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Lindahl prices solve the NIMBY problem

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Abstract

The siting of public facilities such as prisons or waste disposal facilities typically faces rejection by local populations (the "NIMBY" syndrome, for Not In My BackYard). These public goods exhibit a private bad aspect creating an asymmetry: all involved communities benefit from their existence, but only the host bears the local negative externality. We show that the well-known Lindahl pricing scheme constitutes the only cost-sharing method satisfying a set of properties specifically designed to handle the siting problem.

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1. Introduction

The siting of public facilities such as prisons, airports or nuclear waste disposals typically faces rejection by local populations. These goods are socially desirable but come with local externalities. Different factors can be the cause of such rejection: losses in property value, the perceived loss in quality of life or the fear of negative health effects. In economic terms, these public goods have a private bad aspect to them creating a siting problem because only the host bears the local nuisance. This asymmetry typically leads to costly negotiations or inefficient siting[1]. Worse, difficult cases can even result in stalemates (e.g., the case of U.S. nuclear waste disposal; see EPA 2002).

The governing institutions typically want to elicit the hosting cost of communities, in order to select one site and elaborate a compensation scheme. However, in practice, the planner has access to much less information than the involved parties, which causes a revelation problem. The mechanism design literature tackles the problem by designing procedures procedure which are *decision-efficient*: the chosen host should be one which incurs the lowest hosting cost (consisting of the cost of construction and a disutility component) among all communities. Kunreuther and Kleindorfer (1986) propose a sealed-bid auction procedure to create an incentive for each community to truthfully reveal their costs: each community pays its own bid. O'Sullivan (1993), Minehart and Neeman (2002), Perez-Castrillo and Wettstein (2002) also propose auction mechanisms in the same vein, aiming for efficiency and truthful revelation. The traditional trade-off between efficiency, incentive compatibility and budget balance is central in these papers and they address the siting problem exclusively from a strategic viewpoint. Ye and Yezer (1997) tackle the issue by introducing a spatial dimension (the spatial distribution of benefits and costs of alternative waste disposal site location patterns).

However, another aspect of the siting problem relates to the sharing of the cost borne by the host community. Taking into account such redistribution issues helps ease the siting process itself and reinforces the stability of the agreement. Indeed, if not carefully considered, the structure of the compensation itself could result in the rejection of the project (Easterling, 1992; Frey et al., 1996). For example, reviewing several cases of waste disposal facilities in the Canadian context, Khun and Ballard (1998) conclude that inequity perception and political dimensions (beyond the economic implications) were the main causes of the NIMBY effect. The traditional economic approach focusing on the strategic properties of siting procedures is silent with regards to redistribution issues.

By contrast, in a companion paper (Laurent-Lucchetti and Leroux 2009) we design

[1]See Minehart and Neeman (2002).

a simple mechanism which selects an efficient site, preserves incentives and implements any individually rational cost shares. Knowing such a mechanism exists begs careful examination of the NIMBY problem from a redistributive viewpoint. Moreover, we can ignore strategic issues here and assume the relevant parameters are known.

We model the problem using two parameters: the benefit a community obtains from the existence of the public good, b_i, and the hosting cost of each community, c_i. Until now, studies have focused on the cost parameter to dictate redistribution. Adding a benefit component enhances the model in at least two ways: it explicits whether the public good should be constructed (if joint benefits exceed the lowest cost) and, most importantly, it places a bound on cost shares. Thus, ignoring the benefit component amounts to ignoring the voluntary participation of communities, which can be very problematic for the stability of any agreement. In fact, benefits are traditionally central in allocating the costs of public goods.

Other works have suggested pricing in proportion to usage (see Minehart and Neeman, 2002; Sakai, 2008, in the context of waste treatment). Yet, despite its desirable properties this pricing scheme may fail voluntary participation. Moreover, benefits may be unrelated to usage: a community may obtain large benefits from the existence of a prison without sending any of its inhabitants to it.

In practice, migrations are often observed after the host is announced (Baumol and Oates, 1998). For instance, agents with a low disutility may move to the host community because of lower housing prices or other advantages brought about by the compensation scheme (e.g., improved public infrastructures), while agents with high disutility may choose to move out of the host community.

We introduce axioms which specifically handle the physical asymmetry of the NIMBY problem, and the possibility of migrations once the host is announced. We show these axioms characterize Lindahl prices. Traditionally, numerous public finance issues are settled using Lindahl prices. However, despite their well-known properties in the standard public good case, the relevance of Lindahl prices in the NIMBY context had yet to be ascertained. While our characterization is technically related to those in Moulin (1987) and Ju *et al.* (2007) in different contexts, we provide new interpretations to axioms explicitly designed for the problem at hand.

2. The model and axioms

Let $N = \{1, ..., n\}$ be the set of communities. Each community obtains a benefit, $b_i \in \mathbb{R}$, from the existence of the public good and incurs a cost, $c_i \in \mathbb{R}_+$, if it must host of the public good.[2] The cost parameter combines the physical construction cost

[2]For clarity, we use a benefit interpretation for the b_i's, but these parameters can be negative for some communities, if they are against the project altogether.

and the disutility from hosting the public good. Let $(b,c) = (b_i, c_i)_{i\epsilon N}$ be a *benefit-cost profile*.[3]

Without loss of generality, we rank communities from lowest to highest cost: $c_1 \leq c_2 \leq .... \leq c_n$. Efficient siting requires that the host be a lowest-cost community. We assume $\sum_N b_i \geq c_1$ so that it is efficient to build the facility. An efficient cost-sharing method assigns a vector of cost-shares $x(b,c) \in \mathbb{R}^N$ such that $\sum_N x_i(b,c) = c_1$.

A basic incentives property is *Voluntary Participation*: communities should not pay more than the benefits they obtain.

Voluntary Participation (VP): For all $(b,c) \in \mathbb{R}^N \times \mathbb{R}^N_+$ and $i \in N$, $x_i(b,c) \leq b_i$.

Next, we define two properties to overcome the natural asymmetry of the problem. The first axiom is inspired by cost monotonicity, a standard requirement in traditional cost-sharing problems, which states that no community should pay less if the total cost were to increase. Because we wish the solution to not treat the host asymmetrically, *Extended Cost Monotonicity* holds all communities responsible for the total cost:

Extended Cost Monotonicity (ECM): For all $b, b' \in \mathbb{R}^N$, $c, c' \in \mathbb{R}^N_+$ and $i,j \in N$,

$$c_i \geq c'_i \Rightarrow x_j(b,(c'_i, c_{-i})) \geq x_j(b,c)$$

ECM can be justified as follows: because *ex ante* the decision to build a facility is a collective one, the host is not more responsible for the total cost just because its own cost happens to be the lowest in the realized profile. The sharing rule should reflect this fact.[4]

The next property reinforces our view that no community is responsible for the distribution of characteristics; should migrations occur between communities, the latter would collectively pay the same amount while outside communities are unaffected:

Migration Independence (MI): For all $b, b' \in \mathbb{R}^N$, $c, c' \in \mathbb{R}^N_+$ and $S \subseteq N$:

$$\left.\begin{array}{rc} & \sum_{j\epsilon S} c'_j = \sum_{j\epsilon S} c_j \\ \text{and} & \sum_{j\epsilon S} b'_j = \sum_{j\epsilon S} b_j \\ \text{and} & min_{i\in S}(c_i) = min_{i\in S}(c'_i) \end{array}\right\} \Longrightarrow \left\{\begin{array}{rc} & x_i((b'_S, b_{-S}),(c'_S, c_{-S})) = x_i(b,c), \forall i\epsilon N \backslash S \\ \text{and} & \sum_{j\epsilon S} x_j((b'_S, b_{-S}),(c'_S, c_{-S})) = \sum_{j\epsilon S} x_j(b,c) \end{array}\right. .$$

MI insures that the cost shares of communities not involved are unaffected by those maigrations. *MI* is related to the well-known axiom of No Advantageous Reallocation (NAR) in claims problems. NAR addresses the problem of strategic manipulation of claims and is used to characterize the egalitarian rule, the proportional rule, and many other surplus-sharing methods (see Moulin, 1987). Therefore, eventhough

[3] For any community $i \in N$, we denote by (b'_i, b_{-i}) the vector b where b_i has been replaced by b'_i, and for any subset $S \subsetneq N$, b_S denotes the projection of b onto $\mathbb{R}^S_+$. Also, $b_N = \sum_{i\in N} b_i$.

[4] In addition, as argued in Laurent-Lucchetti and Leroux (2009), *ECM* also has an appealing strategic implication: it guarantees that the outcome of the mechanism proposed there is immune to coalitional deviations.

our normative interpretation of *MI* is anything but strategic, *MI* also prevents profitable manipulation by communities (e.g., the manipulation of electoral boundaries).

3. The Result

In our context, Lindahl prices are defined by sharing the cost proportionally to benefits. For any $i \in N$:

$$x_i^{Lindahl}(b,c) = \frac{b_i}{\sum_N b_j} c_1 \tag{1}$$

Theorem 1. *Given* $n \geq 3$*, Lindahl prices are the unique efficient cost-sharing method meeting* VP*,* ECM*, and* MI*.*

Proof. Clearly, Lindahl prices meet *VP*, *ECM*, and *MI*. Conversely, let x be an efficient cost-sharing method meeting *VP*, *ECM* and *MI*.

Step 1: Consider a benefit-cost profile $(b,c) \in \mathbb{R}^N \times \mathbb{R}_+^N$. Let $c' = (c_1, c_1, ...c_1) \in \mathbb{R}_+^N$. By *ECM*, $x_i(b,c) \geq x_i(b,c')$ for all $i \in N$. Therefore, by budget balance $x(b,c) = x(b,c')$.Hence, the cost shares of communities are solely determined by b and c_1: we write $x(b,c_1)$ instead of $x(b,c)$.

Step 2: Let $i \in N$ and $b, b' \in \mathbb{R}^N$ such that $b_i' = b_i$ and $\sum_{N \setminus i} b_j' = \sum_{N \setminus i} b_j$. By *MI*, $x_i(b', c_1) = x_i(b, c_1)$. So, $x_i(b, c_1)$ depends only on $b_i, \sum_{j \neq i} b_j$ and c_1 for all $i \in N$. Alternatively, x_i depends only upon b_i, b_N and c_1 for all $i \in N$. We write $x_i(b_i, b_N, c_1)$.

Step 3: Let $c_1 \in \mathbb{R}_+$, $i, j \in N$ and $b, b' \in \mathbb{R}^N$ be such that $b_i' = b_i + b_j$, $b_j' = 0$ and $b_k' = b_k \; \forall \; k \neq i, j$. By MI, $x_i(b_i', b_N', c_1) + x_j(b_j', b_N', c_1) = x_i(b_i, b_N, c_1) + x_j(b_j, b_N, c_1)$. By *VP*, $x_j(b_j', b_N', c_1) = 0$. Thus, recalling that $b_N' = b_N$, we get

$$x_i(b_i + b_j, b_N, c_1) = x_i(b_i, b_N, c_1) + x_j(b_j, b_N, c_1). \tag{2}$$

Given c_1 and b_N, the cost share of community i is only determined by b_i. Again, we slightly abuse notations and rewrite (2) as follows:

$$x_i(b_i + b_j) = x_i(b_i) + x_j(b_j),$$

which holds for all b_i, b_j such that $b_i, b_j \geq 0$ and $b_i + b_j \leq b_N$. Similarly, $x_j(b_i + b_j) = x_i(b_i) + x_j(b_j)$ on the same domain.

Thus, x_j and x_i coincide on $(0, b_N)$ for all i, j. It follows that:

$$x_i(b_i + b_j) = x_i(b_i) + x_i(b_j) \tag{3}$$

for all $b_i, b_j \geq 0$ such that $b_i + b_j \leq b_N$, which is a Cauchy functional equation.

Step 4: Following a well-known result of functional equations theory (see Aczèl, 1966), the general solution of (3) is a linear function. Thus, for all $b_i \leq b_N$,

$$x(b_i) = \lambda b_i$$

By budget balance, $\lambda = \frac{c_1}{b_N}$, as was to be proved. □

Other intuitive ways of splitting the hosting cost exist. For instance, the constrained egalitarian method, splitting the total cost equally up to the voluntary participation constraint, fails to satisfy *MI*: migrations from an unconstrained community "transferring" higher benefits to a constrained community lead to an increase in their aggregate share while others benefit. Also, sharing the hosting cost in proportion to c_i's fails *ECM*: an increase in the hosting cost for a non-host community means it will pay more, benefitting other communities.

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