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TOWARDS AN EGALITARIAN HEALTH CO-PARTICIPATION FORMULA IN THE BUENOS AIRES PROVINCE: A MATHEMATICAL PROGRAMMING APPROACH

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Towards An Egalitarian Health Co-Participation Formula in the Buenos Aires Province: A Mathematical Programming Approach

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Abstract:

This paper inquires whether a change in the weights of the variables currently used in the Buenos Aires Province health co-participation formula could lead to a more egalitarian allocation of financial resources between the municipalities with devolved health services. We study the determination of the optimal weights of the variables included in the current distribution formula using a mathematical programming approach. We develop two different models, which differ in the way the equality objective is defined. Previous results indicate that substantial increases in equality could be achieved.

JEL codes: C61, I14, H77

Resumen:

Utilizando técnicas de programación matemática, este trabajo analiza la factibilidad de alcanzar una distribución más igualitaria de los fondos de coparticipación por componente salud entre los municipios de la Provincia de Buenos Aires. Se desarrollan dos modelos, los cuales difieren en la forma de hacer operativo el criterio de igualdad en la distribución de fondos. Los resultados previos indican que podrían lograrse incrementos substanciales en el grado de igualdad alterando los valores de los ponderadores utilizados por la actual fórmula de distribución.

Códigos JEL: C61, I14, H77

1) Introduction

Decentralization can be defined as the transference of power and competences from the central government to peripheral government levels (Guimaraens, 2001). The economic literature on fiscal federalism has presented the view that fiscal decentralization can entail substantial benefits in terms of both efficiency and welfare. Applied to health services, the rationalization for the decentralization can be summarized as follows (Arredondo *et al*, 2004):

a) Local decision makers respond better to the community needs and can avoid costly mistakes potentially made by a distant bureaucrat, who might know little about the specific requirements of the served population.
b) Stimulates community involvement in planning and supervision of local services, which in turn promotes democracy.
c) Decision making closer to local needs contribute to a more efficient use of scarce resources and produce greater user satisfaction.

However, a decentralization policy applied to the health sector possesses its own risks. A major concern is that devolution of expenditure responsibilities to sub-national government levels can adversely affect the equitable distribution of financial resources, and hence the provision of health services across local jurisdictions (Okorafor and Thomas, 2007). This could happen if *i)* there exist large differences in the wealth levels among local communities (and, therefore, among local taxable bases) and *ii)* no mechanism exists to redistribute income between communities.

In the Buenos Aires Province (Argentina), a decentralization process of the health services was started at the end of the 1970s. The municipalities were made responsible to provide low complexity health services (e.g., primary health care), mainly demanded by local users. Meanwhile, the provincial government retained the responsibility over high complexity health services, whose potential users belong to several municipalities. This kind of division of duties is consistent with the efficiency case on decentralization as stated above.

At first, this process was not accompanied by a transfer of resources from the province to the municipalities that could assure the proper financing of the devolved services. The result was an increasing pressure over local budgets and large deficits. To guarantee the financing of the local health services, a reform on the provincial co-participation law was passed in 1987. The reformed law stated that the 37% of the co-participation resources were to be allocated between those municipalities with devolved public health facilities, and introduced an explicit formula to allocate the financial resources. Its main objective was to reimburse the cost incurred by the local governments when providing health services.

The essence of formula funding is that the payer (e.g., the provincial government) specifies in advance a mathematical rule that determines the magnitude of the funding received by a municipality with devolved entities in a certain period, and that there is no provision to change the allocation rules after the budgetary period. The overarching objective of formula funding is to contribute to the creation of a budget for the local entity with which it is expected to fulfill its duties, in the form of provision of public services (Smith, 2007).

The health co-participation formula established in Buenos Aires province by the 1987 legislation determines that the percentage of funds assigned to each municipality as follows:

$$\begin{aligned} copart_i = 0.35\left(\frac{beds_i}{\sum_i beds_i}\right) + 0.25\left(\frac{app_i}{\sum_i app_i}\right) + \\ 0.10\left(\frac{out_i}{\sum_i out_i}\right) + 0.20\left(\frac{patday_i}{\sum_i patday_i}\right) + 0.10\left(\frac{cap_i}{\sum_i cap_i}\right) \end{aligned} \quad \forall i \qquad (1)$$

Where[1]:

CSi is the percentage of funds available for municipality *i*

$beds_i$ is the number of hospital beds available in each municipality i, times its average percentage of occupation, times the maximum level of complexity of the hospitals of the district.

app_i is the number of appointments register in the municipality *i.*

out_i is the number of exits from hospitalization (either by medical discharge or death) registered in district *i*.

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[1] All the indicators used are recorded on an annual basis.

$patday_i$ is the number of patient-days of hospitalization registered in district i.

cap_i is the number of primary care facilities available in municipaliy i.

The mere adoption of a formula represented a major achievement[2]. Formula funding has large advantages to finance devolved public services over other methods, such as political patronage, historical precedents or actual spending; offering a widely accepted mechanism for setting budgets for devolved organizations. The use of formulae allows explicit presentation of the funding criteria, which enables the various parties to enter into an informed dialogue. Moreover, by tying the hands of politicians and bureaucrats, it can reduce the scope for inequitable treatment.

However, after some years of being operational, it became evident that the adopted formula presented a number of drawbacks, both in terms of efficiency and equity.

From an efficiency point of view, the formula gave incentives to increase second level activities[3] (number of hospitalizations and length of hospital stays) and infrastructure (number of beds and hospital complexity) in detriment of first level activities (basically, primary health care) which are far more cost-effective (Barbieri, 2007).

From an equity perspective, the formula increased the differences in the amount of funds available to each municipality to finance its health systems. According to Barbieri (2007) "more populated municipalities, with higher than average poverty rates, received significantly less per capita co-participations funds than their less populated and wealthier counterparts". Moreover, Barbieri (2007) found a positive correlation between the *per capita* municipal health expenditure level and the *per capita* health co-participation transfers, concluding that there is an unequal access to health services between the inhabitants without health coverage, which favors the residents of wealthier districts over those who live in poorer ones[4].

At this time, it is widely accepted that fairness should be the cornerstone of any public health system. In a devolved one, as at present in force in Buenos Aires Province, to pursue this objective requires advancing towards a more equitable allocation of health financial resources across municipalities. This in turn asks for a change in the current health co-participation formula.

2) Objectives:

The main objective of this paper is to inquire whether a change in the weights of the variables currently used in the Buenos Aires Province health co-participation formula could lead to a more egalitarian allocation of financial resources between the municipalities with devolved health services. We also test if the introduction of additional variables, reflecting the health needs of the population of each district, can be useful to reduce the inequity currently observed in the allocation of the funds.

3) Methodology:

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[2] To our knowledge, Buenos Aires is the only province in Argentina that includes in its municipal co-participation law health system indicators.

[3] The indicators related to second level activities are: *beds*, *out* and *patday*. Because of the weights attached to them, they jointly explain 65% of the funds distributed.

[4] In Health Economics literature, per capita health expenditure is commonly used as an indicator of access to health services.

We study the determination of the optimal weights of the variables included in the distribution formula using two different models (A and B), which differs in the way the objective function is defined. For each model, two versions are considered. The base models (A) and (B) only include those indicators currently integrated in the co-participation formula. A modified version of these models, adding two different indicators of the population´s health needs (the percentage of households with unmet needs and the percentage of population without health coverage) are also analyzed. The data for the model belongs to the period 2009/7 – 2010/6 and were taken from the Dirección de Información Sistematizada - Ministerio de Salud de la Provincia de Buenos Aires.

The nomenclature used in the models is shown in table 1.

Table 1. Nomenclature

Sets	
i, i'	municipalities
p	indicators
poS	subset of p, optional indicators of structure
poR	subset of p, optional indicators of risk
pno	subset of p, non optional indicators
q	quintiles
Parameters	
$Ncity$	number of municipalities
$Npno$	number of non optional indicators
$data_{p,i}$	municipality i's data for indicator p
pop_i	population (in hundreds of thousands) of municipality i
$maxpop$	population of the most populated municipality
$minpop$	population of the least populated municipality
$budget$	total co-participation budget (in millions of $)
$qqty_q$	number of municipalities that that fall into quintile q
Positive variables	
WT_p	indicator p's weight in co-participation formula
$Ap_{p,i}$	contribution of indicator p's term data of municipality i
$copart_i$	co-participation funds for municipality i
$copcap_i$	co-participation funds *per cápita* (in 10^6\$/10^5 persons) for municipality i
$lowval$	lower limit of the distribution of values of $copcap(i)$
$uppval$	upper limit of the distribution of values of $copcap(i)$
$qpop_q$	sum of the populations of the municipalities that fall into quintile q
Binary variables	
$yq_{q,i}$	=1 if municipality i falls into quintile q, =0 if not
y_p	=1 if indicator p is selected to be used in the co-participation formula, =0 if not

Model (A):

The problem of the egalitarian distribution of co-participation funds is expressed through the following non-linear programming (NLP) model (A):

$$\min\ z$$

$$\text{s.t.}$$

$$z = \frac{uppval}{lowval} \tag{2}$$

$$copcap_i = \frac{budget}{pop_i}\sum_p AP_{p,i} \qquad \forall i \tag{3}$$

$$AP_{p,i} = WT_p \frac{data_{p,i}}{\sum_{i'} data_{p,i'}} \qquad \forall i \tag{4}$$

$$\sum_p WT_p = 1 \tag{5}$$

$$lowval \le copcap_i \qquad \forall i \tag{6}$$

$$copcap_i \le uppval \qquad \forall i \tag{7}$$

Eq. (2) defines the objective of the problem to be minimized:, the ratio between the highest and the lowest values of the co-participation funds' distribution. The model is written such that this ratio is always positive, so therefore, no quadratic terms are required.

Eqs. (3) and (4) define the co-participation funds for each municipality as expressed by the state laws, here shown in *per cápita* terms. For the optimization, the weights of each term, currently fixed by law (Table 2), have been liberated to be used as decision variables.

Eq. (5) enforces the sum of the weights to be equal to 1. in order to ensure that the sum of the co-participation funds is equal to the total budget.

Eqs. (6) and (7) enforces all the co-participation funds to lay within *lowval* and *upval* . The direction of the optimization, to minimize the ratio, will force *lowval* to be equal to the lowest $copcap_i$ value and *uppval* equal to the highest one.

Model (A) optimizes the co-participation distribution using the current formula indicators: *bed*, *out*, *patday*, *app* and *cap*. Model (A) is a nonlinear programming (NLP) problem and will be solved with the BARON solver in the GAMS platform

Model (B)

Model (B) addresses the egalitarian co-participation problem from a different approach. Using the value of $copcap_i$, the municipalities are ordered according to the following quintiles :poorest (lowest value of $copcap_i$), medium-poor, medium, medium-high and highest (maximum $copcap_i$ value). The objective function is to maximize the number of persons that fall within the three intermediate quintiles by manipulating the values of the formula-weights to assign municipalities into quintiles.

$$\max\ z$$

$$\text{s.t.}$$

$$z = qpop_{q=q2q3q4} \tag{8}$$

$$copcap_i = \frac{budget}{pop_i} \sum_p AP_{p,i} \qquad \forall i \tag{9}$$

$$AP_{p,i} = WT_p \frac{data_{p,i}}{\sum_{i'} data_{p,i'}} \qquad \forall i \tag{10}$$

$$\sum_p WT_p = 1 \tag{11}$$

$$\sum_q yq_{q,i} = 1 \qquad \forall i \tag{12}$$

$$\sum_i yq_{q,i} = qqty_q \qquad \forall q \tag{13}$$

$$copcap_i - copcap_{i'} \le \frac{budget}{minpop}\left(2 - yq_{q,i} - yq_{q',i'}\right) \quad \forall i, i \ne i', q, q' > q \tag{14}$$

$$qpop_q = \sum_i pop_i yq_{q,i} \qquad \forall q \tag{15}$$

The quintiles in this problem are grouped in the following elements of set q: q1 (lowest), q2q3q4 (medium-poor, medium and medium-high) and q5 (highest). The three intermediate quintiles were grouped to decrease the size of the problem. Eq. (7), defines the objective function, as the aggregated population of the intermediate quintiles.

Eqs. (9) to (11) are similar to Eqs. (3) to (5) of Model (A). Eq. (12) assures that each municipality falls into only one quintile, whereas Eq. (13) requires that the number of municipalities in each quintile correspond to the following values: *Ncity*/5 for quintiles q1 and q5, 3*Ncity*/5 for the aggregated q2q3q4.

Eq. (14) works in the following manner:if municipalities *i* and *i'* fall into quintiles *q* and *q'* respectively, with quintile *q'* being richer than quintile *q*, both $yq_{q,i}$ and $yq_{q',i'}$ will be 1 and the right hand side of the equation becomes 0, thus forcing $copcap_i$ to be equal or lower than $copcap_{i'}$. If municipality *i* does not fall into quintile *q* and/or municipality *i'* is not in quintile *q'* then the right hand side of the equation becomes greater (*budget/minpop*) than any possible value of $copcap_i$-$copcap_{i'}$ thus relaxing the restriction.

Finally, Eq. (15) calculates the aggregated population in each quintile. Since pop_i is a parameter the equation is linear.

Model (B) is a mixed-integer linear programming (MILP) problem and will be solved with the CPLEX solver in the GAMS platform.

4) Results

Current distribution

Table 2 presents the current values of the formula weights and some indicators of the funding equality (considering a total budget of $\$1\text{x}10^6$). Besides the objective function's value (*uppval*/*lowval*) we also report the difference between the extremes.

Table 2. Current distribution of funds

Variable	Value	Variable	Value
$WT_{i=bed}$	35%	$WT_{i=app}$	25%
$WT_{i=out}$	10%	$WT_{i=cap}$	10%
$WT_{i=patday}$	20%		
		Results	
uppval	0.570	*lowval*	0.006
uppval-lowval	0.564	*uppval/lowval*	88.53

Figure 1 shows the distributions of funds per municipality resulting from the application of the current co-participation formula.

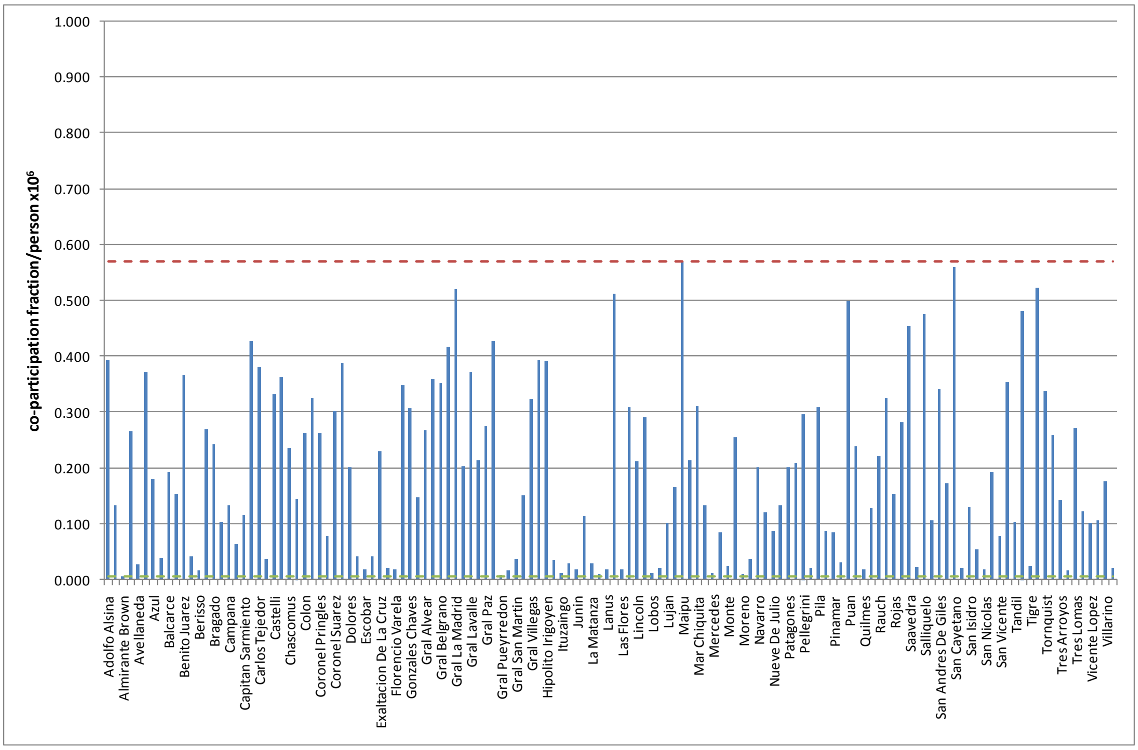

Figure 1. Distribution of co-participation funds/person values with the current formula's weights

Optimal global solution of Model (A)

Table 3 shows the optimal solution of Model (A). This result was obtained with a global optimization solver, using a relative tolerance of 0.001.

Table 3. Optimal global solution of Model (A)

Variable	Value	Variable	Value
$WT_{i=bed}$	0%	$WT_{i=app}$	7.89%
$WT_{i=out}$	0%	$WT_{i=cap}$	92.11%
$WT_{i=patday}$	0%		
		Results	
uppval	0.442	*Lowval*	0.024
uppval-lowval	0.416	*uppval/lowval*	18.41

It can be seen that a much better value of the objective function is found with the proposed model, reducing it by almost 80%. The better equalization of the distribution of funds is also shown in Figure 2.

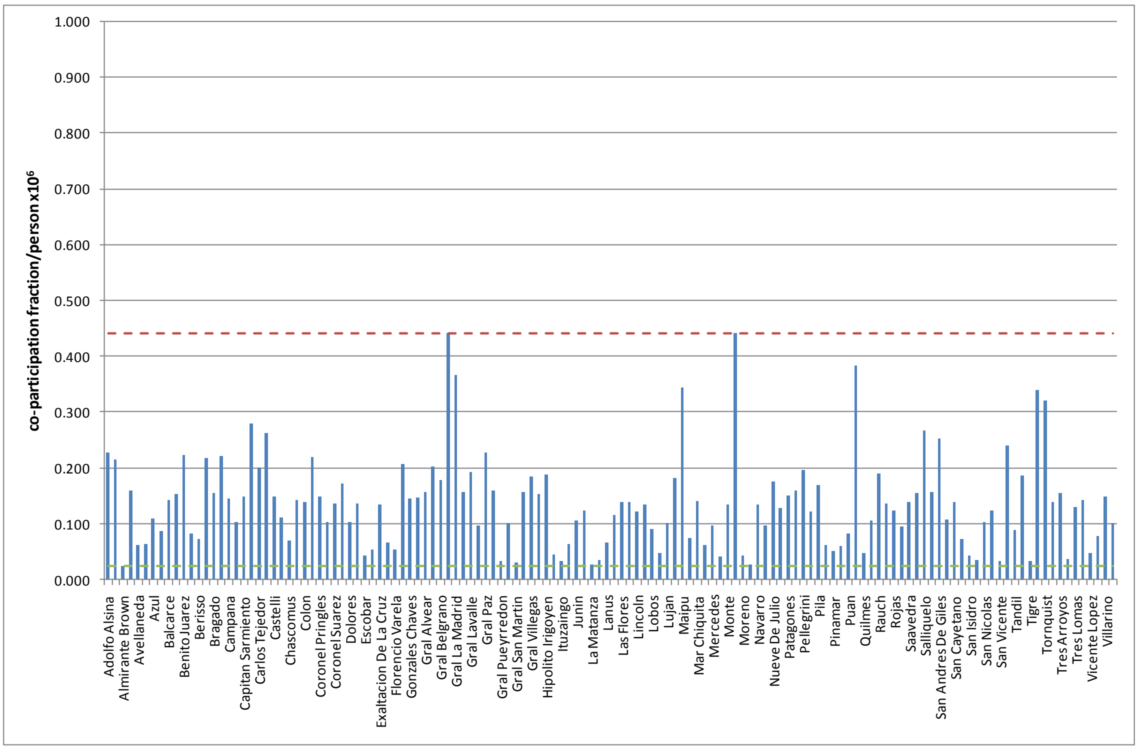

Figure 2. Distribution of co-participation funds/person values for the optimal global solution of Model (A)

Because of the shape of the objective function the optimization solver gives more importance to increasing *lowval* than to decreasing *uppval*, since that way it is easier to change the order of magnitude of one the extremes, thus having greater impact.

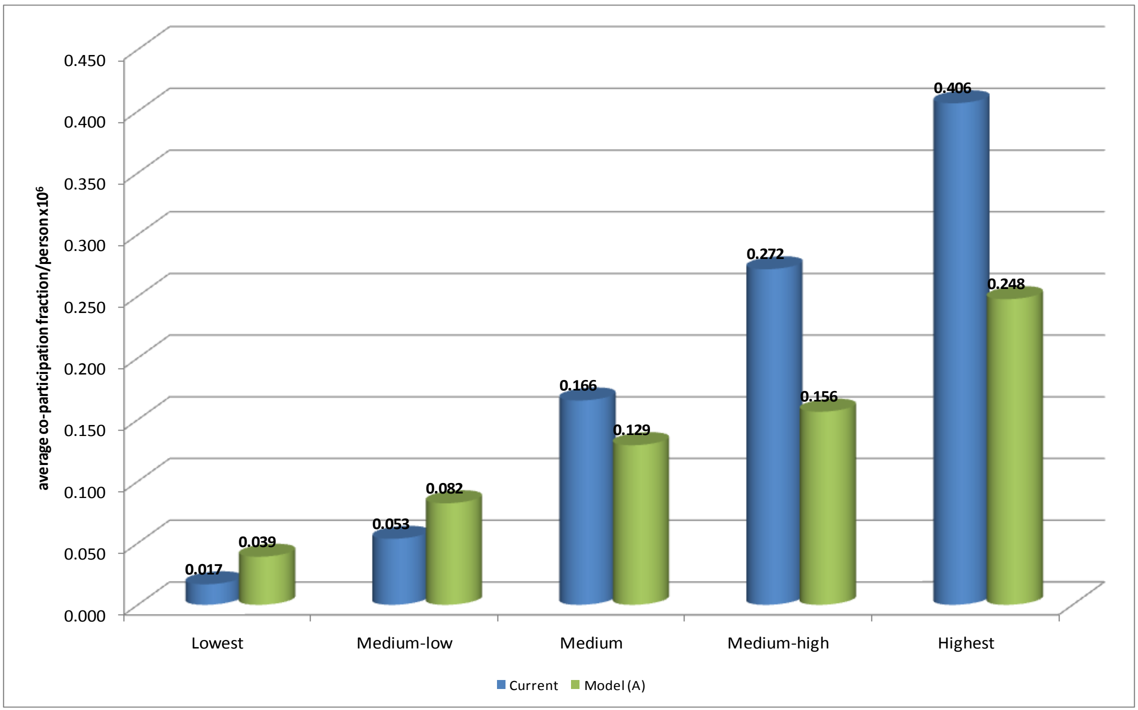

Figure 3. Average fraction *per capita* of funds received in each quintile

Figure 3 shows the average *per capita* co-participation funds when the municipalities are grouped into quintiles. It can be seen that although the optimal solution of Model (A) improves the average co-participation *per capita* of the lower quintiles (Figure 3), it also moves 3 million additional persons to the municipalities of the lowest one (Figure 4).

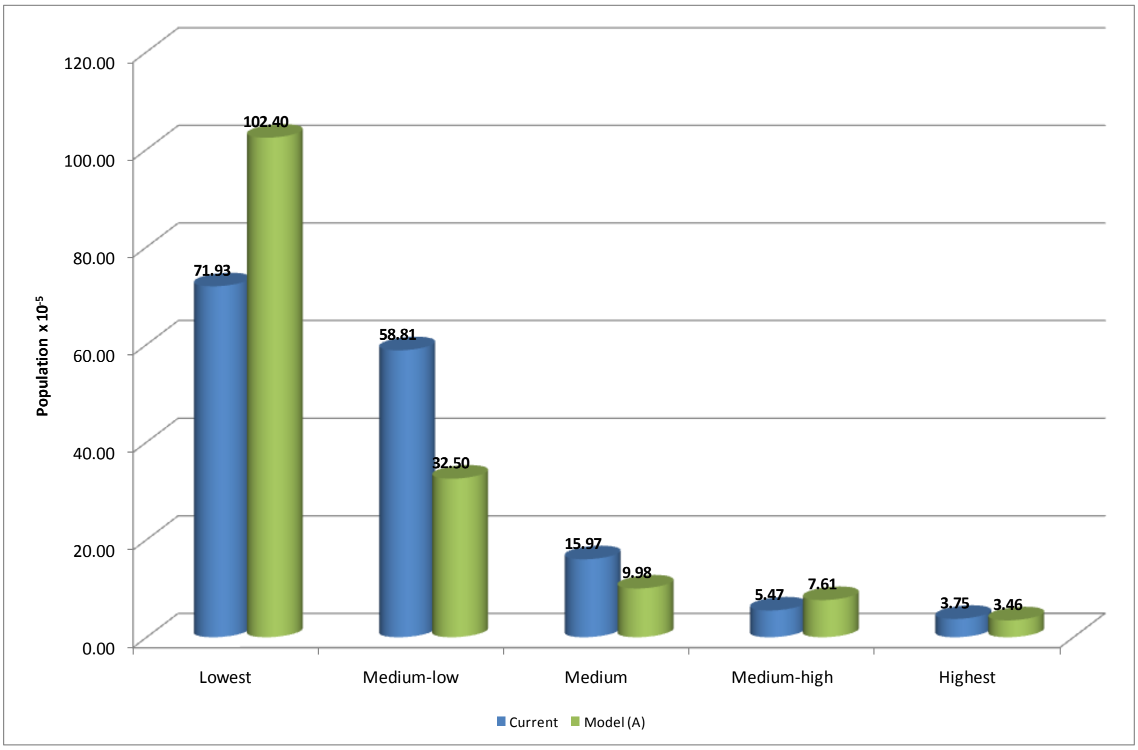

Figure 4. Population in each quintile

Optimal integer solution of Model (B)

Model (B) was solved to 0.001 of integer gap, providing the results shown in (Table 3). The values of *uppval* and *lowval* are not calculated in the model, so, they were obtained post-solve.

Table 3. Integer solution of Model (B)

Variable	Value	Variable	Value
$WT_{i=bed}$	0.510%	$WT_{i=app}$	0%
$WT_{i=out}$	97.88%	$WT_{i=cap}$	1.61%
$WT_{i=patday}$	0%		
Results			
uppval	0.550	*lowval*	0.000
uppval-lowval	0.550	*uppval/lowval*	1383.43

Model (B) was developed to investigate how the funds distribute when a maximization of the number of persons in the three intermediate quintiles is pursued. Model (B) increased this value to 9,374,450 (60.1% of the total population), a 16.8% improvement from the original distribution (8,025,714 persons, 51.5%) and a 87.2% one from the optimal global solution of Model (A) (5,009,000 persons, 32,1%).

Although Model (B) results in an improvement on the distribution of the quintiles (see Figure 6) it does so at the cost of pushing the value of *lowval* to extremely low values respectively. This can be seen in Figure 5 where the average co-participation *per capita* of each quintile is shown.

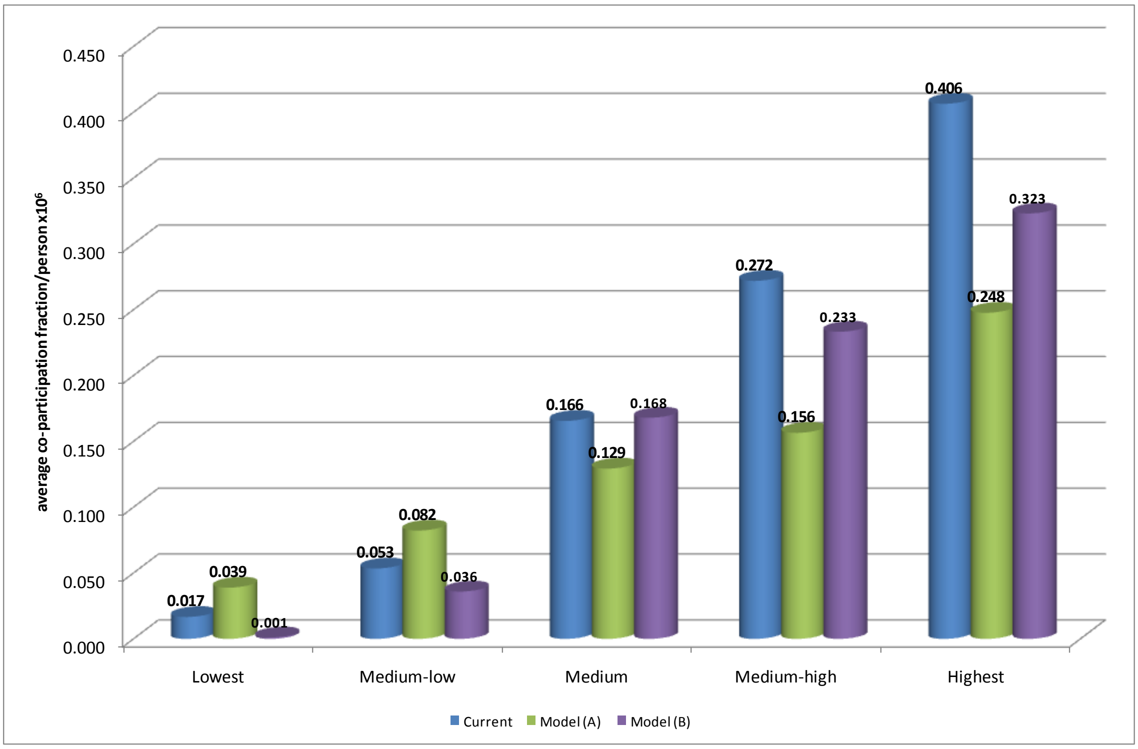

Figure 5. Average fraction *per capita* of funds received in each quintile

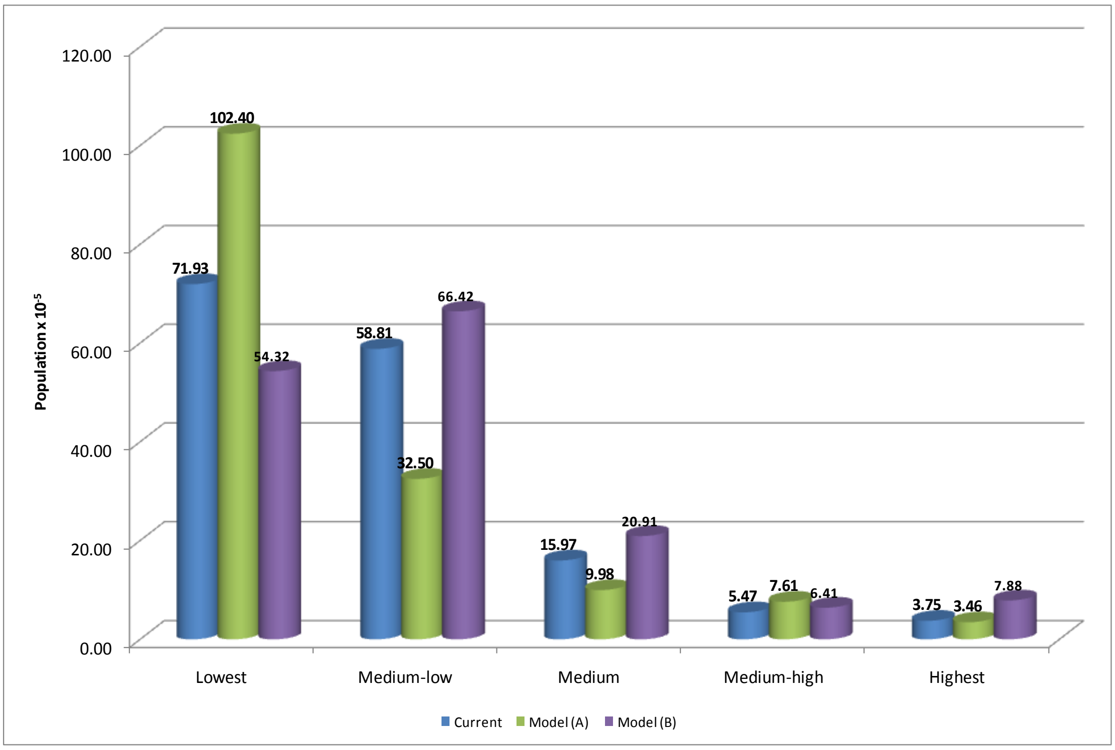

Figure 6. Population in each quintile

Gini coefficient

Because of these contradicting results we calculated another indicator, the Gini coefficient, to measure the equity of the distributions. Figure 7 shows the accumulated fraction of co-participation funds vs. the accumulated fraction of the total population, and the correspondent Gini coefficient of the three distributions.

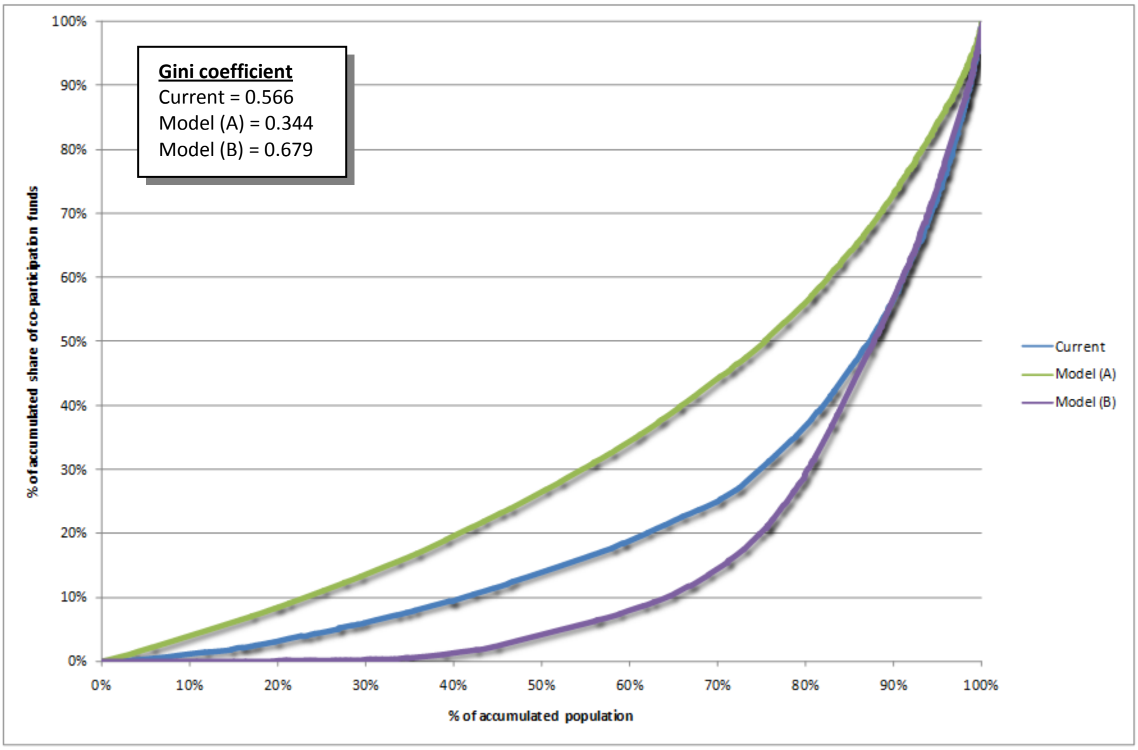

Figure 7. Distribution of co-participation funds/person values for the optimal global solution of Model (A)

It can be concluded that Model (A) has the better performance in terms of the Gini coefficient, improving the corresponding to the current distribution in 33%. Because of these results Model (A) is considered the best one.

Consideration of other indicators

Another proposal for the reformulation of the current distribution of the co-participation funds is to consider a pool of possible indicators and select which ones are to be used in the formula, together with their corresponding weight values, in order to improve the equity

Two additional indicators are proposed, associated to the risk factor, a concept not considered in the current formula. These are:

1. noOS: percentage of the population not included in any kind private or social health system
2. NBI: percentage of the population with unmet needs

It was decided to include in the new formula two of the three structure indicators (beds, medical discharges and patient-days), one of the two risk indicators and to keep from the original formula “appointments” and “primary care units”.

The following equations were added to models (A) and (B) to allow for the selection of the indicators as stated in the previous paragraph.

$$WT_{po1} \leq y_{po1} \qquad \forall po1 \tag{16a}$$

$$WT_{po2} \leq y_{po2} \qquad \forall po2 \tag{16b}$$

$$\sum_{po1} y_{po1} = 2 \tag{17a}$$

$$\sum_{po2} y_{po2} = 1 \tag{17b}$$

$$\sum_{pno} y_{pno} = Npno \tag{17c}$$

Eqs. (16a) and (16b) limit the value of the indicators included in subsets *po*1 and *po*2 respectively. If the indicator *po*1 (or *po*2) is not selected to be included in the formula then y_{po1} (or y_{po2}) is zero and the maximum value that WT_{po1} (or WT_{po2}) can take is zero. If the indicator is selected, the right hand side of Eqs. (16a) and (16b) becomes 1 and the indicator's weight can take any value between 0 and 1.

Eqs. (17a) and (17b) assure that the number of selected structure and risk indicators are to 2 and 1, respectively. Eq. (17c) expresses that all the non optional indicators must be selected to be included in the formula.

Both modified models were solved with the same solving options of the original ones, but the results were the same. In both cases only two of the structure indicators were selected and only one of the risk ones, but those selected were assigned a weight of 0%, resulting in the same distribution of the original models.

5) Conclusions

The Buenos Aires Province (Argentina) implemented in 1987 a formula to finance previously devolved public health services. The adoption of a distributional formula represented a major achievement, improving the transparency of the funds allocation. However, after some years in force, its drawbacks became evident. From an equity perspective, the formula increased the differences in per capita income among the different municipalities.

In order to improve equity, and reduce the detected efficiency problems, a change in the current budget allocation criteria is required.

The global tendency is to pursue a risk adjusted capitation system. This formula funding approach reimburses devolved entities according to the expected level of local activity. Typically, it requires measures of size and characteristics of the populations, and infers the expected level of local service expenditure without any reference to current service use (Smith, 2007). Nevertheless, the implementation of this formula funding approach would not be feasible in the Buenos Aires province, at least in the short term. From a political perspective, any attempt to implement a capitation system is expected to be resisted by the small, less populated municipalities, which represent the vast majority in the Buenos Aires province.

Another impediment is the lack of the required data to build risk adjusted capitation formulae. For example, the RAWP formula for allocating National Health Service (NHS) funds to English regions, makes extensive use on morbidity and mortality data, disaggregated by age, sex and diagnosed condition. Such information is not available in the Buenos Aires Province health statistics system.

In this paper, we addressed the challenge of improving fund´s distribution equity, by making use of the current formula structure and indicators. We also analyzed the possibility of including alternative available health indicators, and studied their effects on equity. We consider that this approach to modify the budget allocation criteria is the most practical in the foreseeable future.

We developed two different models, which differs in the way the equity objective is defined. Base model (A) seeks to minimize the ratio between the highest and the lowest values of the co-participation funds' distribution. Base model (B) seeks to maximize the number of individuals that fall within the three intermediate quintiles, when ordering the municipalities according to the assigned per capita co-participated amount. In each case we calculated the corresponding ginni coefficients.

The best results are obtained with model (A), which reduces the ginni coefficient from 0.566 (original formula) to 0.344 (optimal values). The only parameters with optimal weights different than zero are *app* (0.79%) and *cap* (92.11%). The upval/lowval ratio is reduced from 88.26 (original formula) to 18.41 (optimal values).

The results obtained with model (B) are less attractive than those of model (A). Although it manages to increase the population that falls within the three intermediate quintiles from 8,085,000 (original formula) to 9,374,450 (optimal values), the ginni coefficient increased its value from 0.566 (Original formula) to 0.679 (optimal values). In this model, the parameters with optimal weights different than zero are *bed* (0.51%), *out* (97.88) and *cap* (1.61%)

It was also shown that Modifying models (A) and (B) through the incorporation of two of the three structure indicators (beds, medical discharges and patient-days), one of the two proposed risk indicators (percentage of families with unmet needs and percentage of people without health coverage), and keeping “appointments” and “primary care facilities” from the original formula did not improve the results, because in both models the optimal weighting factors of the risk indicators turned to be zero.

The main contribution of this paper is to show how the use of mathematical programming tools and modeling techniques can contribute to a better (fairer, in this case) allocation of scarce resources in real contexts. These tools can be used to advise decision makers, by providing useful insight about optimal strategies, while taking into account political, budgetary, technical and other relevant constraints faced in the decision making process.

Since the results are strongly dependent on the way the equity objective is defined, it is required to the political debate to set clear objectives to be pursued. As long as these objectives are well defined, the model results will be of greater practicality.

There are several ways in which the developed models could be improved. An obvious approach is to use panel data instead of one-year data. Moreover, the introduction of additional variables, especially those reflecting health needs, should also be considered. Finally, different ways to model the equity objectives should be analyzed. These refinements will be subject of future contributions.

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