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Externalities and fundamental nonconvexities: A reconciliation of approaches to general equilibrium externality modeling and implications for decentralization

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Abstract

Starrett (1972) [33] and Boyd and Conley (1997) [7] approaches to externality modeling are unified by distinguishing between producible and nonproducible public commodities. Nonconvexities are associated with detrimental producible public commodities but not with nonproducible public commodities in Boyd and Conley (1997) [7]. Disposability properties (costly or costless) imply that producible public commodities are either by-products (*e.g.*, pollution) or joint-products (*e.g.*, national defense). Markets fail for both beneficial and detrimental by-products. Nonconvexities imply that price-based equilibria, *e.g.*, Pigovian tax equilibrium, may not be Pareto-efficient. Foley's (1967, 1970) [17,18] "public competitive equilibrium" combines price and quantity signals with a unanimity criterion and restores the equivalence between equilibrium and efficiency.

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1. Introduction

Arrow in [1] perceived the market failure associated with externalities as a problem of incomplete markets. He showed that the equivalence between a competitive equilibrium and a Pareto optimum can be restored if markets for external effects can be created.

However, employing Arrow's framework, where the commodity space is extended to include the rights to generate externalities as additional commodities, Starrett in [33] demonstrated that the presence of detrimental production externalities creates fundamental nonconvexities in the technology sets of firms.[1] As is well known, when the convexity assumption fails, the existence of a competitive equilibrium becomes questionable.

A question then arises about the possibility of existence of some other alternative decentralized or *partially* decentralized mechanism that will, in the presence of externalities, ensure the equivalence between the underlying equilibrium concept and Pareto optimality.[2] In general, [24] shows the impossibility of the existence of finite-dimensional decentralized mechanisms that guarantee Pareto optimality in the presence of externalities, for all economic environments (including nonconvex ones).

A popular candidate among the partially decentralized mechanisms with externalities is the one associated with Pigovian taxes, attributable to [2,30]. As has been well documented, an equilibrium with Pigovian taxes is compatible with nonconvex technology sets of the firms facing detrimental externalities, so long as the technologies of these firms are convex in the appropriate subspaces.[3] With full information about the economic environment, the planner can identify the level of the Pigovian taxes that equate the social marginal benefits to the social marginal costs of the externalities. However, the problem with the Pigovian tax mechanism is that, while any Pareto optimum can be decentralized as a Pigovian tax equilibrium, the reverse is not true. [3] showed that, if the detrimental effects of externalities on victim firms are sufficiently large, the *aggregate* technology set of the economy could well be nonconvex. In such a nonconvex economy, although the first order conditions of Pareto optimality would hold at a Pigovian tax equilibrium, the second order conditions for even a local Pareto optimum may fail. At these stationary points, there may exist adjustments in the underlying allocations that are Pareto improving, that is, if put to a vote, such adjustments would be unanimously accepted by all consumers. Thus, an arbitrary Pigovian tax equilibrium may not be efficient (i.e., the first-welfare theorem analogue for a Pigovian tax equilibrium fails), *unless*, we restrict the class of economies to those where

[1] He considers an example where increases in the level of an externality reduces the maximum output a firm can produce, given the levels of all inputs. But, the maximum output of the firm, for any given level of inputs, is assumed never to fall below zero, even in the face of an unlimited amount of the externality (the firm always has the option of shutting down production). This implies that the frontier of the technology is either asymptotic to the axis reserved for the externality or coincides with it after a critical level of the externality, where the maximum output has fallen to zero, has been reached.

[2] A mechanism is *decentralized* if the response of any agent to messages or signals received depends only on that agent's characteristics. By a *partially decentralized* mechanism we mean one where government is also an agent, but whose responses depend on the characteristics of a subset of all agents.

[3] See, *e.g.*, [3,24,33].