The Unilateral Implementation of a Sustainable Growth Path with Directed Technical Change

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Introduction & Motivation

‣ Unilateral climate policy

  ‣ EU emission trading scheme; California's Global Warming Solutions Act; Germany's Energiewende

  ‣ Carbon leakage (Hoel, 1996; Babiker, 2005; Burniaux & Martins, 2012)

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▶ Unilateral climate policy

  ▸ EU emission trading scheme; California's Global Warming Solutions Act; Germany's Energiewende

  ▸ Carbon leakage (Hoel, 1996; Babiker, 2005; Burniaux & Martins, 2012)

→ Static analysis, given technology (path)

▶ Yet technological change is endogenous

  ▸ Changes in structure of production affect innovation decisions

Introduction & Motivation

A simple line of reasoning

- Innovation is profit-driven

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A simple line of reasoning

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- Unilateral policies (UP) cause carbon leakage
  - → UP increase the size of polluting sectors in nonparticipating countries
  - → UP encourage innovation in polluting sectors in these countries?

Introduction & Motivation

A simple line of reasoning

▸ Innovation is profit-driven

▸ Unilateral policies (UP) cause carbon leakage

→ UP increase the size of polluting sectors in nonparticipating countries

→ UP encourage innovation in polluting sectors in these countries

▸ Dynamic leakage: carbon leakage is worsened in the long run?

Introduction & Motivation

Research questions

- (How) can unilateral policies implement sustainable growth?
  - When is growth sustainable?
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Research questions

- (How) can unilateral policies implement sustainable growth?
    - When is growth sustainable?
    - How does unilateral policy affect production and innovation in nonparticipating countries?
- Will a myopic social planner implement sustainable growth?
- What (coalitions of) countries can implement sustainable growth?

Previous Literature

▸ Directed technical change

　▸ Acemoglu (1998, 2002)

▸ and the environment

　▸ Newell et al. (1999), Popp (2002), Aghion et al. (2012)

　▸ Jaffe et al. (2005), Gerlagh et al. (2009), Acemoglu et al. (2012)

▸ DTC and unilateral env. policy

　▸ Golombek & Hoel (2004), Di Maria & Smulders (2005), Gerlagh & Kuik (2007), Di Maria & van der Werf (2008), Hemous (2012).

Model overview
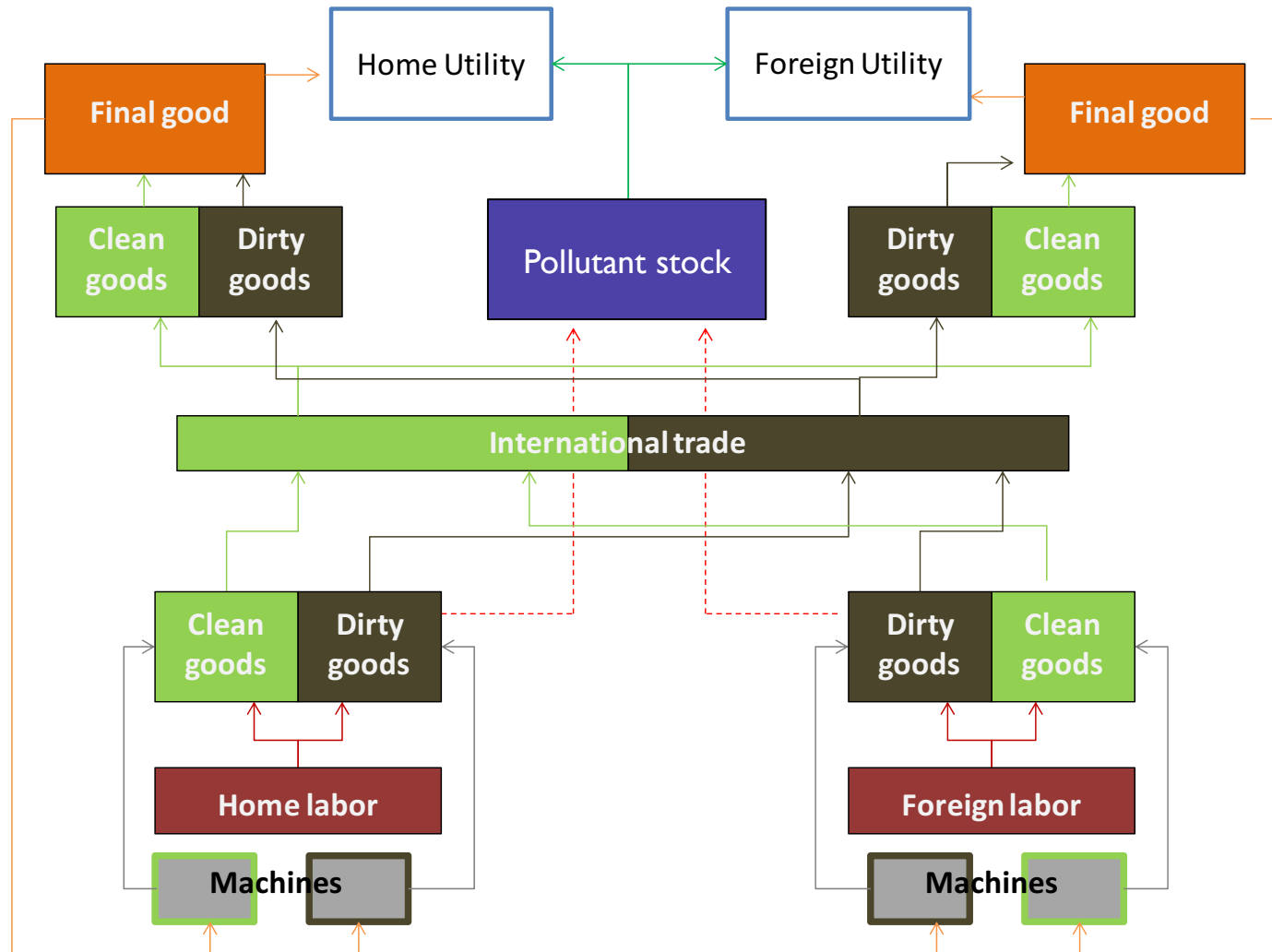
Model overview
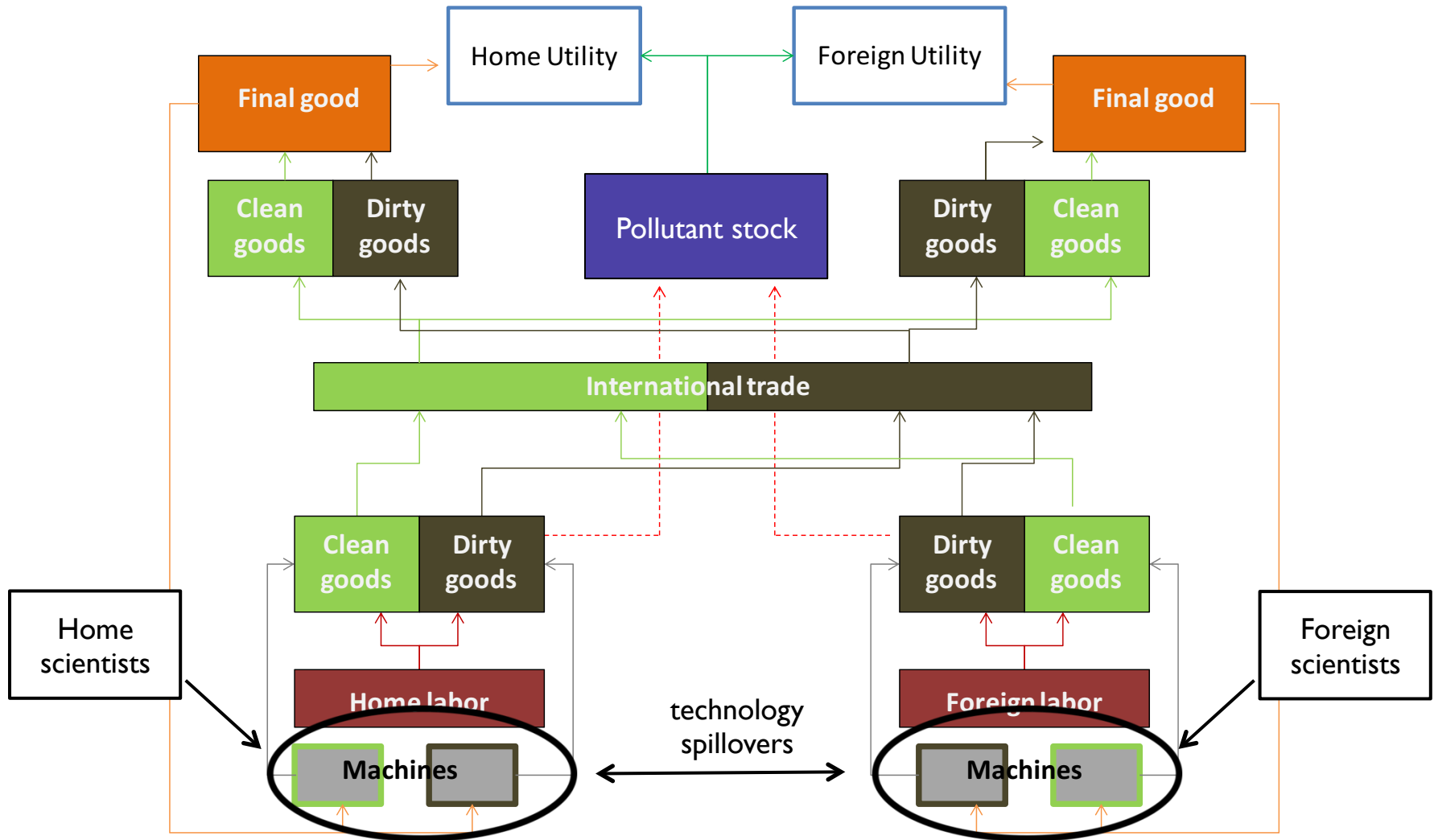
Model overview

- Preferences

$$U_{kt} = u\left(\mathbf{c}_{kt^+}, \mathbf{E}_{t^+}\right)$$

$$\lim_{E_v \to \bar{E}} u\left(\mathbf{c}_{kt^+}, \mathbf{E}_{t^+}\right) = -\infty \ for \ v \geq t$$

- Final output

$$Y_{kt} = \left(Y_{kct}^{\frac{\varepsilon-1}{\varepsilon}} + Y_{kdt}^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}$$

- Intermediates production

$$\tilde{Y}_{kjt} = L_{kjt}^{1-\alpha-\beta} \int_0^1 A_{jit}^{1-\alpha} x_{kjit}^a \, di$$

- Machine production & profits

$$\pi_{kjit} = x_{kjit}\left(p_{kjit} - \psi p_{kt}\right)$$

$$k \in \{h, f\}$$

$$\mathbf{c}_{kt^+} \equiv \{c_{kt}, c_{kt+1}, ..., c_{kt+\infty}\}$$

$$\mathbf{E}_{t^+} \equiv \{E_t, E_{t+1}, ..., E_{t+\infty}\}$$

$$\varepsilon = el. \, of \ substitution$$

$$\varepsilon > 1 \rightarrow substitutes$$

$$j \in \{c, d\}$$

$$\alpha, \beta \in (0,1), \alpha + \beta < 1$$

$$A_{hjit} = A_{fjit} = A_{jit}$$

$$\psi > 0$$

Model overview

▸ **Environment**

$$E_{t+1} = f\left(\tilde{\mathbf{Y}}_{dt^-}^W\right)$$

$$\tilde{\mathbf{Y}}_{dt^-}^W \equiv \left\{\tilde{Y}_{dt}^W, \tilde{Y}_{dt-1}^W, \ldots, \tilde{Y}_{dt-\infty}^W\right\}$$

$$\tilde{Y}_{dt}^W \equiv \tilde{Y}_{hdt} + \tilde{Y}_{fdt}$$

▸ **Growth**

$$A_{jt} = \left(1 + \gamma z s_{jt}^W\right) A_{jt-1}$$

$$A_{jt} \equiv \int_0^1 A_{jit} di$$

$$\gamma z > 0$$

$$s_{jt}^W \equiv s_{hjt} + s_{fjt}$$

▸ **Intermediate goods market clearing and balance trade**

$$\tilde{Y}_{jt}^W = Y_{jt}^W$$

$$Y_{dt}^W \equiv Y_{hdt} + Y_{fdt}$$

$$p_{ct}\left(Y_{kct} - \tilde{Y}_{kct}\right) + p_{dt}\left(Y_{kdt} - \tilde{Y}_{kdt}\right) = 0$$

▸ **Labor and scientist clearing**

  ▸ Labor and scientists are mobile across sectors – move to sector with greatest return

$$L_k = L_{kct} + L_{kdt}$$

$$s_k = s_{kct} + s_{kdt}$$

Policy tools

▸ Intermediate *input* tax (consumption tax)

▸ Intermediate *output* tax (production tax)

▸ Innovation subsidy

▸ All tools can be employed in both sectors

▸ Assume the foreign country does not use any

Results
Effects of unilateral policies on foreign

▸ Unilateral policies affect foreign through the equilibrium world prices

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Effects of unilateral policies on foreign

▸ Unilateral policies affect foreign through the equilibrium world prices

▸ Suppose unilateral policies increase the equilibrium world price of dirty intermediates relative to clean

 1. foreign increases dirty output and becomes a dirty intermediate exporter (static leakage) (Lemma 1)

 2. foreign scientists have a greater incentive to innovate in the dirty sector (dynamic leakage) (Lemma 2)

Results
Requirements for sustainable growth

▸ **Remember:** $\lim\limits_{E_\nu \to \bar{E}} u\left(\mathbf{c}_{kt^+}, \mathbf{E}_{t^+} \right) = -\infty$ *for* $\nu \geq t$

▸ **Sustainable growth:** $E_\nu < \bar{E}$ **for all** ν

  ▸ Assumption: in laissez-faire, all innovation will be in dirty

   → dirty output will grow, so will the emission stock: unsustainable!

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Requirements for sustainable growth

- **Remember:** $\lim\limits_{E_v \to \bar{E}} u\left(\mathbf{c}_{kt^+}, \mathbf{E}_{t^+}\right) = -\infty$ *for* $v \geq t$
- **Sustainable growth:** $E_v < \bar{E}$ for all v
  - Assumption: in laissez-faire, all innovation will be in dirty
    - → dirty output will grow, so will the emission stock: unsustainable!

Sustainable growth requires (Lemma 3)

- foreign to 'voluntarily' abandon dirty consumption growth
  - If clean and dirty inputs are good substitutes
  - If the clean input becomes sufficiently cheap relative to dirty
    - If more innovation in the clean than in the dirty sector $s_{ct}^{W} > s_{dt}^{W}$
- sufficient room to maneuver (large $\bar{E}$)

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Can home unilaterally implement sustainable growth?

▸ Suppose we meet the substitutability requirement and $\bar{E}$ is large enough

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Results
Can home unilaterally implement sustainable growth?

▸ **Suppose we meet the substitutability requirement and $\bar{E}$ is large enough**

▸ **How to implement $s_{ct}^W > s_{dt}^W$?**

  ▸ If $s_h > s_f$: easy, subsidize home scientists (Prop. 1)

  ▸ If $s_h \leq s_f$: redirect *foreign* scientists to the clean sector

    ▸ Increase the price of *clean* intermediates → foreign expands its clean sector → encourages clean innovation in foreign

    ▸ More likely feasible if

      ☐ Home represents a large share of global demand: large L_h / L_f

      ☐ The clean sector was already relatively large to begin with: large A_c / A_d

  (Prop. 2)

Results
How smart need our social planner be?

Suppose we deal with a 'myopic' policymaker

▸ Believes technical change is exogenous

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… and thereby always increase the incentive of foreign scientists to innovate in the dirty sector… (Prop. 3)

… which, if $s_h \leq s_f$ will not implement sustainable growth. (Cor. 1)
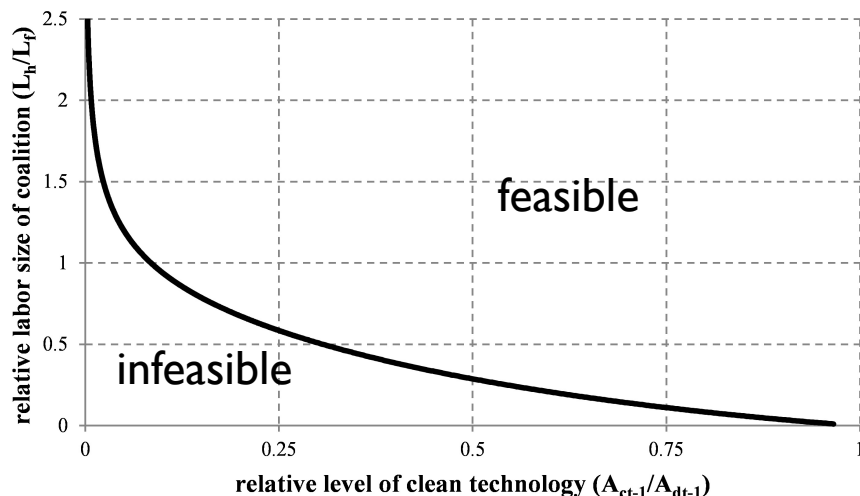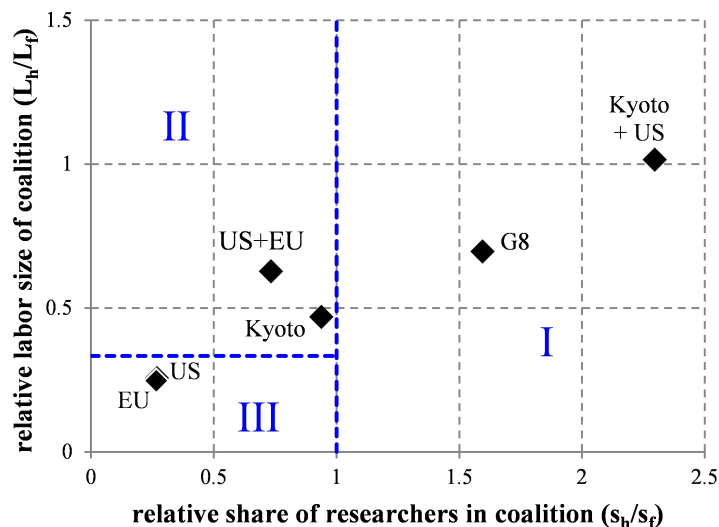
Results
A simple calibration exercise

What coalitions can implement sustainable growth? And what tax rates would that require?

- ▸ Calibration in line with Acemoglu et al (2012), with lowest el. of substitution (3).

Minimum country size for implementing sustainable growth if $s_h \leq s_f$

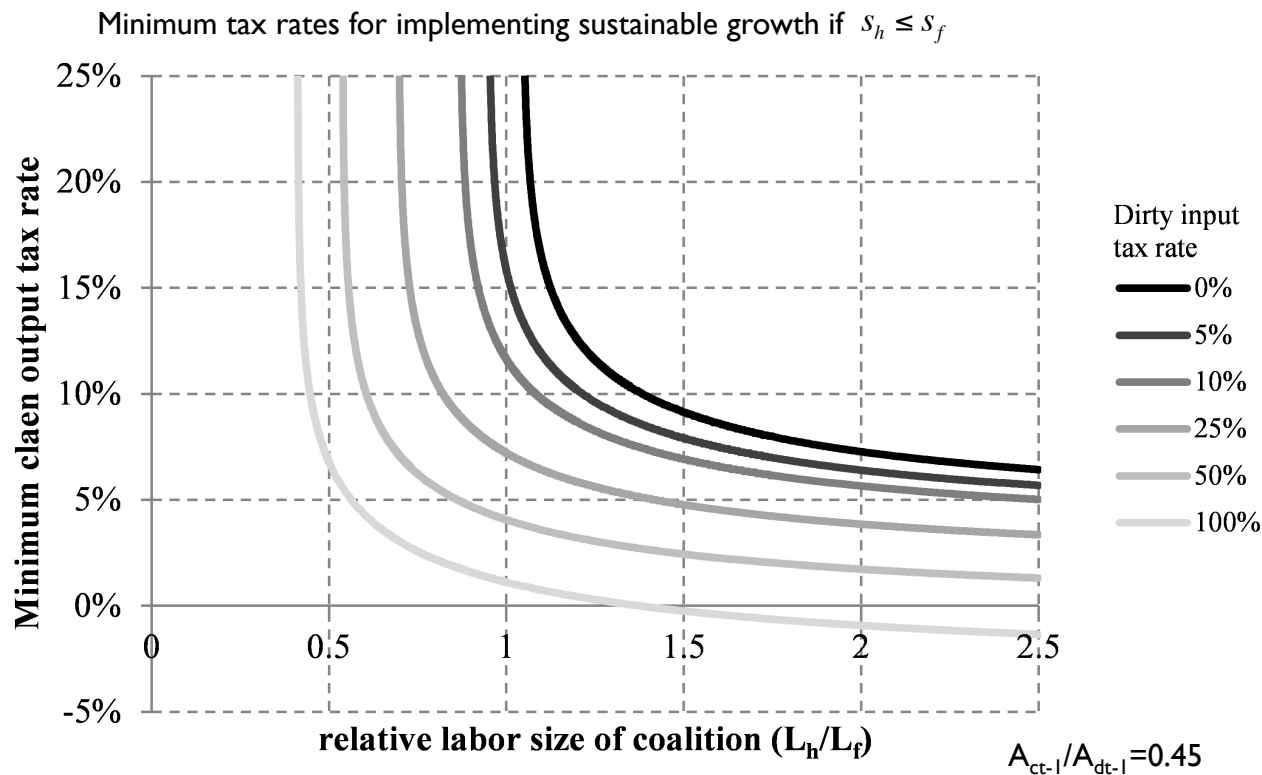Coalitions that can implement sustainable growth

A_{ct-1}/A_{dt-1}=0.45

Results
A simple calibration exercise

What coalitions can implement sustainable growth? **And what tax rates would that require?**

Minimum tax rates for implementing sustainable growth if $s_h \leq s_f$

Y-axis: **Minimum claen output tax rate** (25%, 20%, 15%, 10%, 5%, 0%, -5%)

X-axis: **relative labor size of coalition (L_h/L_f)** (0, 0.5, 1, 1.5, 2, 2.5)

Dirty input tax rate:
- 0%
- 5%
- 10%
- 25%
- 50%
- 100%

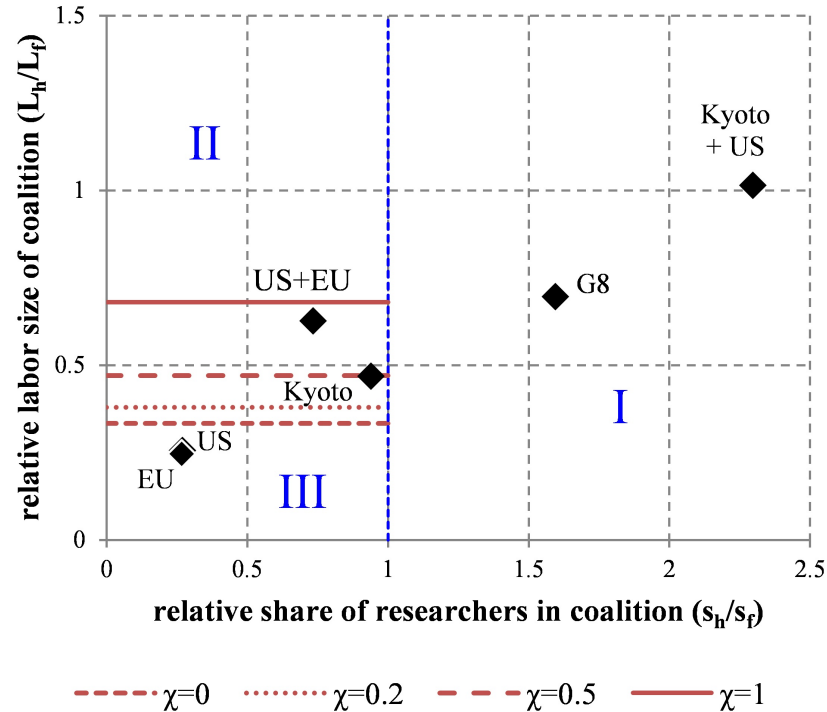$A_{ct-1}/A_{dt-1}=0.45$

Note: 100% tax corresponds to 160-2000 $/tCO2

Discussion

- Assumptions are strong:
  - Innovation dependent on domestic profit incentives only
    - Location of production no longer important with perfect international property rights
    - More likely: intermediate case where domestic incentives matter most
    - Either case: sustainable growth <u>harder</u> to achieve
      - Flip side of shifting clean production to foreign = shifting dirty production to home

Discussion – imperfect property rights

▸ Suppose innovators recoup a share χ of foreign profits

  ▸ How does this affect the coalitions required?

Discussion

- ## Assumptions are strong:
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  - Full & immediate technology spillovers
    - If none: <u>have to</u> encourage clean innovation in foreign
    - If some: long-run direction of innovation still determined by largest scientist mass

Conclusion & Discussion

‣ Unilateral policies that increase the price of the dirty good cause

- ‣ Static leakage – increased dirty output in foreign
- ‣ Dynamic leakage – increased dirty innovation incentives in foreign

‣ If foreign innovation drives global growth, such policies will not implement sustainable growth

- ‣ Policy should focus on redirecting foreign scientists to the clean sector
- ‣ Requires home to reduce the price of dirty intermediates and become a dirty good exporter
- ‣ A myopic social planner never implements such policy.