Why not in your Backyard? On the Location and Size of a Public Facility

GIORGIO BELLETTINI
HUBERT KEMPF

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Abstract

In this paper, we tackle the issue of locating a public facility which provides a public good in a closed and populated territory. This facility generates differentiated benefits to neighborhoods depending on their distance from it. In the case of a Nimby facility, the smaller is the distance, the lower is the individual benefit. The opposite is true in the case of an anti-Nimby facility. We first characterize the optimal location which would be chosen by a social planner. Then we introduce a common-agency lobbying game, where agents attempt to influence the location and provision decisions by the government. Some interesting results arise in the case where only a subset of neighborhoods lobby. First, the solution of the lobbying game can replicate the optimal solution. Second, under-provision and over-provision of the public good may be obtained both in the Nimby and the anti-Nimby cases. The provision outcome depends on the presence of either a congestion effect or an agglomeration effect. Third, some non-lobbying neighborhoods may be better off than in the case where all neighborhoods lobby, which raises the possibility of free-riding at the lobbying stage.

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Giorgio Bellettini
Department of Economics
University of Bologna
Piazza Scaravilli 2
40126 Bologna
Italy
giorgio.bellettini@unibo.it

Hubert Kempf
Research Department
Bank of France
Rue Croix-des-Petits-Champs
75002 Paris
France
hubert.kempf@banque-france.fr

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1 Introduction

The location of a public facility in a territory, providing a public good to the inhabitants of this territory, is a thorny issue. The main reason is that, in most cases, a public facility has differentiated effects on inhabitants, depending on distances. The importance of this issue can hardly be dismissed. The decision over the siting of such facilities is often a very complicated endeavor, especially in the case of noxious facilities, such as landfills, incinerators, prisons, etc. Although everybody acknowledges the importance of the public good, local residents usually oppose the construction of these facilities in their community, showing an attitude which is referred to as the NIMBY ("Not In My Backyard") syndrome. The choice of the location of these facilities is the object of fierce political competition, which leads to long and laborious decision processes and sometimes siting stalemates.[1]

In this paper we adopt a political economy perspective to investigate two interrelated issues: the location of the public facility and its size, measured in terms of the public goods and services that the facility provides to the citizens.[2] We set up a model of one locality, which we will call "city", formed of neighborhoods (households) spread on a closed circular territory.[3] A decision must be taken on the siting and the size of a facility, when neighborhoods are affected by both the amount of the provision of the public good (i.e., the size of the facility) and by the distance to the facility. Abstracting from the location issue, agents value the public good. We refer to the facility as a Nimby facility when the relationship between individual benefits and distance is positive, and as an anti-Nimby facility when the relationship is negative. Thus, for a given amount of public good provision, the closer to a neighborhood is a facility, the worse it is for this neighborhood in the Nimby case and the better in the anti-Nimby case.

We first prove the existence and characterize the optimal solution that would be chosen by the government if it acted as a benevolent social planner. This case serves as a benchmark in the sequel. Then, building on the menu-auction framework developed by Bernheim and Whinston [1] and applied by Grossman and Helpman in a series of studies [7], [8], we turn to the equilibrium of the lobbying game played by the government and the neighborhoods, using as a benchmark the social planner solution.

[1] Examples of public processes related to decisions on the siting of such facilities in Canada, the Netherlands and Switzerland can be found in Kuhn and Ballard [11], Wolsink [15] and Frey, Oberholzer-Gee and Eichenberger [5], respectively.

[2] Given this perspective, we leave aside the issue of optimal taxation policy which could affect the welfare consequences of the location of such a facility, by means of subsidies and taxes.

[3] Our analysis highlights the importance of reasoning on a multi-dimensional space when addressing location issues.

First, we show that the lobbying equilibrium replicates the optimal solution not only when all neighborhoods lobby, but also in cases where only some neighborhoods lobby. Second, with regard to the relationship between the provision of the public good and the location of the facility, we prove that, both in the Nimby and the anti-Nimby case, when the lobbying equilibrium differs from the social planner solution, there may be either under-provision or over-provision. To explain this result, we introduce the notions of "public complements" and "public substitutes" to characterize the relationship between the size of the facility and the distance. When they are public complements, there is a "congestion effect" such that shorter distance is associated with lower demand of the public good. When they are public substitutes, there is an "agglomeration effect" such that shorter distance is associated with higher demand of the public good.[4]

Exploring further the issue of the consequences of the lobbying activities, and turning to the normative aspects of the political game, we show that, when the equilibrium decision differs from the optimal one, some lobbies may be worse off whereas some non-lobbies may be better off. This raises the issue of free-riding on lobbying activities. Therefore our analysis of the political decision of locating a public facility opens new perspectives on the distributional consequences of this problem.

A recent study by Feinerman et al. [3] is close in spirit to ours, as it focuses on the political game being played by lobbies about the location of a waste facility. However it differs from ours in many ways. First, their model is very different from ours, as it is based on a housing price mechanism in a two-city economy, where the two cities are situated at the extremities of a segment. The siting of the facility has only indirect effects on households' utility through the housing price, but does not enter directly in their utility function: as such, it does not properly match the definition of a Nimby facility, that is, an overall advantageous good with local harms based on distance. Hence, they cannot address the link between the location and the supply of the public good. Second, they are interested in the positive issue of the location of the public good but do not address the normative implications of this decision. Third, our analysis is more general as our formalization allows us to study the location and size of a public facility having differentiated effects on an indefinite number of inhabitants disseminated in a territory, be they positive or negative. In other words, our analysis is not restricted to noxious facilities, nor to a one-dimension spatial economy.

[4] This effect is reminiscent of the agglomeration effect used in economic geography, as it refers to a positive effect due to increased density. Here it refers to a public good, and not to the concentration of production factors.

Fredriksson [6] studies the political economy implications of different institutional structures on the choice of capacity of hazardous waste facilities in a federal system and finds that a decentralized system yields the first-best capacity level whereas a centralized system tends to implement sub-optimal levels. His paper has no spatial content and no attention whatsoever is paid to the choice of the (optimal) location of the facility, and to the interaction between (optimal) provision and location, which are instead the main objectives of our investigation. Furthermore, he does not address the lobbying issue.

The plan of this paper is as follows. Section 2 presents the model of a multi-neighborhood city facing the issue of the location and size of a public facility. In section 3, we analyze the optimal solution of this problem made by a social planner. This solution will be used as a benchmark for the assessment of the political solution. Section 4 is devoted to the study of the political game when neighborhoods lobby the policymaker in charge of the city. Section 5 concludes.

2 The model

We consider an economy formed of a territory and populated by n equal-sized neighborhoods ($n > 1$). We call this economy a "city". The territory is spatially defined as the area $\mathcal{S}$ of the trigonometric circle.[5] The city is composed of "neighborhoods". A neighborhood is a set of identical agents, whose mass is normalized to one and is supposed to be located on a single point. On a given point, there is one neighborhood. We denote by O the center of the circle.

According to these assumptions, we introduce the following definition.

Definition 1 *A $n-$ neighborhood structure $\mathcal{P}$ is a set of n points $\{P_1, .., P_i, ..., P_n\}$ such that $x_i^2 + y_i^2 \leq 1$ where $(x_i, y_i) \in \mathbb{R}^2$ are the coordinates of P_i.*

Any point P_i is fully characterized by these coordinates or equivalently by its radian. Without loss of generality, we assume that points are ranked in $\mathcal{P}$ in such a way that $radian\,(P_i) < radian\,(P_{i'})$, for any $i < i'$. We denote by $\widetilde{\mathcal{P}}$ the convex hull defined by the n points $\{P_1, .., P_i, ..., P_n\}$.

A public facility has to be located in the territory $\mathcal{S}$. This facility provides a public good to agents. There exists a single policymaker who decides both on the (per-capita) size of the facility, measured in terms of the amount of the public good that provides,

[5] This assumption is introduced for the sake of simplicity. Our analysis could be generalized to the study of the location of a public facility when a population is spatially disseminated within a bounded territory.

g, and its location, L, included in $\mathcal{S}$. The policymaker of the city, in charge of its public affairs, is called the "mayor".[6] The location L is fully characterized by its coordinates (x_l, y_l). Obviously, the knowledge of these coordinates allows us to obtain the euclidean distance between L and any point P_i belonging to $\mathcal{P}$. We denote this distance by d_i.

The construction of the facility is financed by lump-sum taxes. Assuming that costs depend linearly on the size and there is no deficit spending, we have:

$$g = \tau = \tau_i, \forall i. \tag{1}$$

Each agent is endowed with the same endowment $e \in \mathbb{R}^+$. Each agent appreciates consuming the private and the public goods. In addition the benefits she draws from the public good depends on the distance between her own location in the city and the location of the public facility. Some facilities are such that any agent prefers them to be located as far as possible from her own location when they produce nuisances: think about landfills, hazardous waste facilities, jails, etc. Others, to the contrary, are most appreciated when they are close to individuals; the closer they are from agent i, the better it is for her : schools, museums, (underground) stations, etc., are examples of such facilities. We refer to the first ones as "Nimby" facilities and the second ones, by contrast, as "anti-Nimby" facilities.

Hence, for any agent i belonging to $\mathcal{P}$, we characterize the utility function in these two cases as follows:

$$v_i(g, d_i; e) = e - \tau + H(g) + \theta g^{\alpha} K^j(d_i) \tag{2}$$

with $H(g) > 0$, $H'(g) > 0$, $H''(g) < 0$ and $j = N, A$ in the Nimby and the anti-Nimby case respectively. The public good generates decreasing marginal returns per se.[7]

With regard to the location of the facility and its impact on a given neighborhood, we will introduce the following assumptions:

Assumption 1: *In the case of a "Nimby" facility, θ is negative and the K^N function has the following properties*:

$$K^N(d_i) > 0, \left(K^N\right)'(d_i) < 0, \left(K^N\right)''(d_i) > 0 \tag{3a}$$

A Nimby facility generates "spatial" nuisances, that is, a reduction in the distance d_i has negative impact on individual utility. According to (3a), the marginal "spatial" harm

[6] Here what matters is that there is a closed unique political jurisdiction. The territory can also be seen as a "country" and its policymaker as the "government".

[7] We assume that $K(\cdot)$ ensures that the various solutions that we investigate imply positive and finite provisions of the public good.

generated by a decrease in distance is decreasing with distance, that is $K(d_i)$ is convex. To illustrate the case of a Nimby facility, consider a landfill generating unpleasant views and odors. The farther it is from one's location, the better it is for the agent. Siting this facility one more mile away is less beneficial to the agent when the facility is already far away from her.

Assumption 2: *In the case of an "anti-Nimby" public facility, θ is positive and the K^A function has the following properties*:

$$K^A(d_i) > 0, \left(K^A\right)'(d_i) < 0, \left(K^A\right)''(d_i) < 0 \tag{3b}$$

An anti-Nimby facility generates "spatial" benefits, that is, a reduction in the distance d_i has positive impact on individual utility. According to (3b), the marginal benefit from a reduction in distance is increasing with distance, that is $K(d_i)$ is concave. As an example of an anti-Nimby facility, consider the case of the city hall. Distance is a proxy for the walking time to the city hall. The longer the walking time, the higher the opportunity cost it generates; this opportunity cost is marginally increasing with time (tiredness, lost leisure time, etc.). Remark that the distance variable may capture both transportation costs and other non-pecuniary influences of distance on welfare. Here we do not disentangle the two effects.

In both cases, we assume that these spatial effects are linked to the provision of the public good, that is the size of the facility supplying the public good. More precisely, it depends both on the values of α and θ. Defining the function $\Psi(g, d^i)$ as follows:

$$\Psi(g, d^i) = \theta g^\alpha K^j(d_i)$$

we shall refer to g and d^i as "public complements (public substitutes) for agent i" when the cross derivative $\Psi_{gd^i}(g, d^i)$ is positive (negative).[8] In the case of Nimby facilities (θ negative), g and d^i are public complements when α is positive. Then a decrease in distance induces agent i to demand a decrease in the provision of the public good, as a diminished distance decreases the marginal benefit that agent i draws from the public good. We refer to this case as the "congestion effect". When α is negative, the opposite effect is at work: we refer to this effect as the "agglomeration effect". A decrease in distance augments the desirability of the public good for agent i.

In the case of an anti-Nimby facility (θ positive), the effects are reversed: g and d^i are public complements, that is there is a congestion effect, when α is negative. There is an agglomeration effect when α is positive.

[8] To the best of our knowledge such terminology has not been used before in public economics. We draw it from the literature on strategic interactions and supermodular games.

Typically, we could think of airports as Nimby facilities linked to a positive α. Ceteris paribus, the farther an airport is from residence, the bigger is its desired size (that is the number of connections they offer to travellers): hence air travel and distance are public complements. On the other hand, museums could be thought at first sight as anti-Nimby facilities with public substitutability between art and distance: the closer they are, the bigger is their desired size. This may help to explain why usually capitals enjoy the largest museums and large airports are located faraway from the city center.

In sum, our specification is fairly general and covers many different effects which are often related to the location of public facilities.

3 The optimal solution

First we consider the optimal solution to this problem solved by a social planner. This solution will be used as a benchmark to assess the impact of lobbies on the political process leading to the location of the public facility. Giving equal weight to all individuals, the social planner maximizes the average level of welfare. Taking into account equation (2), it solves the following optimization problem:

$$\max_{g,\, x_l,\, y_l} W(g, x_l, y_l; e, x_i, y_i) = [e - g + H(g)] + \theta g^{\alpha}\left[\frac{1}{n}\sum_{i=1}^{n} K(d_i)\right] \tag{4}$$

$$s.t. \quad d_i = \left[(x_i - x_l)^2 + (y_i - y_l)^2\right]^{\frac{1}{2}} \tag{5}$$

$$x_l \in [-1, 1],\ y_l \in [-1, 1] \tag{6}$$

The first constraint corresponds to the definition of distance, the second one requires that the optimal solution belongs to $\mathcal{S}$.

Then, we are able to state the following[9]:

Proposition 1 ***The social planner solution***

(i) There exists an optimal location $L^* = (x_l^*, y_l^*)$.

(ii) If the facility is Nimby, there may be multiple solutions to the social planner problem. Any optimal location L^* either belongs to the interior of $\widetilde{\mathcal{P}}$ or is on the circumference of $\mathcal{S}$. If $\sum_{i=1}^{n} K^N(d_i)$ is strictly concave in x_l and y_l, there is a unique solution.

(iii) If the facility is anti-Nimby, there is a unique optimal location, which belongs to $\widetilde{\mathcal{P}}$.

[9] We are very indebted to Stephane Rossignol for the proof of this proposition.

(iv) Defining the net social marginal benefit of g as $[H'(g)-1]+\theta\alpha g^{\alpha-1}\left[\frac{1}{n}\sum_{i=1}^{n}K(d_i)\right]$, *the optimal amount of public good g^* is such that net social marginal benefit is zero.*

Proof. See appendix A. ■

The existence of a solution comes from the continuity of welfare function and compactness of the opportunity set, defined in terms of available spatial and physical resources.

When the public facility is Nimby, it is easy to understand that, if the optimal location is located outside the convex hull $\widetilde{\mathcal{P}}$, it must lie on the circumference of $\mathcal{S}$. Suppose it is not the case. Then, moving orthogonally the public facility further away toward the circumference will make all agents better off. The optimal location may not be unique. Suppose that there are two neighborhoods located at $(1,0)$ and $(-1,0)$; then the optimal location, because of the symmetrical characteristics of the problem, is either $(0,1)$ or $(0,-1)$.

As the above example makes clear, uniqueness of the optimal location in the Nimby case depends on the distribution of neighborhoods over the city. In fact, it is easy to provide examples which generate a unique optimal solution in this case (see Appendix A).

When the public facility is anti-Nimby, it will be located within the convex set $\widetilde{\mathcal{P}}$. Suppose it is not the case. Then, moving orthogonally toward the convex hull will make everybody better off, at least until the boundary of the hull is reached. All individuals agree on the fact that the public facility must be as close as possible from their own location.

With regard to uniqueness, a priori multiplicity of equilibria may arise as, although the individual functions $K^j(d_i)$ are concave in d_i, they need not be so in (x_l, y_l). In Appendix A, we show that, in the case of anti-Nimby facilities, concavity holds also with respect to (x_l, y_l), whereas this is not necessarily true in the case of Nimby facilities.

Finally, (iv) extends the Samuelsonian rule for the optimal provision of a public good when location matters. It highlights that the optimal provision interacts with the optimal location. This happens because the spatial externalities depend on the amount of public good supplied to the city's population. To understand this relationship, it is convenient to refer to $\frac{1}{n}\sum_{i=1}^{n}K^j(d_i)$, $j=A,N$, as the average distance impact of the location of the facility on the neighborhoods. Consider the case of a Nimby facility. If $\alpha<0$, the average distance impact and the public good are public substitutes and consequently the optimal size g^* decreases with the average distance impact. The higher the average distance impact provided by the location, the lesser the provision of the public good. In the case of an anti-Nimby facility, the relationship between g^* and the average distance impact is instead positive, as they are perfect complements. The higher the average distance impact provided by the location, the larger the optimal size of public facility. If $\alpha > 0$, these results are reversed. In the Nimby case, the higher is the average distance impact, the larger is the public good provision as a higher distance increases the marginal benefits drawn from the public good; in the anti-Nimby case, the higher the average distance impact, the smaller is the public good provision for the opposite reason.

In many cities, we observe that the city hall or the cultural center is located at the spatial center of the city. In our setting, it corresponds to O. Are there cases where the public good is located at the center of the circle? To answer this question, we introduce the two following definitions:

Definition 2 *A $n-$ neighborhood structure is $O-$ symmetrical when for any point P_i where a neighborhood is located, a neighborhood is located at the point P_j defined by: $x_j = -x_i$ and $y_j = -y_i$, for $i = 1, ..., n$.*

Definition 3 *A $n-$ neighborhood structure is said to be regular if all neighborhoods belong to the circumference of $\mathcal{S}$, and the distances between P_i and P_{i+1} are equal, for any $1 \leq i \leq n$, with $n + 1 \equiv 1$.*

Using these definitions, we can state the following proposition:

Proposition 2 *Let $\sum_{i=1}^{n} K^j(d_i)$, $j = A, N$ be strictly concave in x_l and y_l. Then, if the $n-$ neighborhood structure $\mathcal{P}$ is $O-$ symmetrical or regular $(n > 2)$, the unique optimal location is located at the center of the territory O.*

Proof. See Appendix B. ■

This proposition is easy to understand. Given the symmetry properties of these two types of neighborhood structure, as the social planner weighs equally agents, given the concavity of the function $K(\cdot)$, she chooses as an optimal location the center O of the city: each agent will then be located at the same distance to the public facility, be it Nimby or anti-Nimby.

4 Lobbying on location

We now introduce the possibility that neighborhoods lobby the government for the location *and* the size of the public good. We will formalize the lobbying process as a common agency game à la Bernheim and Whinston [1], where lobbies offer binding contributions to the government, conditional on the chosen policy.

Let us denote with $\mathcal{L} \subseteq \mathcal{P}$ the subset of $\mathcal{P}$ whose elements (neighborhoods) are lobbing and with l the cardinal of $\mathcal{L} : l \leq n$. We refer to $\mathcal{L}$ as the "lobby set" and to $\overline{\mathcal{L}}$, the complement of $\mathcal{L}$ in $\mathcal{P}$, as the "non-lobby set".

The lobbying game on the location and provision of the public good is similar to Grossman and Helpman's analysis of trade policy. It is a two-stage game.

1. In the first stage, lobbies commit to a menu of contributions depending on the policy chosen by the mayor. Given (2), individual contribution schedule by lobby i is a function of g and d_i and is denoted by $C_i(g, d_i)$. It is assumed to be globally truthful, that is $C_i(g, d_i) = \max[0, v(g, d_i; e) - b_i]$ where b_i is a scalar optimally set by lobby i. Lobbies play non-cooperatively with one another: when choosing b_i, each lobby takes other lobbies' contributions as given.

2. In the second stage, the mayor decides on the location and the size of the public facility, taking into account the related contributions that she will receive from the various lobbies. The maximization problem of the mayor in the presence of lobbies is written as:

$$\max_{g, x_l, y_l} \Xi(g, x_l, y_l) \equiv \lambda W(g, x_l, y_l) + (1 - \lambda) \sum_{i \in \mathcal{L}} C_i(g, d_i) \tag{7}$$

   where $W(g, x_l, y_l)$ is the social welfare function given in (4), and $\lambda \in [0, 1]$ is the weight given to the social welfare and is an index of "benevolence". When λ is equal to 1, the mayor acts as the social planner and implements the optimal solution characterized in the previous section; when it is equal to zero, the mayor is fully opportunistic.

A solution to the lobbying game is a vector $(\widehat{x}_l, \widehat{y}_l, \widehat{g}, \widehat{c}_1..., \widehat{c}_i, .., \widehat{c}_l)$, where $\widehat{c}_i$ is the contribution received from lobby i, associated with $(\widehat{x}_l, \widehat{y}_l, \widehat{g})$. We denote by $\widehat{L} = (\widehat{x}_l, \widehat{y}_l)$ the location associated with this solution.

Then, we can state the following result on this lobbying game:

Proposition 3 ***The lobbying game equilibrium***

(i) There exists a solution to the lobbying game.

(ii) If the facility is Nimby, there may be multiple solutions to the lobbying game. Any optimal location $\widehat{L}$ either belongs to the interior of $\widetilde{\mathcal{P}}$ or is on the circumference of $\mathcal{S}$. If $\sum_{i=1}^{n} K^N(d_i)$ is strictly concave in x_l and y_l, there is a unique solution.

(iii) If the facility is anti-Nimby, there exists a unique solution, which belongs to $\widetilde{\mathcal{P}}$.

(iv) if $\mathcal{L} = \mathcal{P}$, the set of optimal locations $\widehat{L}$ is identical to the set of optimal locations L^* and the size $\widehat{g}$ associated to a particular location is identical to the size g^* chosen by the social planner.

(v) $\widehat{C}_i$ are increasing (decreasing) in $\widehat{d}_i$ if the good is (anti-)Nimby good.

Proof. See appendix C. ■

The existence of a solution is immediate, given the standard features of this economy and the assumption of truthful contributions.

The second and the third properties of the lobbying solution can be easily understood by applying the same line of reasoning that we used in the case of the social planner solution. For example, in the Nimby case, if the public facility were located outside the convex hull $\widetilde{\mathcal{P}}$ but not on the circumference, every agent (lobbies and non-lobbies) would agree on moving the facility orthogonally to the circumference and the mayor would implement this move. In this case, there would be no conflict of interests whatsoever between lobbies and non-lobbies. The uniqueness issue can be understood using the reasoning made for Proposition 1.

The fourth property of the lobbying solution is a well-known property of this type of lobbying games: when all neighborhoods lobby, the solution is identical to the optimal one. In our case, it means that both the location and the size of the public facility are equal to the ones chosen by the social planner. When all neighborhoods lobby, their actions nullify each other and the countervailing power of each lobby against all lobbies leaves the mayor in a position to choose the socially optimal solution. Of course, then there is no net gain in lobbying. By Propositions 2 and 3, it is immediate that if $\mathcal{L} = \mathcal{P}$, and $\mathcal{P}$ is $O-$symmetrical or regular, the unique location $\widehat{L}$ is O and $\widehat{C}_i = \widehat{C} > 0$, $\forall i$. The center of the city may well be the solution of the lobbying game, whether the public facility is Nimby or anti-Nimby. In that case, given the symmetric location of all neighborhoods with respect to O, their contributions to the mayor are equal.

Finally, according to equation (2), neighborhood i's utility depends only on her distance to the public facility and on the amount of the public good. In the Nimby case, the more distant is the public facility to agent i, the higher is her level of utility. By truthfulness assumption, contributions must reflect exactly the relative valuation of two alternatives, so that agent i must bid more the closer is the facility. The opposite holds for the anti-Nimby case.

Turning to the case where the lobby set $\mathcal{L}$ is smaller than $\mathcal{P}$, and assuming for simplicity that $\sum_{i=1}^{n} K^{j}(d_i)$ is strictly concave and there is a unique optimal solution,[10] we can prove the following:

Proposition 4 ***Characterization of the equilibrium when $\mathcal{L} \subset \mathcal{P}$***

(i) When $\mathcal{L} \subset \mathcal{P}$, it may be the case that $\widehat{L} = L^{*}$.

(ii) When $L \subset P$ and $\widehat{L} \neq L^{*}$, $\widehat{g} = g^{*}$ if and only if $\alpha = 0$.

(iii) When $L \subset P$ and $\widehat{L} \neq L^{*}$, $\widehat{g} > (<)\, g^{*}$ if and only if $\alpha > (<)\, 0$.

Proof. See appendix D. ■

A simple example will provide the intuition for the result stated in (i). Consider an $O-$ symmetrical structure. According to Proposition 2, the optimal location of the game is O. Suppose that only neighborhoods P_i, with i even, are active lobbies. Then each lobby faces a symmetrical lobby with respect to O. The lobbying game retains the $O-$ symmetry property of the social planner case, and the mayor locates the public facility in O. It happens that each pair of symmetrical lobbies will have a neutral influence on the solution as each lobby will neutralize the action of its counterpart. This proposition differs markedly from the standard result obtained by Grossman and Helpman [7] where the solution when only a subset of agents lobby always differs from the solution when all agents lobby.

This result may provide an explanation for the empirical finding by Feinerman et al. [3]. In their empirical study of the siting of a waste disposal facility in Israel, they found that the actual choice made by the Israeli authorities almost coincides with the "optimal" solution that would have been chosen by the social planner. This is likely to be the consequence of the countervailing influences of the diverse lobbies involved in the decision making process.

Result (ii) is immediate given that when α is nil, there is no interaction between distance and the provision of the public good. Hence there is unanimity in the provision of the public good.

Result (iii) illustrates the suboptimality of the lobbying solution when only some neighborhoods are able to influence the government. To understand this property, consider the simple case of a Nimby facility ($\theta < 0$) with a single lobbying neighborhood, P_1, with $\alpha > 0$. In this case, we have seen that the public good and distance are public complements. The lobbying neighborhood, having no countervailing neighborhood, is able to

[10] In the case of multiple optimal solutions, we would have to use a selection criterion in order to make comparisons. An obvious criterion would to focus on the optimal solution(s) for which the welfare of the lobby set is maximized. Our analysis would then proceed.

induce the mayor to locate the public facility farther from itself, thereby decreasing the negative spatial externalities suffered by P_1. Then, as the distance is increased, P_1 is willing to benefit from a larger amount of the public good, because her marginal benefit from public good consumption, given by $H'(g)+\alpha\theta g^{\alpha-1}K(d_1)$, *increases* with d_1, as the facility is Nimby and $K(d_1)$ decreases. This explains why the mayor is induced by an increase in the contributions of P_1 to choose $\widehat{g}$ larger than the socially optimal g^*. On the contrary if $\alpha < 0$, that is the public good and distance are public substitutes the marginal benefit of public good consumption *decreases* when distance is increased. Thus the mayor is induced by an increase in the contributions of P_1 to choose $\widehat{g}$ smaller than the socially optimal g^*.

In the case of an anti-Nimby facility ($\theta > 0$), a similar reasoning applies. Again suppose that P_1 is the unique lobbying neighborhood, with $\alpha > 0$. She wants the public facility to be located closer to her. But then, as the distance is decreased, the marginal benefit that she draws from the public good increases. Therefore she is willing to redirect some resources to the public good, and the mayor is induced by her contribution schedule to increase the amount $\widehat{g}$ compared to the socially optimal g^*.[11]

In sum, except in a very special case (additive terms related to size and location in the utility function), the location of a facility and its size are intimately related. The two structural features governing this link are the nature of the facility (Nimby or anti-Nimby) and the existence of a congestion effect or an agglomeration effect, or equivalently, whether the public good and distance are public complements or public substitutes. As a consequence, under-provision or over-provision of the public good can occur in both types of facilities.

Turning to the welfare properties of the lobbying solution, we can show that, on this dimension too, the impact of lobbies differs markedly from what was obtained by Grossman and Helpman [7]. Again, for simplicity, we restrict the analysis to the case where $\sum_{i=1}^{n} K^j(d_i)$ is strictly concave and there is a unique optimal solution. Then we can prove:

Proposition 5 *When $\mathcal{L} \subset \mathcal{P}$, and $\widehat{L} \neq L^*$, then*

(i) $\sum_{i\in\mathcal{L}} v\left(\widehat{g}, \widehat{d}_i\right) > \sum_{i\in\mathcal{L}} v(g^*, d_i^*)$ and $\sum_{i\in\overline{\mathcal{L}}} v\left(\widehat{g}, \widehat{d}_i\right) < \sum_{i\in\overline{\mathcal{L}}} v(g^*, d_i^*)$

(ii) there may exist some neighborhoods P_i belonging to $\mathcal{L}$ such that $v\left(\widehat{g}, \widehat{d}_i\right) < v_i(g^*, d_i^*)$ and neighborhoods P_j belonging to $\overline{\mathcal{L}}$ such that $v\left(\widehat{g}, \widehat{d}_j\right) > v_j(g^*, d_i^*)$.

Proof. See appendix E. ∎

[11] Notice that these examples can be generalized to the case of a plurality of lobbies.

This proposition characterizes the welfare properties of the solution when $\mathcal{L} \subset \mathcal{P}$, and the mayor's decision differs from the optimal solution. Property (i) states that, taken collectively, the lobbying neighborhoods benefit from this decision (not taking into account their contributions), at the expense of the non-lobbying neighborhoods: altogether the lobbying neighborhoods are better-off with the decision reached when they lobby than with the solution chosen by the social planner. The reverse is true for the non-lobbying neighborhoods. This result is consistent with what Grossman and Helpman [7] found.

However it is not true that each single lobby benefits from the mayor's decision, nor that each non-lobbying neighborhood is harmed by it (Property (ii)). Two simple examples will help to explain these counter-intuitive results. Assume $\alpha = 1$ and consider a $O-$ symmetrical structure, with n neighborhoods, n being large. The public facility is Nimby. Suppose that all neighborhoods P_i, $i \leq \frac{n}{2}$, are active lobbies and that among the rest of neighborhoods, there is only one active lobby, P_j, $j > \frac{n}{2}$. The $\frac{n}{2}$ first lobbies have a common interest to locate the public facility on the down-half of the trigonometric circle (with negative y). This harms neighborhood P_j as this shortens the distance d_j.

Suppose now that there are only two active lobbying neighborhoods, P_i and P_{i+2}. Their interests coincide and they act so as to increase the distance d_i and d_{i+2}. But by so doing, this increases the distance d_{i+1} and that benefits to the in-between non-lobbying neighborhood P_{i+1}.

Proposition 5 differs markedly from the results obtained by Grossman and Helpman. In their case, the pecuniary externalities generated by any contributing lobby on any other agent (lobby or not) is always *negative*: since all goods are consumed by all agents, rising tariff on one good through the lobbying activity of its producer always harms all other agents. In contrast, in our framework, considering as an example the case of a Nimby facility, increasing the distance between one lobbying neighborhood and the location of the public facility may benefit other neighborhoods, provided they are close enough to the lobby's location. In other words, in opposition to Grossman and Helpman's, here there may be a congruence in interests among different neighbors.

This sheds light on the free riding strategies being played in both settings. In both models, there is an incentive to defect from the solution without contributions: if no agent is actively lobbying, any agent has an incentive to be an active lobby. However, in Grossman and Helpman when other lobbies increase their contributions, any lobby is induced to increase hers because of the negative externalities, whereas in our case, due to the possible convergence of some agents' interests, a lobbying neighborhood may an incentive in free riding on her close neighbors and decrease her contributions when theirs are increased.

5 Conclusion

This paper tackles the issue of the location of a public facility in a territory from a theoretical point of view, adopting a political economy perspective on the subject. The issue of the location of a public facility is important because many of these facilities do have a differentiated impact on the inhabitants depending on their distance from the public facility. This impact may be negative (airports are disliked, almost unanimously) or positive (museums in the vicinity are also almost unanimously appreciated). We call the former ones "Nimby" facilities, and the latter ones "anti-Nimby".

Considering a two-dimensional territory that we call a city, we have characterized the optimal solution chosen by a social planner, which we take as a benchmark. We have then analyzed a lobbying equilibrium à la Grossman and Helpman [7], showing that this equilibrium can replicate the optimal solution not only when all neighborhoods lobby the "mayor", but also when only a subset of neighborhoods is actively involved in lobbying activities. When the mayor's decision differs from the optimal solution, it may lead to either over- or under-capacity of the public facility, be it Nimby or anti-Nimby.

The relation between size and location is complex and depends critically on the nature of the facility and the impact of size over the distance effect on individual utilities. To address this issue, we distinguish between the case where the public good and distance are what we call "public complements", and the case where they are "public substitutes". The public good and distance are public complements (public substitutes) when a decrease in distance decreases (increases) the marginal benefits that individuals enjoy from an increase in the provision of the public good. In the first case, we refer to a "congestion effect", and in the latter case, to an "agglomeration effect". When the facility is Nimby and some neighborhoods are organized in lobbies, there is under-provision (over-provision) when the public good and distance are public substitutes (public complements). These results are reversed when the facility is anti-Nimby.

Turning to the normative analysis of the political game, whereas as a whole lobbies gain from the equilibrium game, and non-lobbies lose, it may happen that some lobbies lose despite their own political involvement and some non-lobbies gain despite their inactivity. This raises the issue of who should lobby and who should not.

Our analysis rests on some simplifying assumptions, which might be relaxed to shed light on new issues related to the location decision of a public facility.

Here the players of our political game are exogenously given. In particular we do not consider the lobbying decision as such. Some recent papers study the endogenous decision to lobby, in different contexts (see for example Felli and Merlo [4] and Mitra [12]). In the context of the location of a public good, our analysis shows how crucial and complex this decision is. Since some lobbies lose and some non-lobbies gain from the equilibrium solution, the incentives to free ride are both straightforward and hard to solve. The endogeneity of lobbies in our context is an open and very interesting question.

Similarly we do not address the issue of the selection of the policymaker, the "mayor". In modern days municipalities,[12] a political contest takes place at regular dates and the mayor is elected, through various electoral mechanisms. In other words, a city is the locus of an active political life and competition which cannot be reduced to the actions of lobbies towards an a-temporal mayor. Besley and Coate [2] have proved in a citizen-candidate model of democracy that the electoral process limits drastically the influence capacity of lobbies. It would be worth to relate (local) democracy to the location issue of a public facility and investigate how this issue impinges on the electoral competition and selection process.

The city we consider is set on a bounded territory and is isolated, with no borders with other cities. However many (anti-) Nimby facilities have transboundary effects. This is particularly relevant with respect to environmental goods (or bads). As such, the decision by a jurisdiction to locate a public facility somewhere on its territory has spillover effects on neighboring jurisdictions. Consider the case of a Nimby facility, serving a city whose neighborhoods are concentrated in one side of the territory. The decision is likely to be to locate the facility in the other side of the territory, thus harming the neighboring city. Addressing the issue of locating local public facilities in a multi-jurisdictions setting is on the agenda.[13]

Lastly, a central dimension of the location of a public facility is the issue of its impact on the location of private production factors. Here we consider that the public good impacts directly on the neighborhoods' utilities, but has no productive effects whatsoever. Actually public infrastructures have an overwhelming effect on the decision to locate or not a firm or a factory in a given jurisdiction. Amenities, that is the set of public facilities offered by a jurisdiction to holders of production factors (labor as well as capital), and the ease of access to them are a major factor in the competition between jurisdictions (see

[12] At least in well-ordered democratic societies.

[13] For an investigation on the siting of noxious facilities and polluting firms in a multi jurisdictional setting see Ingberman [10] and Wellisch [14].

Ottaviano and Thisse [13] for a first exploration of this dimension of competition between communities). The interplay between the public decision of locating a public facility in a given territory and the private decisions of locating private production factors deserves to be investigated in a political economy perspective.

We leave these intriguing issues to future research.

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A Proof of Proposition 1

(i) Define $z \equiv (g, x_l, y_l) \in \mathcal{Z}$. Given that $\mathcal{S}$ is compact and g is finite, $\mathcal{Z}$ is a non-empty subset of the Euclidean space E^3. Therefore, W is continuous on $\mathcal{Z}$ and according to Weierstrass theorem, there exists a maximum which is either interior or on the boundary of $\mathcal{Z}$.

(ii) *The case of a Nimby facility.*

To prove the possibility of non-uniqueness, consider the following example. Assume $\alpha = 1$ and consider a $5-$ neighborhood structure $\mathcal{P}$ formed of the following points: $(0,0), (1,0), (-1,0), (0,1), (0,-1)$. The $K^N(\cdot)$ function is the logarithmic function. Given the log function, $(0,0)$ cannot be a solution as the distance between the first point of $\mathcal{P}$ and this location is nil and the location cost so generated is $-\infty$. Hence there is another location of $\mathcal{S}$, different from O which is an optimal solution. We denote this solution by (x_l^*, y_l^*). But because of the perfect symmetry of $\mathcal{P}$ with respect to O, then $(-x_l^*, -y_l^*), (x_l^*, -y_l^*), (-x_l^*, y_l^*)$ are also optimal locations for the Nimby good. Hence for this example, there exist multiple optimal locations.

To prove the second part of (ii), suppose that L^* does not belong to the interior of $\widetilde{\mathcal{P}}$ nor to the circumference of the circle. Let $\widetilde{L}$ denote the orthogonal projection of L^* on $\widetilde{\mathcal{P}}$. Consider the point C^* located on the circumference of $\mathcal{S}$, and such that its orthogonal projection on $\widetilde{\mathcal{P}}$ is the same point $\widetilde{L}$. Then, the point C^* is more distant than L^* for any P_i, that is:

$$\| C^* - P_i \| > \| L^* - P_i \|, \ \forall i$$

so that:

$$W(g^*(L^*), C^*) > W(g^*(L^*), L^*)$$

(iii) *The case of an anti-Nimby facility.*

To prove uniqueness of the optimal location, let us first prove that $\Psi(x_l, y_l; x_i, y_i) \equiv K^A(d_i)$ is concave in (x_l, y_l). The Hessian associated with Ψ is:

$$Hess(\Psi) = \begin{pmatrix} \frac{K''(d_i)\cdot(x_l-x_i)^2}{d_i^2} + \frac{K'(d_i)\cdot(y_l-y_i)^2}{d_i^3} & \left(\frac{K''(d_i)}{d_i^2} - \frac{K'(d_i)}{d_i^3}\right)(x_l - x_i)(y_l - y_i) \\ \left(\frac{K''(d_i)}{d_i^2} - \frac{K'(d_i)}{d_i^3}\right)(x_l - x_i)(y_l - y_i) & \frac{K''(d_i)\cdot(y_l-y_i)^2}{d_i^2} + \frac{K'(d_i)\cdot(x_l-x_i)^2}{d_i^3} \end{pmatrix}$$

Its trace is then equal to:

$$tr = K''(d_i) + \frac{K'(d_i)}{d_i}$$

which is negative given Assumption 2.

The determinant of the Hessian is given by:

$$\det = \frac{K''(d_i)K'(d_i)}{d_i^5}[(x_l - x_i)^2 + (y_l - y_i)^2]^2$$

which is positive given Assumption 2.

Hence, $\Psi(x_L, y_L; x_i, y_i) \equiv K^A(d_i)$ is strictly concave in (x_l, y_l). Since the sum of concave functions is concave, this concludes the proof.

Notice that, for the Nimby case, the sign of the trace is indeterminate and the determinant is negative.

To prove the second part of (iii), suppose that L^* does not belong to $\widetilde{\mathcal{P}}$. Let $\widetilde{L}$ denote the orthogonal projection of L^* on $\widetilde{\mathcal{P}}$. Then, the point $\widetilde{L}$ is nearer than L^* to any P_i, that is:

$$\parallel L^* - P_i \parallel > \parallel \widetilde{L} - P_i \parallel, \ \forall i$$

so that:

$$W(g^*(L^*), \widetilde{L}^*) > W(g^*(L^*), L^*)$$

(iv) Immediate from the first-order condition.

B Proof of Proposition 2

Given the assumption of uniqueness, the proof reduces to show that the vector $(x_l, y_l) = (0, 0)$ satisfies the first order conditions.

B.1 The $O-$ symmetry case

First order conditions with respect to x_l and y_l can be written as:

$$-\theta g^\alpha \sum_{i=1}^{n} \frac{K'(d_i)(x_i - x_l)}{d_i} = 0 \tag{8}$$

$$-\theta g^{\alpha}\sum_{i=1}^{n}\frac{K'(d_i)(y_i-y_l)}{d_i}=0$$

Let $L^*=O$. First-order conditions are satisfied since:

$$\sum_{i=1}^{n}\frac{K'(d_i)}{d_i}x_i = \sum_{i=1}^{\frac{n}{2}}\left(\frac{K'(d_i)}{d_i}\left(x_i+x_{\frac{n}{2}+i}\right)\right)=0 \quad (9)$$

$$\sum_{i=1}^{n}\frac{K'(d_i)}{d_i}y_i = \sum_{i=1}^{\frac{n}{2}}\left(\frac{K'(d_i)}{d_i}\left(y_i+y_{\frac{n}{2}+i}\right)\right)=0. \quad (10)$$

and by definition of this structure:

$$x_i = -x_{\frac{n}{2}+i}, \forall i=1,...,\frac{n}{2} \quad (11)$$

$$y_i = -y_{\frac{n}{2}+i}, \forall i=1,...,\frac{n}{2} \quad (12)$$

B.2 The $n-$ regular case

Without loss of generality, suppose that the point P_1 is $(1,0)$.

For any $n-$ regular structure, n odd, we get that:

$$x_1 = 1, x_{j+1}=x_{n-j}, j=0,...,n-1$$

$$y_1 = 0, y_{j+1}=-y_{n-j}, j=0,...,n-1.$$

Hence:

$$\sum_{i=1}^{n}y_i=0. \quad (13)$$

Given the symmetry of a regular structure, by permuting axes, it is therefore true that:

$$\sum_{i=1}^{n}x_i=0. \quad (14)$$

Since $d_i=1\forall i$, first order conditions are satisfied. This completes the proof.

C Proof of Proposition 3

(i) Given our assumptions, the maximization problem of the mayor given in (7) reduces to:

$$\max_{g,x_l,y_l}\lambda\sum_{i\in\overline{\mathcal{L}}}v(g,x_l,y_l)+\sum_{i\in\mathcal{L}}v(g,x_l,y_l) \quad (15)$$

that is, the weight of non lobbies in the social welfare function is equal to λ which is smaller than the weight associated to lobbies, which is equal to one. Then the proof proceeds as in the proof of Proposition 1 (i).

(ii) As we know from previous analysis, in the Nimby case, the $v(\cdot)$ functions may not be concave in x_l and y_l so that the maximand in (15) may also not be concave in x_l and y_l and the maximization problem may have multiple solutions. The second part of (ii) can be proven exactly as in the proof of Proposition 1. For the third part of (ii), it is immediate to see that if $\sum_{i=1}^{n} K^j(d_i)$ is concave x_l and y_l then also (15) is concave in x_l and y_l, and the solution to the maximization problem of the mayor is unique.

(iii) Same as (iii) in the proof of Proposition 1.

(iv) If $\mathcal{L} = \mathcal{P}$, the maximization problem of the mayor in (15) becomes:

$$\max_{g,x_l,y_l} \sum_{i\in\mathcal{P}} v(g, x_l, y_l; x_i, y_i)$$

which is exactly the same problem that is solved by the social planner.

(v) Let (g, L) and (g', L') denote two possible vectors of location of the public facility and allocation of the public good and assume that $d_i > d_i^{'}$. Then, for agent i, $v(g, L) > (<)$ $v(g', L')$ in the Nimby (anti-Nimby) case. By the definition of truthful contributions, agent i must offer more (less) for L than for L' if the good is Nimby (anti-Nimby).

D Proof to proposition 4

(i) Let $\mathcal{P}$ be $O-$symmetrical. $(0, 0)$ is the unique solution of the planner's problem. Now suppose that $\mathcal{L} = \{P_j, P_j + \pi\}$ for $j = 2, 4, ..., n$. Then $\mathcal{L}$ and $\overline{\mathcal{L}}$ are both $O-$symmetrical. Hence $\widehat{x}_l = 0$ and $\widehat{y}_l = 0$ satisfy the first order conditions for maximization of (15).

(ii) First, consider the case where $\alpha = 0$. Then the first-order condition with respect to g is identical to the one obtained by the social planner. Hence then $\widehat{g} = g^*$, for any value of λ. This is true both for Nimby and anti-Nimby facilities.

We know that when $\lambda = 1$, $\widehat{g} = g^*$. Moreover, we can calculate $\frac{d\widehat{g}}{d\lambda}$. We get:

$$\frac{d\widehat{g}}{d\lambda} = -\frac{\theta\alpha\widehat{g}^{\alpha-1}\left[\sum_{i\in\mathcal{L}}\frac{\partial K(d_i)}{\partial d_i}\left(\frac{\partial d_i}{\partial\widehat{x}}\frac{\partial\widehat{x}}{\partial\lambda}+\frac{\partial d_i}{\partial\widehat{y}}\frac{\partial\widehat{y}}{\partial\lambda}\right)+\widehat{D}_{\overline{\mathcal{L}}}+\lambda\sum_{i\in\overline{\mathcal{L}}}\frac{\partial K(d_i)}{\partial d_i}\left(\frac{\partial d_i}{\partial\widehat{x}}\frac{\partial\widehat{x}}{\partial\lambda}+\frac{\partial d_i}{\partial\widehat{y}}\frac{\partial\widehat{y}}{\partial\lambda}\right)\right]+H'(\widehat{g})-1}{H''(\widehat{g})+\alpha(\alpha-1)\widehat{g}^{\alpha-2}\theta\left[\lambda\widehat{D}_{\overline{\mathcal{L}}}+\widehat{D}_{\mathcal{L}}\right]} \tag{16}$$

where $\widehat{D}_{\overline{\mathcal{L}}} \equiv \frac{1}{\mathcal{L}}\sum_{i\in\overline{\mathcal{L}}} K(d_i)$ and $\widehat{D}_{\mathcal{L}} \equiv \frac{1}{\mathcal{L}}\sum_{i\in\mathcal{L}} K(d_i)$. As $\widehat{x}_l$ and $\widehat{y}_l$ are chosen optimally, equation 16 reduces to:

$$\frac{d\widehat{g}}{d\lambda} = -\frac{\theta\alpha\widehat{g}^{\alpha-1}\widehat{D}_{\overline{\mathcal{L}}} + H'(\widehat{g}) - 1}{H''(\widehat{g}) + \alpha(\alpha-1)\widehat{g}^{\alpha-2}\theta\left[\lambda\widehat{D}_{\overline{\mathcal{L}}} + \widehat{D}_{\mathcal{L}}\right]}.$$

By the second order condition for a maximum, the denominator is negative. With regard to the sign of the numerator, notice that the first order condition for an interior solution for $\widehat{g}$ is:

$$\lambda[\theta\alpha\widehat{g}^{\alpha-1}\widehat{D}_{\overline{\mathcal{L}}} + H'(\widehat{g}) - 1] + \theta\alpha\widehat{g}^{\alpha-1}\widehat{D}_{\mathcal{L}} + H'(\widehat{g}) - 1 = 0 \tag{17}$$

(a) Consider first $\alpha > 0$ and $\theta < 0$ (Nimby case). Notice that in equilibrium $\widehat{D}_{\overline{\mathcal{L}}}$ must be larger than $\widehat{D}_{\mathcal{L}}$ since lobbies have higher weight in the government's objective function. Thus, it must be:

$$[\theta\alpha\widehat{g}^{\alpha-1}\widehat{D}_{\overline{\mathcal{L}}} + H'(\widehat{g}) - 1] < 0$$

otherwise equation (17) could not be satisfied. If $[\theta\alpha\widehat{g}^{\alpha-1}\widehat{D}_{\overline{\mathcal{L}}} + H'(\widehat{g}) - 1]$ were positive, than $\left[\theta\alpha\widehat{g}^{\alpha-1}\widehat{D}_{\mathcal{L}} + H'(\widehat{g}) - 1\right]$ could not be negative since $\widehat{D}_{\overline{\mathcal{L}}} > \widehat{D}_{\mathcal{L}}$. Thus, in this case, $d\widehat{g}/d\lambda < 0$ and $\widehat{g} > g^*$.

(b) Consider now $\alpha < 0$ and $\theta < 0$ (Nimby case). By the same line of reasoning as before, it must be true that:

$$[\theta\alpha\widehat{g}^{\alpha-1}\widehat{D}_{\overline{\mathcal{L}}} + H'(\widehat{g}) - 1] > 0$$

so that $d\widehat{g}/d\lambda > 0$ and $\widehat{g} < g^*$.

(c) In the anti-Nimby case ($\theta > 0$), the proof is exactly as in the Nimby case. Notice that in this case $\widehat{D}_{\overline{\mathcal{L}}} < \widehat{D}_{\mathcal{L}}$.

E Proof to proposition 5

(i) By definition of d_i^*, $\widehat{d}_i$, g^* and $\widehat{g}$, we have:

$$\begin{aligned}
\sum_{i\in\mathcal{L}} v_i(g^*, d_i^*) + \sum_{i\in\overline{\mathcal{L}}} v_i(g^*, d_i^*) &> \sum_{i\in\mathcal{L}} v_i(\widehat{g}, \widehat{d}_i) + \sum_{i\in\overline{\mathcal{L}}} v_i(\widehat{g}, \widehat{d}_i) \\
\sum_{i\in\mathcal{L}} v_i(g^*, d_i^*) + \lambda\sum_{i\in\overline{\mathcal{L}}} v_i(g^*, d_i^*) &< \sum_{i\in\mathcal{L}} v_i(\widehat{g}, \widehat{d}_i) + \lambda\sum_{i\in\overline{\mathcal{L}}} v_i(\widehat{g}, \widehat{d}_i)
\end{aligned}$$

which can be rewritten as:

$$\begin{aligned}
\sum_{i\in\mathcal{L}} \left[v_i(g^*, d_i^*) - v_i(\widehat{g}, \widehat{d}_i)\right] &> \sum_{i\in\overline{\mathcal{L}}} \left[v_i(\widehat{g}, \widehat{d}_i) - v_i(g^*, d_i^*)\right] \\
\sum_{i\in\mathcal{L}} \left[v_i(g^*, d_i^*) - v_i(\widehat{g}, \widehat{d}_i)\right] &< \lambda\sum_{i\in\overline{\mathcal{L}}} \left[v_i(\widehat{g}, \widehat{d}_i) - v_i(g^*, d_i^*)\right]
\end{aligned}$$

Clearly, these two inequalities can be satisfied together if and only if:

$$\begin{aligned}
\sum_{i\in\mathcal{L}} \left[v_i(g^*, d_i^*) - v_i(\widehat{g}, \widehat{d}_i)\right] &< 0 \\
\sum_{i\in\overline{\mathcal{L}}} \left[v_i(\widehat{g}, \widehat{d}_i) - v_i(g^*, d_i^*)\right] &< 0
\end{aligned}$$

(ii) Consider a 10-neighborhood O - symmetrical structure with P_1 located at 0, P_2 and P_3 between 0 and $\pi/2$ and P_4 and P_5 between $\pi/2$ and π. Suppose also that the distance between P_2 and P_3 is arbitrarily small and that the facility is Nimby. If all neighborhoods lobby, $\widehat{L} = O$. Consider now a different structure where P_2 does not lobby. Then $\widehat{L}$ moves closer to P_2 and inevitably to P_3. Thus P_3 will be worse off than in the equilibrium with complete lobbying. Similarly, in the case of an anti-Nimby facility, consider P_2 as the only lobbying neighborhood. Then $\widehat{L}$ moves closer to P_2 and inevitably to P_3. Thus P_3 will be better off than in the equilibrium with complete lobbying.

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