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

Inge van den Bijgaart
Tilburg University

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)

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)

→ 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

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?

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?
  - How does unilateral policy affect production and innovation in nonparticipating countries?

Introduction & Motivation

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?

Introduction & Motivation

Research questions

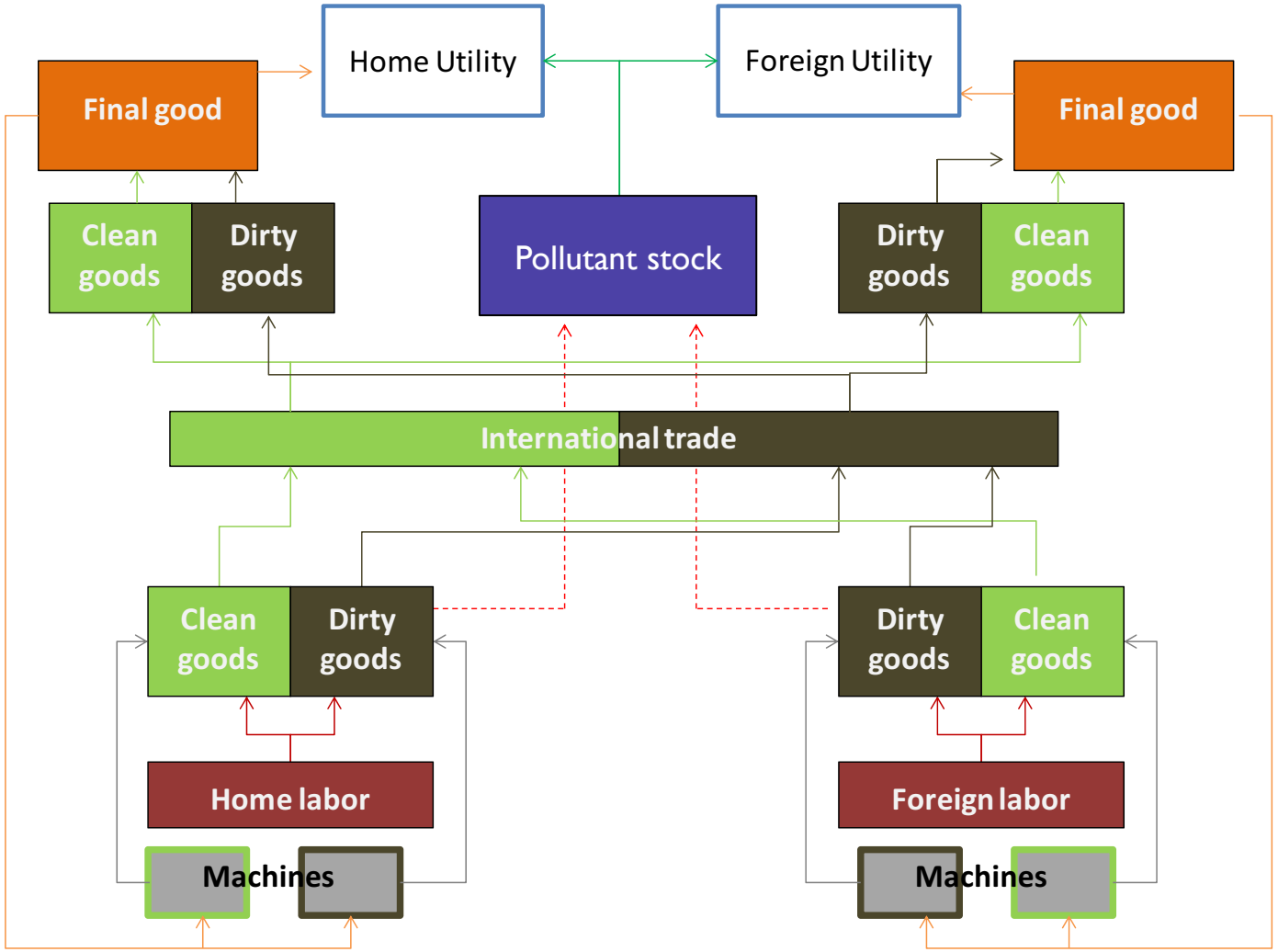
- (How) can unilateral policies implement sustainable growth?
  - When is growth sustainable?
  - How does unilateral policy affect production and innovation in nonparticipating countries?
- Will a myopic social planner implement sustainable growth?
- What (coalitions of) countries can implement sustainable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

Previous Literature

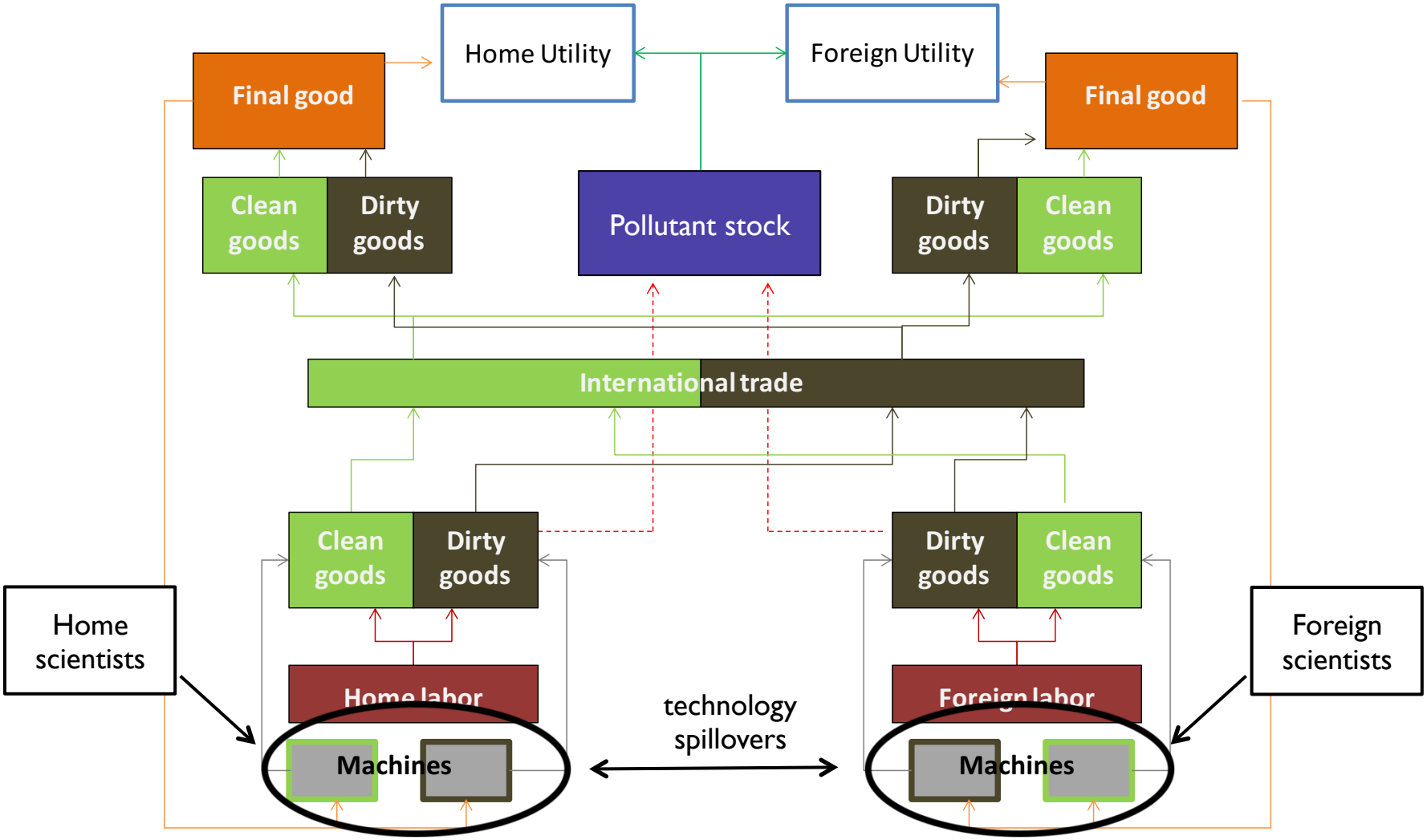
- Directed technical change
  - Acemoglu (1998, 2002)
- and the environment
  - Newell et al. (1999), Popp (2002), Aghion et al. (2012)
  - Jaffe et al. (2005), Gerlagh et al. (2009), Acemoglu et al. (2012)

- 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

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

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

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

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

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

$$\varepsilon > 1 \rightarrow substitutes$$

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

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

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

$$\psi > 0$$

Model overview

- Environment

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

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

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

- Growth

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

$$A_{jt} \equiv \int_{0}^{1} A_{jit}\, di$$

$$\gamma z > 0$$

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

- Intermediate goods market clearing and balance trade

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

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

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

- 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

Results
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: $\lim_{E_\nu \to \bar{E}} u\left(\mathbf{c}_{kt^+}, \mathbf{E}_{t^+}\right) = -\infty \; for \; \nu \geq t$
- 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!

Results
Requirements for sustainable growth

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

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 $\bar{E}$)

Results

Can home unilaterally implement sustainable growth?

- Suppose we meet the substitutability requirement and $\bar{E}$ is large enough
- How to implement $s_{ct}^{W} > s_{dt}^{W}$?

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)

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

Results
How smart need our social planner be?

Suppose we deal with a 'myopic' policymaker

- Believes technical change is exogenous

The myopic policymaker will always implement policies that increase the price of *dirty* intermediates relative to clean…

Results
How smart need our social planner be?

Suppose we deal with a 'myopic' policymaker

- Believes technical change is exogenous

The myopic policymaker will always implement policies that increase the price of *dirty* intermediates relative to clean…

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

Results

How smart need our social planner be?

Suppose we deal with a 'myopic' policymaker

- Believes technical change is exogenous

The myopic policymaker will always implement policies that increase the price of *dirty* intermediates relative to clean…

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

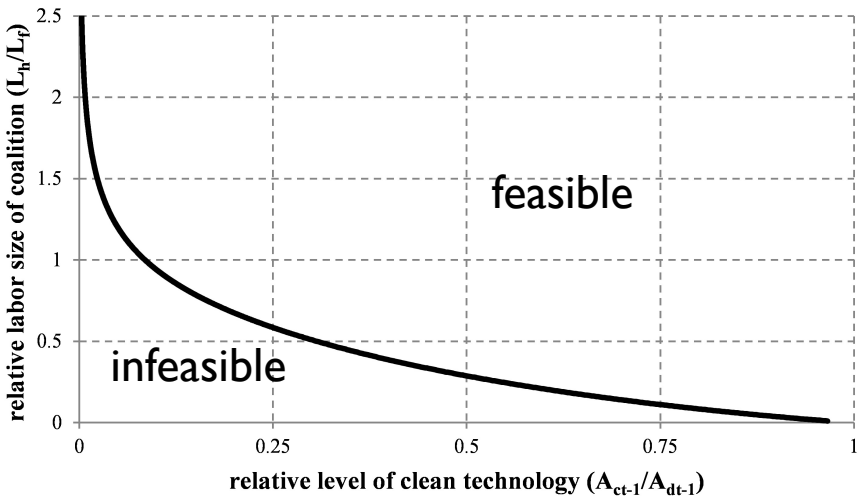
… which, if $s_h \leq s_f$ will not implement sustainable growth. (Cor. 1)

Results
A simple calibration exercise

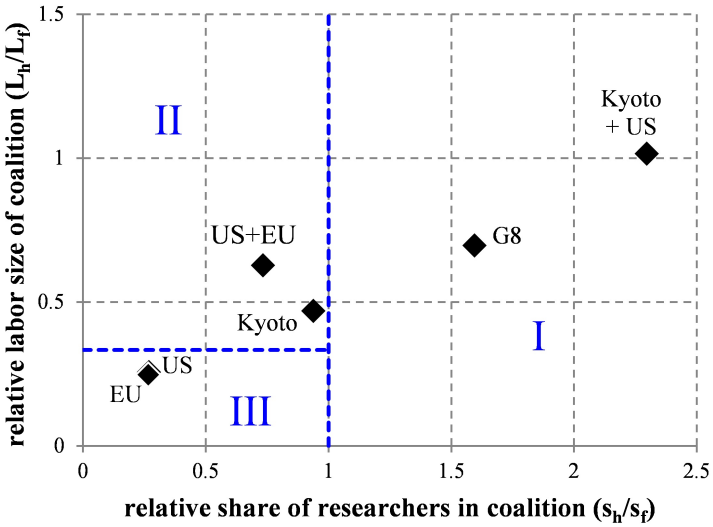
What coalitions can implement sustainable growth? And what tax rates would that require?

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

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



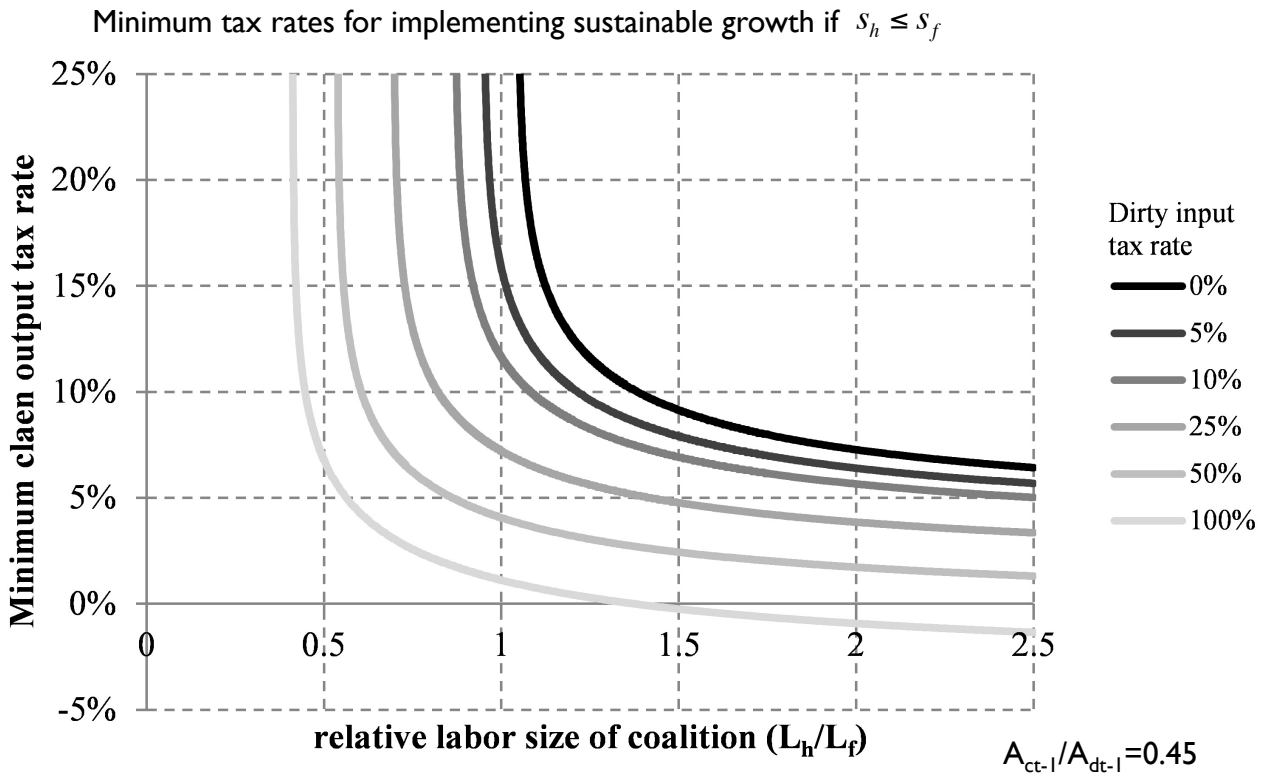
Coalitions that can implement sustainable growth



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?



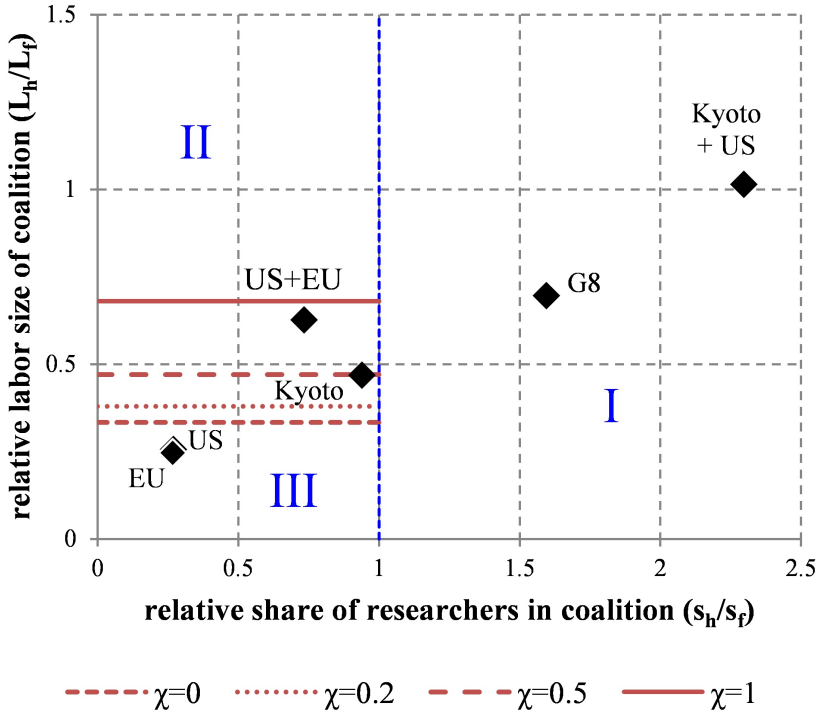
Note: 100% tax corresponds to 160-2000 $/tCO2

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 harder 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:
  - 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 harder to achieve
      - Flip side of shifting clean production to foreign = shifting dirty production to home
  - Full & immediate technology spillovers
    - If none: have to 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.