A centralized directional distance model for efficient and horizontally equitable grants allocation to local governments

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Abstract

This paper proposes a directional distance model for efficient resource allocation when there is a centralized decision maker who oversees all units. The model is designed to allocate grants from an upper-tier government to the municipalities under its jurisdiction. Local governments employ the grants together with levied local taxes to provide services to their citizens. The objective of our formulation is to optimize grants allocation across municipalities taking into account efficiency, effectiveness and horizontal fiscal equity criteria. The model easily allows the setting of alternative priorities of the central decision maker, thus permitting quantification of the trade-off between the potential increase in the provision of local services and its associated cost. The model is applied to the allocation of current grants in the autonomous community of Navarre in northern Spain.

Kew words: Centralized Resource Allocation; Efficiency; Horizontal Equity; Local Governments; Grants.

JEL codes: D24, H71, H72

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1. Introduction

Intergovernmental fiscal transfers or grants are widely used to allocate funds among different levels of the public sector. Current grants, together with the local taxes raised by each municipality, constitute the resources that local decision makers spend to provide services in the municipality.[1] Thus, while the provision and management of local services delivered to citizens are under the control of the local government, the upper-tier government largely determines the funding and consequently the extent of such services. Specifically, a higher authority or entity, typically the national or regional government, carries out centralized allocation of resources (grants) to each municipality.

In practice, the determination of the total pool and the allocation of grants among local governments is primarily based on indicators of the needs of the population and local fiscal capacity[2]. Nevertheless, grant allocation systems typically omit considerations of the relative efficiency and effectiveness of local governments' spending in the delivery of public services. Despite being a centralized decision mechanism, grant allocation systems are not generally designed for encouraging an effective and efficient use of the overall resources available to the decision maker. Moreover, Boadway and Shah (2007) report examples of intergovernmental grants that are ad hoc or arbitrarily determined by the upper-tier government, which tend to maintain the inequalities across municipalities

[1] The terms grant and transfer are often used interchangeably. In the present paper, we refer exclusively to general grants intended to fund current operating local governments' spending, not specific grants for capital expenditure. Oates (1999) reviews the academic literature on the economics of grants-in-aid from central to local governments.

[2] Boadway and Shah (2007) provide a comprehensive review of the design of and worldwide practices in intergovernmental fiscal transfers.

caused by previous allocations, while further undermines the efficiency of local services provision and local governments' fiscal management.[3]

This paper proposes a new model for the centralized allocation of grants by an upper-tier government to municipalities based on efficiency analysis that enables the decision maker to address the interconnection between public transfers, local taxes and the provision of public services. Specifically, we build on the centralized resource allocation models based on data envelopment analysis (DEA) introduced by Lozano and Villa (2004) and Lozano et al (2004). Thus, we model a central public decision maker that in allocating grants to municipalities seeks to accomplish three interrelated goals: increase the overall production and quality of the services provided by local governments; achieve efficiency of local government spending, i.e. minimize the consumption of resources; and eliminate inequalities in the provision of services and citizens' tax burden across municipalities. Furthermore, the central decision maker can define the relative priority given to such objectives. For instance, she or he decides on the relative weighting of output expansion versus cost reduction or on the relative effort given to decreasing centrally allocable resources (e.g. grants) versus reducing resources under the control of the local government (i.e. local taxes).

From the methodological perspective, the paper contributes to the efficiency literature by proposing a directional distance model for the centralized efficient allocation of resources and target setting. From the policy perspective, we discuss and demonstrate the potential of the model to aid public sector decision makers in allocating grants to local governments from an upper-tier government body. The model is applied to simulate the

[3] In this regard, many studies in the public choice field have argued that political factors, such as reelection purposes, partisan effects, and lobbying by interest groups, largely condition the allocation of intergovernmental grants. A number of empirical studies provide evidence for such behavior in different countries (see e.g. Johansson 2003, Veiga and Pinho 2007, Lara and Toro 2019, Solé-Ollé and Sorribas-Navarro 2008, amongst others).

allocation of grants to municipalities by the regional government of Navarre, an autonomous community in northern Spain. The application shows the versatility of the centralized DEA approach to address efficiency, effectiveness and equality criteria in the allocation of intergovernmental grants. In this sense, the paper contributes to an area that, to our knowledge, has remained unexplored since the pioneering work by Athanassopoulos (1995).

The remainder of this paper is structured as follows. Section 2 reviews the related literature on DEA-based centralized resource allocation models. Section 3 presents the model. Section 4 describes the sample and data used in the empirical analysis. Section 5 presents and discuss the results, and Section 6 concludes.

2. **Centralized efficient resource allocation models**

Centralized efficient resource allocation models apply to situations where certain variables are controlled by a central authority rather than by individual unit managers. In such a setting, the goal of the central decision maker is to optimize the aggregate resource utilization by all units in an organization rather than maximize the individual output generation and/or minimize resource consumption by each unit separately. Lozano and Villa (2004, 2005) and Lozano et al (2004) develop a new DEA model formulation for centralized decision-making settings. In this formulation, a single linear programming problem is solved to project all units onto the efficient frontier, instead of solving a model for each unit separately. Depending on the orientation selected, the model either globally reduces the total use of inputs or globally increases the production of outputs.

Related approaches to centralized or intraorganizational resource allocation based on efficiency analysis have also been proposed. Golany and Tamir (1995) introduce a pioneering output-oriented model that seeks the expansion of the aggregate output of all units constrained on the observed total input consumption. Athanassopoulos (1995, 1998) develops a goal programming DEA model to integrate target setting and resource allocation in multi-level planning problems and applies the method to the central government's allocation of grants to local authorities in Greece. Beasley (2003) proposes a non-linear formulation that allocates input resources to individual units and sets output targets for each unit with the objective of maximizing the average efficiency of the organization. Korhonen and Syrjänen (2004) combine DEA and multi-objective linear programing to allow decision makers to incorporate information concerning the relative importance of inputs and outputs into the analysis preference.

Following Lozando and Villa’s (2004, 2005) approach, a number of papers have extended and proposed variants of centralized DEA models. Some focus on radial models, i.e. radial reductions of the total consumption of every input or radial expansion of the total production of every output. Other approaches are based on non-radial measures and allow separate reductions for each input and/or output-specific expansions. Asmild et al (2009) introduce a model formulation that only considers adjustments of previously inefficient units. Mar-Molinero et al (2014) present a modification of Lozano and Villa’s (2004) radial model that makes the model easier to implement while accommodating situations with more or less units than the original number. Fang and Zhang (2013) develop a centralized resource allocation model that extends and generalizes Lozano and Villa’s (2004) and Asmild et al’s (2009) models to a more general case. Lozano et al (2009) present a non-radial model for reallocating pollutant emission permits that allows the central planner to maximize the aggregate output of goods and the reduction of undesirable outputs (pollutants) while minimizing the use of variable inputs. Lotfi et al (2010) present a centralized resource allocation for enhanced Russell models. Lozano et al (2011) propose a number of non-radial Russell output-oriented centralized DEA models to determine individual and collective output targets and decide capital investments for the national Spanish Port Agency under capital budget constraints. Yu et al (2013) construct a centralized DEA model based on a Russell measure applied to human resources reallocation among units (airports) within a single organization (Taiwan Civil Aeronautics Administration). Fang (2016) presents a centralized model that allocates resources across a set of units based on revenue efficiency.

Based on the previous literature, we formulate a centralized efficient resource allocation model based on the directional distance function, which is presented in the next section.

3. A directional distance model for centralized resource allocation

3.1 Centralized allocation of resources and efficient target setting

Suppose there are $j = 1,\ldots,n$ producing units, generally referred to as decision-making units or DMUs.[4] Each unit uses input $x = (x_1, x_2, \ldots x_s) \in \mathbf{R}_+^S$ to produce output $y = (y_1, y_2, \ldots y_m) \in \mathbf{R}_+^M$. The technology is represented by the production set *T*, which summarizes the set of all feasible combinations of input and output vectors and is defined as

$$T = \{(x, y) \in \mathbf{R}_+^{s+m} : x \text{ can produce } y\} \tag{1}$$

where x denotes the *s*-dimensional vector of inputs and y the *m*-dimensional vector of outputs.

[4] DMU can refer to a plant, facility, outlet, division of a company, or a larger entity such as an industry or a region. In our empirical analysis, DMU refers to a municipality.

A DEA piecewise linear reference technology under the assumption of variable returns to scale can be defined as

$$T = \left\{(x,y): \sum_{j=1}^{n} \lambda_j y_{mj} \geq y_m \ \ \forall m, \sum_{j=1}^{n} \lambda_j x_{ij} \leq x_i \ \ \forall i, \sum_{j=1}^{n} \lambda_j = 1, \lambda_j \geq 0 \ \ \forall j \right\} \quad (2)$$

where λ_j are the intensity variables to construct the linear combinations of the observed inputs and outputs.

Following Chambers et al (1998), the directional distance function defined on the technology T is given by

$$\vec{D}(x,y;g) = \sup\{\beta: \left(y + \beta g_y, x - \beta g_x\right) \in T\} \quad (3)$$

where $g = \left(g_y, g_x\right)$ is the nonzero vector that determines the directions in which inputs and outputs are scaled. This distance function simultaneously seeks to expand output and contract input along the direction vector g, which sets the direction in which the input output vector (x,y) is projected onto the boundary of T. The value of β in (3) gives the distance between the observation and the production boundary and is therefore a measure of its relative inefficiency. $\beta = 0$ indicates that the observation lies on the frontier and is efficient compared with the others. The more inefficient an observation, the higher its value of β.

Let us assume that there is a central decision maker (hereafter CDM) that oversees all units. The CDM aims to optimize the combined resource consumption of all units in the organization rather than considering the consumption of each unit separately. Thus, it has the objective of increasing the total system output production (i.e. the aggregate production of all outputs) with the lowest possible consumption of aggregate resources. Let $Y = \sum_{j=1}^{n} y_j$ be the current total system output and $X = \sum_{j=1}^{n} x_j$ the current total system input. Then, the CDM seeks the expansion of Y and the contraction of X.

To that effect, we formulate a centralized resource allocation model based on the directional distance function. Specifically, we employ the weighted Russell directional distance model (WRDDM) developed by Chen et al (2014) (see also Barros et al. 2012 and Fuji et al. 2014). We set first the directional vector $g = (g_x, g_y) = (X, Y)$. That is, the direction chosen is based on the observed aggregate amount of outputs and inputs. This direction vector allows an inefficient organization increasing outputs and decreasing inputs in proportion to the initial combination of outputs and inputs.

Let us now consider two output types: adjustable and non-adjustable. The former refers to outputs whose quantity may be discretionarily changed (increased or decreased) by the DMU. The latter refers to outputs that have a non-discretionary nature and cannot be adjusted either by the DMU or the CDM. Denote by $y^A = (y_1^A, y_2^A, \dots, y_p^A)$ the vector of adjustable outputs and $y^{NA} = (y_1^{NA}, y_2^{NA}, \dots, y_l^{NA})$ the vector of non-adjustable outputs.

Then, the value of $\vec{D}(X, Y; g)$ for the overall organization can be computed by solving the following linear programming problem, which we will refer to as Model I:

$$\vec{D}(X, Y; g) = Max\ \ \omega_y\left(\sum_{m=1}^{p} \varphi_m \beta_m\right) + \omega_x\left(\sum_{i=1}^{s} \alpha_i \gamma_i\right) \qquad (4.1)$$

$$s.t.\ \sum_{r=1}^{n}\sum_{j=1}^{n} \lambda_{jr}\, y_{mj}^A \geq (1 + \beta_m) \sum_{j=1}^{n} y_{mj}^A\ , \qquad m = 1, \dots, p \qquad (4.2)$$

$$\sum_{r=1}^{n}\sum_{j=1}^{n} \lambda_{jr}\, x_{ij} \leq (1 - \gamma_i) \sum_{j=1}^{n} x_{ij}\ , \qquad i = 1, \dots, s \qquad (4.3)$$

$$\sum_{j=1}^{n} \lambda_{jr} y_{kj}^{NA} \geq\ y_{kj}^{NA} \qquad k = 1, \dots, l \qquad (4.4)$$

$$\sum_{j=1}^{n} \lambda_{jr} = 1 \qquad r = 1, \dots, n \qquad (4.5)$$

$$\lambda_{jr} \geq 0 \qquad \forall j, r = 1, \dots, n \qquad (4.6)$$

where λ are the intensity variables to expand or shrink the individual observed activities of each unit to construct convex combinations of the observed inputs and outputs that define the efficient projected points for each unit. Thus, λ_{jr} is the vector of intensity variables of linear combination coefficients for unit *r*. Note that unlike conventional DEA models, the intensity variables in the linear programming problem above have two indexes for referring to DMUs, *j* and *r*. This is a distinctive feature of centralized DEA models. A centralized DEA projects all DMUs onto the frontier by using a single model, while the conventional DEA obtains the projection of each DMU by running *n* separate models separately, one for each DMU. Thus, the centralized DEA generates all of the intensity variables for each DMU simultaneously by running the model only once.

Model I simultaneously seeks the expansion of the total output quantity and the contraction of the total input quantity, given the priorities set by the CDM. In equation (4.1), β_m and γ_i are the aggregate efficiency measures for the *m-th* adjustable outputs and *i-th* inputs, respectively, while ω_x, ω_y, φ_m and α_i are the (non-negative) weights that reflect the decision maker's priority structure. For instance, if the CDM gives higher priority to reducing inputs than to increasing outputs, then $\omega_x > \omega_y$. The coefficients φ_m and α_i play similar roles in the output and input dimensions, respectively. For instance, if the CDM aims to allow greater expansion in the provision of a particular output *m*, then a higher value can be assigned to its corresponding weight φ_m in (4.1) in relation to the rest of the outputs. The sum of the weights is normalized to unity, that is, $\omega_y + \omega_x = 1$ and $\sum_{m=1}^{l} \varphi_m = \sum_{i=1}^{s} \alpha_i = 1$.

The output constraints in (4.2) take all the units and then seek to increase the aggregate amount of each adjustable output as much as possible, ensuring that the *n* projected points cannot lie outside the feasible aggregate output set. Likewise, equations (4.3) seek to decrease the current total amount of inputs as much as possible, ensuring that the *n* projected points cannot lie outside the feasible aggregate input set. Equation (4.4) ensures that the projected point for each unit *j* must obtain at least the quantities of non-adjustable outputs that are currently being obtained by unit *j*. Finally, equation (4.5) indicates that the model allows variable returns to scale (VRS). Note that there is a VRS constraint for each DMU, which ensures that each unit is benchmarked against units of a similar size. Constant returns to scale are imposed when the convexity restrictions (4.5) are dropped; in such a case, a unit could be benchmarked against units that are substantially larger (smaller) than it. Solving Model I yields the optimum values of β_m^* and γ_i^*, which are used to calculate the efficient aggregate quantity for each input $X_i^* = (1-\gamma_i^*)\sum_{j=1}^{n} x_{ij}$ and the efficient aggregate output quantities for each adjustable output $Y_m^{A*} = (1+\beta_m^*)\sum_{j=1}^{n} y_{mj}^A$. Thus, γ_i^* (β_m^*) represents the percentage reduction (increase) with respect to current total system input (output). Furthermore, by using the vector of intensity variables $(\lambda_{j1}^*, \lambda_{j2}^*, \dots \lambda_{jn}^*)$, one computes the target values of inputs and outputs for each unit, which we respectively denote as $x_{ij}^* = \sum_{r=1}^{n} \lambda_{jr}^* x_{ij}$ and $y_{mj}^* = \sum_{r=1}^{n} \lambda_{jr}^* y_{mj}$. For each input, the total target is the sum of the individual input targets $X_i^* = \sum_{j=1}^{n} x_{ij}^*$, and for each output, the total target is the sum of the individual output targets $Y_m^* = \sum_{j=1}^{n} y_{mj}^*$.

3.2 Equity considerations in target setting

It might be the case that the distribution of individual input and output targets determined by Model I (x_i^*, y_m^*) is considered unfair or undesirable for some reason. As stated in the Introduction, the problem that motivates this research is the allocation of grants to municipalities by an upper-tier government body. In this context, the regional government is the CDM that oversees the municipalities (DMUs) under its jurisdiction. The municipalities use resources (e.g. local taxes and grants) to produce outputs (e.g. local services). Thus, the individual target values for grants and taxes as well as the target values for local services obtained from Model I can vary greatly across municipalities, generating inequalities among citizens from different municipalities that may be unacceptable to the regional government. Specifically, it may happen that citizens from some municipalities pay higher local taxes per capita than citizens from other municipalities to receive similar levels of services because the local government receives a relatively lower grant from the regional government. We discussed the horizontal equity issue in the Introduction.

Let us define now two input types: CDM-controlled and unit-controlled inputs. Let $x^u = x_1^u, x_2^u, \dots, x_d^u$ be the subvector of unit-controlled inputs and $x^c = x_1^c, x_2^c, \dots, x_h^c$ the subvector of inputs controlled by the CDM. In the context of municipalities, the amount of local taxes is determined by the local government, while grants are determined by the CDM. Thus, x_j^c denotes the grant allocated by the regional government to municipality *j*, while x_j^u denotes the quantity of local taxes raised by the local government *j*. The sum of grants and taxes $(x_j^c + x_j^u)$ is the total amount of resources that municipality *j* uses to provide output y_j.

Therefore, in addition to efficiency, a further objective of the CDM is to encourage equality among units when allocating the inputs that are under its control while meeting the aggregate system targets determined by Model I. With this aim, we formulate a reallocating model, which we will refer to as Model II. This model is closely related to other reallocating models proposed in the literature, e.g. Lozano et al (2011) and Yu et al (2013).

Let β_m^* and γ_i^*be the optimal solution of Model I. Then Model II is formulated as follows:

$$Min \sum_{f=1}^{h}\sum_{j=1}^{n} w_{fj}^{c}\left(s_{fj}^{+} - s_{fj}^{-}\right) \tag{5.1}$$

$$s.t. \quad \sum_{r=1}^{n}\sum_{j=1}^{n} \lambda_{jr}\, y_{mj}^{A} = (1+\beta_m^*)\sum_{j=1}^{n} y_{mj}^{A}\ , \qquad m = 1, \dots, p \tag{5.2}$$

$$\sum_{r=1}^{n}\sum_{j=1}^{n} \lambda_{jr}\, x_{tj}^{u} = (1-\gamma_u^*)\sum_{j=1}^{n} x_{tj}^{u} \qquad t = 1, \dots, d \tag{5.3}$$

$$\sum_{r=1}^{n}\sum_{j=1}^{n} \lambda_{jr}\, x_{fj}^{c} = (1-\gamma_c^*)\sum_{j=1}^{n} x_{fj}^{c} \qquad f = 1, \dots, h \tag{5.4}$$

$$\sum_{j=1}^{n} \lambda_{jr} x_{fj}^{c} = x_{fj}^{c} + s_{fj}^{+} - s_{fj}^{-} \qquad f = 1, \dots, h \tag{5.5}$$

$$\sum_{j=1}^{n} \lambda_{jr} x_{tj}^{u} = e_t^u * \sum_{r=1}^{n}\sum_{j=1}^{n} \lambda_{jr}\, x_{tj}^{u}, \qquad t = 1, \dots, d \tag{5.6}$$

$$\sum_{j=1}^{n} \lambda_{jr} y_{mj}^{A} = e_m^a * \sum_{r=1}^{n}\sum_{j=1}^{n} \lambda_{jr}\, y_{mj}^{A}, \qquad m = 1, \dots, p \tag{5.7}$$

$$\sum_{j=1}^{n} \lambda_{jr} y_{kj}^{NA} \geq\ y_{kr}^{NA} \qquad k = 1, \dots, l \tag{5.8}$$

$$\sum_{j=1}^{n} \lambda_{jr} = 1 \qquad r = 1, \dots, n \tag{5.9}$$

$$\lambda_{jr}, s_j^{+}, s_j^{-} \geq 0 \qquad \forall j, r = 1, \dots, n \tag{5.10}$$

In equation (5.1), s_j^+ and s_j^- are the reallocated quantities of input *f*, while w_{fj}^c is the unit cost of allocating input *f* to unit *j*. As shown in equation (5.5), s_j^+ and s_j^- are the deviations from the optimum performance of each unit determined by Model I. Such deviations make feasible the reallocation of CDM-controlled inputs x^c across units that may be required due to the inclusion of the equality constraints in equations 5.6 and 5.7. Consequently, equation (5.1) seeks the minimization of the overall cost of reallocation.

For instance, in our empirical analysis we consider a single centrally allocable input x^c (grants) and a single input x^u under the control of the unit (local taxes). Then in equation (5.5) the values of s_j^+ and s_j^- represent the amount of grants that can respectively be transferred to and released from the individual targets obtained from Model I. As grants (and taxes) are measured in monetary units, the unit cost of input reallocation in this case is $w_{fj}^c = 1$. Nevertheless, in the general case, centrally reallocable inputs are frequently measured in physical units, like number of employees. In this case, the subscript j in w_{fj}^c indicates that the unit cost of reallocating input x_f^c may differ across units. For instance, the reallocation of employees within one organization may require transferring employees to/from plants located in cities or regions with substantially different personnel costs (e.g. salaries).

Equation (5.2) ensures that the aggregate levels of outputs are equal to the maximum determined in Model I. In the same way, equations (5.3) and (5.4) respectively ensure that the aggregate volumes of locally and centrally allocable inputs are equal to the optimum obtained in Model I. Note that the equality in (5.4) ensures that the total amount of inputs reallocated to all units, $\sum_{j=1}^{n}(s_j^+)$, is equal to the total amount of inputs reallocated from all units, $\sum_{j=1}^{n}(s_j^-)$.

Equations (5.6) and (5.7) represent the equity constraints. The variables e_t^u and e_m^a are the equity units for ensuring the equalities imposed on input *f* and adjustable output *m*, respectively. In our empirical analysis, we use these constraints to model the horizontal financial balance, often referred to as fiscal equalization or horizontal equity (Buchanan, 1950). Municipalities may differ both in their capacity to raise revenues from their own sources and in the expenditures required to provide given levels and quality of services. Horizontal equity means that every local government has a similar amount of potential revenue (local taxes plus transfers) per unit of equivalent spending need.[5] Thus, we choose $e_f^u = \frac{POP_j}{\sum_{j=1}^{n} POP_j}$, where POP_j is the population of municipality j. Consequently, equation (5.6) removes any tax inequality among citizens in the region by specifying that the proportion of taxes levied by municipality j be proportional to its population share, i.e. every municipality is targeted to raise the same value of taxes per capita. Likewise, we require that $e_m^a = \frac{1}{n}$ in equation (5.7), where n is the number of municipalities, which ensures that each municipality provides the same proportion of the maximum aggregate output; in other words, every municipality has the same target quantity for each adjustable output. Of course, equity criteria other than horizontal fiscal equity can easily be accommodated by alternative specifications for the e variables or by imposing lower and/or upper bounds on the variables.

Similar to equation (4.5) in Model 1, constraint (5.8) guarantees that the quantities of non-adjustable outputs in each municipality after grants reallocation cannot be lower than the original level. Finally, equation (5.9) keeps the variable returns to scale assumption.

The vector of the intensity variables obtained from the solution of Model II defines the target values for each unit, that is, the point on the frontier at which it should aim. The vector of intensity variables $(\hat{\lambda}_{j1}, \ldots, \hat{\lambda}_{jn})$ is used to compute the target values of inputs and outputs for each unit, which we respectively denote as $\hat{x}_j = \sum_{r=1}^{n} \hat{\lambda}_{jr}\, x_{jr}$ and $\hat{y}_j = \sum_{r=1}^{n} \hat{\lambda}_{jr}\, y_{jr}$. Note that for each input the total target is the sum of the individual input targets $\hat{X}_i = X_i^* = \sum_{j=1}^{n} \hat{x}_{ij} = \sum_{j=1}^{n} x_{ij}^* \;\; \forall i$, and for each output the total target is the sum of the individual output targets $\hat{Y}_m = Y_m^* = \sum_{j=1}^{n} \hat{y}_{mj} = \sum_{j=1}^{n} y_{mj}^* \;\; \forall m$.

[5] The duty of the state to establish reasonable equalization procedures is recognized in Article 9 of the European Charter of Local Self-Government (Council of Europe, 1985).

In our case study, the grant allocation that results from Model II guarantees that every municipality receives one transfer from the regional government that enables an efficient local government to provide the same level of output as the rest of the municipalities while raising from its citizens exactly the same amount of local taxes per capita as the rest of the municipalities.

4. Data and variables

The empirical evidence presented in this paper focuses on the municipalities of the autonomous community of Navarre in northern Spain in 2008. Figure 1 depicts the location map of Navarre as well as the geographical distribution of its municipalities. With a total area of 10,391 square kilometers and a population of 622,000 inhabitants distributed in 272 towns, Navarre presents one of the most atomized local structures of the Spanish autonomous communities.

We exclude from our analysis the largest city in the region, Pamplona-Iruña, which is the capital city and accounted for roughly 200,000 inhabitants in 2008. In addition to its population size, the capital city is home to all of the regional and state political institutions, universities, hospitals, law courts, and leisure centers and thus is very different from the rest of the municipalities of Navarre. In fact, because of its special nature in the current system of grants allocation in Navarre, the amount of transfer to the capital city does not come from the same global transfer fund that is distributed among the remaining municipalities. Therefore, our sample comprises 271 municipalities.

[Please insert Figure 1 about here]

For each municipality, we obtain data on output and input variables. Two types of output measures are included: non-adjustable (y^{NA}) and adjustable (y^{A}) outputs. Non-adjustable outputs refer to variables that define the spending needs of the municipality and whose level cannot be adjusted by the local government. Specifically, we consider four non-controllable output measures (l = 4): the population of the municipality (*POP*), the number of dwellings (*HOUSE*), the urbanized area (*URBAN*), and the length of municipal streets and roads (*ROAD*). These output proxies are commonly employed to estimate the demand for public services delivered to citizens. In particular, many studies of municipal efficiency (e.g. following the pioneering work by Vanden Eeckaut et al (1993)) employ similar output variables to obtain a measure of the value and magnitude of municipal services provided.[6] Table 1 shows the definitions of the variables and their descriptive statistics.

A cursory examination of Table 1 reveals substantial variation in the four variables across the municipalities in the sample. As municipalities vary greatly in size, variable returns to scale are assumed in our empirical analysis. Nevertheless, even though the non-adjustable output variables included in the analysis and the VRS assumption appropriately control for size differentials (see footnote 5 below), there might be other environmental variables outside the control of the local government that potentially influence the cost of providing local services, such as the orography, climate and demographic structure of the municipality. Heterogeneity across municipalities can be controlled for by including environmental variables as additional constraints in the model in the manner of non-discretionary inputs/outputs, depending on whether the variable is assumed to have a positive or negative effect (Banker and Morey, 1986). There is not, however, clear evidence on which environmental variables may be relevant for the

[6] Narbón-Perpiñá and de Witte (2018a,b) provide a comprehensive and systematic review of the existing literature on local government efficiency.

municipalities of our sample or on their potential positive or negative effects across municipalities. Hence, we opt for a more parsimonious model for our empirical analysis.

Additionally, we consider four adjustable output measures (p = 4) as proxies for a number of basic goods and services provided by the municipalities and hypothesized to account for fluctuations in the local government spending of any municipality. They measure the provision and quality of street lighting (*LIGHT*), water supply and sewage collection (*W&S*), paving (*PAVING*) and administrative services (*ADMIN*) and are listed in Table 1.

Each of these indicators ranges in value from 0 to 1 to quantify the quality-adjusted degree of coverage of service facilities of each municipality in relation to the area to be served. The four indicators, which are referred to in Table 1, are defined similarly and are computed by the public servants of the Department of Local Administration of the Navarre government. For each municipality and service, the officers first quantify its level of provision on an index with a scale between 0 and 1. They then adjust this index with their technical assessment of the level of quality rated on the following scale: 0, poor quality; 0.5, moderate quality; and 1, good quality. For instance, *LIGHT* = 1 means that lighting covers 100% of the urbanized area of the municipality with optimal quality. These indicators were compiled for each municipality in 2008 and were employed in the Navarre government's ¨Plan for Local Infrastructures 2009-2012" to determine the status of the local infrastructures and endowments and of the services related to them (BON, 2008). Arcelus et al (2015) use similar indicators to assess the cost efficiency of local governments in Navarre.

Table 1 shows that the level of services provision is quite high, with average values equal to or greater than 0.85 except street lighting (0.83). Nevertheless, the minimum values of the four indicators reveal the existence of municipalities with significantly poorer levels of service. In addition to the standard deviation, the last column in Table 1 reports the Gini index to measure the inequality in the distribution of services. A Gini coefficient of zero expresses perfect equality, where all values are the same, i.e. every municipality provides the same level of service. The values of the Gini index are greater than zero, thus confirming the presence of inequality, albeit moderate, in the distribution of services across municipalities.

Two input variables are considered: *GRANTS* and *TAXES*. *GRANTS* accounts for the current or operating transfers received by a municipality from the regional government for funding the provision of services by the local government. Capital grants intended to finance specific investments are not included. *TAXES* is the sum of local taxes, including real estate taxes; taxes on economic activities, vehicle circulation, increases in urban land value, expenditure on luxuries (mostly for hunting and fishing activities), and uninhabited dwellings; and other minor public charges.

The column headed Total in Table 1 shows the aggregate observed values for each input and output variable $\left(X_i = \sum_{j=1}^{271} x_{ij}, Y_m = \sum_{j=1}^{271} y_{mj}\right)$. The two bottom rows of the column indicate that the regional government transferred 156.7 million euros to Navarre municipalities in 2008, while the aggregate volume of local taxes levied by the 271 municipalities amounted to 196.7 million euros. The last column indicates the presence of inequalities across municipalities in the amount of local taxes per capita.

[Please insert Table 1 about here]

5. Results

Table 2 shows the aggregate results of Model I. We solve the model for nine different priority structures between contraction of inputs and expansion of outputs (i.e. cost reduction versus increased service levels), as reflected in the nine different combinations of values for weights (ω_x, ω_y) shown in Table 2. To permit comparison, all cases are computed assuming the same values of $\varphi_m = 1/p\ \forall m$ and $\alpha_i = 1/s\ \forall i$. Given that p =4 and s = 2, φ_m = 0.25 and α_i = 0.5 in solving Model I. Of course, one could select any other combination of weights to reflect alternative priorities.

Let us focus on the first row of Table 2, which corresponds to the case (ω_x = 0.9, ω_y = 0.1), indicating a clear preference of the CDM for reducing the current total cost over the goal of increasing the current level of services. The odd columns in Table 2 report the total targets for inputs and outputs obtained from Model I. Specifically, columns (1) and (3) show the aggregate input targets, $X_i^* = (1-\gamma_i^*)\sum_{j=1}^{n} x_{ij}$, while columns (5), (7), (9) and (11) show the aggregate output targets, $Y_m^{A*} = (1+\beta_m^*)\sum_{j=1}^{n} y_{mj}^{A}$.

Additionally, column (2) reports the volume of grants in per capita terms as the ratio of the aggregate grants target shown in column (1) to the total population. Likewise, column (4) reports taxes per capita as the ratio of the aggregate target of taxes shown in column (3) to total population (423,102 inhabitants as reported in Table 1). Furthermore, columns (6), (8), (10) and (12) in Table 2 present the mean values of each output indicator per municipality as the ratio of the aggregate output values shown in columns (5), (7), (9) and (11) to the number of municipalities (n= 271).

Consequently, the odd columns in the first row of Table 2 indicate that, given the priority scheme (ω_x = 0.9, ω_y = 0.1), all municipalities would require 149.5 million euros of grants and 140.1 million euros of taxes to produce aggregate values of 242.3, 253, 254.1 and 237.9 for the *W&S*, *LIGHT*, *PAVING* and *ADMIN* indicators, respectively.[7]

[7] As a robustness check exercise, one referee suggested to look at the results when the largest (most populated) 10% and smallest (least populated) 10% of municipalities are excluded. This represents the elimination of 54 out of 271 municipalities, which together account for 58.2% of the actual population in Navarre. Notwithstanding the utmost caution that must be observed with any arbitrary modification of the

These figures indicate that substantial reductions in the current amount of grants (4.6%) and local taxes (28.8%) are feasible. The reduction percentages come from the solution of Model I (with ω_x = 0.9, ω_y= 0.1), which yields the aggregate input efficiency measures $\gamma_1^* = 0.046$ and $\gamma_2^* = 0.288$. Likewise, the aggregate efficient target quantities for *W&S* (242.3), *LIGHT* (253), *PAVING* (254.1) and *ADMIN* (237.9) shown in Table 2 are respectively 5.1, 12.3, 2.1 and 2.9 percent greater than the current values reported in Table 1 (230.5, 225.2, 248.9 and 231.1, respectively), which corresponds to the optimal solution of Model I: $\beta_1^* = 0.051, \beta_2^* = 0.123, \beta_3^* = 0.021, \beta_4^* = 0.029$. In summary, our results suggest that with efficient behavior, Navarre local governments in 2008 could have attained a higher level of services while spending 22% less resources (€ 289.6 million as the sum of grants and taxes against € 353.4 million currently spent). [8]

Table 2 illustrates the impact of varying the values of weights (ω_x, ω_y) in Model I. This simulation provides valuable information for the CDM, as it allows the trade-off between the potential for output increase and its associated cost to be quantified. As expected, the figures in Table 2 reveal that as the priority for output expansion (ω_y) increases, the attainable increase in service levels becomes more expensive and requires extra funds. The bottom row of Table 2 shows the case when the maximum priority is given to increasing the adjustable outputs (ω_x = 0.1 ω_y = 0.9). In this case, the regional government should transfer an aggregate amount of 156.7 million euros to municipalities, while the local governments would need to raise 178.1 million in taxes to provide the highest output levels shown in Table 2. These figures result from the optimal values of

size and composition of the reference set in frontier analysis, the exercise reveals that results, not shown here, are highly consistent with those obtained when all municipalities are included. We thank the referee for this suggestion.

[8] This percentage is consistent with the efficiency levels reported by Arcelus et al (2015), who estimate the cost efficiency of 260 Navarre municipalities in 2005 by means of a stochastic cost frontier analysis. They find that the operating cost of municipalities exceeded the estimated minimum cost by 26.4% on average.

Model I (under ω_x = 0.1 ω_y = 0.9): $\gamma_1^* = 0,\ \gamma_2^* = 0.095\ \beta_1^* = 0.164, \beta_2^* = 0.198, \beta_3^* = 0.085, \beta_4^* = 0.166$). That is, increasing *W&S*, *LIGHT*, *PAVING* and *ADMIN* by 10.7%, 6.3%, 6.1% and 13%, respectively, from the levels attainable under the first priority structure would require an additional € 45.2 million.

[Please insert Table 2 about here]

Next, we use the optimal intensity variables λ^* obtained from Model I (with ω_x = 0.9, ω_y = 0.1) to compute the frontier points of inputs and outputs for each unit ($x_{ij}^* = \sum_{r=1}^{n} \lambda_{jr}^* \, x_{ij}$ and $y_{mj}^* = \sum_{r=1}^{n} \lambda_{jr}^* \, y_{mj}$), i.e. the target values for *GRANTS*, *TAXES*, *W&S*, *LIGHT*, *PAVING* and *ADMIN* for each municipality. Figure 2 displays the distribution of these values for each of the 271 municipalities in six radar charts. The 271 municipalities are ordered from lowest to highest population. Thus, in each chart, the first quadrant includes the results for each of the smallest municipalities, specifically the 25 percent of municipalities that are smaller than the first quartile of the population distribution; the second quadrant contains the 25 percent of observations that are greater than the first quartile and smaller than the median population, and so on.

Panels (a) to (d) display the target output levels across municipalities. We recall here that the highest attainable value for each indicator is equal to one, which is the value on the circle that is farthest from the origin in each chart. Panels (e) and (f) display the values of grants and taxes in euros per capita to allow comparisons across municipalities.

Figure 2 illustrates the differences across municipalities resulting from implementing the solution of Model I. That is, Panel (f) clearly shows that allocating the aggregate amount of grants as in Panel (e) would imply substantial differences across municipalities in the level of fiscal effort that citizens should make to finance the provision of local services. Furthermore, Panels (a) to (d) reveal that the distribution of the target level of services across municipalities is also uneven.

[Please insert Figure 2 about here]

If the regional government is concerned with the inequality in the provision of services and local tax per capita across municipalities, then it can allocate grants according to Model II. Model II yields an allocation of the total grants target that is consistent with the provision of identical levels of services and the collection of the same amount of taxes per capita in each municipality. Specifically, each municipality receives a grant that enables the local government to produce the mean target outputs and raise the target value of taxes per capita, which are shown in the even columns of Table 2. The first row of Table 2 shows such values for the case analyzed so far ($\omega_x = 0.9$, $\omega_y = 0.1$). In this case, Model II allocates a grant to each municipality that ensures that, by collecting 331 euros per inhabitant in local taxes, the local government is able to provide output values of 0.894, 0.933, 0.938 and 0.878 for *W&S*, *LIGHT*, *PAVING* and *ADMIN*, respectively, provided that the local government performs efficiently. The total targets for grants, taxes and outputs remain the same as those in Model I, which are shown in the odd columns of Table 2 and were discussed above.

Figure 3 graphically illustrates the effect of the reallocation implied by Model II on the financial structure of each municipality. The radar chart compares the two resulting distribution of transfers among municipalities in terms of the percentage of total resources (grants plus taxes) represented by grants. The lighter line displays the distribution resulting from Model I, while the darker line shows the equality-based distribution resulting from the computation of Model II. Interestingly, Figure 3 shows that the smallest municipalities (i.e. those in the first quadrant of the circle) require a relatively higher proportion of grants than the largest municipalities (those included in the fourth quadrant) to provide similar levels of service. In particular, the average percentage of grants out of total resources in the four groups of municipalities ordered from smallest to greatest is 55.2, 53.4, 52.3 and 50.4 percent, respectively. This is fully consistent with the fact that the cost per capita of providing certain public services (e.g. street lighting or paving) is higher in villages with low and disperse populations than in large towns with more concentrated populations. Thus, as the aggregate fiscal capacity of the smallest municipalities is lower (given a similar tax per capita), they require a higher value of transfers per capita from the central government to be able to provide a similar level of service.

[Please insert Figure 3 about here]

6. Conclusions and discussion

This paper presents a directional distance model for the centralized allocation of resources and efficient target setting. Specifically, the formulation proposed here is based on the weighted Russell directional distance function, which allows the decision maker to seek the simultaneous expansion of outputs and contraction of inputs while facilitating the setting of priorities. The model is designed to deal with the problem of allocation of grants by an upper-local tier government among the municipalities under its jurisdiction. Thus, we apply the model to simulate the allocation of grants by the regional government of Navarre, an autonomous community in northern Spain.

The proposed formulation provides a useful tool to inform policy makers in achieving more effective, efficient and equitable utilization of existing public resources. It helps public decision makers in several ways. First, it allows determining the optimal global amount of financial resources that municipalities require to cover the public tasks they assume and the needs they are expected to satisfy. Thus, it allows to estimate potential savings of public resources that could be achieved in the provision of local services. In our empirical application we find that, depending on the Navarre government's priority structure, the total amounts of grants and taxes could be reduced by up to 9.4 and 28.8 percent, respectively, compared with their current level while simultaneously augmenting the level of all local services.

Second, by simulating alternative priority schemes, the model permits the trade-off between the potential for increased outputs and its associated cost to be quantified. As shown in the empirical simulation, the central decision maker can estimate the magnitude of public transfers and the local fiscal effort for different targets of service provision. This provides valuable information for policy makers as it allows to anticipate the impact of alternative policy priorities, and thereby to improve the management of public resources.

Third, the model allows the policy maker to manage the horizontal equity in allocating grants to municipalities (i.e. every local government has a similar amount of potential resources–local taxes plus grants–per unit of equivalent spending need). In the empirical application, we show that the central decision maker can guarantee that every Navarre municipality receives one transfer that enables an efficient local government to provide the same level of output as the rest of the municipalities while raising from its citizens exactly the same amount of local taxes per capita as the rest of the municipalities. This has important economic and political implications, as such allocation of grants prevents situations in which a municipality provides a higher level of services than others despite being inefficient (e.g. due to the wasteful use of resources or excessive expenditure due to bad management), and/or raising less taxes from their citizens simply because they receive a more generous transfer from the upper-local tier government. Otherwise, a grants allocation system that tolerates inefficient local expenditure and endures arbitrarily unequal treatment of local governments generates unfair competition among municipalities within the region.

Four, the model can be adapted by the public decision maker to account for specific environmental features and investigate their impact on public resources for local service provision. For instance, the model can easily accommodate differences in the cost of allocating grants across municipalities, include alternative equity constraints, or impose minimum or maximum output and input targets.

Finally, although the model proposed in this paper is primarily motivated at addressing a specific decision problem in the public sector, the formulation behind the proposed approach is widely applicable to many other centralized resource allocation settings in any region or organization. For instance, similar models can be applied to allocate resources among public schools, or to distribute a common research budget among university departments.

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Table 1. Variable definition and descriptive statistics

	Variable Definition	*Data Source*	*Total*	*Min*	*Max*	*Mean*[1]	*s.d.*	*Gini*
POP	Number of inhabitants	Navarre's Statistical Institute	423,102	19	33,910	1,561	3,382	-
URBAN	Urbanized area (hectares)	Department of Local Administration	3,363	0.4	179	12.4	19	-
HOUSE	Number of dwelling units	Navarre's Statistical Institute	192,828	5	13,972	712	1,343	-
ROAD	Length of roads (km)	Department of Local Administration	3,215	0.3	112	11.9	14	-
LIGHT	Index that measures the provision and quality of street lighting	Service for the Ordination of the Territory	225.2	0.10	1	0.83	0.17	0.109
W&S	Index that measures the provision and quality of water and sewage collection	Service for the Ordination of the Territory	230.5	0.39	1	0.85	0.13	0.083
PAVING	Index that measures the area and quality of pavement	Service for the Ordination of the Territory	248.9	0.10	1	0.92	0.13	0.065
ADMIN	Index that measures the provision of administrative services	Service for the Ordination of the Territory	231.1	0.15	1	0.85	0.19	0.114
TAXES	Local taxes (€ thousands)	Department of Local Administration	196,701	5.9	17,351	465[2]	267[3]	0.181[4]
GRANTS	Current transfers (€ thousands)	Department of Local Administration	156,697	6.5	13,536	370[2]	127[3]	0.103[4]

(1) $Mean = \frac{Total\ value}{No.\ of\ municipalities}$

(2) $Taxes\ per\ capita = \frac{Total\ Taxes}{Total\ Population}$

(3) $Grants\ per\ capita = \frac{Total\ Grants}{Total\ Population}$

(4) Standard deviation and Gini coefficient values correspond to the distribution of per capita measures.

Table 2. Model I. Results

Priority structure	Grants†		Taxes†		W&S‡		Light‡		Paving‡		Admin‡	
	(1) Aggregate target (€ million)	*(2) Per capita value (€)*	*(3) Aggregate target (€ million)*	*(4) Per capita value (€)*	*(5) Aggregate target*	*(6) Mean*	*(7) Aggregate target*	*(8) Mean*	*(9) Aggregate target*	*(10) Mean*	*(11) Aggregate target*	*(12) Mean*
ω_X=0.9 ω_Y=0.1	149.5	353	140.1	331	242.3	0.894	253.0	0.933	254.1	0.938	237.9	0.878
ω_X=0.8 ω_Y=0.2	149.4	353	141.7	335	246.5	0.909	255.2	0.942	256.0	0.944	248.2	0.916
ω_X=0.7 ω_Y=0.3	148.9	352	144.9	343	253.6	0.936	257.0	0.948	259.7	0.958	254.2	0.938
ω_X=0.6 ω_Y=0.4	148.9	352	148.4	351	258.8	0.955	258.7	0.955	263.8	0.973	259.3	0.957
ω_X=0.5 ω_Y=0.5	148.1	350	151.9	359	261.3	0.964	259.3	0.957	266.4	0.983	261.3	0.964
ω_X=0.4 ω_Y=0.6	149.6	354	156.0	369	265.2	0.979	262.4	0.968	267.8	0.988	263.8	0.973
ω_X=0.3 ω_Y=0.7	150.9	357	157.5	372	265.8	0.981	263.7	0.973	268.6	0.991	265.3	0.979
ω_X=0.2 ω_Y=0.8	153.1	362	159.7	377	266.4	0.983	265.6	0.980	268.9	0.992	266.3	0.983
ω_X=0.1 ω_Y=0.9	156.7	370	178.1	421	268.3	0.990	268.9	0.992	269.6	0.995	268.9	0.992

† $Aggregate\ target_i = X_i^* = (1-\gamma_i^*)\sum_{j=1}^{n} x_{ij}$, $i = Grants, Taxes$. *Per capita value* = $\frac{Aggregate\ target_i}{Total\ Population} = \frac{X_i^*}{423{,}102}$, $i = Grants, Taxes$.

‡ $Aggregate\ target_m = Y_m^* = (1+\beta_m^*)\sum_{j=1}^{n} y_{mj}$, $m = W\&S, Light, Paving, Admin$. $Mean = \frac{Aggregate\ target_m}{No. of\ municipalities} = \frac{Y_m^*}{271}$, $m = W\&S, Light, Paving, Admin$.

Figure 1. Location map of Navarre and the geographical distribution of its municipalities

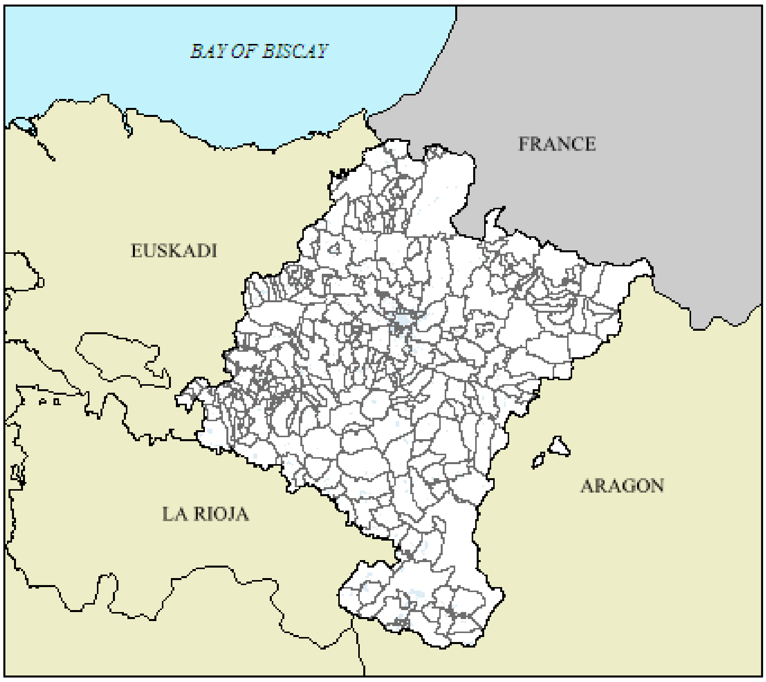

Figure 2. Model I: individual results ($\omega_x = 0.9$, $\omega_y = 0.1$)

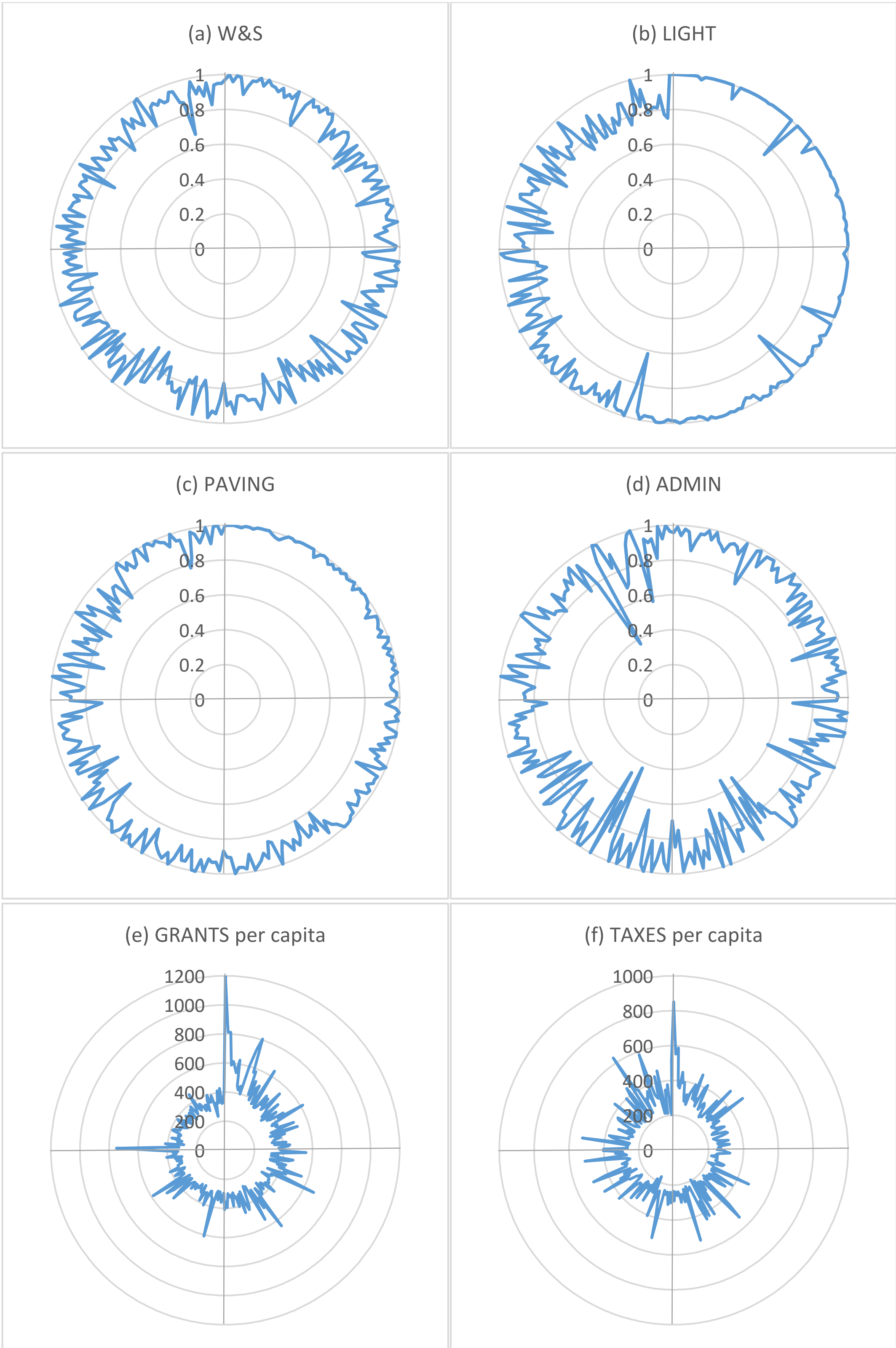

Figure 3. Share of grants in municipalities' funding under Model I and Model II