Environmental Standards, Quality of Vertically Differentiated Products, and the Global Environment

June 12, 2009

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☐ Outline

1) Motivation, Purpose ---
2) The Model
3) Equilibria (Cournot duopoly case)
4) Quality of Products, and the Environment
   (Cournot duopoly case)
5) Equilibria (Bertrand duopoly case)
6) Quality of Products, and the Environment
   (Bertrand duopoly case)
7) Endogenous Choice of Types of Products
8) Concluding Remarks

1. Motivation

☐ Background

- There are various kinds of standards on consumption-related emissions and health problems.
- Since the strictness of standards in one country is different from that in other countries, firms have to comply with various types of regulations if they supply their products more than one country.
- It is possible that a change in an emission standard in one country influences the other countries' markets, and that the effect of the change on the domestic market is different from that on the foreign markets.

☐ Purpose

- Focusing on the emission in the consumption process, this paper investigates the effect of a unilateral change in emission standard of one country (=home country) on the qualities of products, aggregate emissions, and welfare of both domestic and foreign countries.

Related Literature

- Environmental policies in an open economy when pollution is emitted in the production process. → Conrad (1993), Kennedy (1994), Ulph (1996, 1999), Rauscher (1997), Neary (2006).
- Environmentally differentiated products with heterogeneous consumers in terms of environmental consciousness.

  → Moraga-González and Pandrón-Fumero (2002), Toshimitsu (2008a, 2008b).
- Other related literature.
- → Markusen (1993, 1997), Ulph and Valentini (1997).

Features

- Environmentally differentiated products with heterogeneous consumers in terms of environmental consciousness.
- Bertrand duopoly and Cournot duopoly.
- The firm that produces dirtier products may produce two types of dirtier products. (Either one of two types is supplied to either of home and foreign markets.)

Main Results

- When firms compete with each other in a Cournot fashion, as a emission standard by the home country becomes stricter, aggregate emissions of both domestic and foreign countries decrease, if the firm which produces a ‘dirtier product’ supplies the same product to both domestic and foreign markets.

- On the other hand, if the firm supplies different products in environmental features to different markets, the stricter emission standard by the home country increases the aggregate emission of the foreign country.

- Even in the Bertarnd duopoly case, the effect of a strict emission standard on both countries could be different from each other.

- Moreover, endogenous determination of the numbers of types produced by the dirtier firm in the Cournot duopoly case is different from that in the Bertrand duopoly case.

2. The Model

Markets and consumers

- There are two countries: the home country, which is denoted by h , and the foreign country, which is denoted by f .
- There exists a continuum of heterogeneous consumers who differ in their marginal valuations, θ , of the green features of a product.
- To simplify, we assume that the distribution of consumers of both countries are identical, and that the consumer-matching value is uniformly distributed in the market in each country, $\theta \in [0,1]$.

Utility

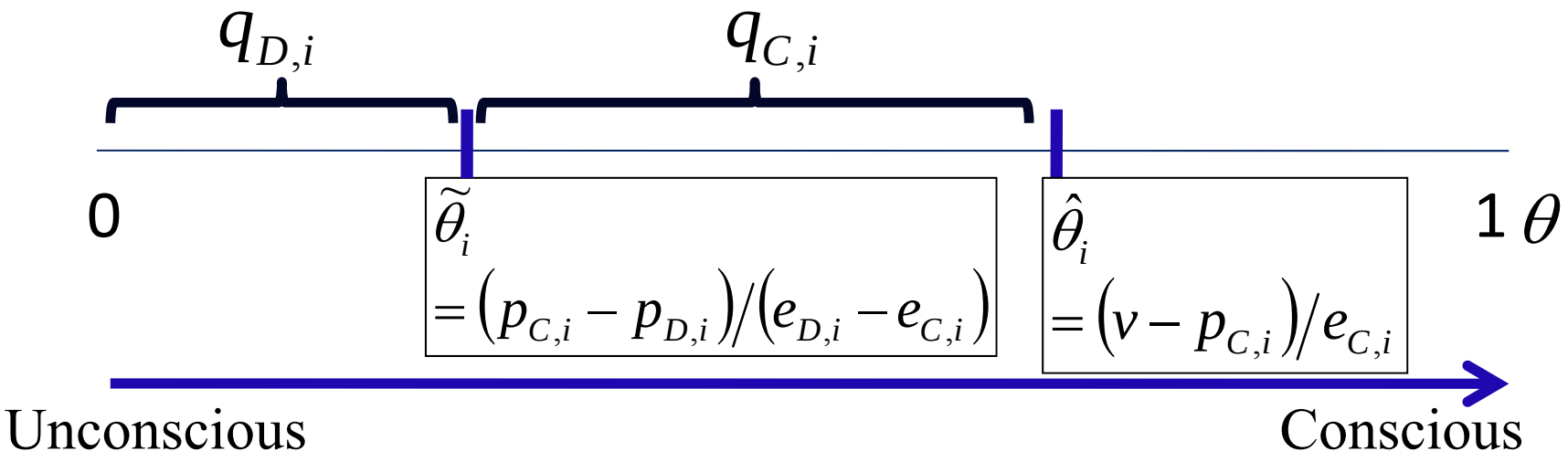
$$u = \max\{v - e\theta - p,\ 0\}$$

e : an emission level per unit consumption.

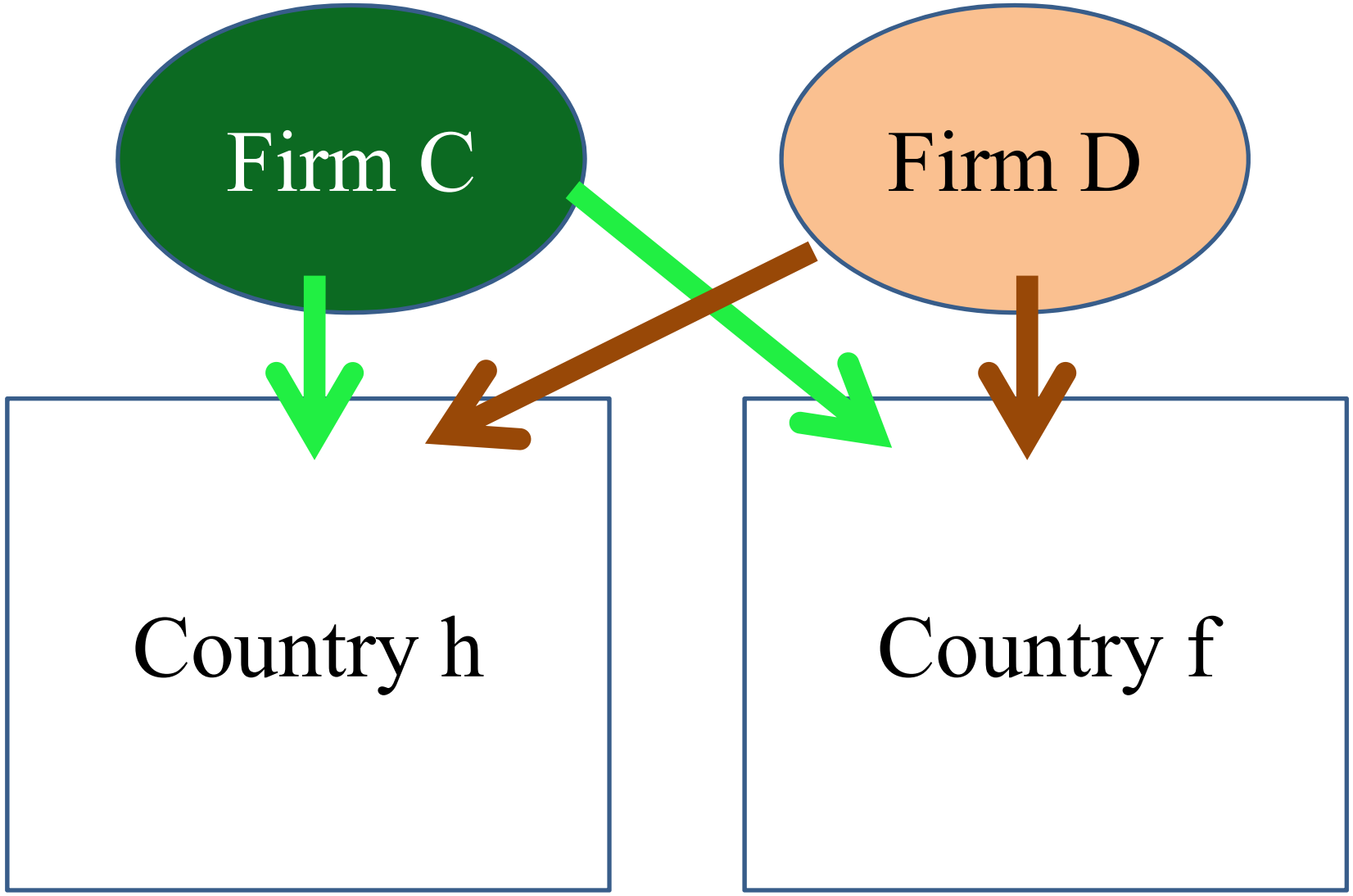
- Products

→ Two products are supplied: cleaner and dirtier products. Their unit emission levels are different from each other: $e_{C,i}$, and $e_{D,i}$. ($i = h, f$)

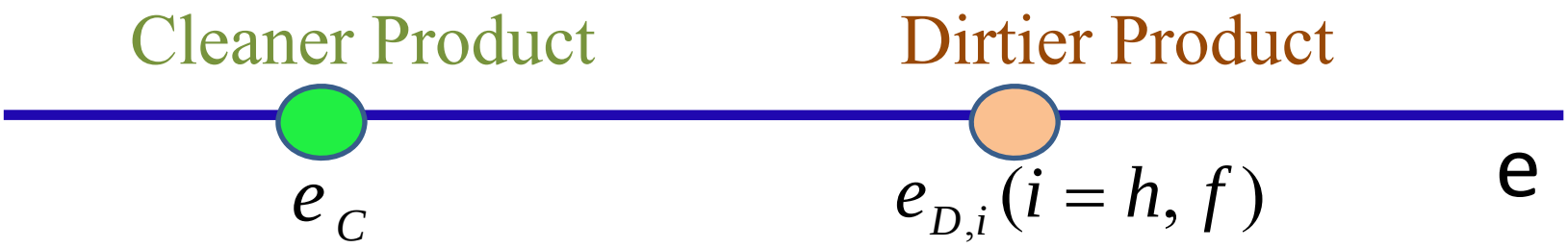
- Demand



Firms



■ Products are environmentally differentiated
→ Unit emission levels of products of both firms are different from each other in each market.

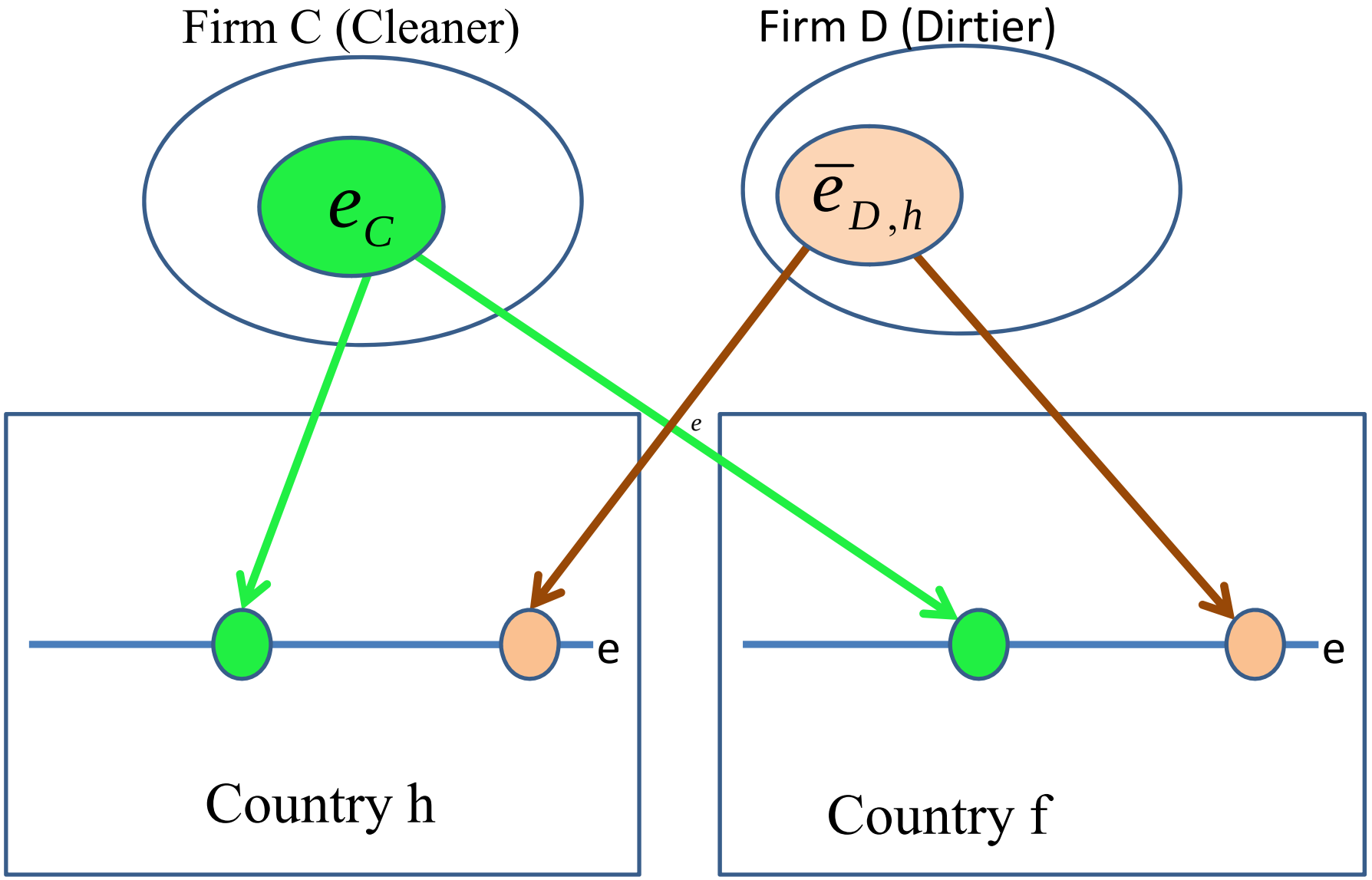


■ The home emission standard is binding: $e_{D,h} = \bar{e}_{D,h}$

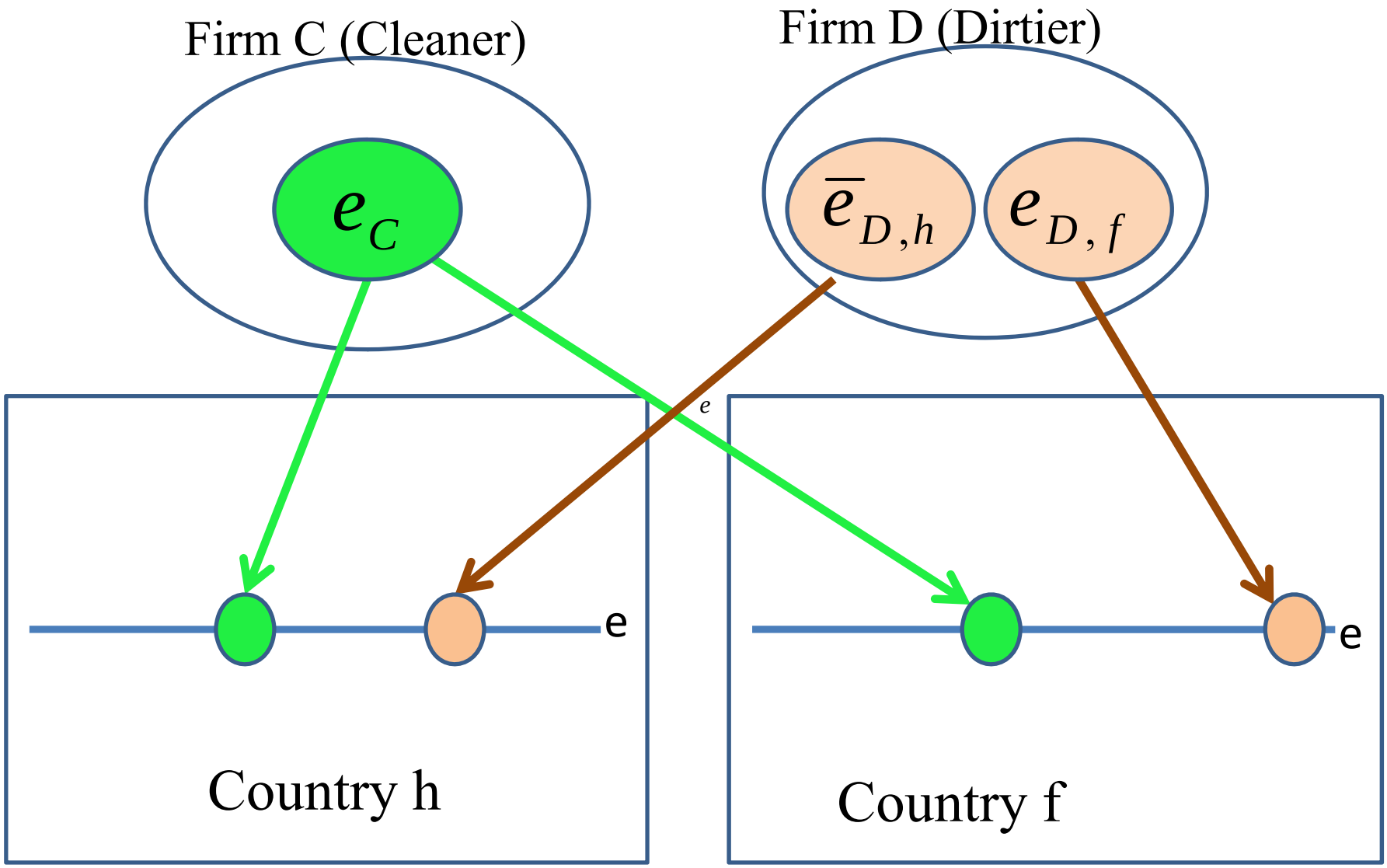
■ Firm D may produce two types of 'dirtier products' $\bar{e}_{D,h} < e_{D,f}$.
In such a case, (a) each type of product is supplied to either of home or foreign market, and (b) only one type is supplied to each market. .

■ Firm C supplies the same type of cleaner product to both markets.

Case1: Firm D supplies the same type of product to both markets.



Case2: Firm D supplies the different products to different markets.



- Three-stage game

  (Two-stage game between firms.)

Stage 0: A home emission standard is determined. (Exogenous in this model.)

Stage 1: Both firms determine the emission levels of their own products.

Stage 2: They compete with each other in a Cournot (or Bertrand) fashion.

- Cost structure

  Fixed cost:

$$F_D(e_D) = \alpha e_D^{-\varepsilon} \qquad F_C(e_C) = e_C^{-\varepsilon}$$

$$F_j' < 0 \qquad F_j'' > 0 \qquad \alpha > 1$$

- Profit functions

$$\pi_D = p_{D,h} q_{D,h} + p_{D,f} q_{D,f} - F_{D,h} - \sigma F_{D,f}$$

$$\pi_C = p_{C,h} q_{C,h} + p_{C,f} q_{C,f} - F_C$$

$$\sigma = 0 \quad \text{if} \quad e_{D,h} = e_{D,f}$$

$$\sigma = 1 \quad \text{if} \quad e_{D,h} \neq e_{D,f}$$

Governments and Social welfare

- Aggregate emissions:

$$E_i = e_{D,i} q_{D,i} + e_{C,i} q_{C,i} \qquad (i = h, f)$$

- The social net surplus:

$$W_i = CS_i - \gamma_i E_i$$

- When the government cares the global environment :

$$CS_i = \int_0^{\tilde{\theta}_i} (v - e_{D,i}\theta) d\theta - p_{D,i} q_{D,i} + \int_{\tilde{\theta}_h}^{\hat{\theta}_h} (v - e_C \theta) d\theta - p_{C,i} q_{C,i}$$

$$W_i^G = CS_i - \gamma_i E^G$$

3. Equilibria (The Cournot duopoly case)

- Quantities $q_{D,i}^{C}=\frac{1}{4e_{D,i}-e_C}v,\qquad q_{C,i}^{C}=\frac{2e_{D,i}-e_C}{e_{C,i}\left(4e_{D,i}-e_C\right)}v$
- Revenues

$$R_D^C=\frac{\bar{e}_{D,h}}{\left(4\bar{e}_{D,h}-e_C\right)^2}v^2+\frac{e_{D,f}}{\left(4e_{D,f}-e_C\right)^2}v^2\qquad R_C^C=\frac{\left(2\bar{e}_{D,h}-e_C\right)^2}{e_C\left(4\bar{e}_{D,h}-e_C\right)^2}v^2+\frac{\left(2e_{D,f}-e_C\right)^2}{e_C\left(4e_{D,f}-e_C\right)^2}v^2$$

- Determination of emission levels
- **Case1:** When firm D supplies the same product to both markets:

$$e_{D,h}=e_{D,f}=\bar{e}_{D,h}$$

- **Case2:** When firm D supplies different types of products according to the market, the first-order condition (FOC) is:

$$-\frac{4e_{D,f}+e_C}{\left(4e_{D,f}-e_C\right)^3}v^2-F'_{D,f}=0$$

The FOC for firm C is:

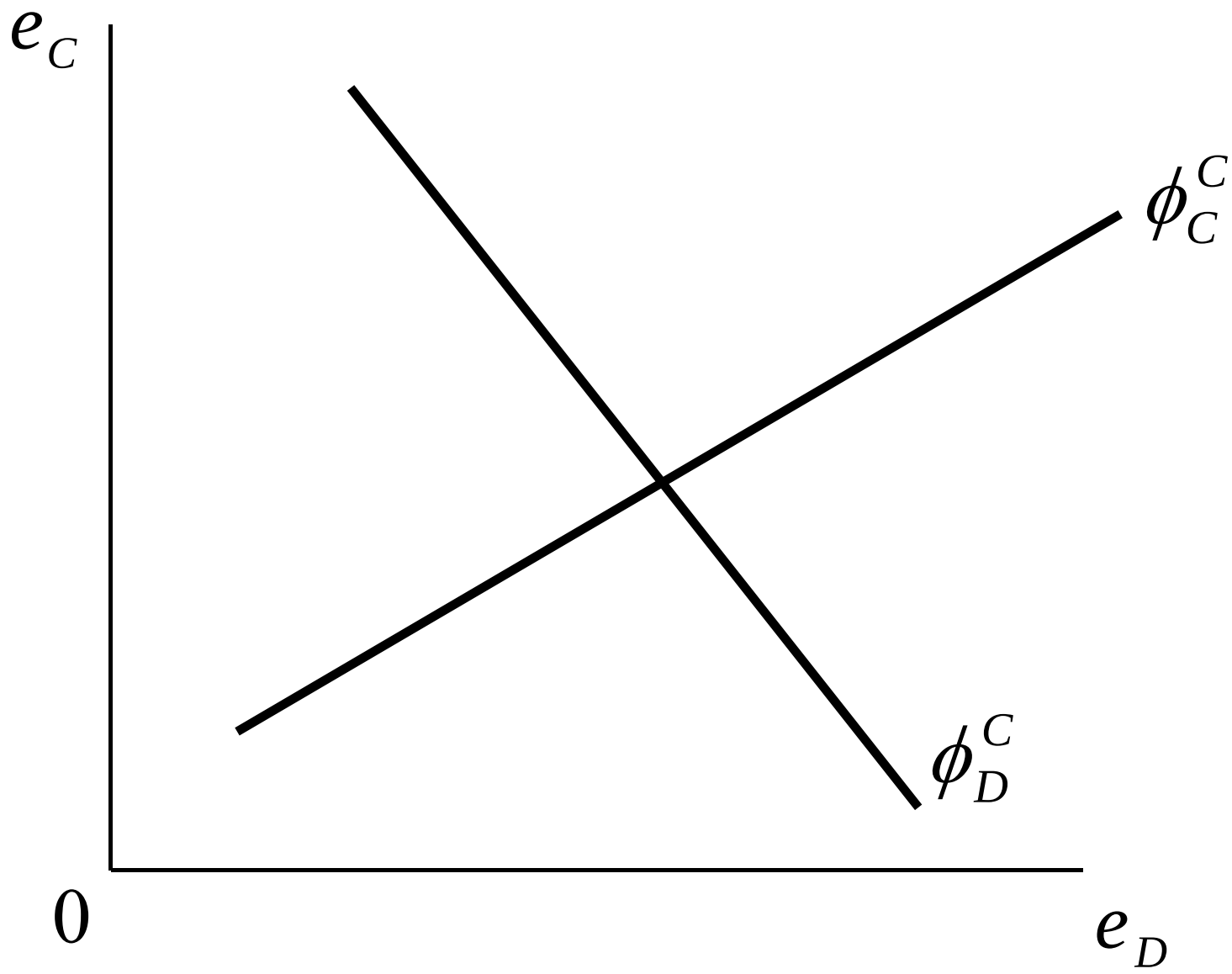
$$-\sum_i\frac{\left(2e_{D,i}-e_C\right)\left(8e_{D,i}^2-2e_{D,i}e_C+e_C^2\right)}{e_C^2\left(4e_{D,i}-e_C\right)^3}v^2-F'_C=0,\quad i=h,f,\quad e_{D,h}=\bar{e}_{D,h}$$

$e_{D,f} = \phi_D^C(e_C),\ \phi_D'^C < 0.$ Strategic Substitutes for firm D

$e_C = \phi_C^C(\bar{e}_{D,h}, e_{D,f}),\quad \partial\phi_C^C/\partial\bar{e}_{D,h} > 0,\ \partial\phi_C^C/\partial e_{D,f} > 0$

Strategic complements for firm C

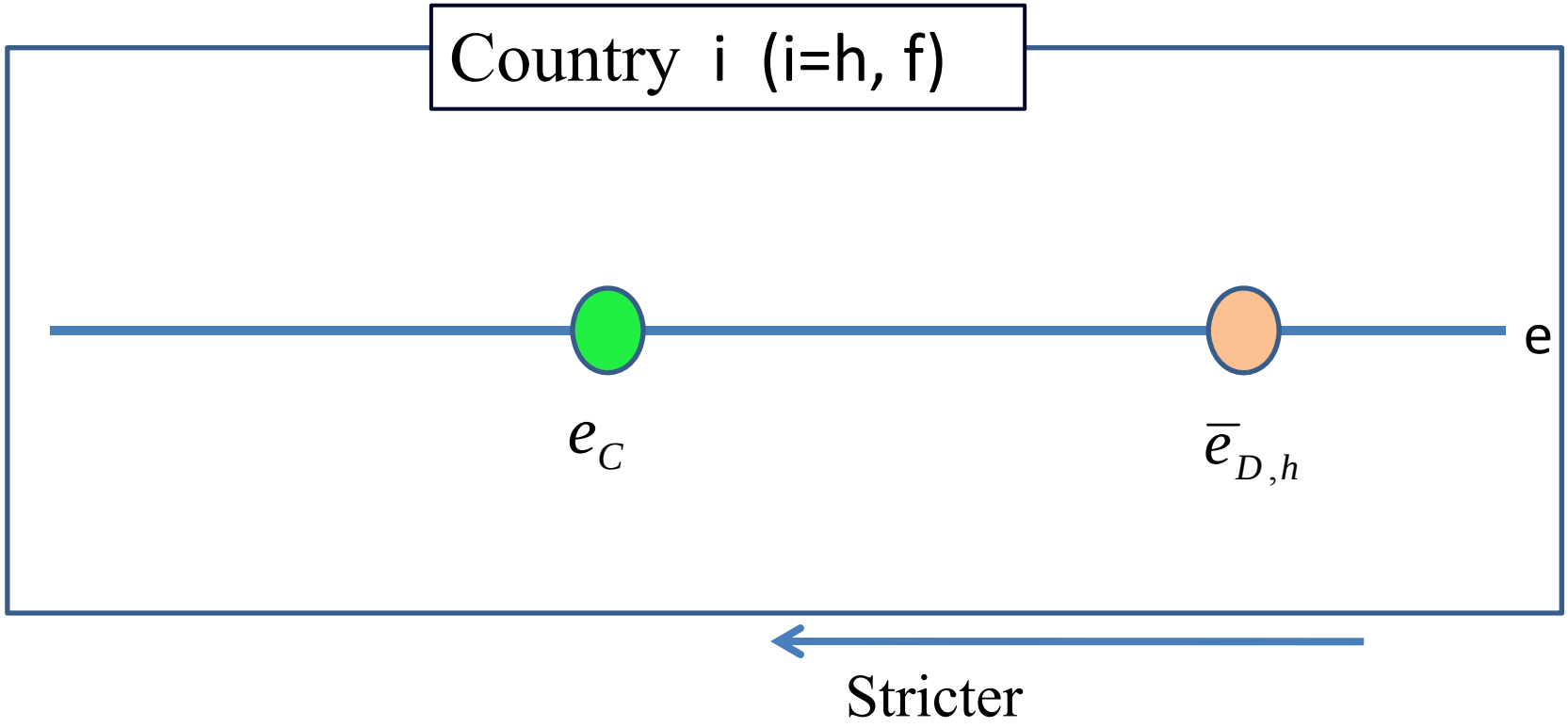
Intuition: An increase in the unit emission level of the cleaner (resp. the dirtier) product reduces (resp. increases) the difference in environmental qualities between products. As the difference becomes smaller (resp. larger), a competition among the firms is intensified (resp. mitigated). Thus, the marginal revenue of increasing the unit emission level for firm (resp. firm) decreases (resp. increases).

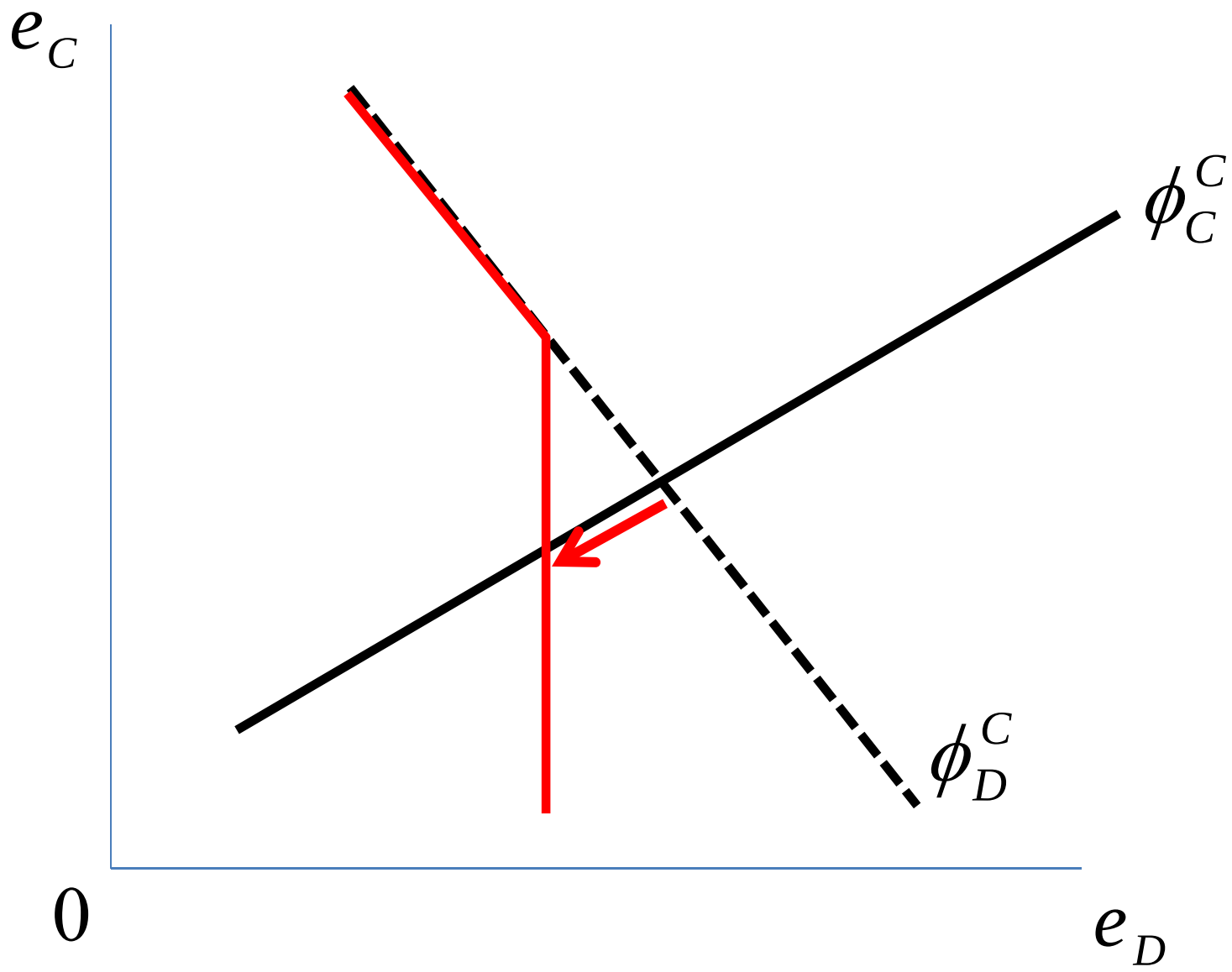

e_C
ϕ_C^C
ϕ_D^C
0
e_D

4. An Emission Standard, Quality of Prodcuts and the Environment (The Cournot duopoly case)

Case 1: The effect of a change in $\bar{e}_{D,h}$

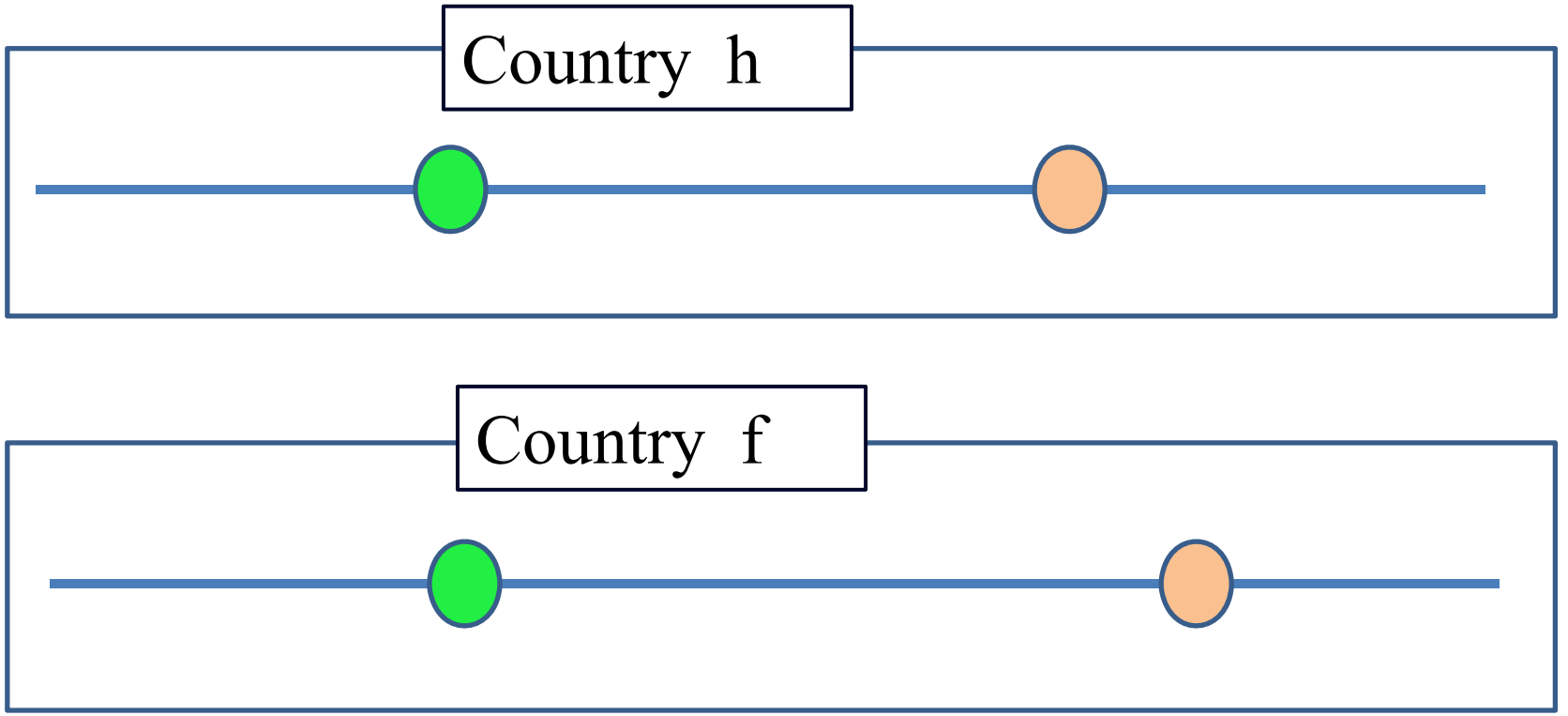
Proposition 1: $0 < \frac{de_C^C}{d\bar{e}_{D,h}} < 1,$ and $0 < \frac{de_C^C}{d\bar{e}_{D,h}} \cdot \frac{\bar{e}_{D,h}}{e_C^C} < 1$ hold.

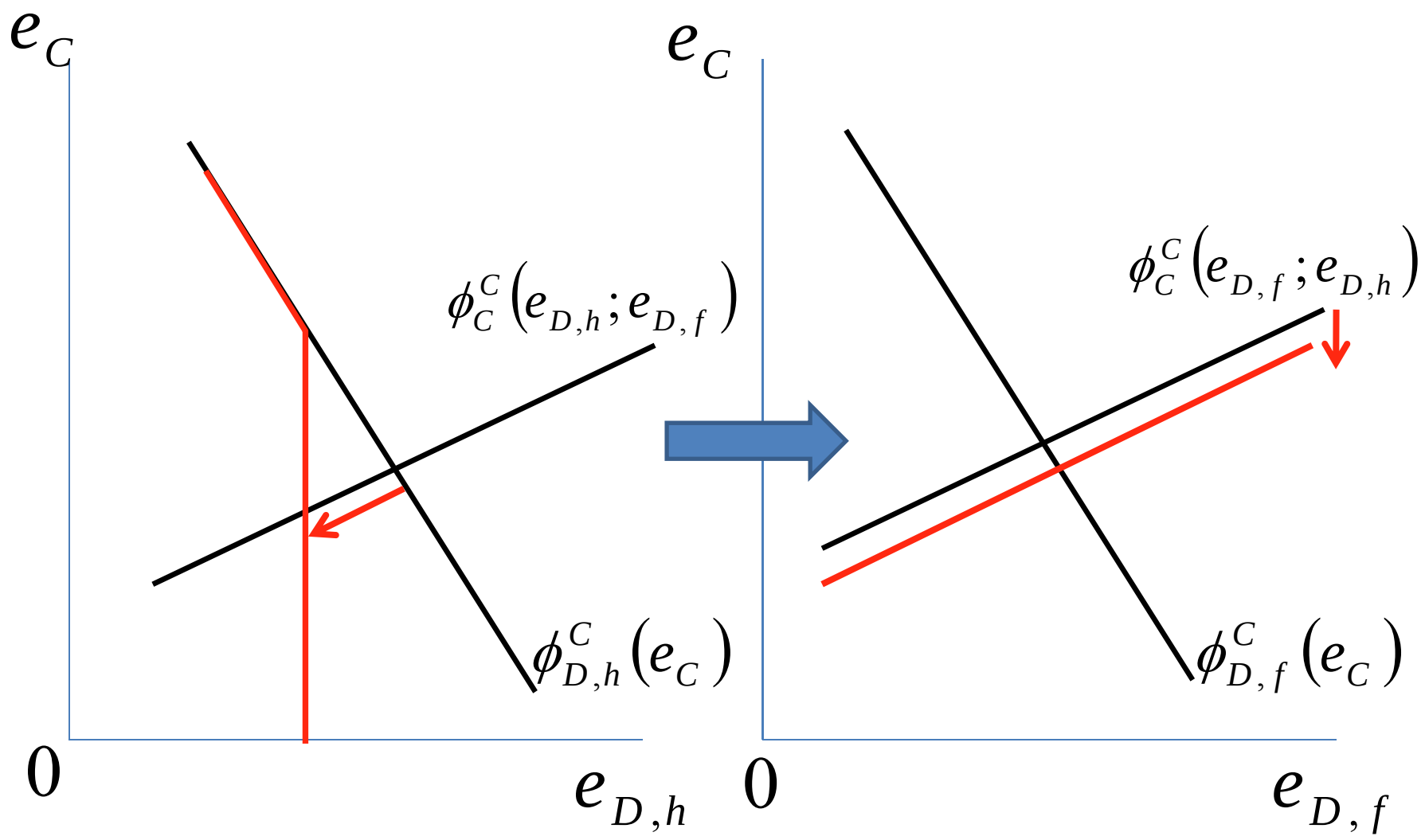



e_C
ϕ_C^C
ϕ_D^C
0
e_D

Case 2: The effect of a change in $\bar{e}_{D,h}$

Proposition 2: $0 < \frac{de_C^C}{d\bar{e}_{D,h}} < 1$, , $0 < \frac{de_C^C}{d\bar{e}_{D,h}} \cdot \frac{\bar{e}_{D,h}}{e_C^C} < 1$ and $\frac{de_{D,f}^C}{d\bar{e}_{D,h}} < 0$ hold.




e_C
$\phi_C^C(e_{D,h};e_{D,f})$
$\phi_{D,h}^C(e_C)$
0
$e_{D,h}$
e_C
$\phi_C^C(e_{D,f};e_{D,h})$
$\phi_{D,f}^C(e_C)$
0
$e_{D,f}$

(1) A change in the unit emission level of the dirtier product.

$$\frac{\partial E_i^C}{\partial e_{D,i}} = \frac{e_{C,i}}{\left(4e_{D,i} - e_{C,i}\right)^2} v > 0,$$

(a) $e_{D,i}$ ↑

Due to The shift of demand from the dirtier to the cleaner:

(b) $q_{C,i}$ ↑ (c) $q_{D,i}$ ↓

→ The effects of (a) and (b) dominate the effect of (c).

(2) A change in the unit emission level of the cleaner product.

$$\frac{\partial E_i^C}{\partial e_{C,i}} = -\frac{e_{D,i}}{\left(4e_{D,i} - e_{C,i}\right)^2} v < 0.$$

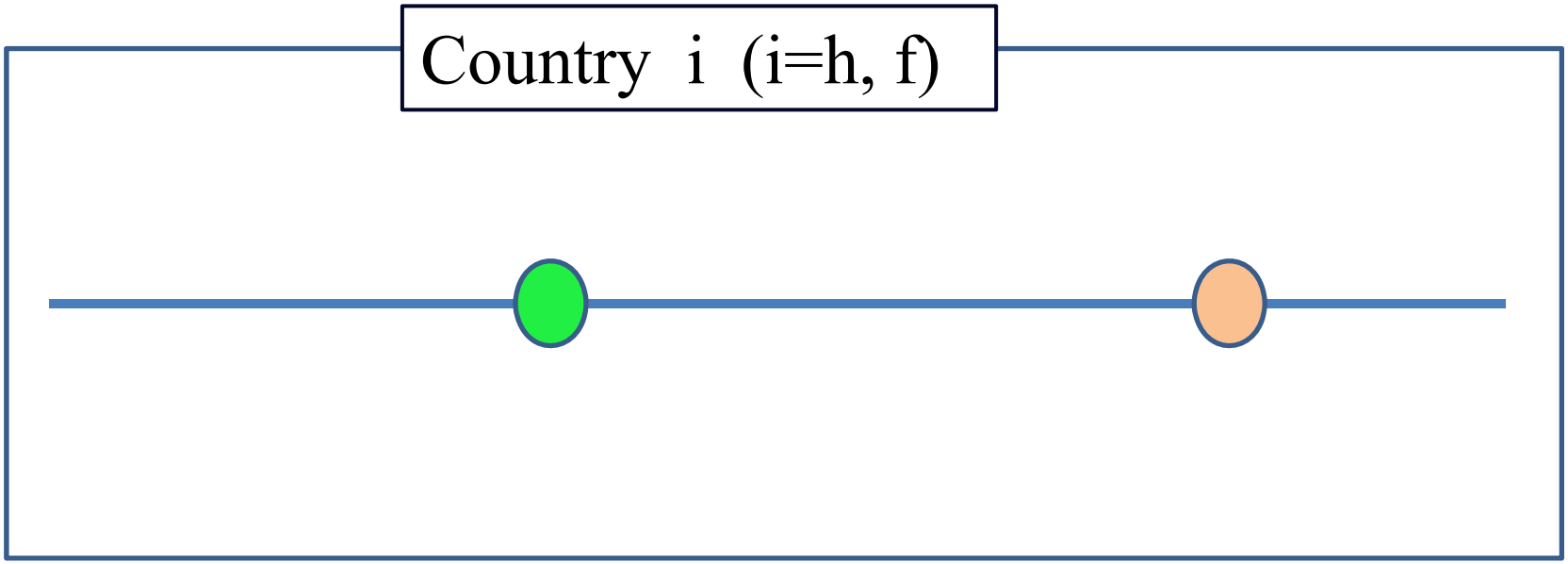
(a) $q_{C,i}$ ↓

(b) $e_{D,i}$ ↓

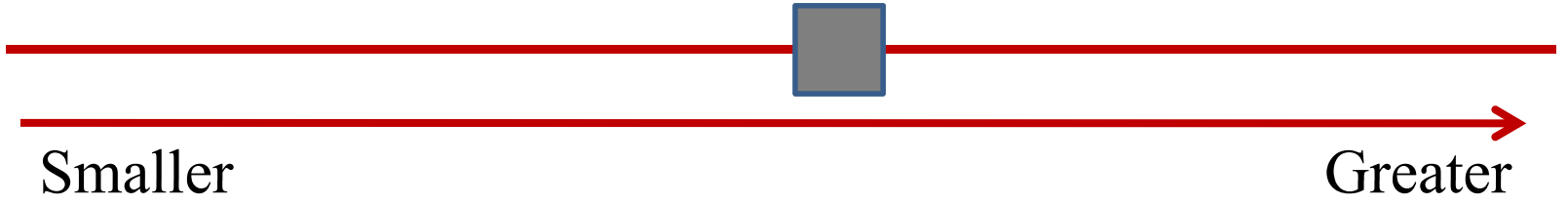
(c) $q_{D,i}$ ↑

→ The effects of (a) and (b) dominate the effect of (c).

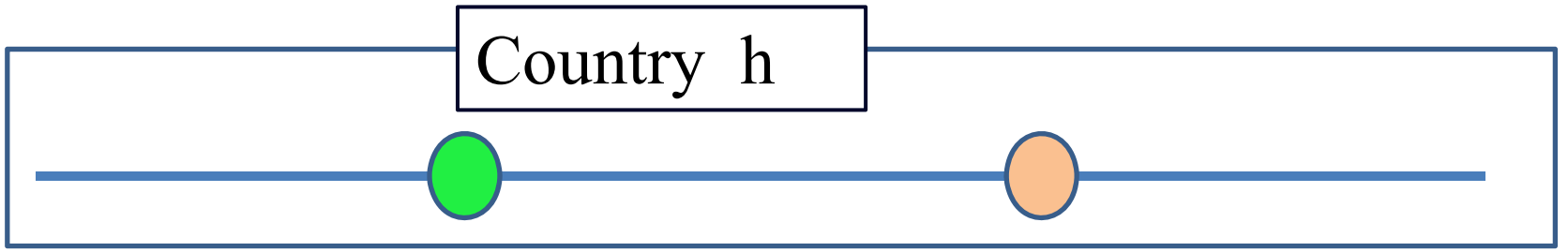
Case 1: The effect of a change in $\bar{e}_{D,h}$



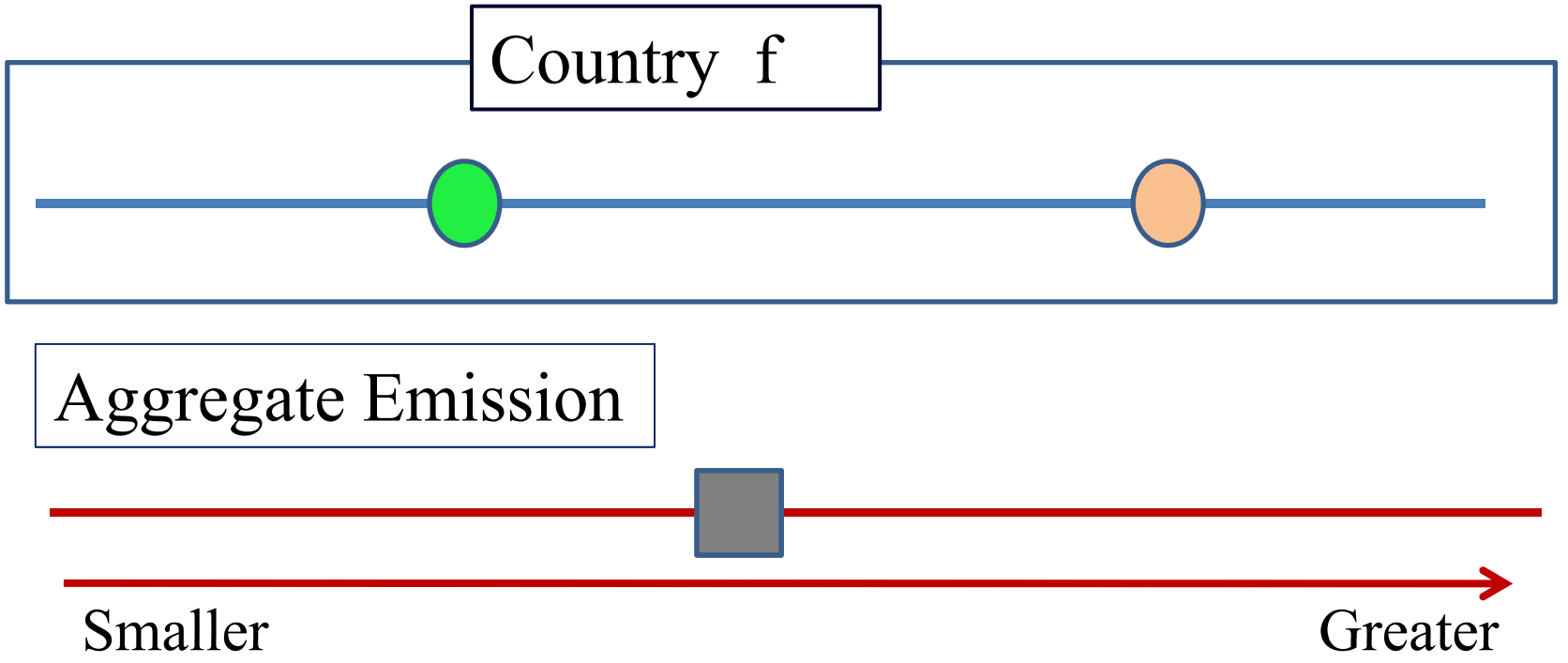
Aggregate Emission



Case 2: The effect of a change in $\overline{e}_{D,h}$



→ The effect on the home aggregate emission is the same as Case 1.



Proposition 3:

Suppose that the firms compete with each other in a Cournot fashion. As the home emission standard become stricter, the home aggregate emission decreases.

On the other hand, the effect on the foreign aggregate emission depends on whether or not firm supplies different types of products to different markets:

(a) when firm supplies the same product to both markets, the foreign aggregate emission also decreases,

(b) when firm supplies different types of products to different markets ($\bar{e}_{D,h} < e_{D,f}$), the foreign aggregate emission increases.

Proposition 4: Suppose that the firms compete with each other in a Cournot fashion.

As the home emission standard becomes stricter, the home social net surplus increases, which is defined as the consumer surplus minus environmental damage.

As far as firm supplies the same product to both markets, the foreign social net surplus also increases.

On the other hand, when firm supplies different types of products to different markets, the foreign social net surplus decreases if the marginal valuation of environmental damage (γ_f) is greater than a certain level.

5. Equilibria (The Bertrand duopoly case)

- Quantities $q_{D,i}^{C} = \dfrac{1}{4e_{D,i} - e_C} v, \qquad q_{C.i}^{B} = \dfrac{2e_{D,i}}{e_C\left(4e_{D,i} - e_C\right)} v,$
- Revenues

$$R_D^B = \frac{\bar{e}_{D,h} - e_C}{\left(4\bar{e}_{D,h} - e_C\right)^2} v^2 + \frac{e_{D,f} - e_C}{\left(4e_{D,f} - e_C\right)^2} v^2 \quad R_C^B = \frac{4\bar{e}_{D,h}\left(\bar{e}_{D,h} - e_C\right)}{e_C\left(4\bar{e}_{D,h} - e_C\right)^2} v^2 + \frac{4e_{D,f}\left(e_{D,f} - e_C\right)}{e_C\left(4e_{D,f} - e_C\right)^2} v^2$$

- Determination of emission levels
- **Case1:** When firm D supplies the same product to both markets:

$$e_{D,h} = e_{D,f} = \bar{e}_{D,h}$$

- **Case2:** When firm D supplies different types of products according to the market, the first-order condition (FOC) is:

$$-\frac{4e_{D,f} - 7e_C}{\left(4e_{D,f} - e_C\right)^3} v^2 - F'_{D,f} = 0$$

The FOC for firm C is:

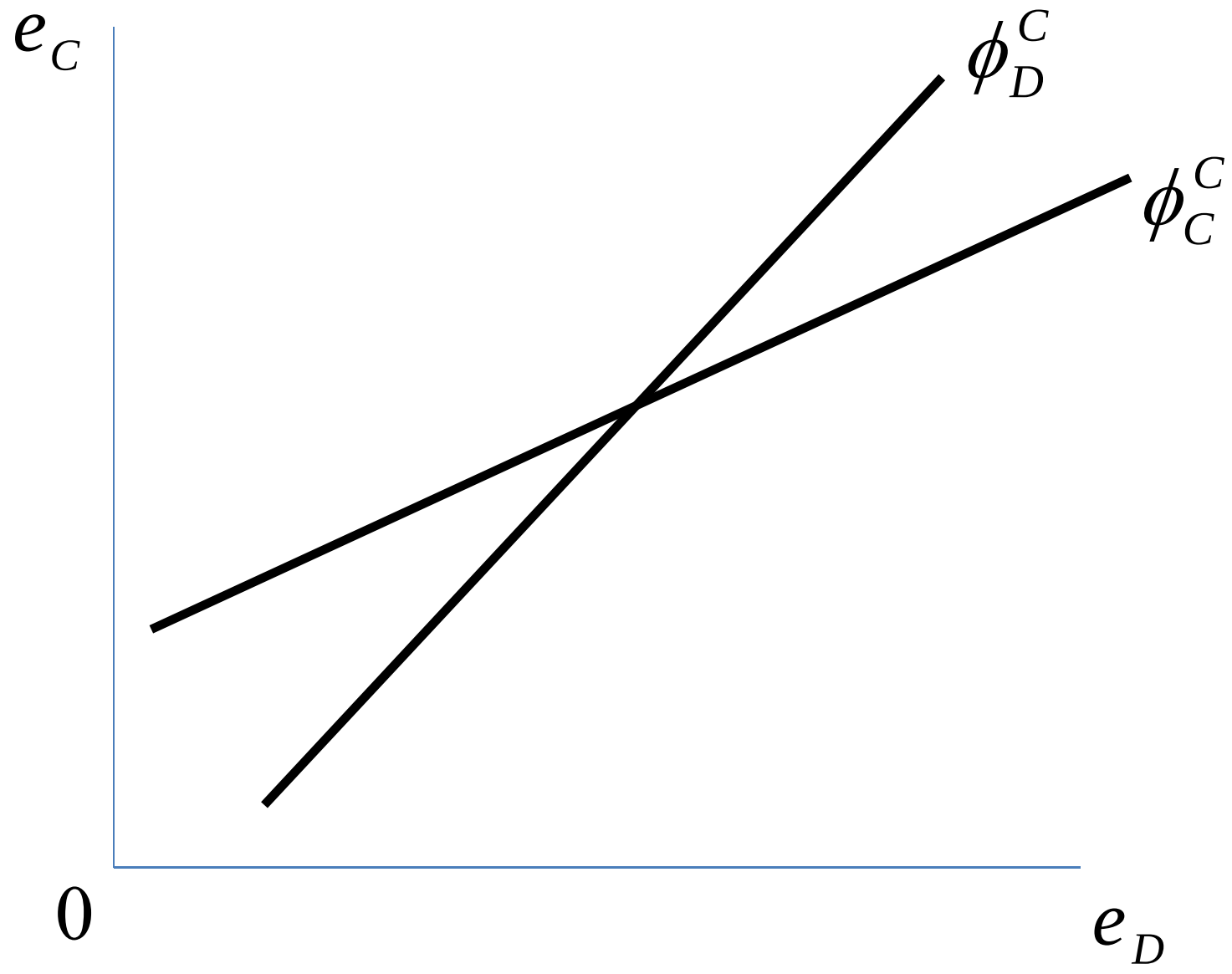
$$-\sum_i \frac{4e_{D,i}\left(4e_{D,i}^2 - 3e_{D,i}e_C + 2e_C^2\right)}{e_C^2\left(4e_{D,i} - e_C\right)^3} v^2 - F'_C = 0, \quad i = h, f, \quad e_{D,h} = \bar{e}_{D,h}$$

$e_{D,f} = \phi_D^B(e_C),\ \phi_D'^B > 0$ Strategic complements for firm D

$e_C = \phi_C^B(\bar{e}_{D,h}, e_{D,f}),\quad \partial\phi_C^B/\partial\bar{e}_{D,h} > 0,\ \partial\phi_C^B/\partial e_{D,f} > 0$

Strategic complements for firm C

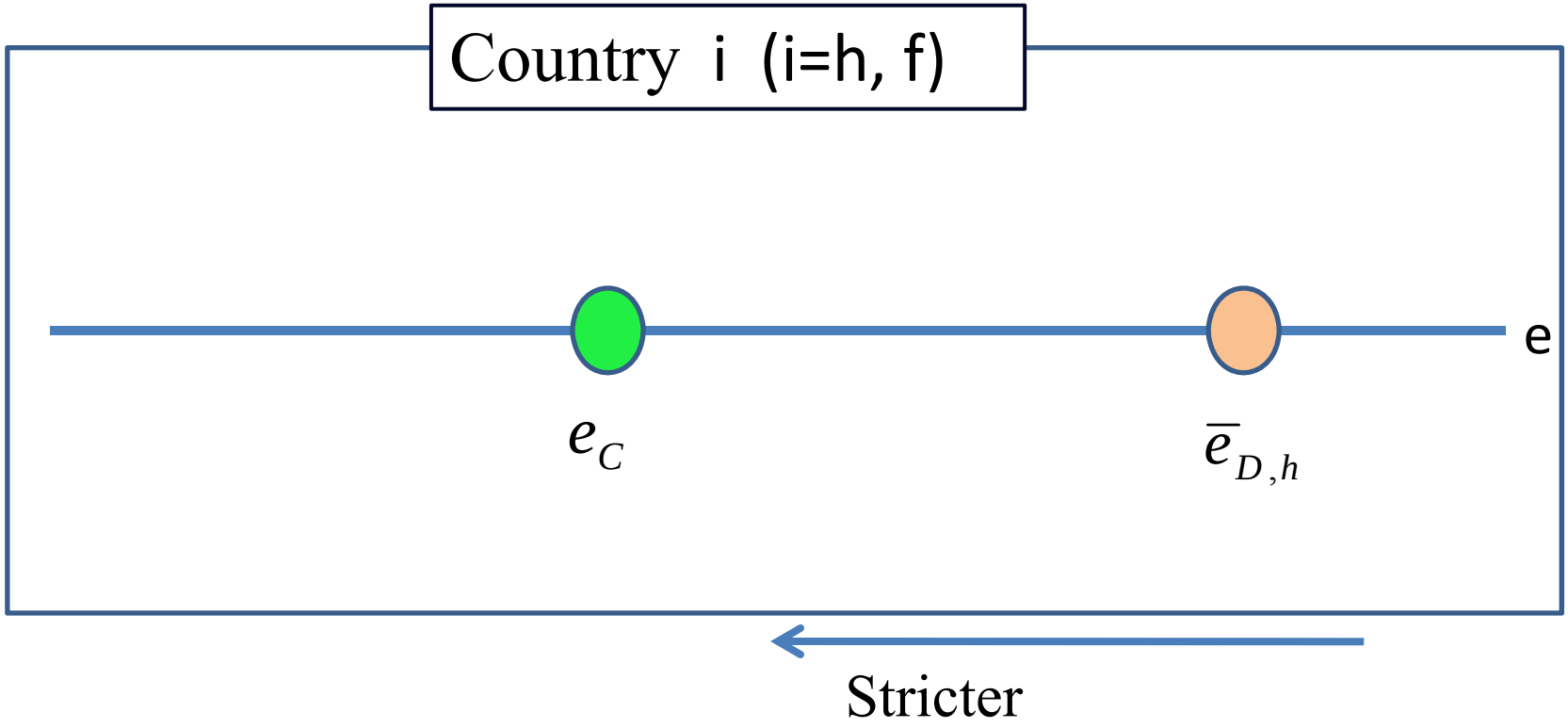
Intuition: An increase in the unit emission level of the cleaner (resp. the dirtier) product reduces (resp. increases) the difference in environmental qualities between products. As the difference becomes smaller (resp. larger), a competition among the firms is intensified (resp. mitigated). Thus, the marginal revenue of increasing the unit emission level for firm (resp. firm) decreases (resp. increases).

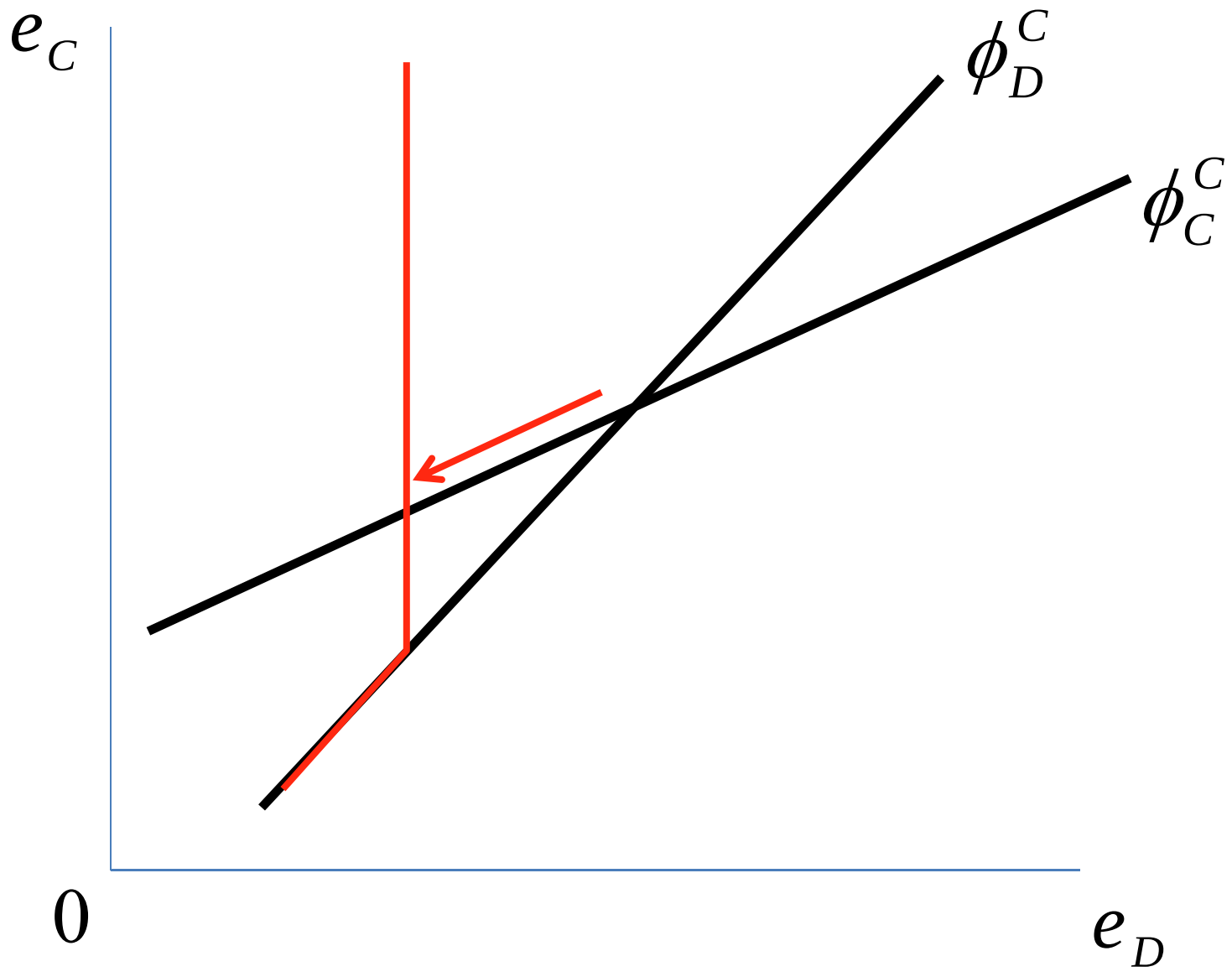

e_C
ϕ_D^C
ϕ_C^C
0
e_D

6. An Emission Standard, Quality of Prodcuts and the Environment (The Bertrand duopoly case)

Case 1: The effect of a change in $\bar{e}_{D,h}$

Proposition 5: $0 < \dfrac{de_C^B}{d\bar{e}_{D,h}} < 1$ and $0 < \dfrac{de_C^B}{d\bar{e}_{D,h}} \cdot \dfrac{\bar{e}_{D,h}}{e_C^B} < 1$ hold.

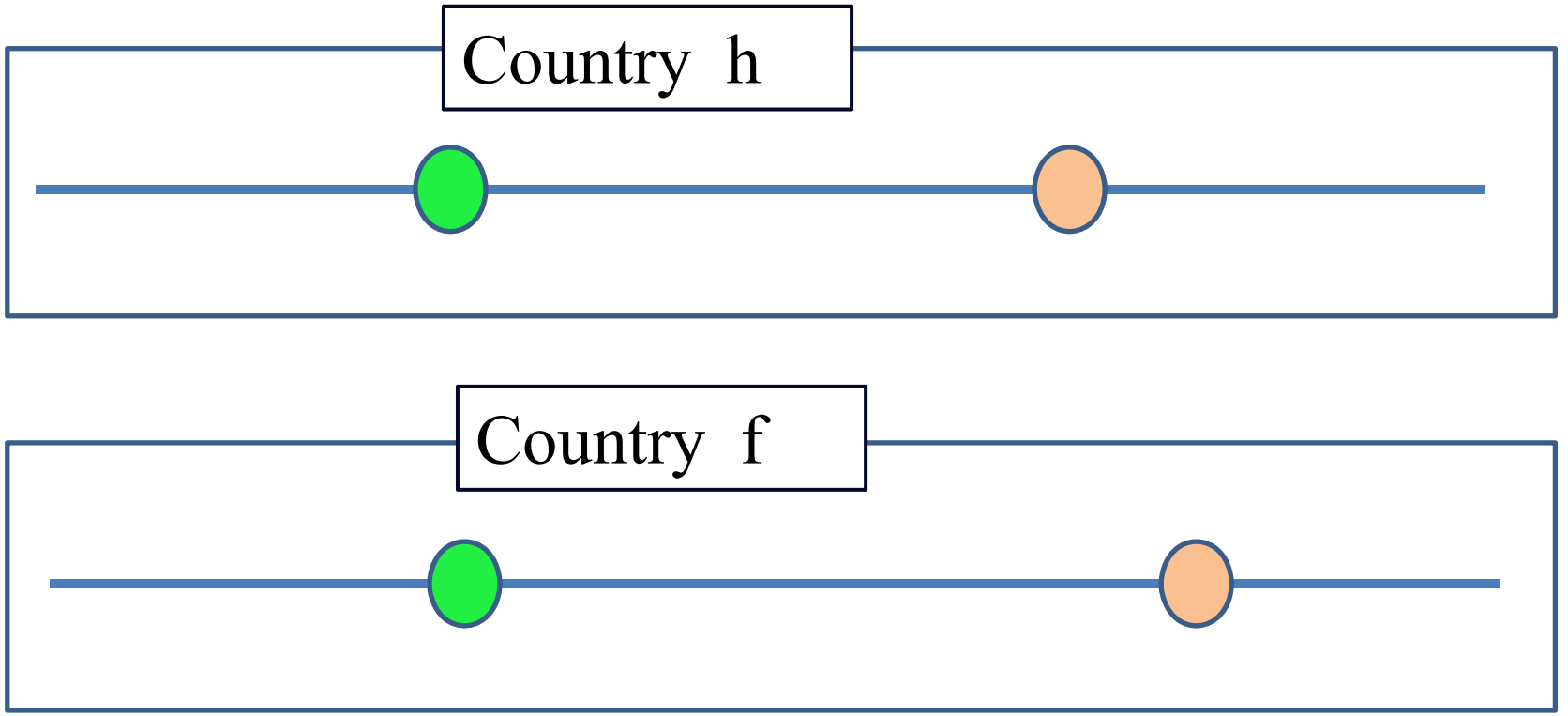


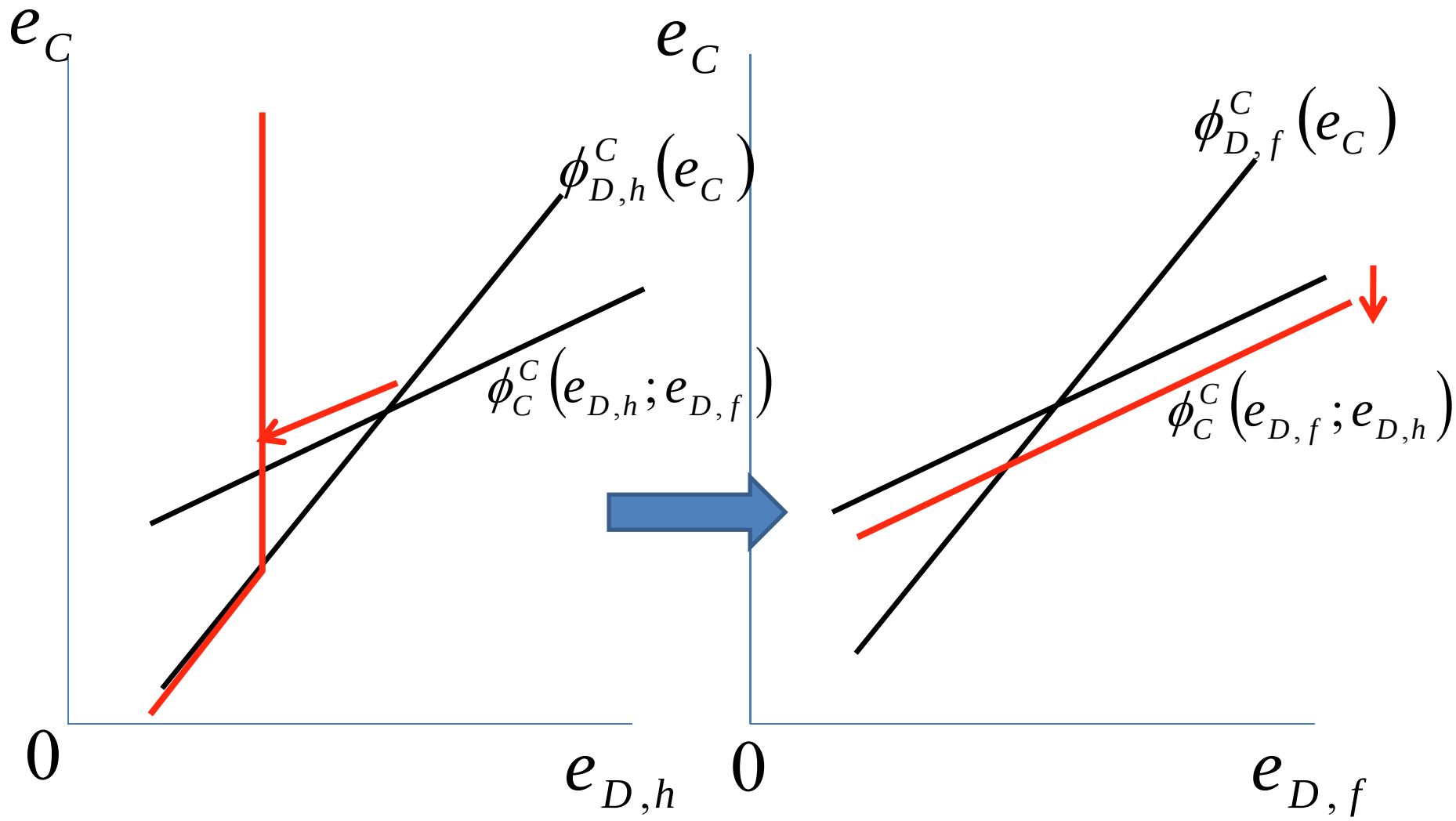

e_C
ϕ_D^C
ϕ_C^C
0
e_D

Case 2: The effect of a change in $\bar{e}_{D,h}$

Proposition 6: $0 < \dfrac{de_C^B}{d\bar{e}_{D,h}} < 1$, $0 < \dfrac{de_C^B}{d\bar{e}_{D,h}} \cdot \dfrac{\bar{e}_{D,h}}{e_C^B} < 1$ $\dfrac{de_{D,f}^B}{d\bar{e}_{D,h}} > 0$

and $0 < \dfrac{de_{D,f}^B \big/ d\bar{e}_{D,h}^B}{de_C^B \big/ d\bar{e}_{D,h}^B} \cdot \dfrac{e_C^B}{e_{D,f}^B} < 1$ hold.




e_C
$\phi^C_{D,h}(e_C)$
$\phi^C_C(e_{D,h};e_{D,f})$
0
$e_{D,h}$
e_C
$\phi^C_{D,f}(e_C)$
$\phi^C_C(e_{D,f};e_{D,h})$
0
$e_{D,f}$

(1) A change in the unit emission level of the dirtier product.

$$\frac{\partial E_i^B}{\partial e_{D,i}} = -\frac{3e_{C,i}}{\left(4e_{D,i} - e_{C,i}\right)^2} v < 0$$

(a) $e_{D,i} \uparrow$

Due to The shift of demand from the dirtier to the cleaner:

(b) $q_{C,i} \uparrow$ (c) $q_{D,i} \downarrow$

→ The effects of (c) dominates the effects of (a) and (b).

(2) A change in the unit emission level of the cleaner product.

$$\frac{\partial E_i^B}{\partial e_{C,i}} = \frac{3e_{D,i}}{\left(4e_{D,i} - e_{C,i}\right)^2} v > 0$$

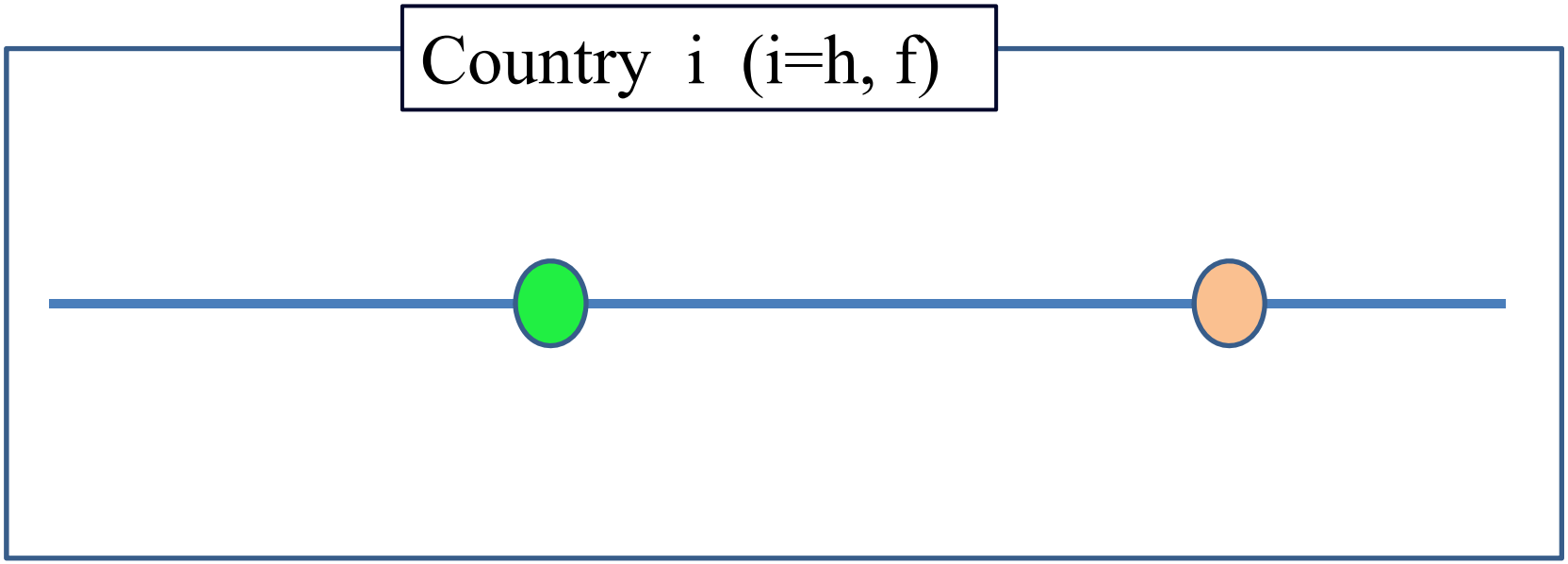
(a) $q_{C,i} \downarrow$

(b) $e_{D,i} \uparrow$

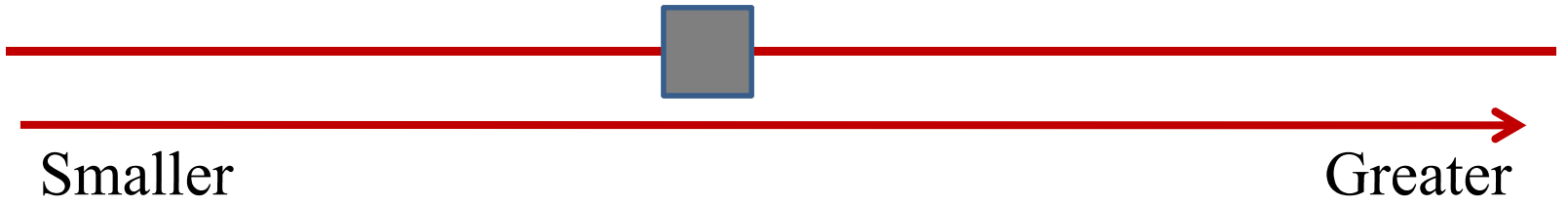
(c) $q_{D,i} \uparrow$

→ The effects of (b) and (c) dominate the effect of (a).

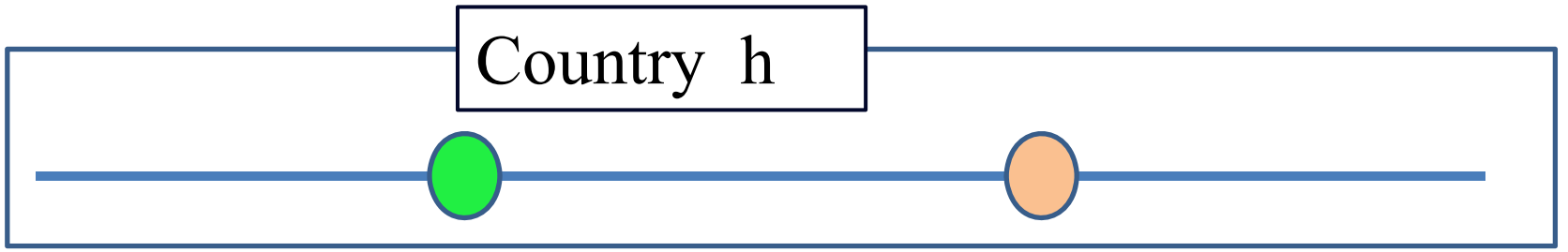
Case 1: The effect of a change in $\bar{e}_{D,h}$



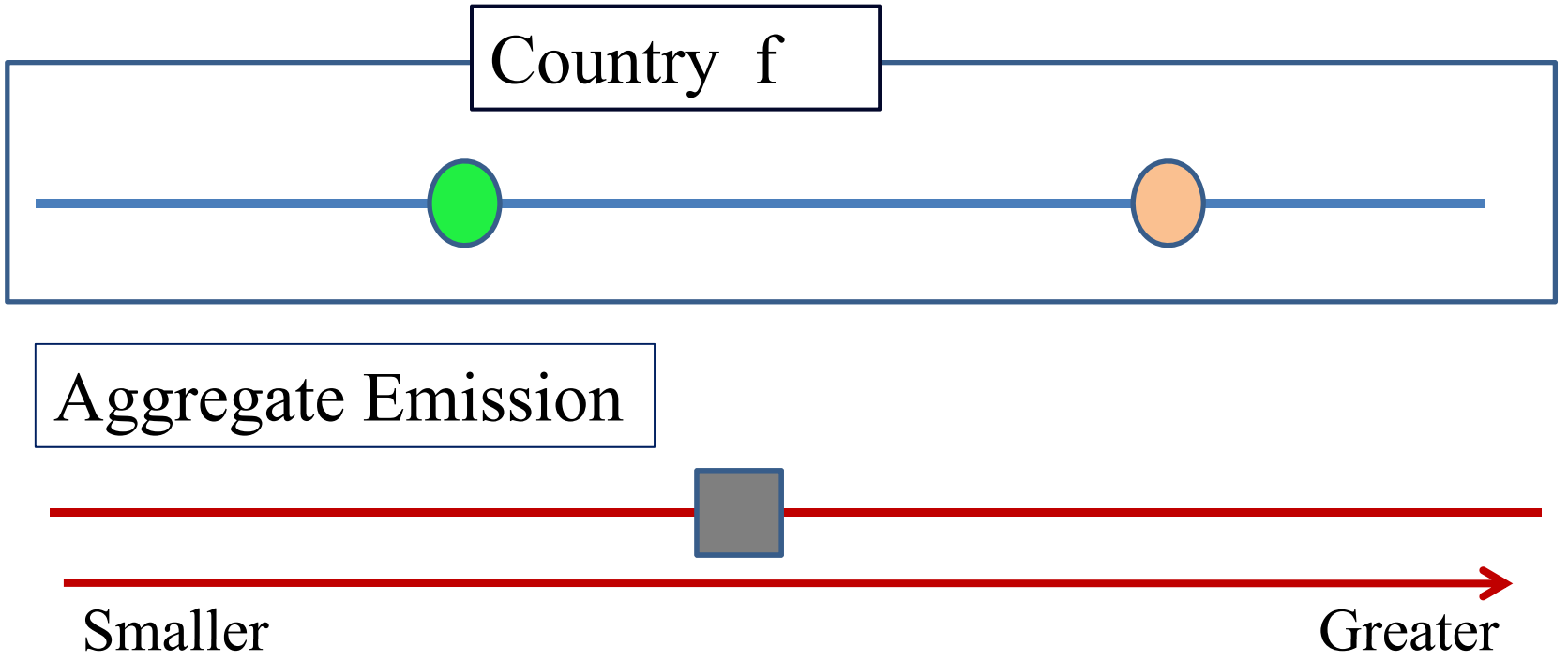
Aggregate Emission



Case 2: The effect of a change in $\bar{e}_{D,h}$



→ The effect on the home aggregate emission is the same as Case 1.



Proposition 7: Suppose that the firms compete with each other in a Bertrand fashion.

As the home emission standard becomes stricter, the home aggregate emission increases.

On the other hand, the effect on the foreign aggregate emission depends on whether or not firm supplies different types of products to different markets:

(a) when firm supplies the same product to both markets, the foreign aggregate emission also increases,

(b) when firm supplies different types of products to different markets, the foreign aggregate emission decreases.

Proposition 8: Suppose that the firms compete with each other in a Bertrand fashion.

When firm supplies different types of products to different markets, as the home emission standard becomes stricter, the foreign social net surplus increases.

On the other hand, if the marginal valuation of environmental damage is smaller than a certain level, a stricter home emission standard increases the home social net surplus, which does not depend on whether firm produces one or two types of dirtier products.

7. Endogenous Determination of the Number of Types of Dirtier Products

- Cournot duopoly case
- It always holds that $\partial R_D^C / \partial e_{D,f} < .0$

Proposition 9: When firms compete with each other in a Cournot fashion. Then, firm supplies the same type of products to both markets irrespective of the strictness of the home emission standard.

Bertrand duopoly case

- The stricter is the home emission standard, the more likely it is that $\partial R_D^B / \partial e_{D,f} > 0$ holds as far as firm supplies the same type of product to both markets.

→ Let us focus on firm 's incentive to deviate from the situation in which $e_{D,f} = \bar{e}_{D,h}$.

- When $e_{D,f} = \bar{e}_{D,h}$,

$$\frac{d\pi_D^B}{d\bar{e}_{D,h}} = \frac{\partial R_D^B}{\partial \bar{e}_{D,h}} + \frac{\partial R_D^B}{\partial e_C^B} \cdot \frac{de_C^B}{d\bar{e}_{D,h}} - F_D'$$

$$= 2 \cdot \left(\frac{-4\bar{e}_{D,h} + 7e_C^B}{\left(4\bar{e}_{D,h} - e_C^B\right)^3} + \frac{-2\bar{e}_{D,h} - e_C^B}{\left(4\bar{e}_{D,h} - e_C^B\right)^3} \cdot \frac{de_C^B}{d\bar{e}_{D,h}} \right) - F_D'$$

- The smaller the difference between the unit emission levels of both firms' products, the more likely it is that $d\pi_D^B / d\bar{e}_{D,h} > 0$ holds.

→ The stricter is the home emission standard, the more likely it is that a small decrease in $\bar{e}_{D,h}$ decreases the profit of firm D.

- Since $\partial R_D^B / \partial e_C < 0$ and $0 < de_C / d\bar{e}_{D,h} < 1$, the profit of firm D when setting the unit emission level for the foreign market equal to $e'_{D,f} (> \bar{e}_{D,h})$ increases, as the home emission standard becomes stricter.

Proposition 10: When firms compete with each other in a Bertrand fashion. Then, the stricter is the home emission standard, the stronger incentive firm has to deviate from the situation in which it supplies the same type of products to both markets.

Concluding Remarks

- The effects of a stricter home emission standard on both the domestic and foreign countries depends on the types of products produced by the firm which supplies dirtier products.

- This means that a unilateral strict emission standard could be either beneficial or harmful to other countries, and that the firms' behavior on how many types of products they supply is crucial. This point does not depend on the mode of competition.

Extension

- Emission standards (labeling criteria) for cleaner products.
- Strategic behavior of governments.