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CESIFO WORKING PAPER NO. 3295
CATEGORY 1: PUBLIC FINANCE
DECEMBER 2010

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Abstract

We consider a sequential game in which one player produces a public good and the other player can influence this decision by making an unconditional transfer. An efficient allocation requires the Lindahl property: the sum of the two (implicit) individual prices has to be equal to the resource cost of the public good. Under mild conditions this requires a personal price for the providing player that lies below half of the resource cost. These results can, for example, justify high marginal taxes on wages of secondary earners.

JEL-Code: C72, D61, H21, H41.

Keywords: Lindahl pricing, noncooperative games, private provision of public goods, Stackelberg equilibrium.

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December 7, 2010

1 Introduction

It is quite common that public goods can be provided by only one party, where coordination takes place in a noncooperative fashion. Such a situation may arise, for example, if a firm can reduce pollution, if a region provides goods but cannot exclude its use by inhabitants from neighboring regions, if a country takes measures against climate change, if an individual decides on household production in a partnership, etc. This paper addresses the question under which circumstances an efficient provision of the public good is achieved in a noncooperative framework where unconditional transfers between players are possible.

We analyze a game between two players in which the second player produces a public good. The first player can affect the decision of the second player by making an unconditional transfer. According to the reaction function of the second player, the first player perceives a (marginal) personal price of the public good. In this framework, it is shown that public good provision satisfies the Samuelson efficiency rule if and only if the sum of the price of the public good for the second player and the perceived price of this good for the first player add up to the resource cost. This summation property is known from the Lindahl equilibrium in which all agents unanimously prefer the same level of the public good at personalized prices. However, in the textbook Lindahl model efficiency is lost when moving to a sequential game structure (Myles, 1995). The Lindahl equilibrium can be implemented, however, when agents announce subsidy rates for contributions of others before the provision decisions are taken (Danziger and Schnytzer, 1991; Althammer and Buchholz, 1993; Varian, 1994).

A second interesting property of the efficient solution is that the perceived price of the public good for the first player will under mild conditions always exceed the price of the second player. As these two prices have to add up to the resource cost to restore efficiency, the personal price of the second player has to fall short of half of the resource cost.

An important application of the analysis above is found in labor supply decisions when couples do not coordinate their actions and where the second player is identified as the secondary earner, producing a public good with leisure, as in the model of Meier and Rainer (2010). The public good production is modeled as the mirror of the labor supply decision, where the price for player 2 is his or her net wage. Our results then have the following implications. Achieving an efficient allocation requires that the price of the public good for player 2 plus the perceived price for purchasing units of this good of player 1 have to add up to the resource cost, which is the gross wage or the marginal productivity of labor of player 2, the secondary earner. As the perceived price of player 1 will generally exceed the net wage of player 2, this net wage has to fall short of half of the corresponding gross wage, implying a marginal tax rate above 50%. This results stands in stark contrast to the mainstream literature on the optimal design of household taxation, stressing welfare losses due to high tax rates on additional wage income by secondary earners as their labor supply elasticities tend to be comparatively large (Boskin and Sheshinski, 1983).

The remainder of this note is organized as follows. After introducing the model in Section 2, first-best allocations and equilibrium outcomes are characterized in Section 3. The main results on the Lindahl property and the price structure for achieving a first-best allocation are collected in Section 4. The concluding Section 5 indicates possibilities for extensions and further applications.

2 The model

Consider two individuals consuming a public good g and a private good c. Preferences of individual $i \in \{1, 2\}$ are given by a quasi-concave utility function $U^i(c^i, g)$ with strictly positive marginal utilities, where c^i and g denote the quantities consumed of the private and the public good, respectively. The private good can be transformed into the public good at a unit cost p. The sequence of events is as follows. At the outset, the incomes of the individuals, M^1 and M^2, and the price player 2 faces for producing or purchasing the public good, p^2, are common knowledge. Player 1 then selects an unconditional nonnegative transfer θ to player 2. Having received the transfer, player 2 chooses the level of the public good g.

3 First-best allocations and equilibrium outcome

The overall resource constraint is $c^1 + c^2 + pg \leq M$, where M represents aggregate income of the two players.

The set of first-best allocations can be derived from the Lagrangian

$$L = U^1(c^1, g) + \alpha U^2(c^2, g) + \lambda \left(M - c^1 - c^2 - g \right) \tag{1}$$

with $\alpha > 0$ and λ denoting the Lagrange multiplier. In any interior solution, the first-order conditions imply the Samuelson rule, stating that the sum of the marginal rates of substitution betwen the public and the private good must be equal to the marginal rate of transformation between these two goods.

$$\frac{U_g^1}{U_c^1} + \frac{U_g^2}{U_c^2} = p = \frac{dc}{dg} \tag{2}$$

The decentralized equilibrium can be found through solving by backward induction. Player 2 maximizes $U^2(c^2, g)$ subject to $M^2 + \theta \geq c^2 + p^2 g$. The optimization leads to the familiar equality between the marginal rate of substitution and the relative price,

$$\frac{U_g^2}{U_c^2} = p^2. \tag{3}$$

Given an interior solution, the reaction of player 2 to an increase of the transfer can be derived from the first-order condition $Z = -U_c^2 p^2 + U_g^2 = 0$

as

$$\frac{\partial g}{\partial \theta} = -\frac{\partial Z/\partial \theta}{\partial Z/\partial g} = -\frac{-U^2_{cc}p^2 + U^2_{gc}}{U^2_{cc}(p^2)^2 + U^2_{gg} - 2U^2_{gc}p^2} \tag{4}$$

In the preceding stage, player 1 chooses the transfer $\theta \geq 0$ so as to maximize $U^1(c^1, g(\theta))$ subject to the budget constraint $M^1 - \theta - c^1 \geq 0$. In case of an interior solution of the transfer, the marginal rate of substitution between the public and the private good will be equal to the inverse of the reaction term $\partial g/\partial \theta$, which can be interpreted as the perceived price of the public good from the point of view of the first player, p^1.

$$\frac{U^1_g}{U^1_c} = \frac{1}{\partial g/\partial \theta} \equiv p^1 \tag{5}$$

4 Decentralization of the first-best: Lindahl property

Proposition 1 states that decentralizing the first-best allocation requires the Lindahl property: The sum of the price of the public good of player 2 and the perceived prive of player 1 have to add up to the resource cost.

Proposition 1 *In case of interior solutions for θ and g, the private provision of the public good will be efficient if and only if*

$$p^1 + p^2 = p. \tag{6}$$

Proof. An efficient allocation requires (2). The claim then follows immediately from (3) and (5). □

Interestingly, an efficient allocation requires the Lindahl property although the noncooperative framework with the transfer is quite different from the well-known Lindahl game. Moreover, in Lindahl's framework of voting on the preferred level of the public good at individualized prices, a sequential game structure would destroy efficiency. In that event, player 1, by taking into account the reaction curve of the player 2, will no longer equate the marginal rate of substitution with the personal relative price level. Nevertheless, our framework bears some similarities with the Lindahl game. The equilibrium looks as if both players choose the same level of the public good.

The second proposition concerns the relation of the two prices in equilibrium. If both goods are normal from the point of view of player 2, the perceived price of the public good for player one will always exceed the price player 2 faces.

Proposition 2 *If both goods are normal for player 2, that is,* $U^2_{gg} - U^2_{gc}p^2 < 0$ *and* $-U^2_{cc}p^2 + U^2_{gc} > 0$*, then* $p^1 > p^2$*.*

Proof. Notice that $U^2_{cc}(p^2)^2 + U^2_{gg} - 2U^2_{gc}p^2 \leq 0$ is necessary to satisfy the second-order condition to the optimization problem of player 2, where we may ignore the case that the condition only holds with equality. Further, it can easily be shown that

$$\frac{1}{\partial g/\partial \theta} = p^2 + \frac{U^2_{gg} - U^2_{gc}p^2}{U^2_{cc}p^2 - U^2_{gc}} \tag{7}$$

If both goods are normal, that is, associated with a strictly positive income elasticity, we have $U^2_{gg} - U^2_{gc}p^2 < 0$ and $U^2_{cc}p^2 - U^2_{gc} < 0$, implying $p^1 > p^2$.□

Proposition 2 is easily understood, If both goods are normal, the demand for the public good by player 2 increases, but only part of the transfer will be spent on this good. Therefore, the public good will turn out to be more expensive from the point of view of player 1 in comparison to the situation in which he can directly buy these units at the price p^2. Recalling Proposition 1, this implies that achieving an efficient allocation requires that the personal price of the second player falls short of half of the resource cost.

5 Concluding discussion

Of course, it may be perceived as restrictive that only player 2 can produce the public good. Clearly, if player 1 has also some technology to produce it at price p^0, he will refrain from production if the perceived price for purchasing units from player 2 falls short of this cost, $p^1 < p^0$. If on the other hand, we have $p^0 < p^1$, there will be no transfer to player 2, that is, $\theta = 0$. It will often turn out that production of the public good will be chosen either only by player 1 or only by player 2 (see Meier and Rainer, 2010).

Externality problems between firms can also lead to the structure analyzed above if more specific contract clauses cannot be enforced. For example, a polluting firm may be interested to reduce its level of pollution due to its positive impact on public opinion, where employing filter technologies reduce the profit. Another firm is harmed by this pollution, but can only make an unconditional transfer to the first firm. If the government cannot make use of a Pigouvian tax, an appropriate level of the profit tax may be employed for implementing an efficient level of pollution by implicit Lindahl pricing.

In negotiations on climate change, the framework of the game seems quite realistic. Further examples of applications may be found in foreign aid if a developing country produces a global public good, or in similar interregional or international voluntary transfer schemes. However, implicit Lindahl pricing can be implemented for many of these problems only if a central authority exists, because otherwise the country or region that produces the public good has to face its full marginal cost.

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