \frac{1}{2}\sum_{r=1}^{R}\sum_{k=1}^{K}\beta_k ln(y_{rit}) ln(y_{kit}) + \sum_{j=1}^{J}\beta_j x_{jt} + v_{it} + u_{it} \qquad (15)$$

where $C(y_{it},\beta)$ is the cost function of municipality i in period t. y_{it} is the output of municipality i in period t; β is a vector of unknown parameters to be estimated; We also include the variable x_t which are dummies that control for time. v_{it} is a white noise which is assumed independent and identically distributed (iid) $N\left(0,\sigma_v^2\right)$ and independent of u_{it}. u_{it} represents the non negative inefficiency term which may vary over time and distributed as truncated-normal ($N^+\left(z_{it}\delta,\sigma_u^2\right)$). This is:

$$u_{it} = z'_{it}\delta + W_{it} \qquad (16)$$

where z_{it} are the determinants of the inefficiency of municipality i at time t, δ is a vector of unknown parameters to be estimated and W_{it} is a white noise distributed $N^+\left(0,\sigma_u^2\right)$ .As the cost measure is usually specified in natural logs, the inefficiency term, u_{it}, can be interpreted as the percentage deviation of observed performance from the municipality's own frontier (at least for small deviations).

Finally, we incorporate municipalities observed heterogeneity in the estimated distribution of inefficiency, specifically in the mean of the distribution of inefficiency. Hence, following Kopsakangas-Savolainen and Svento (2011), we can write:

$$z_{it} = \delta_0 + \delta_1 h_{it} \tag{17}$$

where h_{it} is heterogeneity summarizing covariates explaining the mean of the inefficiency distribution, z_{it}, and δ_0 and δ_1 are new parameters to be estimated.

The model follows Battese and Coelli (1995) but applied to cost minimization. Their model consider the joint maximization of equations (15) and (16) by maximum likelihood (ML). The estimated parameters should be replaced in equation (15) obtaining the estimated variables presented in equations (11) and (12). Then these variables are used in equation (14) to estimate municipal inefficiency. Our approach to take into account municipalities observed heterogeneity follows Kopsakangas-Savolainen and Svento (2011), incorporating such specific effects in the mean of the distribution of inefficiency *(17).*

5 Data and Summary Statistics

The data for this study comes from the National System of Municipal Information (*SINIM*). This system is a management tool which consolidate a group of variables and statistical data of municipalities. *SINIM* is updated once a year and has information of all 345 municipalities in Chile from 2001 to 2019. For this study we use data for 2008-2018, that consist of a balanced panel that includes 324 municipalities for these eleven years, which gives a total of: 3,564 observations[10]. The reason for this is that for some of the variables needed to carry out the analysis there are some missing entries. The main sources of information for *SINIM* are municipalities (40% of the information) and ministries or other public services (60%). *SINIM* is the main source of information for municipal issues as it includes information on management, finance, human resources and municipal characterization.

For our analysis we use output and input variables as well as determinants. We now explain which variables were included in each of these categories.

5.1 Output Variables

Due to the inherent difficulties to quantify the output provided by municipalities, we propose a number of proxy variables. These variables consider the multiple functions assigned to municipalities and capture the results obtained in all areas in which they deliver goods and services. After the revision of the empirical literature and given the data available in the Chilean context we included in the analysis the output variables described below and whose summary statistics are described in **Table 3**. It should be noted that all of our monetary data are in 2018 Chilean pesos.

[10] There are variables that are not available for some specific years and municipalities, so the number of observations varies a little in some estimations. We report this number in all of our regression analysis.

5.1.1 Education

One of the main services provided by municipalities is education. Municipalities provide education throughout municipal, public, schools. To measure the amount of education provided we use 2 variables:

a. number of rural and urban municipal education establishments and
b. average monthly enrollment municipal education establishment.

5.1.2 Health

This is another of the most important services provided by municipalities. To capture the amount of health services provided we use the number of health centres operating within each municipality. Specifically, we consider the following types of health centers:

a. Number of Centers for Mental Health (COSAM in Spanish)
b. Number of Health Laboratories
c. Number of General Rural Clinics
d. Number of General Urban Clinics
e. Number of Rural Health Posts
f. Number of Other Municipal Health Facilities in the Commune
g. Number of Emergency Primary Care Services (SAPU in Spanish)

5.1.3 Urbanism

Another function of municipalities is to provide roads and places of recreation such as parks, squares, etc. To measure the services provided in this area we include the variable: square meters of maintained green areas.

5.1.4 Hygiene

Municipalities are in charge of basic services in order to promote wellbeing. In order to have a measure of the amount of services provided in this item we use two variables:

a. City cleaning services, garbage collection and landfill services: corresponds to a municipal expense and refers to the expense accrued by *city cleaning services, garbage collection and landfill services* (includes all areas of internal management and community services).

b. Drinking Water Coverage.

5.1.5 Social Services

We consider services provided to social organizations which have municipal promotion and funding such as sport clubs, municipal services, elderly clubs, etc. To measure the amount of this kind of services we include the variable social organization which register all social organizations by municipality. Specifically, we consider the following types of Community Organizations:

a. Sports Clubs
b. Mother's Centers
c. Older Adult Organizations
d. Parent Centers
e. Neighborhood Councils
f. Functional Community Organizations

g. Community organizations with legal status in the commune
h. Community Unions.

5.2 Input Variables

After the definition of the output variables we define the financial resources used for the provision of public services such as those presented above. Previous literature use current (i.e. operational) expenditure as input. The reason for this is because capital expenditure is highly volatile. We follow the same approach as in the Chilean case capital expenditure is also volatile. Additionally, current expenditure represents more than 75% of total expenditure, hence we are including most of its main components. Given this, we have two alternatives: (a) use total current expenditure or (b) use current expenditure of those services provided. The differences between the two is that the former also includes expenditure on items that are not easily or directly attributed to some particular output. For this reason we choose to use as input the current expenditure of those services provided (i.e. expenditure in: employees, consumption of good and services and transfers for education and health).

Specifically, as input variables, we use the current expenditure as defined by the Chilean public finance accounting system, which includes the following items:
a. Expenditure on Personnel
b. Consumer Goods and Services
c. Expenditure on Education: transfers to Private Legal Entities[11]
d. Expenditure on Health: transfers to Private Legal Entities[12]
e. Transfers to Health Services
f. Transfers to public Education Schools
g. Transfers to public Health centers.

5.3 Determinants of Municipal Efficiency

To measure the effect of demographic, economic and fiscal factors on inefficiency, the model must incorporate some exogenous variables that may be considered relevant for municipal performance. Determinants can represent direct effects on municipal efficiency or discretionary inputs or unobservable outputs. Discretionary inputs refer to production in a favorable environment while unobservable outputs indicate service quality (as the included output variable in the model above do not measure quality but quantity).

Determinants can have several effects on inefficiency, thus it is complex to identify the limits of the effect of each determinant. Previous literature on the determinants of municipal inefficiency use similar variables for this purpose and for estimating inefficiency. Particularly, these are the variables we use to estimate the determinants of inefficiency:

5.3.1 Population

The hypothesis is that the bigger the population the bigger are the economics of scale and hence such municipalities could reach higher levels of efficiency on the provision of goods and services. To control by this determinant we use the following variables:

[11] Articule 13, Executive Order N^o 1, 3063/1980.
[12] Articule 13, Executive Order N^o 1, 3063/1980.

a. Municipality population
b. Dummies for municipality population: We include dummy variables for three categories:
- Population under 10,000 inhabitants
- Population between 10.000 and 30.000 inhabitants
- Population over 100,000.

5.3.2 Geography

As Stastna and Gregor (2011) pointed out, the hypothesis is that the closer the geographic distance between the municipality and the regional centre the more intense will be the competition between them and at the same time access to regional public services gets easier. For these reasons we should observe that closer municipalities relative to the regional centre would be more efficient. To capture this we include a variable that measures:
a. Distance to the Regional Capital.

5.3.3 Fiscal Capacity

A lower fiscal capacity of municipalities implies a tighter budget constraint reducing the operational surplus, which may affect municipal efficiency. To measure this effect we use four variables aimed at measuring budgetary tightness:
a. Dependency from the common municipal fund (FCM) relative to self-generated income,
b. Percentage of public investment relative to total expenditure,
c. Current transfers from public institutions, where the latter is in per capita terms.

5.3.4 Political Factors

Political characteristics of a municipality may affect efficiency in an important way. The hypothesis is that a high level of political concentration is associated to a lower efficiency because of lack of political competition (Besley et al, 2005). To measure this we use two variables:

a. A Herfindahl index to capture the monopolistic degree of the City council[13] This index measures the concentration of political parties in the city council and is defined as follows: $HHI = \sum \left(\frac{\text{City Councillors Political Party i}}{\text{Total Number of City Councillors}} x100 \right)^2$. It transpires that if the index is greater than 2500 it means that one single party concentrates the greatest number of total councillors that a municipality can have, for example, if the councillors are 8, there is a party that has 3 positions or there are two parties that have 2 positions each.

b. The percentage of the council who belongs to the governmental coalition: $officialism = \left(\frac{\text{City Councillors from Mayor's Political Party}}{\text{Total Number of City Councillors + Major}} \right)$, where Total Number of City Councillors is the sum of the councillors and the mayor. For example, if this variable has the value 0.6, it means that 60% of the council is composed of people who are part of the mayor's party.

5.3.5 Observed Heterogeneity Variables

As we are including the exogenous determinants into the mean of the inefficiency term (see Battese and Coelli, 1995), in order to take into account municipalities observed heterogeneity in our

[13] This index was constructed using the seats of each political party in the Council.

stochastic frontier model, we also incorporate such specific effects in the estimated distribution of inefficiency (see Kopsakangas-Savolainen and Svento, 2011).

a. Population density per square kilometer.

b. Urban: it is a dummy that takes value 1 when the commune has an urban population greater than a rural population. For the period 2012-2017 the information of urban and rural population was not for the communes, so it was assumed that if the commune was urban in 2011 it would also be in 2012 and so on. This assumption is valid, since the population composition in terms of urban or rural is not something that changes substantially from time to time.

c. Municipal Territorial Tax: This is tax imposed to agricultural and non-agricultural land.

d. Political Administrative Hierarchy: This variable is constructed by assigning the value 1 to the communes that fulfill the condition of being regional capitals. Then, it is multiplied by the percentage of the population of the region, in relation to the total country. In the same way, a value of 0.5 is assigned to those that fulfill the condition of provincial capital, and this value is multiplied by the total population of the Province, in relation to the total country. Finally, a value of 0 is assigned to the other communes.

e. Income from Municipal Commercial Rights.

f. Percentage of Population living in Poverty Conditions within the municipality, according to the National Socioeconomic Characterization Survey (*In Spanish, Encuesta de Caracterización Socioeconómica Nacional,CASEN*).

Clearly, a large number of individuals living below the poverty line puts an important pressure on the provision of essential good and services aimed at improving the quality of life of that sector of the population. In addition, a municipality with an important proportion of poor population will probably have lower self-generated revenues coming from territorial taxes, commercial rights and transport taxes, for example. These effects plausible hypothesis to explain this result is that current expenditure that go below some threshold may prevent local governments to provide municipal goods and services in an efficient way.

6 Results

The model is estimated by maximum likelihood using the R-Project programme. This software uses the parametrization of Battese and Corra (1977) which gives $\gamma = \frac{\sigma_u^2}{\sigma^2}$ instead of $\lambda = \frac{\sigma_u^2}{\sigma_v^2}$. By replacing $\sigma^2 = \sigma_v^2 + \sigma_u^2$ we obtain $\gamma = \frac{\sigma_u^2}{\sigma_v^2+\sigma_u^2}$, which has a value in the range (0-1). The software allows us to test the significance of the parameter γ in order to evaluate the existence of inefficiency.[14] In this way, if the null hypothesis $\gamma = 0$ is not rejected, implies that $\sigma_u^2 = 0$ and then the term u should be dropped from the model allowing the estimation by OLS.

6.1 General Results

Our preferred general model uses the current expenditure on selected services as *input variable*. The *output variables* include the average monthly enrollment municipal education establishment, the number of rural and urban municipal education establishments, the number of health centers,

[14] The generalized statistic LR, λ, is defined as: $\lambda = -2ln(\frac{L(H_0)}{L(H_1)})$, where H_0 and H_1 are the null and the alternative hypothesis respectively.If H_0 is true then λ asymptoticaly distributes as chi-squared. If H_0 includes $\gamma = 0$ (as in our case), then λ distributes as a combined chi-squared. The critical values for this test were obtained from Table 1 of Kodde and Pam (1986).

municipal expenditure on city *cleaning services, garbage collection and landfill services,* square meters of maintained green areas and social organizations. The *determinants of municipal efficiency* include dummy variables for population under 10,000 inhabitants (Population Dummy 2), between 10.000 and 30.000 inhabitants (Population Dummy 3) and over 100,000 (Population Dummy 4), distance to the regional capital, dependency from the common municipal fund (FCM) relative to self-generated income, percentage of public investment relative to total expenditure, current transfers from public institutions in per capita terms, the Herfindahl index measuring the concentration of political parties in the city council, and the percentage of the council who belongs to the governmental coalition.

From the results of the general model presented in column1 of **Table 4** it can be seen that most of the determinants are significant at 1% with the exception of the variable "Current transfers from public institutions" that is significant at 5% and the political factor variables, which are not significant at all.

6.1.1 Population

Results from **Table 4** show that population variables: population dummy 2, population dummy 3 and population dummy 4 are all significant at 1%. While population under 10,000 inhabitants (Population Dummy 2) and between 10.000 and 30.000 inhabitants (Population Dummy 3) have a negative impact on municipal efficiency levels, municipalities with populations over 100,000 (Population Dummy 4) do have a positive effect on efficiency. This suggests that large municipalities, with populations over 100,000 inhabitants, are more efficient than smaller municipalities.

An hypothesis to explain this result is that small municipalities face some difficulties to provide a minimum of goods and services due to their lack of economics of scale and scope and moral hazard. As there are negative correlations between the dependency level of the *FCM* and population (see **Table 8**), a municipality with a smaller population will have higher dependency of the *FCM* and lower self-generated income which may suffer of moral hazard induced behavior as resources are not generated by the municipality but transferred from others regardless of municipal financial performance. This hypothesis is sometimes also referred as *fiscal laziness in local governments*.

6.1.2 Geography

Results from **Table 4** suggest that the variable: "Distance to the Regional Capital" is negative and statistically significant at 1%. This results gives support to the hypothesis that the closer municipalities are to the regional centre the more efficient they are. The rationale behind this result is that being closer to the regional capital allows municipalities to compete for better resources, financial as well as for best qualified human capital, and at the same time access to get an easier access to regional public services.

6.1.3 Fiscal Capacity

Table 4 shows that variables: "% common municipal fund (*FCM*) to self-generated income" and "% public investment to total expenditure" have negative coefficients and are both significant at 1%. Municipalities have a lower fiscal capacity whenever the dependency of the *FCM* relative to their self-generated revenues increases. This lower fiscal capacity generate a tighter budget constraint, decreasing in this way current expenditure. Similarly, whenever the percentage of investment over total expenditure increases, municipalities will have a tighter budget constraint since they will face a lower current expenditure. A plausible hypothesis to explain this result is that current expenditure that goes below some threshold may prevent local governments to provide municipal goods and services in an efficient way. In addition, another explanation that could be put forward is that a municipality with greater dependency on the *FCM* and lower self-generated income may induce moral hazard as resources are not generated by the municipality but transferred from others regardless of municipal financial performance.

By contrast, the variable: "Current transfers from public institutions" has a positive coefficient, being statistically significant at the 5%. An explanation for this result is that higher current transfers from public institutions may improve municipal fiscal capacity, increasing their current expenditure, and as these transfers are followed and monitored by these institutions (such as ministries or other public services from the central government) and specifically directed to the provision of certain municipal goods and services, local governments tend to comply with fiscal discipline criteria and with quality and timing standards associated to these transfers.

6.1.4 Political Factors

Table 4 shows that the variable: "Herfindahl Index", that measures the concentration of political parties in the city council, is zero and not statistically significant, while "% Governmental Coalition seats", that measures the percentage of the council who belongs to the governmental coalition, is positive and not statistically significant. While the main hypothesis behind the later is the importance of political competition to improve municipal efficiency (Besley et al, 2005), this result, although not statistically significant, can point towards more coordination and governmentally given by the majority of city councillors belonging to the same political trend.

6.1.5 Trend

From **Table 3**, it is easy to realize that some of the economic variables used in this study have a common tendency of growing over time. Hence, we recognize the need to incorporate a time trend in order to draw causal inference using our time series data. Ignoring the fact that two (or more) sequences are trending in the same or opposite directions can lead us to falsely conclude that changes in one variable are actually caused by changes in another variable. In many cases, two time series processes appear to be correlated only because they are both trending over time for reasons related to other unobserved factors. For this reason we include the variable: "Trend" that runs from one in 2008 to eleven in 2018. **Table 4** shows that "Trend" is positive and statistically significant at 5%, reflecting the fact that indeed many of the time series data we use in our study have a tendency of growing over time. This is not surprise as we use data from local government budgets which usually grow in time.

6.1.6 Observed Heterogeneity Variables

In **Table 4** we also report results regarding the inclusion of variables to account for municipalities observed heterogeneity.

a. Poverty: The variable: "% Poverty", that represents the percentage of population living in poverty conditions within the municipality, is negative, very close to zero, and not statistically significant.

b. Political Administrative Hierarchy: The variable: "Administrative hierarchy" is positive, close to 1, and statistically significant at 1%. This result suggests that municipalities that are also regional or provincial capitals, with big populations are more efficient than those that are not. We can explain this result by the fact that Chile is a very centralized country, in which the capital Santiago concentrates 36% of the country's population and where regional and provincial capitals are also the more populated areas in regions, and so they tend to concentrate most of the advance human capital, more developed infrastructure, industry and markets. Hence, it transpires, that given this level of centralization, regional or provincial capitals are favored with better and more resources and therefore are more efficient than other local governments that do not share this characteristic.

c. Municipal Territorial Tax: "Territorial Tax" is a tax imposed to agricultural and non-agricultural land within the commune. This variable is positive and statistically significant at 5%. This result implies that the most money a municipality collect due to this tax, the more efficient the local government is. This finding is consistent with the negative sign and significance of the variable "% common municipal fund (FCM) to self-generated income" discussed previously, since territorial tax is one of the most important sources of self-generated income for Chilean local governments. Again, an explanation for this could be the fact that pro-active local governments that try to generate their own income, take better care of those resources than those municipalities that receive most of their revenues from the common municipal fund. In other words, local governments with greater levels of self-generated income may reduce the incentives for moral hazard behavior as resources are generated by the own municipality and so their results are aligned with their financial performance.

d. Municipal Commercial Rights: The variable: "Mun. Commercial Rights" is positive and statistically significant at 1%. This rationale of this result is similar to the one presented for the case of the "Territorial Tax" variable, since is also one of the most important sources of self-generated income for Chilean local governments.

Finally, from our analysis, it can be concluded that our general model is very robust to the inclusion of variables used in order to account for municipalities observed heterogeneity. Indeed, from **Table 4** it transpires that the signs and statistically significance of the variables from our General Model are not affected by the inclusion of these variables, even when we estimate our General Model including all the Heterogeneity Variables. It should be noted that when all the *heterogeneity variables* were added, the variables "Herfindhal Index" and "% Governmental Coalition seats" were dropped as the model was losing specificity by having so many determinants.

7 Overall results

Regarding the overall results, **Table 4** suggests that Chilean municipalities have a significantly different from zero degree of inefficiency (i.e. the LR test $H_0 : \sigma_u^2 = 0$, rejects the null). In particular, **Table 5** shows that the aggregate inefficiency estimated by our General Model reaches **61%**. This result suggests that Chilean municipalities could provide the same amount of services but with a **61%** less of resources. Again the results are very robust to the incorporation of covariates to control for municipalities observed heterogeneity such as: %Poverty, "Administrative hierarchy", "Territorial Tax", and "Mun. Commercial Rights". The different estimates of aggregate inefficiency go from 61% to 59,10%, which results from adding the variable "Mun. Commercial Rights" to the determinants. When all heterogeneity variables are added to the General model, the estimated aggregate inefficiency is reduced to 52,9%. From **Table 5**, it can also be noted that the standard deviation of average efficiency is, for all estimations, very close to 50%, which implies that the efficiency levels of the 324 local governments under analysis are spread out over a large range of values, as also noted by the maximum and minimum values.

Table 6 reports the evolution of average efficiency for the period 2008-2018. The histogram presented in **Figure 1** shows an approximate representation of the distribution of average efficiency levels for all the local governments in the sample for years 2008, 2013 and 2018. From this graph, it transpires that in 2008 there was an important number of municipalities with efficiency levels above 70%, in fact that year the average efficiency level for all local governments was around 63%. By 2013, only a few number of municipalities showed efficiency levels above 75%, being the average efficiency level 38% that year. Finally, in 2018 this trend shows that most local governments present efficiency levels below 50%, being the average efficiency level 22% that year. Finally, **Figure 2** shows that, consequently, the levels of aggregated inefficiency have sharply risen during this period, from 37,5% to 78,4%, being the average aggregate inefficiency for the period the 61% already reported.

8 Sensitivity Analysis

In order to check the sensitivity of our results we modify some of the assumptions.

8.1 Multicollinearity

In the first place we check the correlations between the variables. This is important as the Translog function used for our analysis may be susceptible of multicollinearity and degrees of freedom problems. Hence, in order to check the level of multicollinearity of the output variables included in the model, we analyze the correlation between them and the results are presented in **Table 7**. Results suggest that levels of correlation are not very high. Furthermore, we repeat the same exercise with the determinants. Results are presented in **Table 8** and suggest that correlations between them are not high at all.

8.2 Alternative Costs Function

All the analysis was carried out using a Translog cost function which gives flexibility and relax some of the assumptions of the more commonly used Cobb-Douglas. Even though Greene (2005c) pointed out that results are overall similar irrespective of the function, we now check how our results change when we vary the cost function. For this, we re estimate the baseline general model but now using the more restrictive Cobb-Douglas instead of the Translog. Results are presented in **Table 9** and suggest that the overall results are indeed similar (rankings of municipalities are similar as well).

8.3 Alternative definition of inputs

As current expenditure on the services included in our model was used as input for our estimations, we now check the sensitivity of our results to a slight modification of the input variable. We reestimate the model but now using total current expenditure. In this way we are considering all the current resources used by municipalities on the provision of good and services. From **Table 10** we observe that results are similar when input variable is slightly modified.

8.4 Unobservable Heterogeneity

As previously pointed out, parametric methods can take into account unobserved heterogeneity in explaining municipal performance. As a random effect approach is used in this study, an assumption is implicitly imposed. This relates to the assumption that there is no correlation between the covariates and the composed error term. As in the error term unobserved heterogeneity is included, this is included in our assumption. As in the municipal case, it could be questionable that unobserved heterogeneity is not correlated with the covariates, we relax the assumption by using Mundlak's (1978) approach. This approach consist on parameterizing the unobserved heterogeneity with the average (across time) of the time variables covariates. Results with the Mundlak parametrization are shown in **Table 11** and suggest that there are no significant differences relative the original model without Mundlak's parametrization.

8.5 Quality

As previously stated, we did not include quality measures in our determinants and thus the general model focuses in quantity of services provided. Despite this, we indirectly take educational quality into account by incorporating as output within our General Model the following two variables:

a. The average scores of the Education Quality Measurement System (*in Spanish: Sistema de Medición de la Calidad de la Educación, SIMCE*) of 4^{th} grade for language and mathematics subjects, per municipality.

b. The percentage of municipal education establishments that obtain, on average, a score equal to or higher than 450 points in the University Selection Test (*in Spanish: Prueba de Selección Universitaria,PSU*) per municipality.

Similarly, in order to measure quality in Health we also incorporated to our General Model the following variable:

a. Infant mortality rate at the municipal level. This rate is the number of deaths per 1,000 live births of children under one year of age by municipality.

In order to further investigate this issue, we reestimate the general model but now controlling by our quality variables in education and health. Results are presented in **Table 12** and suggest that the effects of quality in education and health are not significantly different from zero.

9 Concluding Remarks & Policy Recommendations

This study estimates a stochastic frontier model in order to analyze municipal efficiency and its determinants. To estimate the model, unlike most of previous literature, we use panel data from 2008-2018 of 324 Chilean Municipalities and a one stage approach in order to avoid the problems from the two stages approach. We take into account observed and unobserved heterogeneity, incorporating them both into the frontier and jointly estimating efficiency of all the municipalities in the sample.

Our results suggest that Chilean municipalities present on average inefficiency levels of **61%** approximately for the period 2008-2018. In other words, Chilean municipalities could provide the same amount of services but with a **61%** less of resources. We also report the evolution of average efficiency for the period 2008-2018 showing that the levels of aggregated inefficiency have sharply risen during this period, from **37.5%** to **78.4%**.

In particular, we found that large municipalities, with populations over 100,000 inhabitants, are more efficient than smaller municipalities and that the closer municipalities are to the regional centers the more efficient they are. We also report that regional or provincial capitals are more efficient on average than the rest. All these findings seem to point to Chile's uneven population distribution and the extremely centralized political organization of Chilean regions as key factors of municipalities efficiency levels. Indeed, Chile is a very centralized country, in which the capital Santiago concentrates 36% of the country's population and where regional and provincial capitals are also the more populated areas in regions, and so they tend to concentrate most of the advance human capital, more developed infrastructure, industry and markets. Hence, it transpires, that given this level of centralization, regional or provincial capitals are favored with better and more resources and therefore are more efficient than other local governments that do not share this characteristic. Clearly, in order to address these issues structural changes are need it. This issue has been recently recognized by Chilean politicians and in February 2018, two laws were enacted regarding Chile's decentralization: Law No. 21,073, which regulates the election of regional governors and other aspects, and Law No. 21,074, on Strengthening the Country's Regionalization, which will have important consequences for public management. These two laws will introduce significant changes to the decentralization model. Specifically, the biggest change will be reflected in October 2020, when regional governors will be elected by direct vote, replacing the current mayors. In addition, the mechanism for transferring powers from the central government to the regional governments will be implemented from 2022 onwards. The results presented in this paper support the need to implement these two laws on Chile's decentralization.

Furthermore, we also found evidence that municipalities with a high dependency on the Municipal Common Fund (as percentage to self-generated income) and with a high percentage of public investment with respect to total expenditure are, ceteris paribus, less efficient. We argue that this result can point towards the notion that municipalities with lower self-generated income may suffer of moral hazard induced behavior as resources are not generated by them but transferred from others regardless of municipal financial performance. If local governments financial resources are not tied to their performance in any way, they do not have economic incentives to either take good care of their efficient use nor to generate new revenue sources. This notion is sometimes also referred as *local governments fiscal laziness* in the literature. This is probably one of the main explanations of the sharp risen in local governments levels of aggregated inefficiency for the period 2008-2018 (from **37.5%** to **78.4%)**. In fact, several Laws improving public health and education have been passed in recent years, which mainly increase the salaries of municipal employees in those sectors, without incorporating incentives to improve the efficiency of the provision of municipalities services. In other words, the municipal production costs importantly increased during this period without implying a corresponding inrease in output.

By contrast, we found that local governments with higher self-generated revenues coming from higher territorial taxes collected or higher municipal commercial rights are more efficient. Finally, we also report that current transfers from public institutions (namely, Ministries and other public services) to municipalities also increase efficiency, which provides an interesting policy recommendation for the Chilean Central Government to implement in the future regarding local government development.

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Table N^{o}1: Sources of Funding of the FCM

Structure of FCM	**Municipal Contribution**	**Contribution from the wealthiest Municipalities***
Territorial Tax	60%	65%
Commercial Rights	0%	55% Santiago and 65% Providencia, Las Condes and Vitacura
Transport Tax	62.5%	62.5%
Vehicles Transfers	50%	50%
Penalties and Fines	100%	100%
Central Government Transfers	218,000 UTM	218,000 UTM

*Santiago, Providencia, Las Condes and Vitacura

Table N^{o}2: Mechanism of Distribution of the FCM

Indicator	**Percentage**
same proportion	25%
Poverty	10%
Exempted Land	30%
Permanent Self-generated Revenue (IPP)	35%
Total	**100%**

Table 3: Output Variables Summary Statistics

Year		Current Exp.	Current Exp. on selected serv.	Population	Aver Monthly Regist. Students	Mun. Schools	Mun. Health Centers	Squared Mts of green areas	Rubbish Exp.	Water Coverage	Social Organizations	4th grade Lang. average score	4th grade Math average score.	% Mun. Schools with >450 in Univ. Sel Test	Infant Mortality rate	N
2008	average	2734643	2758021	50825.85	4890.98	17	6	176353.3	325480.6	0.64	365	256	240	0.35	9.49	324
	SD	4678794	4541134	83481.02	6397.58	13	5	360362.8	585931.6	0.23	383	12	15	0.2	12.34	
2009	average	3033885	3124001	51328.31	4729.79	17	7	199699.9	364746.4	0.76	388	256	244	0.34	8.24	324
	SD	5063085	5024241	85362.09	6158.16	13	5	396438	639784.3	0.22	433	13	16	0.2	7.42	
2010	average	3414762	3320053	51830.7	4531.65	17	7	240076.4	388152.4	0.76	395	266	245	0.36	8.6	324
	SD	5775577	5272394	87262.12	5858.67	13	5	599585.5	686944.1	0.22	428	12	15	0.19	10.18	
2011	average	3944154	3917360	52298.31	4975.75	18	5	233721.1	461011.8	0.76	413	264	253	0.35	7.4	324
	SD	6516930	6148064	89295.68	6388.3	33	5	605560.5	817645.7	0.22	521	12	15	0.19	6.88	
2012	average	4524661	4463804	52766.17	4653.36	17	5	210045.5	525506.4	0.76	486	250	252	0.36	8.34	324
	SD	7349662	7002743	91373.65	5824.4	12	4	396650.5	906309.9	0.22	1320	19	12	0.2	10.94	
2013	average	5146329	5020273	53234.03	4383.7	17	5	225413.3	586725.8	0.76	429	260	250	0.37	7.75	324
	SD	8497247	7959027	93536.63	5504.41	14	4	398639.2	1036466	0.22	572	13	14	0.19	7.92	
2014	average	6557043	6311532	54042.58	4282.39	16	5	231371.5	689636	0.76	438	260	250	0.38	7.48	324
	SD	10659996	9940042	81936.61	5393.44	12	4	422505.3	1246756	0.22	530	11	14	0.19	7.61	
2015	average	7689990	7375485	54610.92	4404.01	16	6	249867.1	804234.5	0.76	453	262	254	0.39	7.04	324
	SD	12535660	11655241	82906.77	5533.14	12	5	736736.7	1435383	0.22	559	11	15	0.18	8.75	
2016	average	8816468	8511929	55174.21	4344.53	16	5	237173.3	920368.8	0.76	512	262	255	0.38	7.8	324
	SD	14169930	13311656	83893.53	5454.1	12	4	446654.3	1664220	0.22	724	13	15	0.17	8.22	
2017	average	9584513	9214677	55725.1	4466.04	15	5	242229.5	1019064	0.76	471	264	254	0.42	6.6	324
	SD	15569249	14469661	84856.21	5536.7	12	4	439198.1	1819057	0.22	633	13	15	0.17	6.87	
2018	average	10595529	10093117	56264.48	4331.01	16	5	269214.6	1124086	0.81	479	265	252	0.4	9.36	324
	SD	16989098	15668914	85821.65	5635.91	13	4	470929.8	1995399	0.18	589	14	16	0.18	15.66	

Table N^o 4: Results for the General Model and controlling for Heterogeneity

Determinants	**General Model**	**+ % Poverty**	**+ Admin. Hierarchy**	**+ Territ. Tax**	**+ M. Comm Rights**	**+Heterog Variables**
Constant	1.007***	1.033***	1.024***	0.810***	0.363**	-1.056***
Population Dummy 2	-0.298***	-0.301***	-0.320***	-0.292***	-0.281***	-0.269***
Population Dummy 3	-0.242***	-0.241***	-0.255***	-0.241***	-0.235***	-0.231***
Population Dummy 4	0.446***	0.442***	0.450***	0.446***	0.445***	0.436***
Distance to Regional Capital	-0.042***	-0.042***	-0.038***	-0.041***	-0.040***	-0.042***
% CMF to self-generated income	-0.691***	-0.683***	-0.669***	-0.645***	-0.521***	-0.168***
% public investment to total exp.	-0.540***	-0.544***	-0.533***	-0.535***	-0.538***	-0.500***
Current transfers from public inst.	0.039**	0.035**	0.036**	0.046***	0.047**	0.068***
Herfindhal Index	0	0	0	0	0	
% Governmental Coalition seats	0.029	0.029	0.026	0.024	0.033	
%¨Poverty		-0.069				0.011
Administrative hierarchy			0.933***			0.969 ***
Territorial Tax				0.011**		0.027***
Mun. Commercial Rights					0.039***	0.098 ***
Trend	0.103***	0.103***	0.102***	0.100***	0.098***	0.085***
σ^2	0.552***	0.073***	0.072***	0.072***	0.071***	0.086***
γ	0.073***	0.597***	0.542***	0.523***	0.399**	0.0004***
LR test on $\sigma_u^2 = 0$	-333.35***	-328.28***	-315.13***	-328.98***	-310.09***	-247.52***
Number of Observations	3,474***	3,463	3,474	3,474	3,474	3,463

***p<1%, **p<5%, *p<10%

Table N^o 5: Average Efficiency for the General Model and controlling for Heterogeneity

Model	Avarage Efficiency	Standard Deviation	Maximum	Minimum
General Model	0.390	0.200	0.958	0.050
General Model + % Poverty	0.390	0.200	0.962	0.049
General Model + Administrative hierarchy	0.384	0.198	0.957	0.042
General Model + Territorial Tax	0.392	0.202	0.957	0.051
General Model + Mun. Commercial Rights	0.409	0.212	0.965	0.053
General Model + Heterogeneity Variables	0.471	0.257	0.999	0.035

Table N^o 6: Evolution of Average Efficiency for the Period 2008-2018

Year	Average Efficiency	Standard Deviation	Maximum	Minimum
2008	0.625	0.22	0.959	0.124
2009	0.568	0.205	0.938	0.112
2010	0.528	0.188	0.881	0.103
2011	0.463	0.167	0.856	0.089
2012	0.418	0.153	0.803	0.088
2013	0.375	0.142	0.775	0.079
2014	0.326	0.124	0.638	0.072
2015	0.293	0.111	0.553	0.068
2016	0.258	0.096	0.473	0.062
2017	0.236	0.086	0.474	0.056
2018	0.216	0.08	0.438	0.051

Table N^o 7: Multicollinearity of Output Variables

Output Variables	v_1	v_2	v_3	v_4	v_5	v_6	v_7
Average Monthly Student Enrollment (v_1)	1						
Number of Education Establishments (v_2)	0.59	1					
Number of Health Centers (v_3)	0.50	0.56	1				
Exp. on *Cleaning Services & Garbage Collection (v_4)*	0.66	0.33	0.27	1			
Square meters of Green Areas (v_5)	0.56	0.32	0.29	0.62	1		
Drinking Water Coverage (v_6)	0.45	0.13	0.06	0.42	0.33	1	
Social Organizations (v_7)	0.52	0.41	0.34	0.43	0.35	0.29	1

Table N^o 8: Multicollinearity of Determinants

Determinant Variables	v_1	v_2	v_3	v_4	v_5	v_6	v_7
Population (v_1)	1						
Distance to Regional Capital (ln Km) (v_2)	-0.18	1					
% Common Municipal Fund to self-generated income (v_3)	-0.41	0.23	1				
% Public Investment to Total Expenditure *(v_4)*	-0.29	0.12	0.28	1			
Current Transfers from Public Institutions (v_5)	0.76	-0.16	-0.40	-0.30	1		
Herfindhal Index (v_6)	-0.04	0.02	0.02	-0.16	0.18	1	
% Governmental Coalition seats (v_7)	0.04	-0.07	-0.05	-0.03	0.02	0.1	1

Table N^{o}9: Alternative Costs Functions

Determinants	**Translog**	**Cobb-Douglas**
Constant	1.007***	1.803***
Population Dummy 2	-0.298***	-0.653***
Population Dummy 3	-0.242***	-0.508***
Population Dummy 4	0.446***	0.791***
Distance to Regional Capital (ln Km)	-0.042***	-0.063***
% common municipal fund (FCM) to self-generated income	-0.691***	-0.959***
% public investment to total expenditure	-0.540***	-0.697***
Current transfers from public institutions	0.039**	-0.018
Herfindhal Index	0	0
% Governmental Coalition seats	0.029	0.035
Trend	0.103***	0.130***
σ^2	0.552***	0.106***
γ	0.073***	0.661***
LR test on $\sigma_u^2 = 0$	-333.35***	-927***
Number of Observations	3,474	3,474

***p<1%, **p<5%, *p<10%

Table N^{o}10: Alternative Input variable

Determinants	**Current Expenditure**	**Total Current Expenditure**
Constant	1.007***	0.865***
Population Dummy 2	-0.298***	-0.258***
Population Dummy 3	-0.242***	-0.223***
Population Dummy 4	0.446***	0.448***
Distance to Regional Capital (ln Km)	-0.042***	-0.043***
% common municipal fund (FCM) to self-generated income	-0.691***	-0.695***
% public investment to total expenditure	-0.540***	-0.533***
Current transfers from public institutions	0.039**	0.054**
Herfindhal Index	0	0
% Governmental Coalition seats	0.029	0.046*
Trend	0.103***	0.106***
σ^2	0.552***	0.649***
γ	0.073***	0.078***
LR test on $\sigma_u^2 = 0$	-333.35***	422.54***
Number of Observations	3,474	3,474

***p<1%, **p<5%, *p<10%

Table N^{o}11: Parametrization of Unobserved Heterogeneity (Mundlack)

Determinants	Random Effect	Random Effect + Mundlak
Population Dummy 2	-0.298***	-0.190***
Population Dummy 3	-0.242***	-0.120***
Population Dummy 4	0.446***	0.244***
Distance to Regional Capital (ln Km)	-0.042***	-0.025***
% common municipal fund (FCM) to self-generated income	-0.691***	-0.609***
% public investment to total expenditure	-0.540***	-0.489***
Current transfers from public institutions	0.039**	0.103***
Herfindhal Index	0.000	0.000
% Governmental Coalition seats	0.029	-0.007
Trend	0.103***	0.114***
σ^2	0.552***	0.055***
γ	0.073***	0.404***
LR test on $\sigma_u^2 = 0$	-333.35***	99.31***
Number of Observations	3,474	3,474

***p<1%, **p<5%, *p<10%

Table N^{o}12: Introducing Quality

Determinants	General Model	+ Quality in Education	+ Quality in Health
Constant	1.007***	1.030****	1.021***
Population Dummy 2	-0.298***	-0.290***	-0.295***
Population Dummy 3	-0.242***	-0.234***	-0.239***
Population Dummy 4	0.446***	0.432***	0.438***
Distance to Regional Capital (ln Km)	-0.042***	-0.040***	-0.042***
% common municipal fund (FCM) to self-generated income	-0.691***	-0.660***	-0.686***
% public investment to total expenditure	-0.540***	-0.553***	-0.539***
Current transfers from public institutions	0.039**	0.035**	0.038**
Herfindhal Index	0	0	0
% Governmental Coalition seats	0.029	0.02	0.026
Trend	0.103***	0.103***	0.102***
σ^2	0.552***	0.546***	0.509***
γ	0.073***	0.070***	0.072***
LR test on $\sigma_u^2 = 0$	-333.35***	270.44***	320.17***
Number of Observations	3,474	3,467	3,474

***p<1%, **p<5%, *p<10%

Figure N^{o}1: Histogram of Inefficiency

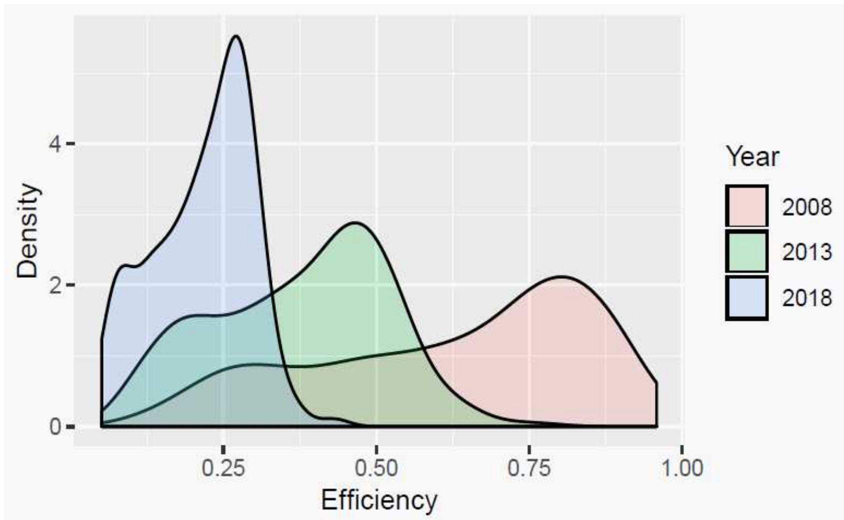

Figure N^{o}2: Aggregated Estimated Inefficiency (%), 2008-2018