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Multilateral externalities: Contracts with private information either about costs or benefits

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ABSTRACT

This note uses the framework of Martimort and Sand-Zantmann (2013, forthcoming) about international environmental agreements. The objective is to demonstrate how a shift of private information from cost to benefit affects contracts and permit market outcomes although this seemingly ad hoc choice has no effect outside contracts and absent market interventions.

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1. Introduction

This note draws on Martimort and Sand-Zantman (forthcoming), MS in the following. The objective is to show how seemingly equivalent benefit–cost trade-offs can lead to different outcomes. More precisely, the following is shown: In the setting of Martimort and Sand-Zantman (2013, forthcoming) of infinitesimally small actors, Proposition 1 about an efficient market mechanism breaks down once private information is attached to benefits instead of costs (Section 3). Furthermore, choosing the private information parameter in benefit–cost trade-offs affects contracts between 'large' players although out-of-contract outcomes are identical (Section 4).

2. The MS model

MS considers costly efforts that induce individual and common benefits. For parsimony, we focus on common benefits which are more relevant for global warming. Payoffs are quadratic in costly individual and observable effort (e_i, e.g., abatement) of player i and linear in common benefits ($\mathcal{E}$, i.e., due to less global warming),

$$V_i = -\frac{e_i^2}{2\theta_i} + \mathcal{E}. \tag{1}$$

Private information is about costs (θ_i) while damages are known. Actually in the context of global warming it is presumably the effort that is better known than the benefit because effort is so far primarily technical – gas instead of coal, more efficient power plants without or with carbon capture and storage, solar and wind energy, etc. – of which the costs are roughly known. Therefore, we consider the alternative: private information is attached to the damage while effort costs are known,

$$W_i = \theta_i \mathcal{E} - \frac{e_i^2}{2}. \tag{2}$$

Since W_i is a linear transformation of the original objective, both formulations must yield the same outcome under autarky. Moving beyond autarky (in the following *business as usual scenario*, short **BAU**) may require transfers to player i denoted by t_i.

3. BAU and permits with small players

MS consider BAU, the first best, and then show in their Proposition 1 that the first best can be implemented by a global permit market. This exercise is repeated for the seemingly

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equivalent objective (2). Each player maximizing the own objective W_i,

$$0 = e_N(\theta) = \arg\max_e \theta_i E_{\tilde{\theta}}\left(\mathcal{E}_N\left(\tilde{\theta}\right)\right) - \frac{e_i^2}{2} \quad \text{so that } W_N = 0 \tag{3}$$

characterizes BAU (subscripted N for Nash equilibrium) where $E_{\tilde{\theta}}$ denotes the expectation operator over the random variable $\tilde{\theta}$. With a continuum of infinitesimally small countries, each individual country has no benefit from abatement, thus $e_N = 0$.

It is straightforward to compute worldwide welfare

$$\begin{aligned} W &= \int_i W_i di = \int_i \left(t_i + \theta_i \mathcal{E} - \frac{e_i^2}{2}\right) di = \int_i \left(\theta_i \mathcal{E} - \frac{e_i^2}{2}\right) di \\ &= \mathcal{E} \int_i \theta_i di - \int_i \frac{e_i^2}{2} di \\ &= \int_i e_i di \int_i \theta_i di - \int_i \frac{e_i^2}{2} di = \int_\Theta e(\theta) f(\theta) d\theta \\ &\quad \times \int_\Theta \theta f(\theta) d\theta - \int_\Theta \frac{e(\theta)^2}{2} f(\theta) d\theta \\ &= \int_\Theta \left[e(\theta) \int_\Theta \theta f(\theta) d\theta - \frac{e(\theta)^2}{2}\right] f(\theta) d\theta, \end{aligned}$$

where the 3rd line follows from budget balance condition $\int_i t_i di = 0$. The corresponding first best allocation of efforts contrasts BAU and must satisfy the following first order optimality condition,

$$\int_\Theta \theta f(\theta) d\theta - e^{FB}(\theta) = 0 \quad \text{for all } \theta, \tag{4}$$

where $\int_\Theta \theta f(\theta) d\theta$ is the average θ. Therefore,

$$e^{FB}(\theta) = E_\theta = \text{constant for all } \theta, \tag{5}$$

which simply says that aggregate marginal damages of emissions equal marginal abatement cost. With private information about benefits the first best would be characterized by $\theta - e(\theta) = 0$ for all θ (see MS). Accordingly, the result is the same if and only if all countries are identical. Intuitively, countries with different abatement cost should choose different abatement levels.

Consider a permit market. Let E_0 denote the permit endowments per country, p the permit price and

$$U_0(\theta, p, E_0) = \max_e p(e - E_0) + \theta \mathcal{E}_0 - \frac{e^2}{2}, \tag{6}$$

the payoff of permit trading of country with type θ. The first order optimality condition implies, $e(\theta, p) = p$, i.e. all countries choose same abatement (due to equal abatement cost), in contrast to MS. Market clearance,

$$E_{\tilde{\theta}}\left(e\left(\tilde{\theta}, p_0\right)\right) = E_0 \iff E_{\tilde{\theta}}(p_0) = p_0 = E_0,$$

implies that each country chooses

$$e(\theta, p_0) = E_0.$$

The market mechanism is efficient if

$$E_0 = \int_\Theta \theta f(\theta) d\theta := E_{\tilde{\theta}}\left(\tilde{\theta}\right)$$

and only if this level of permit allowance induces the participation of all countries, i.e., $U_0(\theta, p, E_0) \geq U_N$ for all θ. Using

$$\begin{aligned} E_{\tilde{\theta}}\left(e\left(\tilde{\theta}\right)\right) &= \int_\Theta e\left(\tilde{\theta}\right) f(\theta) d\theta \\ &= \int_\Theta E_0 f(\theta) d\theta = E_0 \int_\Theta f(\theta) d\theta = E_0 \end{aligned}$$

yields

$$\begin{aligned} U_0(\theta, p_0, E_0) &= p_0(e - E_0) + \theta \mathcal{E}_0 - \frac{e^2}{2} \\ &= \theta E_{\tilde{\theta}}\left(e\left(\tilde{\theta}\right)\right) - \frac{E_{\tilde{\theta}}\left(\tilde{\theta}\right)^2}{2} \\ &= E_{\tilde{\theta}}\left(\tilde{\theta}\right)\left(\theta - \frac{E_{\tilde{\theta}}\left(\tilde{\theta}\right)}{2}\right) \geq 0 \\ &\iff \theta \geq \frac{E_{\tilde{\theta}}\left(\tilde{\theta}\right)}{2} \quad \text{for all } \theta. \end{aligned}$$

Obviously, this criterion will be violated for a positive measure of types for all kinds of distributions of θ. This is fundamentally different from Proposition 1 in MS which says that market mechanism induces participation worldwide. However, the result in MS has not directly something to do with private information only in the sense that abatement cannot be conditioned on type θ. Even so, the outcomes and more important the policy recommendations differ depending on the specification of the payoffs, either (1) or (2).

4. Contracts

Attaching private information either to benefits or costs is even more consequential if global warming mitigation contracts are considered. In order to make this point, we simplify to two countries/regions with $i = 1$ being the principal ('she') offering the contract and the other, $i = 2$, the agent ('he'). A contract consists of efforts, e_i, $i = 1, 2$ and thus also of the principal due to the multi-(here bi-) lateral externality and of transfers t from the principal to the agent.

Using the specification (1) from MS and assuming that the principal has nothing to hide (thus $\theta_1 = 1$), implies the objectives,

$$V_i = -\frac{e_i^2}{2\theta_i} + \mathcal{E}, \quad \mathcal{E} = e_1 + e_2, \; i = 1, 2, \; \theta_1 = 1,$$
$$\theta_2 = \theta \in \left[\underline{\theta}, 1\right]. \tag{7}$$

The choice of $\theta < 1$ reflects that the industrialized world $i = 1$ has lower opportunity costs of mitigation efforts (due to technology and high incomes) and that they offer a contract to developing countries. Alternatively, attaching the private information to the benefit as in (2) and keeping all other assumption from above leads to the objectives,

$$W_i = -\frac{e_i^2}{2} + \beta_i \mathcal{E}, \quad i = 1, 2, \; \beta_1 = 1, \; \beta_2 = \beta \in \left[\underline{\beta}, 1\right], \; \underline{\beta} = \underline{\theta}. \tag{8}$$

Both private information parameters (θ, β) are identical and thus identically distributed, $F(\theta)$ and $F(\beta)$, and for simplicity uniformly. The out-of-contract outcomes are the same whether the payoffs are V_i or W_i due to the simple re-scaling of the payoffs.

4.1. Costs are private information

Starting with the version in MS, we obtain for BAU,

$$e_2^0(e_1, \theta) = \arg\max_{e_2} V_2 = \theta, \tag{9}$$

which is independent of the principal's actions (due to linear benefits) such that the principal's maximization of her expected payoff yields

$$e_1^0 = \arg\max_{e_1} \int_{\underline{\theta}}^1 \left(-\frac{e_1^2}{2} + e_1 + \theta\right) dF(\theta) = 1. \tag{10}$$

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