Greenhouse-Gas Emission Controls and International Carbon Leakage through Trade Liberalization

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Introduction

- Globalisation promotes free trade and high capital/labour mobility (footloose workers and firms)
- Recent environmental issues are global (trans boundary)
- Relationship between globalisation and global warming (GHG emissions) are controversial issue (Antweiler et al., 2001; Copeland and Taylor, 1995)
- Issue: Pollution Haven (carbon leakage by firm relocation) Sectoral difference (Ederington et al. 2005; Cole et al, 2010)

This paper

- This paper studies NEG model and emission policies
  - Impact of emission policies on location choice
  - Trade liberalisation impact on pollution haven, or carbon leakage by firm relocation
- Three sectors FC model
  - Two different manufacturing sectors: pollution intensive sector (D-sector) and less intensive sector (C-sector)
- Three emission policies
  - Emission tax
  - Emission quota
  - Emission standard
- Unilateral environmental policy
  - Only North take policies
- For simplicity (focus on location issue)
  - No North-South game structure

Main findings

- Pollution haven occurs under emission policies
- Trade liberalisation increases pollution haven
- Quota occurs spatial sorting
  - D-sector moves to South and C-sector moves to North
  - Less carbon leakage (polution haven) than other policies
- Dispersion force is larger in tax. Tax is the worst with small trade costs: All firms move to South. Complete carbon leakage.

Basic model

- Three sectors (A sector + Two manufacturing sectors, i.e. C-sector and D-sector)
- A sector (CRS, PC without trade costs)
- D and C sectors (monopolistic comp with trade costs and with emissions)
  - Dixit-Stiglitz type of Monopolistic comp
  - Iceberg type trade costs
  - Sectoral difference: Emission intensities: D-sector: $\gamma>1$ unit of GHG per production, C-sector: 1 unit of GHGs
- Different market size (North is bigger than South)

Standard FC Model

- Utility func

$$U = \mu \ln C + \mu \ln D + A - f(\chi + \chi^*),$$

$$C \equiv \left(nc^{1-1/\sigma} + n^* c_S^{1-1/\sigma}\right)^{1/(1-1/\sigma)}, \quad D \equiv \left(md^{1-1/\sigma} + m^* d_S^{1-1/\sigma}\right)^{1/(1-1/\sigma)}, \quad 1 > \mu > 0, \quad \sigma > 1$$

- Demand func

$$c = \frac{\mu p^{-\sigma} s}{np^{1-\sigma} + n^* p^{*1-\sigma}}$$

- Profit func:

$$\pi_C = \left(\frac{s}{\Delta_C} s + \frac{\phi(1-s)}{\Delta_C^*}\right)\frac{\mu}{\sigma} \quad \text{and} \quad \pi_C^* = \left(\frac{\phi s}{\Delta_C} + \frac{1-s}{\Delta_C^*}\right)\frac{\mu}{\sigma}$$

- Emissions:

$$\chi \equiv n(x + x^*) + m\gamma(y + y^*) = n\beta\left(\frac{s}{\Delta_C} + \phi\frac{1-s}{\Delta_C^*}\right) + m\beta\gamma\left(\frac{s}{\Delta_D} + \phi\frac{1-s}{\Delta_D^*}\right)$$

$$\chi^* \equiv n^*\beta\left(\phi\frac{s}{\Delta_C} + \frac{1-s}{\Delta_C^*}\right) + m^*\beta\gamma\left(\phi\frac{s}{\Delta_D} + \frac{1-s}{\Delta_D^*}\right),$$

- Eq
  - Profit eq:

$$\pi_C - \pi_C^* = \frac{\mu(1-\phi)}{\sigma}\left(\frac{s}{\Delta_C} - \frac{1-s}{\Delta_C^*}\right) = 0.$$

  - Firm share

$$n = m = \frac{1}{2} + \left(\frac{1+\phi}{1-\phi}\right)(s - \frac{1}{2})$$

  - Emissions

$$\chi_0 = \frac{(1+\gamma)(s-(1-s)\phi)}{1-\phi}, \quad \chi_0^* = \frac{(1+\gamma)(1-s-s\phi)}{1-\phi} \quad \text{and} \quad \chi_0^W = 1+\gamma.$$

No emission policies

- No emission policies
- Never affects cost (nor impact on prices)
- Eq is equivalent to the standard model
  - Gradual agglomeration in both sectors
  - All firms in both sectors make full agglomeration in North
- Gradually increasing global emissions

Emission Tax

Tax

- Tax (Only North) , t (per-unit emission tax)
  - C-sector in North $p = \frac{1+t}{1-1/\sigma}; \quad p^* = \frac{\tau(1+t)}{1-1/\sigma}.$
  - D-sector in North $p = \frac{1+\gamma t}{1-1/\sigma}; \quad p^* = \frac{\tau(1+\gamma t)}{1-1/\sigma}$
- Profit equalisation

$$\pi_C - \pi_C^* = \frac{\mu}{\sigma}\left(\frac{s}{\Delta_C} + \frac{\phi(1-s)}{\Delta_C^*}\right)(1+t)^{1-\sigma} - \frac{\mu}{\sigma}\left(\phi\frac{s}{\Delta_C} + \frac{1-s}{\Delta_C^*}\right) = 0 \quad \text{a}$$

$$\pi_D - \pi_D^* = \frac{\mu}{\sigma}\left(\frac{s}{\Delta_D} + \frac{\phi(1-s)}{\Delta_D^*}\right)(1+\gamma t)^{1-\sigma} - \frac{\mu}{\sigma}\left(\phi\frac{s}{\Delta_D} + \frac{1-s}{\Delta_D^*}\right) = 0.$$

- Eq

$$n = \frac{(1+t)^{1-\sigma}(s+\phi^2-s\phi^2)-\phi}{(1-\phi(1+t)^{1-\sigma})((1+t)^{1-\sigma}-\phi)} \quad \text{and} \quad m = \frac{(1+\gamma t)^{1-\sigma}(s+\phi^2-s\phi^2)-\phi}{(1-\phi(1+\gamma t)^{1-\sigma})((1+\gamma t)^{1-\sigma}-\phi)}$$

Tax (results)

- Full agglomeration in North with intermediate trade costs
- Full agglomeration in South with small trade costs
- D-sector is more likely to make agglomeration in South and less likely to make agglomeration in North.

Figure 1: Locational Equilibrium (Low Tax rates)

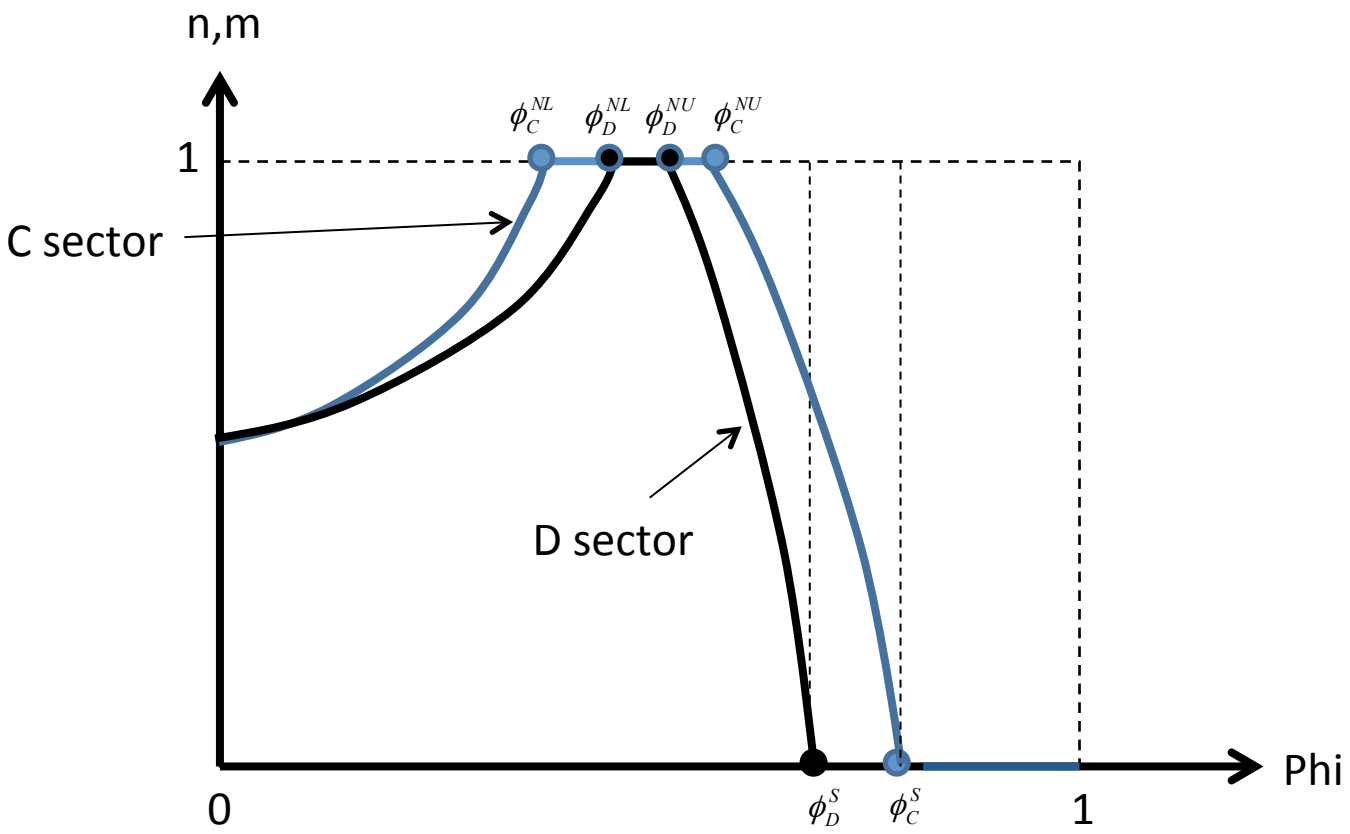


Figure 2: Locational Equilibrium (High tax rates)

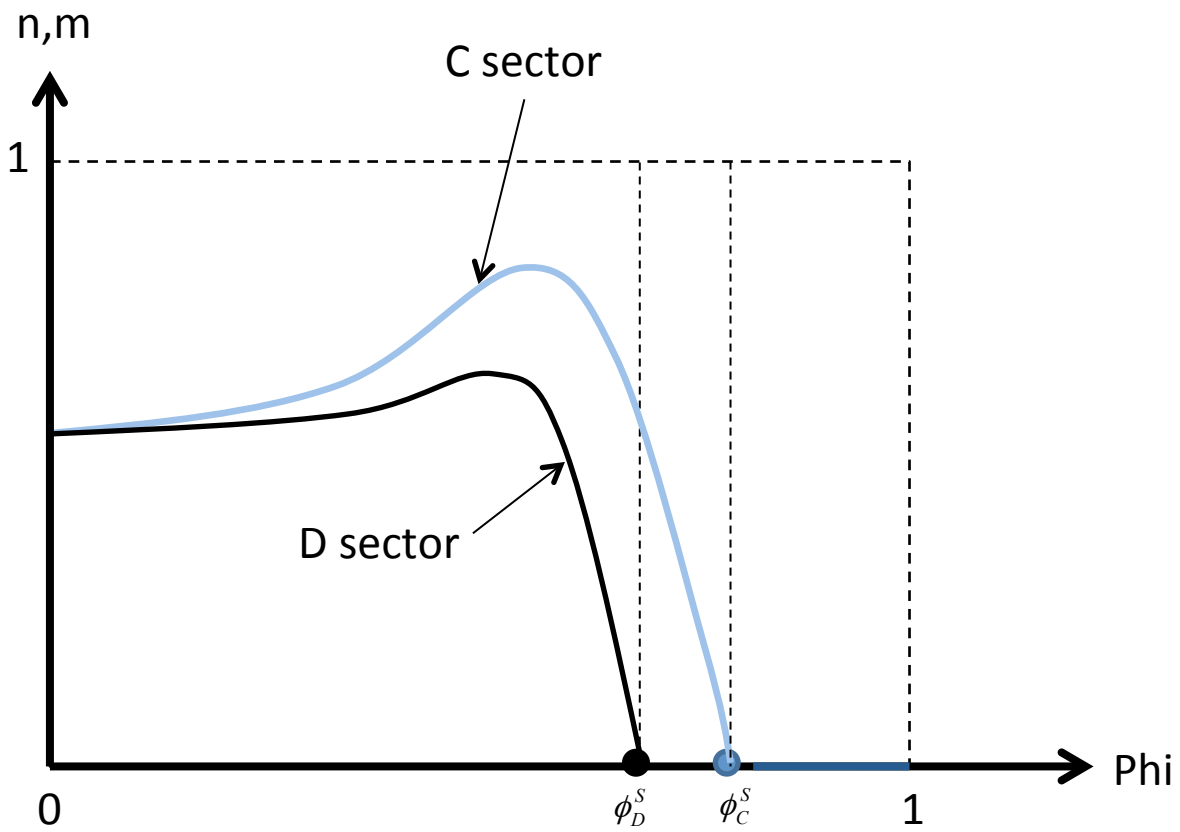
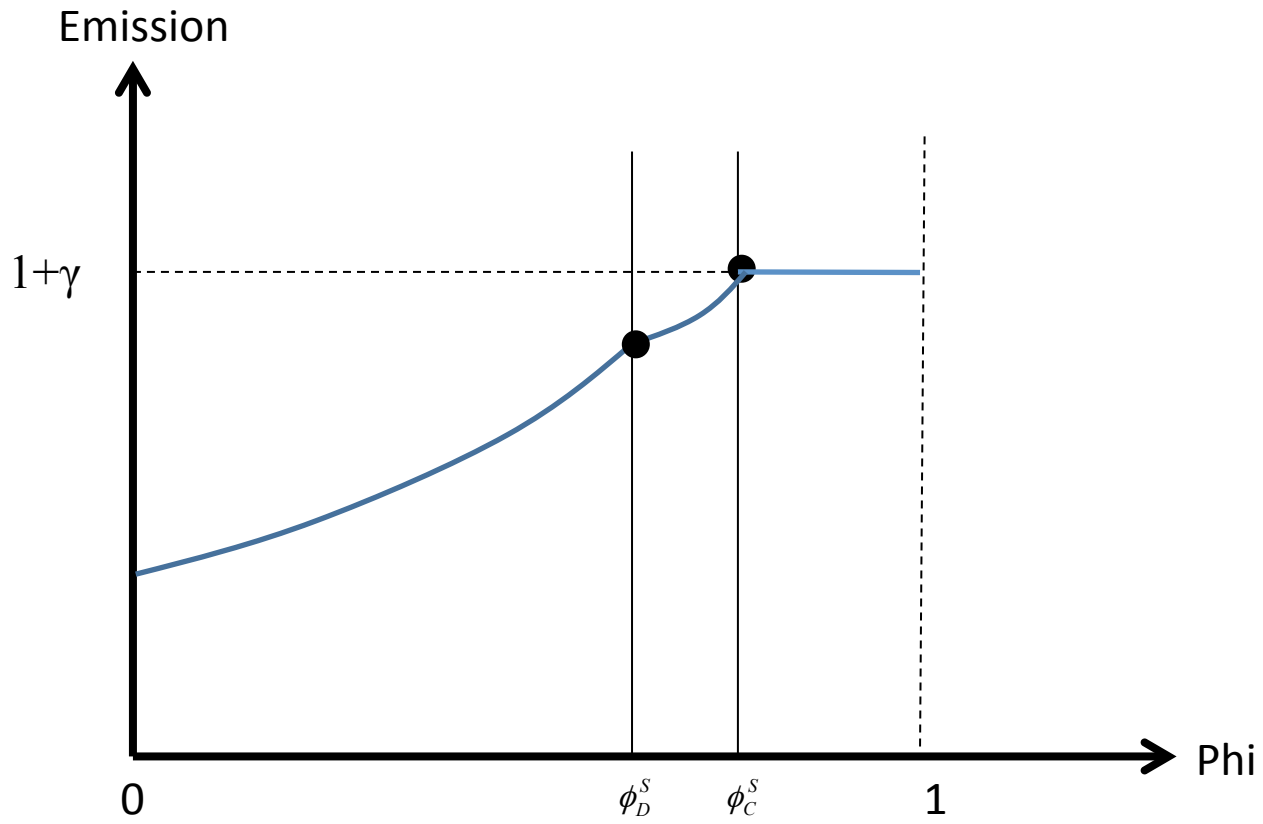


Figure 3: Global Emissions (tax)



Emission quota

Quota

- Quota (endogenously determined, q) in North
  - Given total Northern emission with quota market.
- C-sector and D-sector

$$p = \frac{1+q}{1-1/\sigma} \qquad p = \frac{1+\gamma q}{1-1/\sigma}$$

- Eq: profit eq plus "Quota constraint"

$$n\left(\frac{s}{\Delta_C} + \frac{\phi(1-s)}{\Delta_C^*}\right)(1+q)^{-\sigma} + \gamma m\left(\frac{s}{\Delta_D} + \frac{\phi(1-s)}{\Delta_D^*}\right)(1+\gamma q)^{-\sigma} - \overline{\chi} = 0,$$

$$\pi_C - \pi_C^* = \frac{\mu}{\sigma}\left(\frac{s}{\Delta_C} + \frac{\phi(1-s)}{\Delta_C^*}\right)(1+q)^{1-\sigma} - \frac{\mu}{\sigma}\left(\phi\frac{s}{\Delta_C} + \frac{1-s}{\Delta_C^*}\right) = 0,$$

$$\pi_D - \pi_D^* = \frac{\mu}{\sigma}\left(\frac{s}{\Delta_D} + \frac{\phi(1-s)}{\Delta_D^*}\right)(1+\gamma q)^{1-\sigma} - \frac{\mu}{\sigma}\left(\phi\frac{s}{\Delta_D} + \frac{1-s}{\Delta_D^*}\right) = 0$$

Figure 4: Locational Equilibrium (Quota)

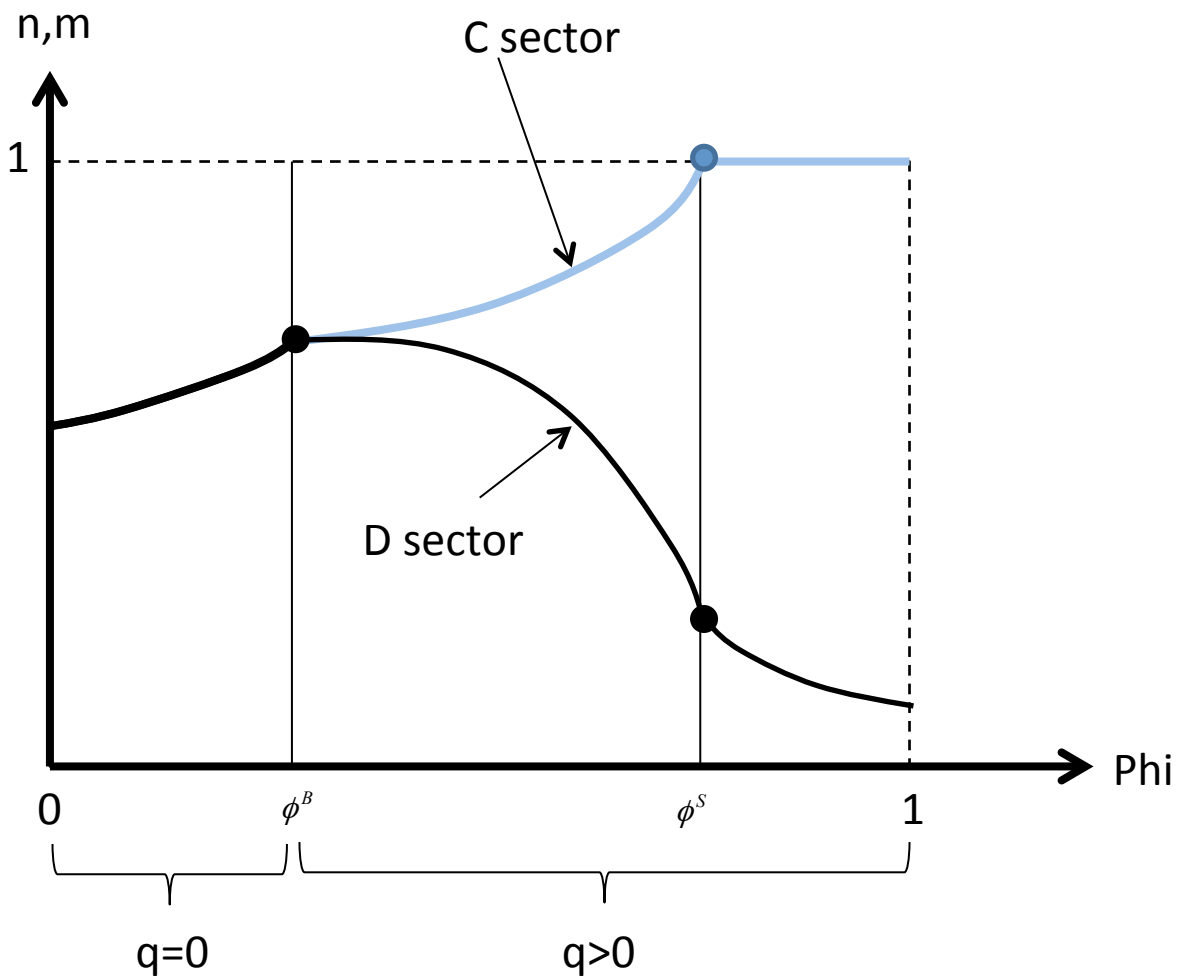


Figure 5: Quota prices

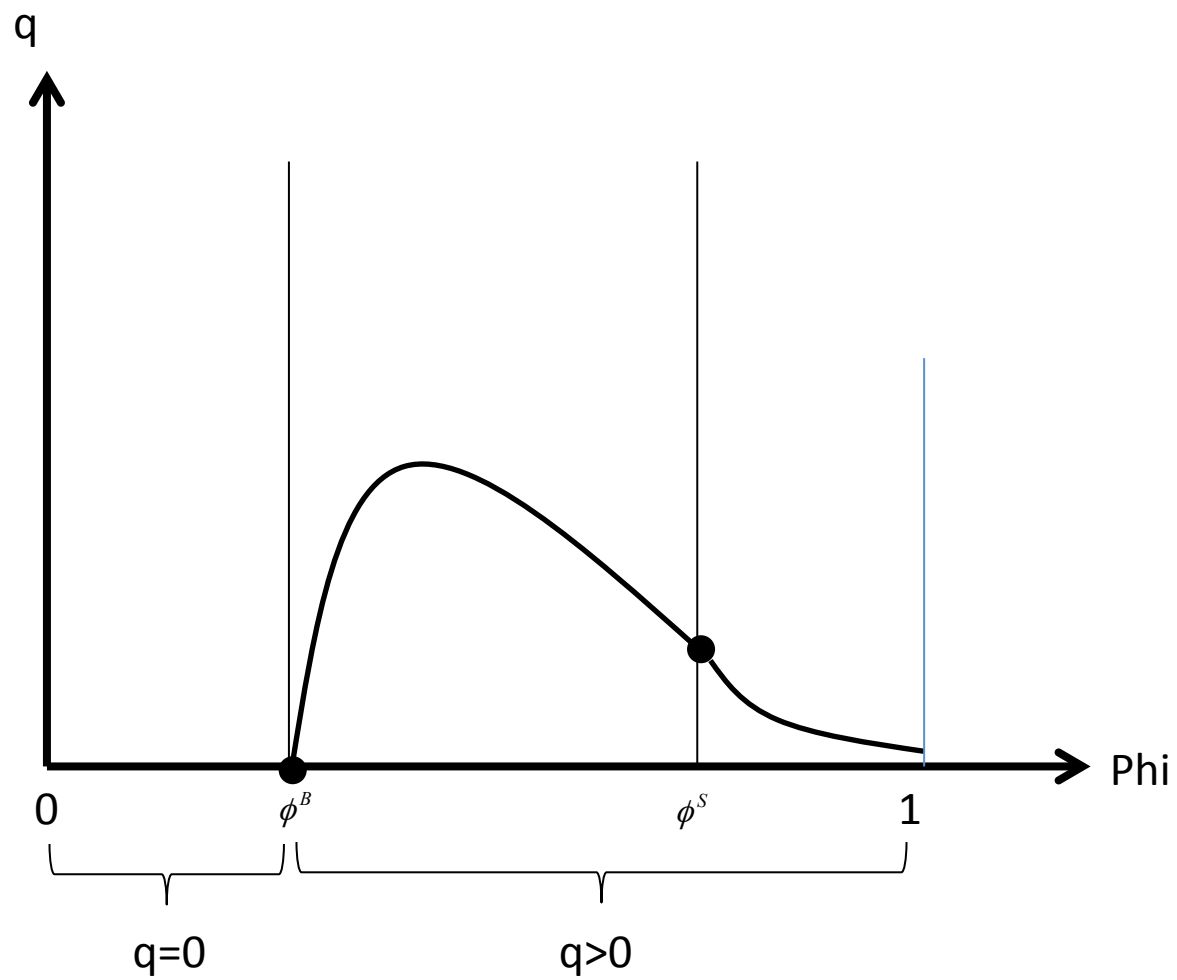
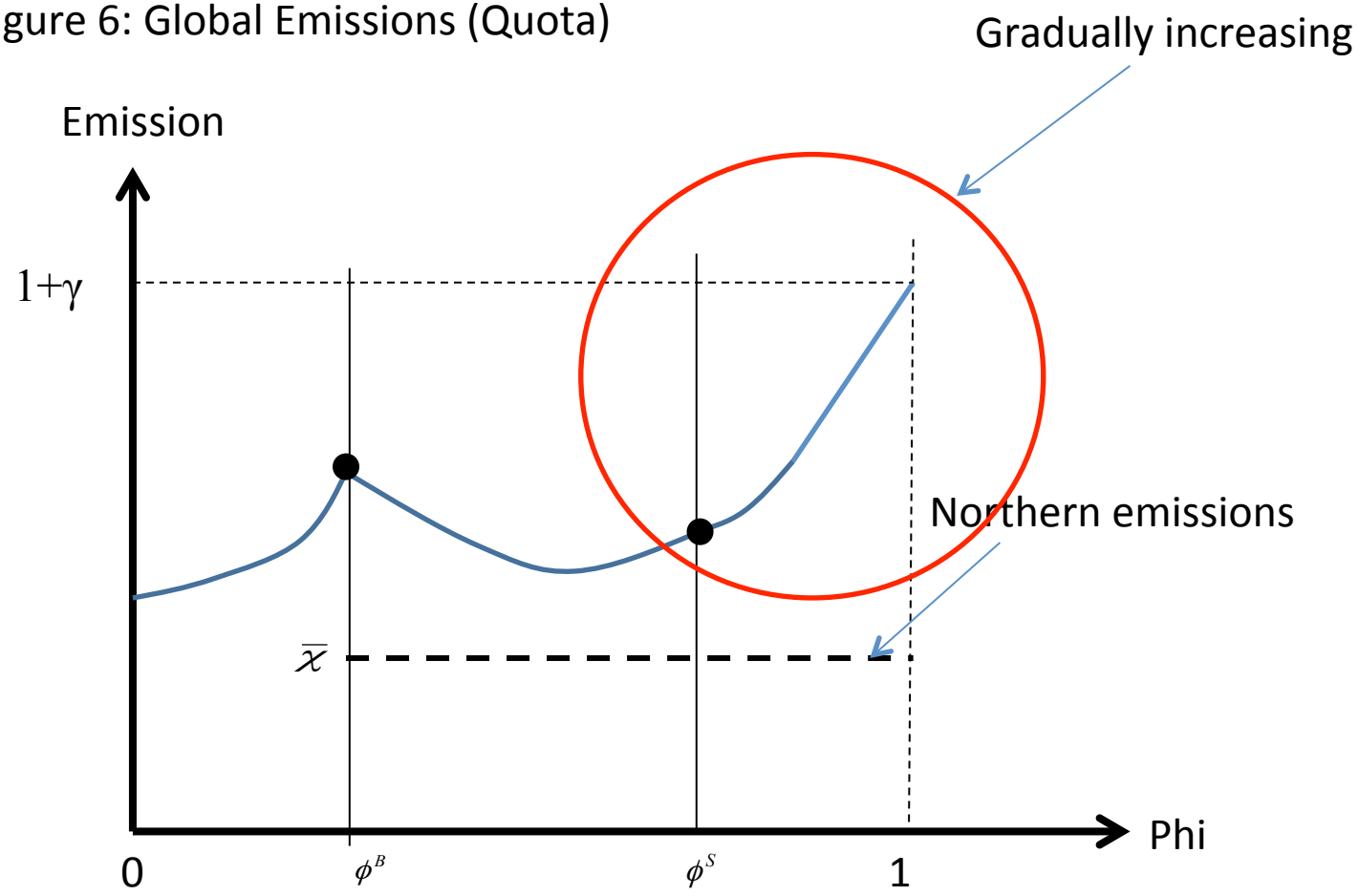
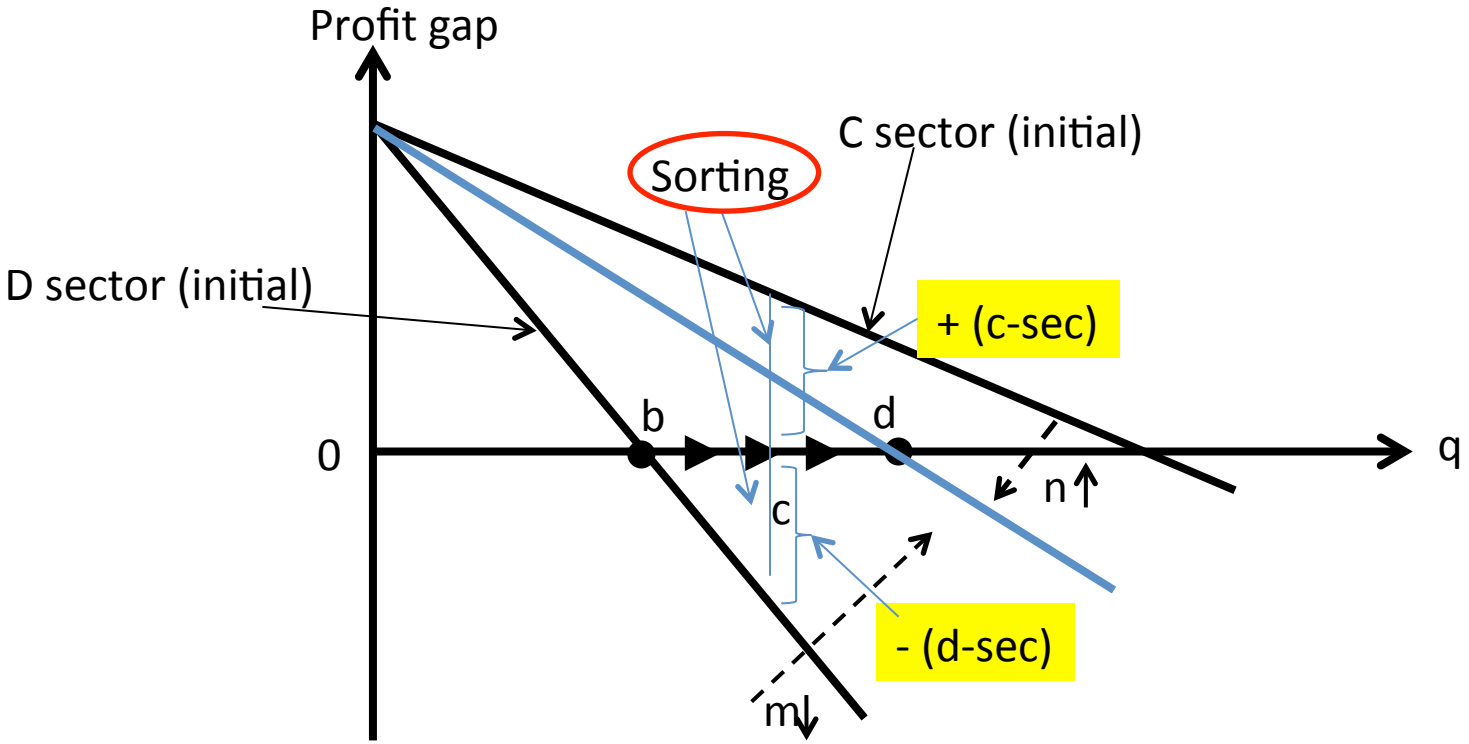


Figure 6: Global Emissions (Quota)



Marginal decline of “phi” ➡ Profit gap>0 ➡ Firm relocation ➡ New eq



Emission standard

Emission standard

- North sets a maximum unit of emissions
- Ass: Only D-sector is not satisfactory.
- D-firms are required to pay abatement costs (b>1) so as to satisfy the standard

$$(21)\quad \pi_C - \pi_C^* = \frac{\mu}{\sigma}\left(\frac{s}{\Delta_C} + \frac{\phi(1-s)}{\Delta_C^*}\right) - \frac{\mu}{\sigma}\left(\phi\frac{s}{\Delta_C} + \frac{1-s}{\Delta_C^*}\right) = 0,$$

$$(22)\quad \pi_D - \pi_D^* = \frac{\mu}{\sigma}\left(\frac{s}{\Delta_D} + \frac{\phi(1-s)}{\Delta_D^*}\right)b^{1-\sigma} - \frac{\mu}{\sigma}\left(\phi\frac{s}{\Delta_D} + \frac{1-s}{\Delta_D^*}\right) = 0$$

Figure 7: Locational Equilibrium (Emission standard)

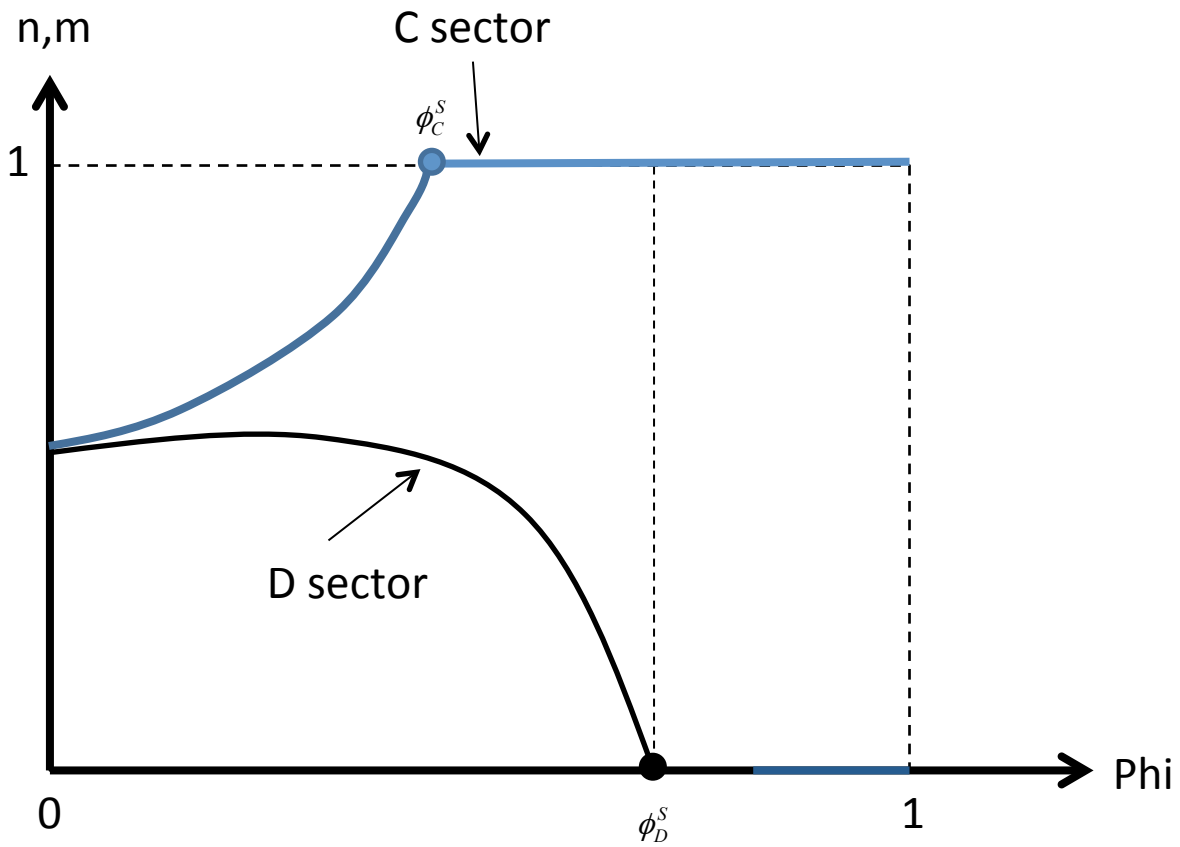
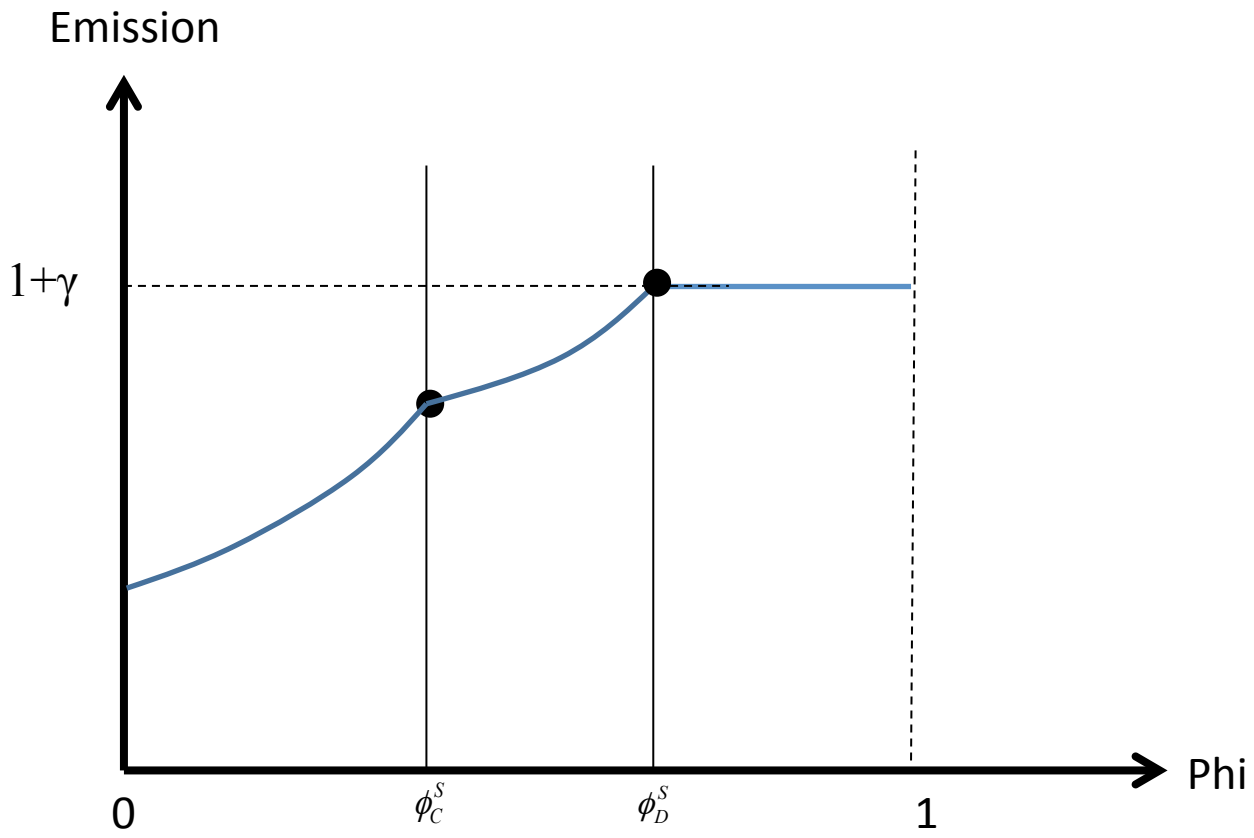


Figure 8: Global Emissions (emission standard)



Welfare implications

- Social welfare function

$$V \equiv Y^W + s\frac{\mu}{\sigma-1}(\ln\Delta_C + \ln\Delta_D) + (1-s)\frac{\mu}{\sigma-1}(\ln\Delta_C^* + \ln\Delta_D^*) - f(\chi+\chi^*).$$

- FC model without any policies: ¨socially optimal" (Baldwin et al 2003)
- Our model has two twists: one is emission policy (tax, quota and standard) (which affects location patterns) and the other is global emissions
- Difficulty: unsolvable outcomes (e.g. quota prices) and case by case (many variables, emission intensities, disutility of emissions, etc).

Location patterns

- Standard FC model: bigger market should have more firms
- More firms in North is better.
  - Quota and Standard are better
  - All in South in case of tax

Global emissions

- Global emissions should be lower
- Pollution haven should be minimised
- North (under regulations) should have more firms
  - With small trade costs
    - Quota is better (All C-firms plus some D-firms)
    - Standard (All C-firms)
    - Tax (No firms in North)

Conclusions

- Environmental policies with free relocation results in carbon leakage
- Trade liberalisation increases carbon leakage
- Different policies affect different location patterns. Different emission levels
- Quota softens pollution haven. In this sense, quota is better policy.