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Interfaces with Other Disciplines

A participatory budget model under uncertainty

J. Gomez[a,*], D. Rios Insua[b], C. Alfaro[a]

[a] Rey Juan Carlos University, Department of Statistics and Operations Research, Fuenlabrada, 28943 Madrid, Spain
[b] ICMAT-CSIC, 28049 Madrid, Spain

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ABSTRACT

Participatory budgets are becoming increasingly popular in many municipalities all over the world. The underlying idea is to allow citizens to participate in the allocation of a fraction of the municipal budget. There are many variants of such processes. However, in most cases they assume a fixed budget based upon a maximum amount of money to be spent. This approach seems lacking, especially in times of crisis when public funding suffers high volatility and widespread cuts. In this paper, we propose a model for participatory budgeting under uncertainty based on stochastic programming.

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1. Introduction

Over the last years there have been movements demanding increased participation in public policy, especially at the local level (Matheus & Ribeiro, 2009; Smith, 2009). For this reason, institutions worldwide are promoting various participatory initiatives, see Ríos Insua and French (2010) for reviews. A paradigm for these is participatory budgeting (PB) which allows citizens to take part in the allocation of a fraction of the available financial resources, typically, in local governments and municipalities.

PBs have spread to over 1500 municipalities across the world since its inception in Porto Alegre (Brazil) in 1989, see Sintomer, Herzberg, Allegretti, and Rocke (2010). The dissemination of PBs started in Latin America including countries such as Ecuador, Argentina or Uruguay. In 2001, PBs expanded to Europe with Italy, France and Spain becoming the main countries of initial adoption. Over the last years, PBs have also been implemented in municipalities in Asia, Oceania and Africa. More recently, PB processes have reached the USA where they have been tested in large cities such as Chicago or New York.

There are many variants of PBs according to several factors such as the number and duration of meetings or the roles assigned to officials (who typically promote the PB experience), technical staff (who support the implementation of the PB by providing cost estimates, facilitate preference elicitation or suggest initial criteria for project assessment) and citizens or participants (who provide input concerning projects, preferences in various phases or criteria), see Alfaro, Gomez, and Rios (2010) or Gomez, Ríos Insua, Lavin, and Alfaro (2013) for details. The amount of capital funds allocated through PBs varies widely across experiences: there are places where the expenditure is limited to a small proportion of the municipal budget, whereas in other locations, like Rubí (Spain) or Campinas (Brazil), citizens have been allowed to decide how to spend the entire investment budget, see Cabannes (2004) and Nebot (2004) for details. However, most of the PB experiences incorporate quantities, such as costs or budget available, which are assumed to be fixed before the execution period begins. They are, therefore, static budgets, see Kriens, van Lieshout, Roemen, and Verheyen (1983) or Horngren et al. (2010).

There is another type of budget called flexible (Horngren, Bhimani, Datar, & Foster, 2002; Mak & Roush, 1994; Nam Lee & Soo Kim, 1994), with growing acceptance in the private sector. This is an important tool applied to perform budget uncertainty analysis, usually through scenarios, especially in times of economic crisis. However, the use of flexible budgets is unusual in the public sector as it entails administrative and bureaucratic difficulties (Robinson & Ysander, 1981). Most countries have a strict legal framework that regulates budgetary processes. For example, in Spain, the General Budgetary Act requires approval of the budget before the fiscal year starts. In order to ensure the adoption of flexible budget methods, it would be necessary to introduce budget reforms by amending existing laws or adopting new ones. This reform process is complex and could take a long time, see Lienert and Jung (2004). Furthermore, the elaboration of flexible budgets requires the use of multiple tools and methods such as Monte Carlo simulation, forecasting or game theory models (Verbeeten, 2006) and public administrations do not frequently have experts in such fields.

* Corresponding author. Tel.: +34 914888414.
E-mail addresses: javier.gomez@urjc.es (J. Gomez), david.rios@icmat.es (D.R. Insua), cesar.alfaro@urjc.es (C. Alfaro).

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We propose in this paper a model for PBs under uncertainty, combining the recent interest in participatory and flexible budgeting. In Section 2, we introduce the problem. Then, we briefly describe an approach that can be used to solve problems in which there is uncertainty about the values of some of its parameters. Section 4 proposes a scheme based on the joint chance constraints method, adapting typical participatory decision tasks (negotiation, voting, arbitration) to the presence of stochastic elements. Section 5 illustrates our methodology with a simple example. We conclude with some remarks and lines for future research.

2. Participatory budgeting under uncertainty

PBs (see Alfaro et al., 2010) provide citizens with the possibility of jointly deciding how to spend an amount of public funds in neighborhood investment projects. Methodologically, we assimilate PBs with allocating limited resources among several projects subject to constraints, with the aim of somehow maximizing the satisfaction of all participants. Some of the quantities involved in a PB, like project costs, income, available budget,..., may be subject to considerable uncertainty, which we shall denote with the $\sim$ symbol on top to describe the corresponding random variable. Salo, Keisler, and Morton (2011) provide various perspectives on resource allocation problems.

We thus incorporate uncertainty to the classical PB problem (Alfaro et al., 2010; Ríos & Ríos Insua, 2008). Assume, therefore, that a group of n persons has to decide how to spend a budget $\tilde{b}$. There is a set X of q possible projects, $X = \{a_1, \ldots, a_q\}$. Project a_i has an estimated cost $\tilde{c}_i$, and is evaluated with respect to m criteria with values $\tilde{x}_i^j$, $j = 1, \ldots, m$. We assume that the criteria are initially proposed by municipality technicians but may be subject to discussion with participants. The random variables $\tilde{b}$, $\tilde{c}_i$ and $\tilde{x}_i^j$ will be typically assessed or estimated by the organization technical staff. We represent this information as in Table 1, which is exemplified in Table 4.

A feasible budget for the PB problem is a subset of projects, defined by the corresponding subset of indices $F \subseteq I = \{1, 2, \ldots, q\}$, which satisfies all constraints, including the maximum budget one. Formally, we represent this through

$$\sum_{i \in F} \tilde{c}_i \le \tilde{b}. \tag{1}$$

This is a stochastic constraint, as both the left and right terms are random variables. In addition, there may be other constraints that further restrict the set of feasible budgets. We describe some of them as an illustration:

1. *Restrict the maximum investment on one type of projects:* Due to logistic, political or economic reasons, we could consider assigning a maximum amount c of the budget to be invested in a particular subset $F_1 \subset I$ of projects. This could be represented through

$$\sum_{i \in F \cap F_1} \tilde{c}_i \le c. \tag{2}$$

2. *Mutually exclusive projects:* In some cases, due to their similarity, the inclusion of some projects would entail the exclusion of others. Analogously, there could be a maximum number k of projects of a certain type, say concerning cultural services, which we denote as $J \subseteq I$, to be included in the final budget. Formally, we could represent this constraint through

$$\sum_{i \in F} y_i \le k, \quad \text{with} \begin{cases} y_i = 1 & \text{if } i \in J \\ y_i = 0 & \text{if } i \notin J \end{cases}. \tag{3}$$

3. *Dependent projects:* Sometimes a project requires another one to be in the final budget. As an example, suppose there is a project concerning building a new geriatric center and another one to build its parking. Clearly the second one makes sense only if the geriatric center is built as well. We represent this type of constraints through

$$y_{i_1} \le y_{j_1}, \qquad y_{i_1}, y_{j_1} \in \{0, 1\}, \text{ for certain } i_1, j_1 \in I, \tag{4}$$

where $y_k = 1(0)$ means that the kth project is (not) in the final budget. In example (4), we can include project a_{i_1}, only if project a_{j_1} has been included.

Table 1
Participatory budget under uncertainty. Basic data.

Project	Cost	Performance
a_1	$\tilde{c}_1$	$(\tilde{x}_1^1, \ldots, \tilde{x}_1^m)$
$\vdots$	$\vdots$	$\vdots$
a_i	$\tilde{c}_i$	$(\tilde{x}_i^1, \ldots, \tilde{x}_i^m)$
$\vdots$	$\vdots$	$\vdots$
a_q	$\tilde{c}_q$	$(\tilde{x}_q^1, \ldots, \tilde{x}_q^m)$

Table 2
Matrix of (random) utilities for the PB problem.

		Participants				
Project	Cost	1	...	j	...	n
a_1	$\tilde{c}_1$	$\tilde{u}_1^1$	...	$\tilde{u}_1^j$	...	$\tilde{u}_1^n$
$\vdots$	$\vdots$	$\vdots$		$\vdots$		$\vdots$
a_i	$\tilde{c}_i$	$\tilde{u}_i^1$	...	$\tilde{u}_i^j$	...	$\tilde{u}_i^n$
$\vdots$	$\vdots$	$\vdots$		$\vdots$		$\vdots$
a_q	$\tilde{c}_q$	$\tilde{u}_q^1$	...	$\tilde{u}_q^j$	...	$\tilde{u}_q^n$

In what follows, to fix ideas, when modeling the PB problem we shall include the (stochastic) budget constraint (1) and constraints of the types (2)–(4).

We assume that we may model each participant's preferences through a multiattribute utility function u_j, $j = 1, \ldots, n$, whose expected value should be maximized, see e.g. French (1986). The utility functions account for the preferences and risk attitudes of participants. We shall further assume that such utility functions are additive.[1] Thus, if w_{jk} is the weight that the jth participant gives to the kth criterion, his utility for a performance $x = (x_1, \ldots, x_m)$ would be

$$u_j(x) = \sum_{k=1}^{m} w_{jk} u_{jk}(x_k),$$

with $w_{jk} \ge 0$, $\sum_{k=1}^{m} w_{jk} = 1$, $k = 1, \ldots, m$. If a participant disregards one criteria, he/she just needs to give it weight zero. Once with the utility functions, we associate with the PB problem a random matrix where each entry $\tilde{u}_i^j$ is the utility that the jth participant would obtain if the ith project was in the final budget, where $\tilde{u}_i^j = \sum_{k=1}^{m} w_{jk} u_{jk}(\tilde{x}_i^k)$. Thus, we propagate the uncertainty in Table 1 through the participants' utility functions to obtain Table 2.

3. The case of a single participant

We first describe how to obtain the optimal budget for a single participant, as it will be a basic ingredient for the multiple participant case. For the jth decision maker, we have to solve the following problem which provides the maximum expected utility project portfolio, where E stands for expected value of the corresponding random variable:

$$\begin{aligned} \max_{F \subset I} \quad & E(\tilde{u}^j(F)) = \sum_{i \in F} E(\tilde{u}_i^j) \\ \text{s.t.} \quad & \sum_{i \in F} \tilde{c}_i \le \tilde{b}, \end{aligned} \tag{5}$$

[1] Additivity of utility functions require preferential independence conditions, reasonably frequently verified in practice, see Von Winterfeldt and Edwards (1986).

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