PUBLIC GOODS

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Contents:

Summary

We require an economic system to cater to individual wants to the maximum possible extent - expressed formally by means of an efficiency condition. Because the set of efficient outcomes is a function of individual preferences, a successful system must elicit information about those preferences. That desideratum, along with the fact that the information disclosed by an individual will be dictated by his or her self interest, puts severe constraints on an economic system - also called a mechanism. We characterize the family of mechanisms that satisfy those constraints when public goods are involved. Because it is a narrow family, we can also identify its limitations.

1. Introduction

Is the pursuit of self interest by each individual a recipe for success, or a formula for chaos? Both views are false. The narrow pursuit of self interest is a formula for disaster in *some* situations. If a fire breaks out in a crowded building and everyone races for the exits, the hallways will be jammed and it is likely that many will perish. Each individual would have had a greater chance of survival if there had been a mechanism to slow him *and* everyone else down. Note, however, that each person is acting in his own self interest when each dashes for the exit. In other words, each person is maximizing his own welfare given the actions of the others. If everyone else runs for the exit, it will be to my disadvantage to walk. On the other hand, if everyone walks, then it is in my self interest to run ahead. If some walk and some run, I can improve my chances of escape by running.

There are many situations in which the pursuit of self interest by each individual is *not* self defeating. Consider profit maximization, which obviously promotes the welfare of the owners of firms. What about consumers? In a competitive environment, profit maximization also enhances general consumer welfare. Here's why: Profit equals revenue minus cost. The revenue taken in by firm F equals expenditure by its customers, who will not part with their money if they do not derive a sufficiently large increase in their own welfare by purchasing the commodity. The more one spends per unit of a good, the larger must be the anticipated benefit - otherwise, the expenditure would have been directed elsewhere. Therefore, firm F's revenue can be used as a measure of the value to consumers of its output. Producing that output requires resources, which could have been employed elsewhere. The more productive these inputs are in the economy as a whole, the greater the demand for them, and the higher their price, and the higher the market value of the inputs employed in firm F. Therefore, the cost incurred by F is a measure of the value of goods and services that could have been produced instead, in other sectors of the economy. Subtracting revenue from cost gives us a measure of the net value of a firm's activities to consumers. This net value is maximized when the firm maximizes profit in a competitive environment.

The claim that the profit motive is highly advantageous to consumers depends on the absence of *spillovers*, as well as the assumption that firms face vigorous competition. Spillovers - also called externalities - are benefits or costs of consumption or production activities that fall on others, in addition to the agents who made those consumption or production decisions. Harnessing self interest is especially problematic when one individual's consumption generates spillover benefits that accrue to others. This chapter considers the possibilities for precipitating an outcome that delivers a high level of individual welfare throughout the economy, even when spillovers are substantial, and in spite of the fact that each individual decision maker will be motivated by self interest.

2. What are Public Goods?

A public good is created when one individual or institution's action generates widespread benefit, and it is impossible (or very costly) for the agent creating the benefit to be compensated by those receiving it. Important examples include: containment of a virulent disease by a health organization; retardation of global warming or ozone depletion by international treaty; dissemination of information concerning public safety.

In each of these cases the agent's action generates *positive spillovers*. Agent A's action generates a positive spillover if some other agent B benefits as a result of that action. For example, if A removes weeds from his own property, then neighbor B's grass will have fewer weeds because one seed source has been eliminated. In this case, most of the benefit of A's effort is captured by A himself, so we say that the spillover is incomplete. On the other hand, if household A produces a fireworks display then everyone else in town will have just as good a view of it as the members of A.

The Aindividual@ decision maker can be a country, or a province within a country. When one country takes costly measures to reduce its output of CO_2, any resulting retardation of global warming is a benefit that is captured by every country. When a province or a state within a single country imposes restrictions on the firms within its borders to reduce the amount of SO_2 dumped into the air, the benefits are enjoyed throughout the country - particularly if the region is a popular vacation site.

When the spillover is complete, as in the fireworks case, we refer to the commodity generating it as a *pure public good*. Formally, commodity X is a pure public good if it is possible for every member of the community to consume every unit of the good that has been produced, and the utility derived by anyone is independent of the number of individuals who avail themselves of the opportunity to consume the good. Everyone consumes the same amount of the public good, but they derive different levels of satisfaction. Most cases that economists treat as pure public goods, fall short of the ideal in one way or another, but the polar case is a useful laboratory device for investigating non-cooperative behavior.

A large bridge connecting two small towns is a pure public good because any number of residents can travel across the bridge without delaying anyone else who uses the bridge. But the owner of the bridge can exclude motorists at fairly low cost by means of a toll booth, or even a computer chip installed in the driver's car to count the number of trips. At the other extreme, there are public goods, such as a fireworks display, or containment of an epidemic, which by their nature cannot be denied to any member of the community. Exclusion costs are infinite in such cases. *Assuming that each individual's preference ordering is known*, there is no reason why the exclusion cost should play a role: Efficiency (defined in Section 7) implies that the good should be made available to all, because if anyone is excluded we have reduced that individual's utility without generating any corresponding benefit to anyone else. Of course, an individual's preference ordering *is* private information, known only to the individual herself. Therefore, she may have an opportunity to profit by supplying false information. Here is a simple illustration:

Example 1. Choosing one of three public projects

A is the status quo, B is new highway construction, and project C would add more teachers to the public school system. The government uses the following selection rule: Each voter is asked to name her most-preferred alternative. If at least one person names A then A is adopted; otherwise B is selected, unless everyone nominates C, in which case C is adopted. Suppose that there are three voters 1, 2, and 3 with the respective true preference orderings:

1	2	3
C	B	B
A	C	C
B	A	A

(The top alternative is most preferred, and the bottom is least preferred.) If each reports truthfully then the outcome is B. However, person 1 can profit from misrepresentation. If she nominates A then A will be selected, and she prefers that alternative to B.

Although person 1 profits from misrepresenting her preferences (in Example 1), the resulting outcome A is inferior to C in terms of *everyone's* true preferences. Economists refer to A as an inefficient outcome for the given preference pattern.

3. Voluntary Contributions

A lot of activities generate spillover benefits. If one homeowner puts some effort into mosquito control, or cleaning up litter in the local park, or pollution reduction, or crime prevention, her neighbors benefit from the activity even if they have not made a contribution themselves. The economics literature refers to the non-contributors as *free riders*. We will examine a simple model to show that, in the presence of the free rider problem, individual self interest will not lead to enough voluntary contributions to sustain an appropriate level of the public good.

Example 2: Two neighbors

The neighbors are A and B, and each is bothered by the debris (or CO_2, if A and B are countries) that motorists discharge. If A supplies e_A units of effort to cleaning up then A and B will each derive $2e_A$ units of benefit. If B supplies e_B units of effort to pollution reduction then A will receive an additional $2e_B$ units of benefit from that activity, and so will B. We assume that each unit of effort expended by an agent reduces her utility by 3 units. Therefore, the net payoff to A when B supplies e_B units of effort to clean-up and A supplies e_A units of effort is

$$2(e_A + e_B) - 3e_A = 2e_B - e_A$$

and B's net payoff is $2(e_A + e_B) - 3e_B = 2e_A - e_B$

If $e_A = e_B = 1$, then the payoff to each is $2 \times (1+1) - 3 = 1$. However, we have here a continuum version of the prisoner's dilemma game: Each player i chooses a number e_i between zero and 1 inclusive, and for any choice of e_j by the opponent j, the response that maximizes player *i*'s payoff is $e_i = 0$, treating e_j as a constant. We say that $e_i = 0$ is a *dominant strategy* for player i $(i = 1, 2)$. However, when $e_A = 0 = e_B$ then each player's payoff is zero, while each derives a payoff of 1 from the cooperative outcome $e_A = 1 = e_B$.

The pursuit of self interest is self defeating in this case. Moreover, as the number of players increases, so does the gap between the individual payoff when everyone cooperates and the individual payoff when each plays the dominant strategy.

We assumed that A chooses e_A on the understanding that e_B will not be affected, because we want some insight into real world cases with many agents. If, for example, one person decides to take public transportation instead of his car - to reduce air pollution - he cannot assume that it will motivate others to do the same. However, when the number of players is small and they confront each other repeatedly, playing the game over a long stretch of time, the cooperative outcome

$e_A = 1 = e_B$ can be sustained as a Nash equilibrium because the players will have a future opportunity to punish an opponent who deviates from cooperative play in the present. Unfortunately, almost any other pattern can also be sustained under repeated play if players are sufficiently patient - not just for this game, but for any game. (This claim is known as the *folk theorem*.) Therefore, we do not have strong theoretical support for the cooperative outcome.

The rule that we used to assign payoffs as a function of individual strategies is just one possible technology. For example, the assurance game gives each player a net benefit only if *both* contribute effort. Then $e_A = 0 = e_B$ is still a Nash equilibrium, but so is $e_A = 1 = e_B$.

Many experiments have been designed to test the Nash prediction of zero voluntary contributions. In fact, around half the efficient level of the public good is typically reached in these experiments, although the level diminishes somewhat when the subjects repeat the experiment. When the players can meet face to face, the voluntary contributions can result in individual effort levels close to 1 (or whatever the cooperative input is for the game being played).

Why, then, should we take the theory seriously? First, face to face encounters are feasible only in very small communities. They would be too costly to arrange in the case of a funding drive for public television, say. Second, the theory may not predict the level that would actually be reached in a particular application, but it does point to a substantial inefficiency, and that is borne out in the experiments, which result in half the efficient level of output at best. There is clearly much to be gained from an allocation technique that delivered close to the efficient level. Before we evaluate alternative mechanisms, we specify a formal model (in the next section) and define an efficient outcome (in Section 7).

4. The Model

$N = \{1, 2, \ldots, n\}$ is the set of agents, and $Q = \{q, q', q'', \ldots\}$ is the (possibly infinite) set of available public projects. The society N may be a small town, in which case the members of N are the individual households in that town. N could be the set of residents of an entire country, however. In one application each i in N is a state or province of a particular country; in another, each i is a person or household. The members of N could even be countries of the world. Each agent i has a payoff function $U_i = V_i(q) + t_i$, where V_i is a real valued function on Q and t_i is a transfer payment to agent i. The transfer could be negative, in which case agent i pays $-t_i$ units of money. We refer to V_i as i ‘s *benefit function*. $V_i(q)$ is net benefit, really - it is net of i ‘s share of the total cost of producing q. Our key assumption is that V_i is known only to individual i. To allow an efficient project to be selected, it is necessary to design an incentive scheme - a mechanism - to induce an agent to reveal her true benefit function. (The next section defines efficiency.)

Example 3: Retardation of global warming

N is the set of countries of the world, and each $q \in Q$ is a proposal to reduce global warming by q per cent by imposing an adjustment cost $c(q)$ on each $i \in N$. Then $V(q) = \mu(q) - c(q)$, where $\mu(q)$ is the gross benefit that country i receives from q.

Suppose, for instance, that the function μ is the same for each $i \in N$ (or each μ is known). The cost functions c are unknown, however, and a central authority wants to learn each country's true cost function because its goal is to find the least cost way of achieving a given climate change. We will see that it is possible to design an incentive scheme to induce each agent to report truthfully, in spite of the apparent incentive to claim to be a high cost country so that the burden will fall elsewhere.

In many applications there are only two projects under discussion, the status quo and a new proposal:

Example 4: The binary choice model

The Agents can be countries, at one extreme, or individuals in a small community, at the other.

$Q = \{0, 1\}$, where 0 represents the status quo and 1 is the new proposal. We can let V be a *number* - the difference between i 's benefit at the proposal and at the status quo.

An important special case of the general framework is the resource allocation model with pure public goods:

Example 5: The public goods model for a society of consumers

N is the set of households in the economy. Each agent i 's preference scheme is represented by a utility function $U(x, y)$, where (x, y) specifies i 's consumption $y \geq 0$ of a single private good Y, and the amount $x \geq 0$ of a public good X available to all. We further simplify by assuming that utility is *quasilinear*: For each $i \in N$ there is a real-valued function μ defined on the set of non-negative real numbers, such that

$$U(x, y) = \mu(x) + y$$

Each i has an endowment W of the private good, which cannot be produced (think of it as leisure, or land), but which can be used to produce the public good. We complete the specification of the fundamental data of the economy by assuming a real cost function g that specifies the amount $g(x)$ of the private good required for the production of x units of the public good.

An *allocation* (x, y) identifies the level of the public good and the vector $y = (y, y, \ldots, y)$ of private good consumption levels. Allocation (x, y) is *feasible* if $x \geq 0$, $y \geq 0$, and

$$\sum_{i\in N} y_i + g(x) \leq \sum_{i\in N} W_i$$

This is called the *resource constraint*. In words, the total amount of the private good allocated to agents plus the amount used up in producing the public good cannot exceed the sum of the endowments.

Each feasible allocation (x, y) corresponds to the project q for which $x(q) = x$ and $c_i(q) = W_i - y_i$. Therefore, the set Q has been implicitly defined. The benefit function is $V_i(q) = \mu_i(x(q)) - c_i(q) = \mu_i(x) + y_i$.

Our framework can even be used to model the distribution of indivisible private goods. We illustrate with the case of a single object, which could be a painting or an office building:

Example 6: Allocation of a single indivisible asset

Q is the set of vectors $(q_1, q_2, \ldots, q_n)$ such that $q_i \{0,1\}$ for each $i \in N$, and $\sum_{i\in N} q_i = 1$ Agent i gets the asset if and only if $q_i = 1$. If R_i is agent i ‘s reservation value for the asset, then $V_i(q) = R_i$ if $q_i = 1$, and $V_i(q) = 0$ if $q_i = 0$. (An agent’s reservation value is the maximum that she=d be willing to pay for the asset.)

If the Aasset@ is undesirable then R_i is negative. For instance, $q_i = 1$ means that a nuclear waste storage facility is constructed in region i.

We abstract from uncertainty throughout, although mitigation of the risks of catastrophes such as global warming, ozone depletion, colossal oil spills, virulent viruses, etc., have an important public goods aspect. Graciela Chichilnisky and Geoffrey Heal propose using tradable commodities to gives an individual some insulation from such risks, where the probability distribution of casualties is not known. They propose a dual solution: The individual can purchase a menu of different insurance contracts, one for each probability distribution, and at the same time hedge by buying a portfolio of securities, each one paying off if and only if a specific distribution of casualties is realized. (Catastrophe securities have traded on the Chicago Board of Trade since 1994.) Individuals will disagree about which project should be adopted. Nevertheless, it is possible to single out one project in a way that treats individuals symmetrically, while taking their preferences into account.

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