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Optimal tax policy under heterogeneous environmental preferences

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HIGHLIGHTS

- We model a federation of K jurisdictions where agents value consumption vs. nature differently.
- First-best efficiency is obtained with the combination of pollution tax rates and lump-sum transfers.
- The optimal tax rates depend only (but in a non-trivial way) on the externality parameters.
- For arbitrary preferences optimal transfers depend on regions' preferences and stocks of nature.

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ABSTRACT

We model an economy of K heterogeneous regions where agents value consumption vs. nature differently. Consumption obtained through pollution-inducing production also generates a negative externality on neighbors. We show that even with a decentralized policy we can obtain first-best efficiency by choosing a combination of pollution taxes in both regions and lump-sum transfers. Moreover, we show that optimal pollution taxes are determined only by the externality parameters, independent of agents' preferences for consumption and nature.

1. Introduction

We study a K-region economy model where regions face trade-offs between consumption, obtained through pollution-generating economic activities, and the quality of the environment. Pollution not only damages the local environment, but also creates negative externalities on neighbors. We view environmental externalities as generators of public "bads", along the lines of Meade (1952) and his concept of "atmospheric externalities" (Sandmo, 2011). We show that when regions are heterogeneous in three dimensions (nature endowment, damage spillovers and valuation of consumption vs. nature), we can achieve first-best efficiency by using pollution tax rates and a lump-sum transfer together.[1]

Optimal pollution tax rates are determined only by externality parameters. Such Pigouvian taxation aims to charge a region with the social cost of its consumption, and its tax rate is thus increasing in the damage it imposes on its neighbors. The optimal transfer plays a redistributive role and is affected by each region's endowment of nature and the degree of environmental damage spillovers. Wealth is redistributed through lump-sum transfers, irrespective of the economic decisions taken by the regions, while the pollution tax has built-in liability, with the polluter compensating its neighbors.

The inefficiency of decentralized policymaking has long been established as the norm in the theoretical public and environmental economics literature on production efficiency in the face of externalities (Pigou, 1920; Samuelson, 1954). In a model with heterogeneous jurisdictions and interjurisdictional environmental damage spillovers, Ogawa and Wildasin (2009) find that decentralized policymaking leads to efficient resource allocation, even in the complete absence of corrective interventions by governments or coordination of policy. Decentralized policymaking can result

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[1] There is an extensive literature dedicated to alternative policies: carbon taxation, cap-and-trade, tradable permits, and regulations related to pollution control (see, for instance, Montgomery, 1972; Baumol and Oates, 1988; Muller and Mendelsohn, 2009).

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in globally efficient allocations, even when preferences and production technologies differ among regions and governments care only about local environmental impacts. Fell and Kaffine (2014) argue that Ogawa and Wildasin (2009) result hinges on the fact that in their model, there is a fixed sum of environmental damages across regions, and their central result breaks down if the model endogenizes environmental damages. Even though in our model the sum of environmental damage is affected by the policy choices, the decentralized outcome is still efficient.

2. The economy

We consider an economy with a set of regions $\mathcal{K} = \{1, \ldots, K\}$ inhabited by a large number of agents with identical preferences. We define all variables in per capita terms and consider the case of a constant population. Each region is endowed with an initial environment of quality N_i, which is then reduced by environmental damages (i.e., pollution) e_i linked to production. Each unit of output produced in region i, labeled as Y_i, results in one unit of environmental damage there. Production in region i has a negative atmospheric externality and causes environmental damage in the other regions. The degree of environmental damage spillovers from the other regions is captured by a region specific parameter $\beta_j \in \left[0, \frac{1}{K-1}\right]$, $\forall j \in \mathcal{K}$, so that the environmental damage experienced by region i is given by

$$e_i = Y_i + \sum_{j \in \mathcal{K} \setminus i} \beta_j Y_j. \tag{1}$$

In our economy, if β_i is strictly positive, local economic activity causes damage not only to the local environment but in other regions as well. Oates and Schwab (1988) assume no interjurisdictional environmental spillovers and environmental quality in any jurisdiction depends only on local economic activity, i.e., $\beta_j = 0$ in Eq. (1), $\forall j \in \mathcal{K}, j \neq i$. The upper limit of $\beta_i = \frac{1}{K-1}$ corresponds to the case in which a unit of output produced in region i does just as much damage elsewhere as it does locally. The analyses of Ogawa and Wildasin (2009) and Fell and Kaffine (2014) are restricted to the case $\beta_i = \beta_j = \beta, \forall i, j \in \mathcal{K}$.

The cumulative level of environmental damage is

$$\sum_{i=1}^{K} e_i = \sum_{i=1}^{K} \left[1 + (K-1)\,\beta_i\right] Y_i. \tag{2}$$

We do not assume that the sum of the environmental damage is equal to an exogenous constant. In such a case, the planner can only shift environmental damages across regions, but not reduce aggregate damages. We depart from Ogawa and Wildasin (2009) by allowing the planner to choose (indirectly) the optimal level of environmental damage in each region. Hence, the choice of consumption-nature quality allocations is affected by the heterogeneity of the regions with respect to their preferences for environmental quality and consumption.

The utility function of the representative agent residing in region i is denoted as $u_i(c_i, n_i)$, where c_i is the agent's consumption of a private good in region i and

$$n_i = N_i - Y_i - \sum_{j \in \mathcal{K} \setminus i} \beta_j Y_j \tag{3}$$

denotes nature quality enjoyed locally using Eq. (1). We make the usual assumptions on utility functions (differentiable, increasing and strictly quasi-concave). We allow for agents in different regions to have different preferences for nature versus consumption.

3. The centralized and decentralized problems

3.1. The centralized problem

Consider an economy where a central government cares equally about agents in all regions and can directly choose production and consumption in all regions, with the constraint that $\sum_{i=1}^{K} c_i \leq \sum_{i=1}^{K} Y_i$.

In order to derive a closed-form expression of the optimal pollution tax, we first write Eq. (3) in matrix form:

$$\mathbf{BY} \equiv \begin{pmatrix} 1 & \beta_2 & \beta_3 & \ldots & \beta_K \\ \beta_1 & 1 & \beta_3 & \ldots & \beta_K \\ \beta_1 & \beta_2 & 1 & \ldots & \beta_K \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \beta_1 & \beta_2 & \beta_3 & \ldots & 1 \end{pmatrix} \begin{pmatrix} Y_1 \\ Y_2 \\ Y_3 \\ \vdots \\ Y_K \end{pmatrix} = \begin{pmatrix} N_1 - n_1 \\ N_2 - n_2 \\ N_3 - n_3 \\ \vdots \\ N_K - n_K \end{pmatrix} \equiv \mathbf{N} \tag{4}$$

where $\mathbf{B}$ is a (non-singular and non-symmetric) $K \times K$ matrix and $\mathbf{Y}$ and $\mathbf{N}$ are $K \times 1$ vectors. Rearranging Eq. (4), we have

$$\begin{pmatrix} Y_1 \\ Y_2 \\ Y_3 \\ \vdots \\ Y_K \end{pmatrix} = \begin{pmatrix} 1 & \beta_2 & \beta_3 & \ldots & \beta_K \\ \beta_1 & 1 & \beta_3 & \ldots & \beta_K \\ \beta_1 & \beta_2 & 1 & \ldots & \beta_K \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \beta_1 & \beta_2 & \beta_3 & \ldots & 1 \end{pmatrix}^{-1} \begin{pmatrix} N_1 - n_1 \\ N_2 - n_2 \\ N_3 - n_3 \\ \vdots \\ N_K - n_K \end{pmatrix}. \tag{5}$$

Summing up over the Y_i we get

$$\sum_{i=1}^{K} Y_i = \Phi\left(n_1, \ldots, n_K, N_1, \ldots, N_K, \beta_1, \ldots, \beta_K\right)$$

which can be rewritten as

$$\mathbf{1}'\mathbf{Y} = \mathbf{1}'\mathbf{B}^{-1}\mathbf{N}$$

where $\mathbf{1}'$ is the transpose of an $K \times 1$ vector, $\mathbf{B}^{-1}$ is the inverse of the $\mathbf{B}$ matrix and $\Phi = \mathbf{1}'\mathbf{B}^{-1}\mathbf{N}$. We can show (see Appendix A for details) that

$$\begin{aligned} &\Phi\left(n_1, \ldots, n_K, N_1, \ldots, N_K, \beta_1, \ldots, \beta_K\right) \\ &\quad = \left(\frac{1}{det(\mathbf{B})}\right) \sum_{j \in \mathcal{K}} A_j \left(N_j - n_j\right) \end{aligned} \tag{6}$$

where $\Phi(\cdot)$ is a function of exogenous parameters only, and for each $i \in \mathcal{K}$,

$$A_i = \sum_{S \subseteq \mathcal{K} \setminus i} (-1)^{|S|+1} \left((K - |S| - 1)\,\beta_i + |S| - 1\right) \prod_{j \in S} \beta_j, \tag{7}$$

$$det(\mathbf{B}) = \sum_{S \subseteq \mathcal{K}} (-1)^{|S|+1} \left(|S| - 1\right) \prod_{j \in S} \beta_j \tag{8}$$

where S is a coalition of regions.

Re-expressing the problem in terms of consumption and nature levels, c_i and n_i, the planner chooses a first-best allocation by solving the following problem:

$$\max_{\{c_i, n_i\}} \sum_{i=1}^{K} u_i\left(c_i, n_i\right)$$

under the constraint that

$$\sum_{i=1}^{K} c_i = \Phi(\cdot). \tag{9}$$