IEAs: Optimal Constraints on Flexibility

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Introduction

- International Environmental Agreements ask each member country to internalize the externalily it inflicts on other members.
- If there were perfect information, each country would be asked by IEA to commit to an entire future stream of emissions.
- This paper: There is imperfect information about (i) future costs and benefits (which are country-specific), and (ii) the future politician's type.
- Research Question: How much flexibility should the contracting parties of an IEA give to future governments?
- I use a two-period model to address this issue.

Sources of uncertainty

- We focus on two sources of uncertainty about period 2.
- First, uncertainty about the pains and anger of losers (e.g., coal mine workers, coal mine owners).
- We refer to this as the "political economy" parameter (Bagwell and Staiger, 2005; Amador and Bagwell, 2013).
- Second, uncertainty about the bias of the 'politician' (e.g., voters do not know the 'true type' of the candidate they elected)
- We refer to this as "citizen candidate" parameter (Besley and Coate, 1997; Grosser and Palfrey 2014)
- IEAs cannot dictate actions contingent on these parameters (as these are the politician's private information).

A principal-agent model

- Assume the IEA involves only two countries. (Similar to "trade agreement model" by Bagwell and Staiger, 2005)
- Period 1: The signatories (the principal) impose constraints on actions of period 2 governments (called "the politicians" for short)
- Period 2: The politicians (the agents) choose actions (and must satisfy the constraints imposed by IEA)
- This is a non-standard principal-agent problem, in that there are no transfers between the principal and the agent.
- Bagwell and Staiger: "Contingent transfers may be infeasible, or at least severely restricted, in several setting of economic and political interest." See Alonso and Matouschek (2008)
- A principal-agent problem without transfers is called "delegation problem" (Holmström, 1977, 1984)

New features

- Compared to Holmström, Bagwell and Staiger, and Amador and Bagwell, my model has an added feature: "the citizen candidate". She has private information about (i) her type, denoted by t, as well as (ii) the political economy parameter, denoted by θ.
- t is uniformly distributed over interval $[-\delta, \delta]$ (e.g. $t > 0$ corresponds to (hidden) climate skeptic, while $t < 0$ may be a (hidden) Green sympathizer)
- θ is uniformly distributed over interval $[-\varepsilon, \varepsilon]$
- Assume $\delta < \varepsilon$. (There is "greater uncertainty" about the political economy parameter than about politician's type.)

A simplifying assumption

- Following Bagwell and Staiger (2005) and Amador and Bagwell (2013), I assume the two countries are symmetric, and the country-specific random variables are i.i.d.
- Separate treatment of the two agents (no strategic interaction between the agents).

Benefits and Costs of Emissions in Period 2

- In both countries, emissions are proportional to outputs
- x is emissions in Home (H), y is emissions in Foreign (F)
- Damage costs in H is $D_H(x+y)$, in F is $D_F(x+y)$
- Non-environmental welfare in H is $W_H = W(x,\theta)$ where θ is the political economy parameter, and in F is $W_F = W(y,\theta^*)$
- θ and $\theta^*$are independently distributed (θ is private information of H's politician; θ^* private information of F's politician)
- $W(x,\theta)$ is concave in x, increasing in θ, and $W_{x\theta} > 0$.
- Joint net welfare is $J = (W_H - D_H) + (W_F - D_F)$

Objective of IEA

- IEA (signed in period 1) aims at maximizing period 2 joint net welfare.
- IEA can dictate x and y to period 2 politicians, but in general this would be inefficient because IEA does not observe θ and θ^*.
- Should IEA allow period-2 politicians to have complete freedom to choose x and y?

Objective of Period-2 Politicians

- Assume period-2 politician of H wants to maximize $W_H - D_H + tx$ (where t is the politician's type), $-\delta \leq t \leq \delta$.
- Thus, there are two sources of bias in H politician's choice of x
- First bias: she does not internalize the effect of x on F's damage costs. This is an upward bias: it leads to higher x than optimal.
- Second bias: her type t, where $-\delta \leq t \leq \delta$.
- If $t > 0$, this is an additional upward bias.
- If $t < 0$, this is a downward bias that counters the upward bias of not internalizing effect of x on F's damage costs.

A linear-quadratic formulation

- Assume $W(x, \theta) = (A + \theta)x - \frac{1}{2}x^2$
- Assume $D_H(x + y) = (x + y)\gamma_H$, where $\gamma_H > 0$
- Assume $D_F(x + y) = (x + y)\gamma_F$, where $\gamma_F > 0$
- Assume $A > \gamma_H + \gamma_F$, and $A - \varepsilon > \gamma_H + \gamma_F$ so that socially optimal emission is always positive.

First Best

- If θ and θ^* were known, IEA would set x and y to maximize

$$(A+\theta)x - \frac{1}{2}x^2 + (A+\theta^*)y - \frac{1}{2}y^2 - (\gamma_H + \gamma_F)(x+y)$$

- FOCs

$$A+\theta - x = \gamma_H + \gamma_F \text{ and } A+\theta^* - y = \gamma_H + \gamma_F$$

Note: The optimal x is never greater than $A+\varepsilon-(\gamma_H+\gamma_F) \equiv x^P_{\max}$ and never smaller than $A-\varepsilon-\gamma_H+\gamma_F \equiv x^P_{\min}$

- But IEA does not have information on θ and θ^*
- In constrast, H politician (in period 2), if un-constrained, would choose x to maximize $(A+\theta)x - \frac{1}{2}x^2 - (x+y)\gamma_H + tx$

$$A+(\theta+t)-x = \gamma_H$$

- Assume $A-(\varepsilon+\delta)-\gamma_H > 0$. Then she always chooses $x > 0$.Her optimal x is $\leq A+\varepsilon+\delta-\gamma_H \equiv x^A_{\max}$ and $\geq A-\varepsilon-\delta-\gamma_H \equiv x^P_{\min}$

Principal-Agent Problem Without Transfers

- How to constrain the politician, given that transfers are not allowed?
- This is a "delegation problem" (Holmström, 1977, 1984).
- We can apply the revelation principle to this problem, by defining

$$\alpha = \theta + t$$

- Note: We can show that if θ and t are uniformly distributed (and independent) then density function of α has the shape of a trapezoid.

Trapezoid density function

- For any given $\alpha \in [-\varepsilon - \delta, \varepsilon + \delta]$, let us denote by $\Omega(\alpha)$ the set of θ values that are consistent with $t \in [-\delta, \delta]$, i.e.,
- Then, as shown in Laussel and Long (2018), the density function of α is given by

$$f(\alpha) = \int_{\Omega(\alpha)} \frac{1}{4\delta\varepsilon} d\theta$$

which is

$$f(\alpha) = \begin{cases} \frac{\varepsilon+\delta+\alpha}{4\varepsilon\delta}, & \forall \alpha \in [-\varepsilon - \delta, \delta - \varepsilon] \\ \frac{1}{2\varepsilon}, & \forall \alpha \in [\delta - \varepsilon, \varepsilon - \delta] \\ \frac{\varepsilon+\delta-\alpha}{4\varepsilon\delta} & \forall \alpha \in [\varepsilon - \delta, \varepsilon + \delta] \end{cases}$$

Payoff function of the principal

- Define $B \equiv A - \gamma_H - \gamma_F$ and $\alpha \equiv \theta + t$. Given any prescribed schedule $x(.)$ that associates to each α the emission rate $x(\alpha)$, the principal's expected payoff is

$$V^P = \int_{-\delta}^{\delta} \left[\int_{-\varepsilon}^{\varepsilon} \left((B+\theta)x\left(\theta + t\right) - \frac{1}{2}\left(x\left(\theta + t\right)\right)^2 \right) \frac{1}{2\varepsilon} d\theta \right] \frac{1}{2\delta} dt$$

- i.e.

$$V^P = E\left[(B+\theta)x\right] - \frac{1}{2} E\left[x^2\right]$$

with

$$E\left[x^2\right] \equiv \int_{\underline{\alpha}}^{\overline{\alpha}} \left[x(\alpha)^2\right] f(\alpha) d\alpha \equiv \int_{-\varepsilon-\delta}^{\varepsilon+\delta} \left[x(\alpha)^2\right] f(\alpha) d\alpha$$

Payoff of Principal

- and

$$E\left[(B+\theta)x\right] \equiv \int_{-\delta}^{\delta}\left[\int_{-\varepsilon}^{\varepsilon}(B+\theta)x\left(\theta+t\right)\frac{1}{2\varepsilon}d\theta\right]\frac{1}{2\delta}dt$$
$$= \int_{-\varepsilon-\delta}^{\varepsilon+\delta}x(\alpha)\left[\int_{\Omega(\alpha)}\frac{(B+\theta)}{4\delta\varepsilon}d\theta\right]d\alpha.$$

- **Problem 1:** Choose a function $x(.)$ that maximizes V^P, subject to the *incentive-compatibility constraint*: an agent that has private information α would choose action $x(\alpha)$ in preference to any other action $x(\widehat{\alpha})$. In symbol,

$$\alpha = \arg\max_{\widehat{\alpha}}\left[(B+\gamma_F+\alpha)x(\widehat{\alpha}) - \frac{1}{2}\left(x(\widehat{\alpha})\right)^2\right]$$

Incentive-compatible mechanism

- Find properties that any incentive-compatible scheme $x(.)$ must satisfy, given that transfers are not feasible.
- The principal offers the future politician of H a schedule $x(\alpha)$.
- Principal passes a law which tells the future politician the following message: "Here is the schedule $x(.)$ defined over the set of possible values of $\alpha \in [-\varepsilon - \delta, \varepsilon + \delta]$. You must report a value of α. If your reported value is $\widehat{\alpha}$, you will be required to take action $x(\widehat{\alpha})$."
- A schedule $x(.)$ induces the agent to report α truthfully iff the agent cannot obtain a better payoff by reporting a false value $\widehat{\alpha} \neq \alpha$.

Properties of incentive-compatible schedules

- Given a schedule $x(.)$, let $\pi(\widehat{\alpha}, \alpha)$ denote the agent's payoff, where the second argument of $\pi(.,.)$ denotes the true value and the first argument denotes the reported value, i.e.,

$$\pi(\widehat{\alpha}, \alpha) \equiv (B + \gamma_F + \alpha)x(\widehat{\alpha}) - \frac{1}{2}x(\widehat{\alpha})^2$$

- By a standard revealed preference argument, any incentive-compatible schedule $x(\alpha)$ is *non-decreasing* for all $\alpha \in [-\varepsilon - \delta, \varepsilon + \delta]$.
- Under an incentive-compatible scheme, the agent will tell the truth, and her payoff is

$$V^A(\alpha) \equiv (B + \gamma_F + \alpha)x(\alpha) - \frac{1}{2}x(\alpha)^2 \geq (B + \gamma_F + \alpha)x(\widehat{\alpha}) - \frac{1}{2}x(\widehat{\alpha})^2$$

Properties

- From Berge's maximum theorem, $V^A(\alpha)$ is a continuous function.
- Over any interval (α_1, α_2) such that $x(\alpha)$ is differentiable, since $\pi(\widehat{\alpha}, \alpha)$ is maximized at $\widehat{\alpha} = \alpha$, the following first order condition must hold, where $x(\widehat{\alpha})$ is evaluated at $\widehat{\alpha} = \alpha$,

$$[(B + \gamma_F + \alpha) - x(\alpha)] \frac{dx}{d\alpha} = 0$$

- That is, either $x(\alpha) - (B + \gamma_F) = \alpha$ or $dx/d\alpha = 0$ on (α_1, α_2).
- Recall that $B \equiv A - (\gamma_H + \gamma_F) > \alpha$ for all $\alpha \in [-\varepsilon - \delta, \varepsilon + \delta]$.
- In general, any incentive-compatible schedule $x(.)$, while being non-decreasing and almost everywhere differentiable, may exhibit an *upward jump discontinuity*. However, it is never optimal for the principal to sets schedules that have jumps.

Agent's payoff

- Agent's payoff $V^A(\alpha)$ has the property that

$$\frac{dV^A}{d\alpha} = \frac{\partial \pi(\widehat{\alpha}, \alpha)}{\partial \alpha} = x(\widehat{\alpha}) \text{ where } \widehat{\alpha} = \alpha$$

- It follows that

$$V^A(\alpha) = V^A(\underline{\alpha}) + \int_{\underline{\alpha}}^{\alpha} \frac{dV^A(\alpha')}{d\alpha'} d\alpha' = V^A(\underline{\alpha}) + \int_{\underline{\alpha}}^{\alpha} x(\alpha') d\alpha'$$

and

$$V^A(\alpha) = V^A(\overline{\alpha}) - \int_{\alpha}^{\overline{\alpha}} \frac{dV^A(\alpha')}{d\alpha'} d\alpha' = V^A(\overline{\alpha}) - \int_{\alpha}^{\overline{\alpha}} x(\alpha') d\alpha'$$

- where $\underline{\alpha} \equiv -\varepsilon - \delta$, and $\overline{\alpha} \equiv \varepsilon + \delta$. We cannot treat $V^A(\underline{\alpha})$ and $V^A(\overline{\alpha})$ as known constants. These values must be determined endogenously, as part of the optimization problem of the principal.

Two Benchmark Scenarios

- Before solving for the optimal schedule $x(.)$, we consider two benchmark scenarios.
- In the first benchmark, the principal is restricted to making a choice between two extreme alternatives:
- (i) giving the period-2 politician complete freedom to choose x she wants; OR
- (ii) setting an "immutable emission rate": the principal dictates x while being completely uninformed about the realized values of θ and t
- **Proposition1 (Choice between fixing the tariff rate and giving the period-2 government complete freedom)** *Giving complete freedom to the period-2 government of H would give rise to a higher welfare level, as compared with fixing the emission rate for H, iff $\varepsilon^2 - \delta^2 > 3\gamma_F^2$. This condition is satisfied if $\varepsilon^2 > 3\gamma_F^2$ and the uncertainty about the politician's type is sufficiently smaller than the uncertainty about the political economy parameter θ.*

Second Benchmark Scenario: politician's type is known

- Assume the bias t is a known number (it may be positive or negative).
- We assume that the absolute value of t is not too large
- **Proposition 2:** *Given a* **known** *postive bias* $t + \gamma_F > 0$, *the optimal incentive-compatible schedule* $x(\alpha) - (B + \gamma_F)$ *has the properties that: (i) for all* $\alpha < \varepsilon - t - 2\gamma_F$ *the politician is given the freedom to select her self-interest-maximizing choice, i.e.,* $x = B + \theta + t + \gamma_F$, *and (ii) for all* $\alpha \geq \varepsilon - t - 2\gamma_F$, $x(\alpha)$ *must be equal to the capped value* $B + \varepsilon - (t + \gamma_F) < B + \varepsilon$. *It is not optimal to set a floor on the emission rate.*

Second Benchmark (continued)

- **Corollary 2:** *Given a known negative (combined) bias* $t + \gamma_F$ *such that* $-\varepsilon < t + \gamma_F < 0$, *the optimal incentive-compatible schedule* $x(\alpha) - (B + \gamma_F)$ *has the properties that (i) for all* $\alpha > -\varepsilon - t - 2\gamma_F$, *the politician is given the freedom to choose her self-interest-maximizing choice, and (ii) for all* $\alpha \leq -\varepsilon - t - 2\gamma_F$, x *must equal the floor value* $B - \varepsilon - (t + \gamma_F) > B - \varepsilon$.

Optimal Schedule When Politician's type is unknown

- **Proposition 3:** *It is optimal for the contracting to set both a policy cap and a policy floor, and to delegate the policy choice to the politician only for intermediate values of* α.

(i) *The cap is* $\overline{x} = B + \varepsilon - (\frac{\delta}{2} + \gamma_F)$, *that is,* $x(\alpha) - B = \varepsilon - (\frac{\delta}{2} + \gamma_F)$ *for all* $\alpha \in \left[\varepsilon - (\frac{\delta}{2} + b), \varepsilon + \delta\right]$. *That is, the gap between the ceiling rate* $\overline{x}$ *and the hypothetical maximum rate that a benevolent planner could conceivably impose, is equal to* $(\delta/2 + \gamma_F)$, *where* $\delta/2$ is *the condition mean of* t, *given* $t \geq 0$.
(ii) *The floor is* $x(\alpha) = B - \varepsilon + (\frac{\delta}{2} + \gamma_F)$ *for all* $\alpha \in \left[-\varepsilon - \delta, -\varepsilon + (\frac{\delta}{2} + b)\right]$.
(iii) *For all* $\alpha \in \left[-\varepsilon + \frac{\delta}{2} + \gamma_F, \varepsilon - \frac{\delta}{2} - \gamma_F\right]$, *the politician is free to choose her* x, *and her choice is* $x(\alpha) = B + \gamma_F + \alpha$.
(iv) *The length of the delegation interval is* $2\varepsilon - \delta$. *Thus, the greater is the uncertainty about political bias, the smaller is the delegation interval.*

Conclusion

- Thank you!