Journal of Public Economics 134 (2016) 35–41

Contents lists available at ScienceDirect

Journal of Public Economics

journal homepage: www.elsevier.com/locate/jpube

Voting and optimal provision of a public good☆

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ARTICLE INFO

Article history:
Received 1 December 2014
Received in revised form 8 October 2015
Accepted 22 December 2015
Available online 31 December 2015

Keywords:
Public good
Mechanisms
Dominant-incentive compatibility
VCG mechanisms
Quotas
Committees

ABSTRACT

In this paper, we study the optimal provision of a costly public good using an average efficiency criterion. For every fixed cost, we identify a quota mechanism as the optimal mechanism among those that are dominant-incentive-compatible, deficit-free and kind. Moreover, we also consider the asymmetric case and demonstrate that a committee mechanism is optimal for a large class of mechanisms. In particular, this mechanism dominates all VCG (pivotal) mechanisms.

1. Introduction

When agents' preferences are private information, it is difficult for the central planner to provide public goods efficiently. This well-known free-rider problem has challenged public officials and scholars for years. There are several related issues. First, how can one solicit agents' preferences to determine the proper level of public goods? Second, how can one design tax/transfer schemes that finance the provision of public goods? Third, how can one choose the most efficient method of providing of public goods from among the different methods?

Many scholars favor the use of VCG (Vickrey–Clarke–Groves) mechanisms (Vickrey, 1961; Clarke, 1971; Groves, 1973). By introducing proper taxes/transfers among agents, the celebrated VCG mechanisms induce agents to reveal private information truthfully, which, in turn, leads to the efficient allocation of public goods. However, VCG mechanisms do not solve the problem of efficient provision of public goods, as the aggregate tax revenues they collect often exceed the costs needed to finance the public goods.

In practice, decisions on public-good provision are often made through more straightforward mechanisms. For example, when a city decides whether to build a new public transportation system, it may put the issue to a public vote, and if the funding of the project is approved, it is usually in the form of an added tax. There might be variations in the voting rules: simple majority rule, unanimity rules, committee approval, etc. A common feature of these voting rules is that, should the project fail to pass, no money is wasted since no additional tax will be raised. However, there is no guarantee that voting results always correspond to efficient levels of the public good.

Clearly, neither VCG mechanisms nor voting schemes guarantee the efficient provision of public goods. This is inevitable since, as Green and Laffont (1977) demonstrate, there exists no dominant-incentive-compatible (DIC) mechanism that always yields both efficient levels of public goods and exact budget balance. Thus, to determine which mechanisms are better than others, one needs a criterion by which to evaluate their performance. But once a criterion is adopted, a more natural question would be: Which mechanism is *optimal* among all DIC mechanisms? That is the main question we address in this paper.

We focus on dominant-incentive-compatible mechanisms since they have the strongest incentive-compatibility property. Earlier scholars studied efficient Bayesian mechanisms that may provide partial solutions to the Green–Laffont conundrum (Arrow, 1979; D'Aspremont and Gérard-Varet, 1979). However, such solutions are highly sensitive to the specification of prior distributions of agents' types. If the priors are mis-specified, the proposed mechanism is not even incentive-compatible, let alone efficient. DIC mechanisms are the only mechanisms immune to this problem as a

☆ A previous version of this paper has been circulated under the title Optimal Provision of a Non-excludable Public Good. Lin Zhou's research is supported by the Ministry of Education of China through the Program for Changjiang Scholars and Innovative Research Team in University (IRT13030).

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http://dx.doi.org/10.1016/j.jpubeco.2015.12.006
0047-2727/

mechanism is dominant-incentive-compatible if and only if it is Bayesian-incentive-compatible for all prior distributions of agents' types. Interested readers can find more related discussion in Chung and Ely (2007) and, Bergemann and Morris (2005).

Although we consider only DIC mechanisms, we can use various criteria to evaluate their efficiencies. The first natural one is the dominance criterion: a DIC mechanism *A* is better than a DIC mechanism *B* if *A* is better than *B* for all realizations of agents' types. However, as the Green–Laffont classic result indicates, there is no optimal DIC mechanism according to the dominance criterion. Hence, we must work with some weaker criteria. Some scholars propose the minmax criterion (minimizing the maximal welfare loss): a DIC mechanism *A* is better than a DIC mechanism *B* if the worst outcome under *A* is better than the worst outcome under *B*. They use the minmax criterion to study both budget-balanced and VCG mechanisms in the public-good setting—e.g., Deb and Seo (1998) and Moulin and Shenker (2001). In this paper, we consider another criterion—the average criterion: a DIC mechanism *A* is better than a DIC mechanism *B* if *A* is better than *B*, on average. This idea of evaluating the efficiency of mechanisms by an average criterion dates back to Rae (1969). In more-recent papers, Shao and Zhou (2011), Drexl and Kleiner (2012, 2013) and Gershkov et al. (2014) all carry out the same type of exercise. Agents' types follow prior distributions. Although agents do not need or have such information under any DIC mechanism, the planner can and should use this information to evaluate the average efficiencies of various DIC mechanisms. We do not argue that the average criterion is necessarily better than the minmax criterion, but, rather, that both are worthy alternatives that merit serious investigation.

In this paper, we study a public-good model in which one must decide whether to build a public project—a binary social-choice problem. The public project can be built at a fixed cost of c. Each agent i's utility reservation value is zero in the absence of the public project. If the project is built, each i derives an additional utility of θ_i. θ_i is considered agent i's type and is privately known to agent i only. One uses the mechanism first to solicit all agents' types and then to decide whether or not to build the project and how much tax to impose on all agents.

Our main result identifies the most efficient DIC mechanisms according to the average criterion. More precisely, we find the best mechanism among all mechanisms that satisfy DIC, deficit-free, and one kindness condition. The optimal mechanism is a voting system with equal cost sharing. For each value of c, there is a quota $q(c)$; the public project is built if and only if the number of agents whose types are higher than the cost per capita c/n exceeds $q(c)$; and all agents equally share the total cost c. We further prove that the optimal quota mechanism outperforms all VCG mechanisms.

We want to make a couple of observations regarding our main result. First, we compare the voting system with VCG mechanisms. In the voting system, there might be under-provision or over-provision of the public good relative to the fully efficient outcome, but the budget is always balanced. In VCG mechanisms, the public good is always provided at the optimal level, but there are wasted funds at many type profiles. Many people who like VCG mechanisms tend to overlook their inability to balance the budget. Our result highlights the importance of budget-balancedness, as it is actually a consequence of optimality, albeit in our specific model.

Second, although the social choice literature has extensively studied voting systems very few studies have identified them as optimal mechanisms. An exception is a recent paper by Drexl and Kleiner (2013), which studies a case in which agents can have negative valuations, which corresponds roughly to our model with $c = 0$. With cost c as a parameter in our model, we obtain very interesting comparative statics about the structure of the optimal voting system. As the cost c increases, the minimum level of type for an agent to favor the project increases, and, at the same time, the quota $q(c)$ that is needed for approval of the project also increases. Undertaking a more costly public project requires more enthusiasm from more agents.

Our results can be extended to asymmetric cases in which agents' types may not follow the same distribution. We demonstrate two important points. First, every VCG mechanism is dominated by a committee mechanism. Second, a particular committee mechanism is optimal for a large class of asymmetric mechanisms that are DIC and satisfy a boundedness condition.

Before proceeding with the formal analysis, we briefly review several related results in the literature. As mentioned earlier, some recent papers have connected voting systems with optimal DIC mechanisms in public-good provision. Drexl and Kleiner (2013) study the case in which agents can have negative valuations with zero production cost and demonstrate that the optimal DIC mechanism is a voting system with zero transfers. But, as our result shows, this claim is not robust when the production cost becomes non-zero, which is most often the case in real situations. In several articles (for example, Schmitz and Tröger, 2012; Gershkov et al. 2014), the authors consider optimal DIC mechanisms that maximize ex-ante utilities of agents when choosing from finite alternatives without monetary transfers. Gershkov et al. (2013) establish an equivalence result between Bayesian mechanisms and dominant-strategy mechanisms. However, their result does not apply to our model, which imposes a budgetary constraint. Focusing on Bayesian mechanisms, Ledyard and Palfrey (2002) show that any optimal Bayesian incentive-compatible mechanisms can be approximated by a voting mechanism when the population grows large. In contrast, our results imply that the voting mechanism with a carefully chosen voting rule is optimal in the class of DIC mechanisms, regardless of the size of the population. Finally, Bierbrauer and Hellwig (2012) study a public-good model of a continuum of agents and prove that the mechanism that satisfies anonymity, robustness and coalition-proofness must take the form of a voting mechanism. Although our result and theirs are not comparable formally, both support the use of voting in public-good provision.

Our paper is organized as follows. In Section 2, we introduce the formal model and our main result. In Section 3, we generalize our model to deal with asymmetric cases. Section 4 concludes. We present all proofs in the Appendix.

2. The model and the main result

There is a society of n agents. A benevolent planner contemplates whether to provide a non-excludable public good—a bridge, a park, etc.—at a fixed cost $c \leq n$. If the public good is produced, the cost must be covered by taxes collected from the agents. Agent i's utility is $\theta_i + t_i$, in which θ_i is her benefit (her type) from the public good when it is provided, and t_i is the amount of tax she pays. If the public good is not provided, agents' benefits are zero. An agent's type is privately known only to herself, but agents' types are independently distributed on $[0, 1]$ according to a prior distribution function F with a density function f. We assume that the distribution function is regular:

Regularity. $(1 - F(\theta))/f(\theta)$ is decreasing in θ; $F(\theta)/f(\theta)$ is increasing in θ. [1]

[1] The first part of this condition is also known as the hazard-rate condition, and the second part means that F is logconcave. For example, all $F(\theta) = \theta^\alpha$ with $\alpha \geq 1$ satisfies these conditions. Both parts are commonly used in the literature. The regularity condition can also be implied by assuming that density f is logconcave. Bagnoli and Bergstrom (2005) have a nice discussion of these assumptions.