# Global Warming Policy in a Federation: Federal vs. Regional Roles

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# Purpose

Emissions policies lead to special problems in federations since responsibilities not assigned: Often divided and change over time

National emissions have imperceptible effect on current global warming, so social preferences underlie policy

Explore efficiency of federal vs regional responsibility for greenhouse gas emissions policies in a stylized small open economy general equilibrium setting

Policies include emissions pricing and regulation of emissions technology (green transition)

# Introduction: Emissions Control Policies

Key distinction between

- Emissions from consumption & production of dirty goods
- Technology of emissions (green vs brown)

Two types of policies

- Emissions pricing can be taxes or marketable permits
- Regulation of emissions technology includes quantity and technology restrictions

Optimal emissions taxes are variants of Pigovian taxes

- General equilibrium effects irrelevant
- Border tax adjustments unnecessary

Case for federal vs regional control ambiguous

# Introduction: Special Issues with Greenhouse Gases Long-Lived, Accumulate over Several Generations

- Effect of current emissions imperceptibly small and largely occur several decades hence
- Double free-rider problem:
  Between generations and across countries
- Self-interest incentive for reducing emissions minimal
  Emissions policies must be based on non-selfish motives:
  Social norms/solidarity/altruism
- Emissions technologies and social preferences vary by region
- Collection of emissions pricing revenues is challenging
  Depends on federal vs regional cost of information

# Introduction: The Model

- Small open economy: federal and two regional governments
- Two traded goods with fixed world prices: one dirty, one clean
  One non-traded good with endogenous regional prices
- Unit population with fixed labour supply in each region
- Goods produced by labour with regional wages endogenous
- Governments tax emissions and transfer revenues net of collection costs to households
- Emissions fixed proportion of production and consumption of dirty traded good
- Can adopt green emissions technology at a cost
  Emissions per output fall with number of agents

# Introduction: Preferences

- Private utility depends on consumption of the three goods:
  Quasilinear in nontraded good and additive
- Social disutility of region $j$ resident depends on own emissions (social norm/altruism) and those of other region (peer effect)
  Social disutility higher if regions responsible for emissions
- Private utility determines private behaviour
- Government policy based on total utility
  Private utility plus social disutility of emissions
  Additive so no equity concerns
- In base model, emissions technology given: Extensions to adoption of green technology (with increasing returns) and border tax adjustments

# The Basic Model: Assumptions for Region $j = A, B$

- Representative household utility: $U^j = x_0^j + u_1^j(x_1^j) + u_2^j(x_2^j)$
  Good 0 is nontradable; Goods 1 and 2 are tradable
  Labour supply $\bar{\ell}^j$ fixed and immobile
  Utility of world emissions fixed so suppressed
- Production functions: $y_i^j = f_i^j(\ell_i^j), \ i = 0, 1, 2$
- Emissions from consumption and production of good 1:
  $e_x^j = \phi^j x_1^j, \quad e_y^j = \mu^j y_1^j \implies e^j = e_x^j + e_y^j$
- Regional social preferences: $U_S^j = U^j - s^j(e^j, e^{-j})$
  where $s_{e^j}^j > 0, \ s_{e_{-j}}^j > 0, \ s_{e^j e^j}^j > 0, \ s_{e^j e^{-j}}^j < 0$
- Federal social preferences:
  $W = \sum_j U^j - \sum_j \sigma s^j(e^j, e^{-j})$
  where $\sigma < 1$ (less social solidarity)

# Prices, Taxes, Transfers in Region $j = A, B$

- Wage rates $w^j$ (endogenous)
- Nontraded good prices $p_0^j$ (endogenous)
- Traded goods prices $p_i = \epsilon r_i$ ($\epsilon$ endogenous)
  $r_i$ = fixed world price, $\epsilon$ = exchange rate
- Taxes on consumption and production emissions: $\tau_x^j, \tau_y^j$
- Cost of collecting taxes (in terms of good 2)
  $\epsilon r_2 c^j = \gamma_x^j e_x^j + \gamma_y^j e_y^j$
- Transfers to households: $b^j$
- Household incomes: $m^j$ (= wages + profits + transfers)
- Government budgets:
  Regional: $(\tau_x^i - \gamma_x^j)e_x^j + (\tau_y^j - \gamma_y^j)e_y^j = b^j$
  Federal: $(\tau_x - \gamma_x)\sum_j e_x^j + (\tau_y - \gamma_y)\sum_j e_y^j = \sum_j b^j$

# Producer Behaviour in Region $j = A, B$

Nontraded goods

$$\pi_0^j(p_0^j, w^j) = \{\max_{\ell_0^j} \; p_0^j f_0^j(\ell_0^j) - w^j \ell_0^j\}$$

$$\frac{\partial \pi_0^j}{\partial p_0^j} = y_0^j(p_0^j, w^j), \;\; \frac{\partial \pi_0^j}{\partial w^j} = -\ell_0^j(p_0^j, w^j)$$

Dirty good 1

$$\pi_1^j(\epsilon r_1, w^j, \tau_y^j) = \{\max_{\ell_1^j} \; \epsilon r_1 f_1^j(\ell_1^j) - w^j \ell_1^j - \tau_y^j \mu_1^j f_1^j(\ell_1^j)\}$$

$$\frac{\partial \pi_1^j}{\partial \epsilon r_1} = y_1^j(\epsilon r_1, w^j, \tau_y^j), \;\; \frac{\partial \pi_1^j}{\partial w^j} = -\ell_1^j(\epsilon r_1, w^j, \tau_y^j),$$

$$\frac{\partial \pi_1^j}{\partial \tau_y^j} = -e_y^j(\epsilon r_1, w^j, \tau_y^j)$$

Clean good 2

$$\pi_2^j(\epsilon r_2, w^j) = \{\max_{\ell_2^j} \; \epsilon r_2 f_2^j(\ell_2^j) - w^j \ell_2^j - \tau_y^j \mu_2^j f_2^j(\ell_2^j)\}$$

$$\frac{\partial \pi_2^j}{\partial \epsilon r_2} = y_2^j(\epsilon r_2, w^j), \;\; \frac{\partial \pi_2^j}{\partial w^j} = -\ell_2^j(\epsilon r_2, w^j)$$

# Consumer Behaviour in Region $j = A, B$

Based on private preferences

$$V^j\left(p_0^j, \epsilon r_1, \epsilon r_2, \tau_x^j, m^j\right) = \\ \{\max U^j \text{ s.t. } p_0^j x_0^j + \textstyle\sum_{i=1,2} \epsilon r_i x_i^j + \tau_x^j \phi^j x_1^j = m^j\}$$

where $m^j = w^j \bar{\ell}^j + b^j + \pi_0^j(p_0^j, w^j) + \pi_1^j(w^j, \tau_y^j) + \pi_2^j(w^j)$
and $x_0^j$ is a residual use of income after $x_1^j, x_2^j$ satisfied

Envelope theorem:

$$V_{p_0}^j = -\frac{x_0^j(p_0^j, \epsilon r_1, \epsilon r_2, \tau_x^j, m^j)}{p_0^j}, \quad V_{\epsilon r_1}^j = -\frac{x_1^j(p_0^j, \epsilon r_1, \tau_x^j)}{p_0^j}$$

$$V_{\epsilon r_2}^j = -\frac{x_2^j(p_0^j, \epsilon r_2)}{p_0^j}, \quad V_{\tau_x}^j = -\frac{e_x^j}{p_0^j}, \quad V_m^j = \frac{1}{p_0^j}$$

# National General Equilibrium

Normalize $\epsilon = 1$: Foreign exchange is numeraire

Labour market equilibrium

$$\ell_0^j(p_0^j, w^j) + \ell_1^j(w^j, \tau_y^j) + \ell_2^j(w^j) = \bar{\ell}^j, \qquad j = A, B$$

National trade balance

$$\sum_j \left( r_1 \left( y_1^j(w^j, \tau_y^j) - x_1^j(p_0^j, \tau_x^j) \right) + r_2 \left( y_2^j(w^j) - x_2^j(p_0^j) - c^j \right) \right) = 0$$

Nontradable good equilibrium

$$y_0^j(p_0^j, w^j) = x_0^j(p_0^j, \tau_x^j, m^j), \qquad j = A, B$$

5 equations in $w^A, w^B, p_0^A, p_0^B$

One equation redundant using all budgets:
$\Longrightarrow$ Drop national trade balance

# Properties of General Equilibrium

Solution: $p_0^j(b^j, \tau_x^j, \tau_y^j), \quad w^j(b^j, \tau_x^j, \tau_y^j), \quad j = A, B$

Regional emissions

$$e_x^j\left(p_0^j(b^j, \tau_x^j, \tau_y^j), \tau_x^j\right) = \phi^j x_1^j\left(p_0^j(b^j, \tau_x^j, \tau_y^j), \tau_x^j\right),$$

$$e_y^j\left(w^j(b^j, \tau_x^j, \tau_y^j), \tau_y^j\right) = \mu^j y_1^j\left(w^j(b^j, \tau_x^j, \tau_y^j), \tau_y^j\right)$$

Household private utility

Using $m^j(\cdot), p_0^j(\cdot), w^j(\cdot)$,

$$V^j(b^j, \tau_x^j, \tau_y^j) \equiv V^j\left(p_0^j, \tau_x^j, m^j(p_0^j, w^j, b^j, \tau_y^j)\right)$$

where

$$\frac{dV^j}{dp_0^j} = \frac{dV^j}{dw^j} = 0, \quad V_b^j = \frac{1}{p_0^j}, \quad V_{\tau_x}^j = -\frac{e_x^j}{p_0^j}, \quad V_{\tau_y}^j = -\frac{e_y^j}{p_0^j}$$

# Policy I: Regions Control Emissions

Region $j$ maximizes

$$V^j\left(b^j, \tau_x^j, \tau_y^j\right) - s^j\left(e^j\left(p_0^j(b^j, \tau_x^j, \tau_y^j), w^j(b^j, \tau_x^j, \tau_y^j), \tau_x^j, \tau_y^j\right), e^{-j}\right)$$

subject to

$$(\tau_x^j - \gamma_x^j)e_x^j\left(p_0^j(b^j, \tau_x^j, \tau_y^j), \tau_x^j\right) + (\tau_y^j - \gamma_y^j)e_y^j\left(w^j(b^j, \tau_x^j, \tau_y^j), \tau_y^j\right) = b^j$$

$\Longrightarrow$ using the FOCs $\Longrightarrow$

Adjusted Pigovian taxes on consumption and production emissions:

$$\tau_x^j - \gamma_x^j = \tau_y^j - \gamma_y^j = p_0^j s_{e^j}^j(e^j, e^{-j}), \quad j = A, B$$

- Tax differs on consumption and production and by region
- No account taken of spillover effects on other region
- No need to account for general equilibrium effects via $p_0^j, w^j$

# Regional Emissions Control: Extensions

Identical regions

$$\tau_x - \gamma_x = \tau_y - \gamma_y = p_0 s_e(e, e^-)$$

Nash equilibrium

Using region $j$ government budget and emissions tax rate,

$$\frac{d\tau_x^j}{d\tau_x^{-j}} > 0 \text{ if } (\tau_x^j - \gamma_x^j)\frac{de_x^j}{db^j} + (\tau_y^j - \gamma_y^j)\frac{de_x^j}{db^j} < 1$$

$\implies \tau_x^j$ and $\tau_x^{-j}$ strategic complements

Coordinated regional policy changes

Starting from a Nash equilibrium, if both regions increase their emissions tax rates by a common amount, both representative households better off provided $de^j/d\tau_x^j, de^j/d\tau_y^j < 0$ for $j = A, B$

# Policy II: Federal Government Controls Emissions

Federal government chooses $\tau_x, \tau_y, b^A, b^B$ to maximize

$$\sum_j V^j(b^j, \tau_x, \tau_y) - \sum_j \sigma s^j\Big(e^j(b^j, \tau_x, \tau_y), e^{-j}(b^{-j}, \tau_x, \tau_y)\Big)$$

subject to

$$(\tau_x - \gamma_x) \sum_j e^j_x(b^j, \tau_x, \tau_y) + (\tau_y - \gamma_y) \sum_{j=A,B} e^j_y(b^j, \tau_x, \tau_y) = \sum_j b^j$$

Differences with regions

- Emissions taxes $\tau_x, \tau_y$ same in both regions (by assumption)
- Fed internalizes spillover benefits of emissions reductions
- Social disutility of emissions lower for fed ($\sigma < 1$)
- Cost of collecting taxes higher for fed ($\gamma_x > \gamma^j_x, \gamma_y > \gamma^j_y$)

## Federal Government Emissions Taxes:
## Weighted Average Pigovian Taxes in Different Scenarios

Consumption emissions only ($e_y = 0$)

$$\tau_x - \gamma_x = \sum_{j=A,B} \left( \frac{\rho^j_{xx}}{\rho^A_{xx} + \rho^B_{xx}} \right) p^j_0 \sigma \left( s^j_{e^j} + s^{-j}_{e^j} \right)$$

Production emissions only ($e_x = 0$)

$$\tau_y - \gamma_y = \sum_{j=A,B} \left( \frac{\rho^j_{yy}}{\rho^A_{yy} + \rho^B_{yy}} \right) p^j_0 \sigma \left( s^j_{e^j} + s^{-j}_{e^j} \right)$$

Weights $\rho^j_{xx}$, $\rho^j_{yy}$ depend on responses of emissions to $\tau_x$, $\tau_y$, resp.

Optimal emissions taxes in identical regions case:

$$t_x - \gamma_x = t_y - \gamma_y = \sigma p_0 (s_e + s^-_e)$$

Could be greater or less than optimal regional emissions taxes

# Federal Government Emissions Taxes: Continued

Both consumption and production emissions

$$\tau_x - \gamma_x = \sum_j \left( \frac{\Psi^j}{\Psi^A + \Psi^B} \right) p_0^j \sigma \left( s_{ej}^A + s_{ej}^B \right)$$

$$\tau_y - \gamma_y = \sum_j \left( \frac{\Phi^j}{\Phi^A + \Phi^B} \right) p_0^j \sigma \left( s_{ej}^A + s_{ej}^B \right)$$

where coefficients are complicated functions of emissions responses

Identical regions case

$$\tau_x - \gamma_x = \tau_y - \gamma_y = \sigma p_0 \left( s_e^A + s_e^B \right)$$

Differences with regional emissions taxes as above

- Fed internalizes spillover benefits of emissions reductions
- Social disutility of emissions lower for fed ($\sigma < 1$)
- Cost of collecting taxes higher for fed ($\gamma_x > \gamma_x^j, \gamma_y > \gamma_y^j$)

# Federal Border Carbon Tax Adjustments (BCTAs)

Keen and Kotsogiannis (CESifo WP 2014) use representative-agent two-country model with home and foreign production emissions $b, B$ that reduce home utility by $\theta b, \theta B$.

Optimal tariff $t$ on imports of dirty good $M$ when home country ignores benefits to foreign country is:

$$t = M(M_P)^{-1} + \theta B - (\theta - s^*)b$$

First term $M(M_P)^{-1}$ is optimal tariff

Second term $\theta B$ is marginal damage on home by foreign emissions

Third term $(\theta - s^*)b$ corrects for difference between home emissions tax $s^*$ and marginal damage $\theta$

All these are zero in our model: No case for BCTA in our model regardless of foreign emissions tax

# Adoption of Green Technologies

- Emissions in base case $\phi^j x_1^j, \mu^j y_1^j$ use brown technology $\phi^j, \mu^j$
- In alternative green technology, $\phi^j, \mu^j$ reduced as number of consumers/producers increases due to network externalities, innovation, infrastructure, (van der Ploeg & Venables, 2022)
- Investment in green technology costly: $k^j$ per agent
- Two equilibria: brown and green; move to green equilibrium only efficient if sufficient number of agents adopt it
- Temporary policy needed to induce once-over investment in green technology: case for regulation
- Regional governments have administrative advantage, but have fewer agents than federal government

Begin by investigating effect on household utility of small changes in $\phi^j$ and $\mu^j$

# Technologies Affect Economic Outcomes

Production variables: $\ell_1^j(w^j, \tau_y^j, \mu^j)$, $y_1^j(w^j, \tau_y^j, \mu^j)$, $\pi_1^j(w^j, \tau_y^j, \mu^j)$

Demand variables: $x_1^j(p_0^j, \tau_x^j, \phi^j)$, $x_0^j\left(p_0^j, \tau_x^j, \phi^j, m^j\right)$

Endogenous variables: $m^j(p_0^j, w^j, b^j, \tau_x^j, \mu^j)$, $w^j(b^j, \tau_x^j, \tau_y^j, \phi^j, \mu^j)$, $p_0^j(b^j, \tau_x^j, \tau_y^j, \phi^j, \mu^j)$

Household private utility: $V^j\left(p_0^j(\cdot), \tau_x^j, \phi^j, m^j(\cdot)\right)$

$$V_\phi^j = -\frac{\tau_x^j x_1^j}{p_0^j} < 0, \qquad V_\mu^j = -\frac{\tau_y^j y_1^j}{p_0^j} < 0$$

Emissions:

$$e_y^j\left(w^j(b^j, \tau_x^j, \tau_y^j, \phi^j, \mu^j), \tau_y^j, \mu^j\right) = \mu^j y_1^j\left(w^j(b^j, \tau_x^j, \tau_y^j, \phi^j, \mu^j), \tau_y^j, \mu^j\right)$$
$$e_x^j\left(p_0^j(b^j, \tau_x^j, \tau_y^j, \phi^j, \mu^j), \tau_x^j, \phi^j\right) = \phi^j x_1^j\left(p_0^j(b^j, \tau_x^j, \tau_y^j, \phi^j, \mu^j), \tau_x^j, \phi^j\right)$$

# Regional Governments Induce Technology Change

Differentiate value function for regional emissions problem, use FOCs on $\tau_x^j, \tau_y^j$ and properties of $e_x^j(\cdot), e_y^j(\cdot)$:

$$\frac{\partial \mathcal{V}^j}{\partial \phi^j} = -(s_e^j + \lambda^j \gamma_x^j) x_1^j < 0, \quad j = A, B$$

$$\frac{\partial \mathcal{V}^j}{\partial \mu^j} = -(s_e^j + \lambda^j \gamma_y^j) y_1^j < 0, \quad j = A, B$$

- Small increases (decreases) in $\phi^j$ and $\mu^j$ reduce (increase) regional social welfare by first-order effect (no GE effects)
- Increase in $\phi^j(\mu^j)$ increases emissions by $x_1^j(y_1^j)$, which increases social damages and cost of emissions tax revenue
- Private utility not affected by small changes in emissions technology: social disutility of emissions changes
- Changes in social disutility in other region neglected

# Federal Government Induces Technology Change

Differentiate value function of federal problem $\mathcal{V}^F$ wrt $\phi$ and $\mu$, assuming $d\phi = d\phi^j = d\phi^{-j}$ and $d\mu = d\mu^j = d\mu^{-j}$

If $\phi^j = \phi^{-j} = \phi$ and $\mu^j = \mu^{-j} = \mu$,

$$\frac{\partial \mathcal{V}^F}{\partial \phi} = -\sum_j \left(\sigma(s_{ej}^j + s_{ej}^{-j}) + \lambda^F \gamma_x\right) x_1^j$$

$$\frac{\partial \mathcal{V}^F}{\partial \mu} = -\sum_j \left(\sigma(s_{ej}^j + s_{ej}^{-j}) + \lambda^F \gamma_y\right) y_1^j$$

Differences with regional case:

- Federal government takes account of benefits of changes in emissions in one region on social disutility in other
- Federal evaluation of disutility of emissions discounted by $\sigma$
- Federal government incurs higher tax collection costs, $\gamma_x$, $\gamma_y$

# Discrete Emissions Technology Changes

First-order approximation to change in $\mathcal{V}(\cdot)$ in unitary nation:

$$\Delta\mathcal{V}_x \approx -(\bar{s}_e + \bar{\lambda}\gamma_x)\Delta e_x, \qquad \Delta\mathcal{V}_y \approx -(\bar{s}_e + \bar{\lambda}\gamma_y)\Delta e_y$$

where $\Delta e_x = \Delta(\phi x_1) < 0$, $\Delta e_y = \Delta(\mu y_1) < 0$ in green transition

- $\Delta\mathcal{V}_x(\Delta\mathcal{V}_y)$ increasing in number of households (dirty firms)
- Green transition beneficial if $\Delta\mathcal{V}_x > k_x, \Delta\mathcal{V}_y > k_y$
- Government temporary inducement necessary

# Implications for Environmental Policy Assignment

Incentive for regions to adopt green technologies lower than for the federal government, especially with more regions

Federal decision-making spans more agents so leads to correspondingly larger net social benefits than regions

Decentralization policy could lead to inefficient brown equilibrium

# Concluding Remarks

## Key features of our approach

- Emissions depend on both consumption and production, and upon emissions technologies
- Current emissions are given, household choices based on private utility
- Government choices determined by private plus social disutility of emissions based on social norms/altruism/solidarity
- Policy choices include emissions pricing (taxes) and emissions technology control (regulation)
- Optimal policies reflect social disutility and do not depend on general equilibrium effects
- Optimality based on social disutility rather than worldwide private disutility from global warming

# Differences in Federal vs. Regional Responsibility

- Federal policies endogenize benefits of emissions pricing and regulatory policies across regions
- Social disutility effects are stronger if regional governments responsible: higher social cohesion
- Federal government has advantage in investing in green technologies due to benefits rising with number of consumers and producers
- Federal government incurs higher costs of collecting emissions tax revenues since regions better informed
- Regions can choose different emissions prices to reflect social disutility differences

Overall, federal control could lead to lower or higher emissions than regional control

# Extensions

- More than two regions
- Interregional equity considerations and equalization
- Endogenous traded goods prices
- Responsibilities shared by federal and regional governments: consumption versus production emissions, emissions versus green transition
- Federal-regional environmental co-jurisdiction with policy harmonization
- Incorporate policy dynamics into analysis
  - Green transition (van der Ploeg-Venables, Persson-Tabellini)
  - Green paradox (Sinn)
  - Intergenerational effects (Stern)