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CLUB EFFICIENCY AND LINDAHL EQUILIBRIUM

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Club Efficiency and Lindahl Equilibrium

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Abstract. Club efficient allocations are the ones that remain in the core of a replicated economy. Schweizer's price support theorem unifies not only the welfare and core limit theorems for private good economies, and the Henry George Theorem for economies with fixed public goods, but also encompasses Vasil'ev's core limit theorem for economies with congested public goods. This is shown by appropriate choice of aggregation rule defining local public goods and by proof of a theorem according to which club efficiency implies Lindahl equilibrium.

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1 Introduction

This paper is about public goods and the competitive basis for equilibrium prices. The story is well known for economies with private goods only. They admit Walrasian equilibria and those are the only allocation that cannot be improved upon by coalitions of agents when the economy is large. Here largeness is modeled by replication of agents or by admitting clubs of different types of agents with the agents entering in free numbers. Allocations that cannot be improved upon "remain in the core" or, equivalently, "are club efficient."

With pure public goods there is a problem. Such items are not replicated along with the rest of the economy. The resources foregone in their provision are independent of the size of a club. Utility levels can therefore be increased by admitting new members and spreading the burden of the public good. Schweizer (1983) provides price support of a club efficient allocation in an economy with public goods, but must assume that some agents or endowments are given in fixed numbers. The variable agents can escape taxation by the above logic and are, therefore, free riders. The use of the exogenous club endowment for the funding of the public goods amounts to the Henry George Theorem.

If there are no fixed numbers, there still is the Lindahl equilibrium. Its competitive basis is meager, however, for it is just one of many allocations of economies with pure public goods that remain in the core or are club efficient (Milleron, 1972). My perspective on public goods and local public goods is that of aggregation. Private goods and pure public goods are just polar cases; individual demands are aggregated by summation and maximization, respectively. In this paper I propose an intermediate nature of goods. Member demands are aggregated like public goods, but the consequent public goods get replicated along with the rest of the economy. I coin them local public goods.

The result of this paper extends price support of club efficient allocations to economies with local public goods. For such economies, a club efficient allocation is in fact a Lindahl equilibrium.

2 The model

Any given population can be represented by a list of consumer types, $t = 1, \ldots, T$, and a vector of numbers of consumers for each type, $n_0 \in \mathbb{R}^T_+$. Replication is carried out by means of a club. A club $n \in \mathbb{R}^T_+$ comprises n^t members of type t. A club is the replication device; the population remains a fixed n_0, such as $(1, \ldots, 1)$. Consider for each type t individual demands for goods, $y^t \in \mathbb{R}^l$, the commodity space. Club demand amounts

$\sum n^t y^t$ if the goods are private and $\max y^t$ if the goods are purely public. Summations and maximizations are over $t = 1, \ldots, T$. The maximum over a number of vectors is defined component by component. Club demand amounts $(\max n^t)(\max y^t)$ if the goods are locally public.

For a first understanding, consider a scalar replicate, $n = (r, \ldots, r)$, of an economy with population $n_0 = (1, \ldots, 1)$, but no excessive consumer (demanding more of a public good than anyone else). The elimination of an individual demand, be it by putting either y^t or n^t equal to zero, does not reduce club demand for the local public good. Yet club demand gets replicated with the size of the economy, $\max n^t$. Notice that there are constant returns of scale of local public good provision with respect to scalar replication. The size of a club does not matter, but its composition is crucial.

Since size is measured by $\max n^t$, local public goods favour mixed populations, such as $(1, \ldots, 1)$. If the size of the economy were measured by $\sum n^t$ instead, separation by type would occur. For example, if $y^1 = (1\ 0)$, $y^2 = (0\ 1)$, $n_0 = (1\ 1)$, then $\sum n_0^t \max y^t = (2\ 2)$. Now consider $n = (1\ 0)$ and $n = (0\ 1)$ separately. Club demands would be $(1\ 0)$ and $(0\ 1)$, summing to $(1\ 1)$ only. In other words, mixing the clubs is uneconomical when size is measured by $\sum n^t$. This lack of convexity would invalidate price support of club efficient allocations.

Consumer t has initial endowment $w^t \in \mathbb{R}^l_+$, net trade $x^t \in \mathbb{R}^l$, private consumption $x^t + w^t \in \mathbb{R}^l_+$, and (local) public consumption $y^t \in \mathbb{R}^l_+$. There are $n^t \in \mathbb{R}_+$ of consumers of type t member of a club. An *allocation* $(x^t, y^t, n^t)_{t=1,\ldots,T}$ is *feasible* if

$$\Sigma n^t x^t + \max n^t \max y^t \leq 0.$$

Net demands for the private and public goods sum to zero at most. For simplicity, there is no production. Local public goods are obtained by setting private goods aside. The local public goods sector has as input commodity vector $\max n^t \max y^t$ and as outputs individual demands for public goods, $y^1, \ldots, y^T$. Public goods production could be modeled by letting commodity input $\max n^t \max y^t$ be the output of a production process. Notice, however, that this would be covered by the introduction of a production possibility set for the private goods, which is a straightforward extension of the model. Indeed, (local) public goods are special by the consumption rather than the production technology.

Consumer t has a utility function U^t over his private and public consumption. However, since his initial endowment is fixed, I write $U^t(x^t, y^t)$. Consider feasible allocations $(x^t, y^t, n^t)_{t=1,\ldots,T}$ and $(x_0^t, y_0^t, n_0^t)_{t=1,\ldots,T}$. The former is a *club improvement* over the latter if

$$U^t(x^t, y^t) > U^t(x_0^t, y_0^t)$$

for all $t = 1, \ldots, T$. (Note that this definition anticipates strong monotonicity of utility which will be assumed in the next section indeed.) If no such club improvement exists, allocation $(x_0^t, y_0^t, n_0^t)_{t=1,\ldots,T}$ is called *club efficient*, following Schweizer (1983).

A feasible allocation $(x_0^t, y_0^t, n_0^t)_{t=1,\ldots,T}$ is a *Lindahl equilibrium* if price vectors $p, p^1, \ldots, p^T \in \mathbb{R}_+^l$ exist with

$$(x_0^t, y_0^t) = \text{ argmax } U^t(x^t, y^t) \text{ subject to } px^t + p^t y^t \leq 0$$

$$\Sigma n_0^t p^t y_0^t = p \max n_0^t \max y_0^t$$

$$(y_0^1, \ldots, y_0^T, n_0) = \text{ argmax } \Sigma n^t p^t y^t - p \max n^t \max y^t).$$

By the first condition, consumers maximize utility given the market prices for the private goods and the personal fees for the local public goods. The fees cover the costs of provision by the second condition. The third condition is not always included: the public administration is in charge of the provision and admission policies, as to maximize profit. (Profit is zero by the second condition.)

3 The theorem

Little is assumed. Following Schweizer (1983), positivity of prices is ensured to render a quasi-equilibrium equilibrium.

Assumption. Each consumer has positive initial endowment of at least some commodity, i.e. $w^t > 0$. Club $n_0 = (n_0^1, \ldots, n_0^T)$ has strictly positive endowment, i.e. $\sum n_0^t w^t \gg 0$. Utility U^t is continuous, quasi-concave, and strongly monotonic.

In the context of this assumption we have the following result.

Theorem. A club efficient allocation is a Lindahl equilibrium.

Proof. Let $(x_0^t, y_0^t, n_0^t)_{t=1,\ldots,T}$ be club efficient. Define the following subsets of $\mathbb{R}^{l(1+T)}$:

$$\begin{aligned} B &= \{(\sum n^t x^t, n^1 y^1, \ldots, n^T y^T) | U^t(x^t, y^t) > U^t(x_0^t, y_0^t), n > 0\} \\ C &= \{(-\max n^t \max y^t - y, n^1 y^1, \ldots, n^T y^T) | y^1, \ldots, y^T, y \in \mathbb{R}_+^l, \ \ n > 0\} \end{aligned}$$

B is convex by quasi-concavity of U^t. To show that C is convex, let $(y^1, \ldots, y^T, y, n)$ and $(\bar{y}^1, \ldots, \bar{y}^T, \bar{y}, \bar{n})$ constitute (not be) members of C and let ϑ and $\bar{\vartheta}$ be positive numbers summing to one. We must find $\tilde{y}^1, \ldots, \tilde{y}^T, \tilde{y} \in \mathbb{R}_+^l, \tilde{n} > 0$ such that $-\max \tilde{n}^t \max \tilde{y}^t - \tilde{y} = -\vartheta \max n^t \max y^t - \vartheta y - \bar{\vartheta} \max \bar{n}^t \max \bar{y}^t - \bar{\vartheta} \bar{y}$ and $\tilde{n}^t \tilde{y}^t = \vartheta n^t y^t + \bar{\vartheta} \bar{n}^t \bar{y}^t$. Solution is $\tilde{y}^t = \vartheta n^t y^t + \bar{\vartheta} \bar{n}^t \bar{y}^t$, $\tilde{y} = \vartheta \max n^t \max y^t + \bar{\vartheta} \max \bar{n}^t \max \bar{y}^t - \max(\vartheta n^t y^t + \bar{\vartheta} \bar{n}^t \bar{y}^t) + \vartheta y + \bar{\vartheta} \bar{y}, \tilde{n}^t = 1$. Clearly $\tilde{y} \geq 0$ since $\vartheta \max n^t \max y^t + \bar{\vartheta} \max \bar{n}^t \max \bar{y}^t \geq \vartheta n^t y^t + \bar{\vartheta} \bar{n}^t \bar{y}^t$ for all t. This is true. Hence C is convex.

By club efficiency, the intersection of B and C is empty. By the separating hyperplane theorem there exist $p, p^1, \ldots, p^T$ not all equal to zero such that

$(p, p^1, \ldots, p^T)B \geq (p, p^1, \ldots, p^T)C.$

In fact, since C is a cone,

$(p, p^1, \ldots, p^T)B \geq 0 \geq (p, p^1, \ldots, p^T)C.$

Hence, by strong monotonicity of $U^t : p, p^t \geq 0$. Hence, by assumed positive endowment, $\sum n_0^t p w^t > 0$. Hence, there is a t with $n_0^t > 0$ and $p w^t > 0$. For this t an interior consumption plan is feasible with respect to $p x^t + p^t y^t \leq 0$. Hence, by strong monotonicity and continuity of U^t, using a standard argument, $p \gg 0$ and this $p^t \gg 0$. Hence, by nonzero endowment assumption, $p w^t > 0$ for all t. By the same argument, all $p^t \gg 0$. I will now prove that these prices are Lindahl.

First the consumer's condition. Suppose $(x^t, 0, \ldots, 0, y^t, 0, \ldots, 0)$ (with y^t on location $1 + t$) fulfills $U^t(x^t, y^t) > U^t(x_0^t, y_0^t)$. In fact, since $p w^t > 0$ and utility is strongly monotonic and continuous, the same holds for a slightly smaller vector. Using strict positivity of prices, it follows that B-member $(x^t, 0, \ldots, 0, y^t, 0, \ldots, 0)$ fulfills $p x^t + p^t y^t > 0$. This proves that (x_0^t, y_0^t) solves the consumer's problem.

Next the financial balance. By strong monotonicity of the U^t's, there is no slack in the feasibility constraint of club efficient $(x_0^t, y_0^t, n_0^t)_{t=1,\ldots,T}$:

$\Sigma n_0^t x_0^t = -\max n_0^t \max y_0^t.$

Hence, $(-\max n_0^t \max y_0^t, n_0^1 y_0^1, \ldots, n_0^T y_0^T)$ belongs to the boundary of B, using strong monotonicity and continuity of the U^t's. It also belongs to C. Since prices were shown to separate B and C at zero, the value is zero, yielding financial balance.

Lastly the problem of the public administration. Any other $(-\max n^t \max y^t, n^1 y^1, \ldots, n^T y^T)$ also belongs to C and, therefore, is priced nonpositively, which is less than or equal to zero. This proves that $(y_0^1, \ldots, y_0^T, n_0)$ solves the public administration's problem and completes the proof of the theorem.

Remarks.

1. In the proof it was shown that all prices and fees are positive.
2. Club efficiency implies that all individual demands for public goods are equalized, if the utility functions are strictly quasi-concave.
3. The public administration breaks even.
4. If the population is not replicated, $n_0 = (1, \ldots, 1)$, the financial balance condition of the Lindahl equilibrium can be simplified further into $\sum p^t y_0 = py_0$. Hence, if only one local public good is supplied and it is designated the numerair, then the fees sum to unity.
5. The converse of the theorem is also true. A Lindahl equilibrium is club efficient. The proof is easy: a straightforward adaptation of Schweizer's (1983) proof of his theorem 2.

4 Discussion

The theorem provides price support to allocations that cannot be improved upon by clubs. The prices are linear, unlike Mas-Colell's (1980) personalized price schedules (also used by Gilles and Scotchmer, forthcoming) or Barham and Wooder's (1994) admission fees or "wages." The theorem and its proof are adaptations of Schweizer's (1983) theorem on club efficient allocations. He obtains the Henry George Theorem for economies with fixed public goods and associated inputs and, if the latter are zero, the welfare and core limit theorems. In the present paper, public goods are not exogenous, but endogenous, namely the outcome of competition among utility maximizers. Moreover, they are not pure, but local. I admit that my definition of local public goods involves a fairly opportunistic aggregation rule, but there is little hope for more general results.

After all, it is well known that there is no competitive basis for Lindahl equilibria in pure public goods economies (Milleron, 1972, and Bewley, 1981). Wooders (1978) has conjectured that the core shrinks when there is crowding, but Conley and Wooders (1994) show that the second welfare theorem is generally false. Barham and Wooders (1994) provides useful relationships between optima and competitive equilibria, but all these papers concern economies with one private and one public good only.

Equally opportunistic in modelling an economy with multiple public goods such that the Lindahl equilibrium emerges, is Vasil'ev, Weber, and Wiesmeth (1996). That paper uses an alternative core definition, with utility levels of members of blocking coalitions depending on replica size and coalition structure. Although my approach to local public goods may seem cleaner, I hasten to say that the two approaches are essentially equivalent. In either case, the opportunity cost of individual public goods consumption is independent of the size of the economy. From this perspective my paper makes but a modest contribution by showing that Schweizer's theorem encompasses Vasil'ev's core limit theorem. A novelty is the simplicity of the analysis. Club efficiency is quite a powerful tool.

The price I pay for the use of club efficiency, is the assumption that membership numbers are real. The integer problem is ignored. For large economies it is known to disappear and even some small economies may have crowding or congestion technologies that "click" (see the just referenced works of Scotchmer, Wooders, and co-authors), but I remain silent on the size of efficient clubs, having assumed constant returns to scale.

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