Products R&D, Export Subsidies and Dynamic Efficiency of the Cournot Equilibrium in an Open Economy

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Motivations and purpose (1)

- Which is more efficient, Cournot (outputs) competition or Bertrand (prices) competition?
- Conventional wisdom on this issue:
  - Bertrand competition is more efficient statically than Cournot one.
  - ‘statically’ means that in one stage game firms face the same demand and cost conditions in both types of competition.

Motivations and purpose (2)

- 'more efficient' means higher consumer surplus and national welfare.

- Dynamics
  - Actually firms compete not only on outputs or prices but also on R&D investments, capacity or location choices and so on before their supply of commodities. Therefore, in order to investigate such dynamic issues, models in two-stage or multi-stage game have been developed.

Motivations and purpose (3)

- In such dynamic models can the superiority of the Cournot equilibrium be obtained easily, or are some specific conditions needed?
- To demonstrate cases of the superiority of the Cournot equilibrium over the Bertrand equilibrium, Qiu (1997) and Symeonidis (2003) introduce strong cross-firms spillover effects into two-stage (dynamic) differentiated duopoly model with the R&D investments.

Motivations and purpose (4)

- In their model, without spillover effects the Bertrand equilibrium is still more efficient.
- I try to demonstrate a case of the superiority of the Cournot equilibrium over the Bertrand equilibrium, in the “third-market” framework by Brander and Spencer (1985) to allow duopoly firms to invest in R&D for quality improvement, without spillover effects.
- More efficient means higher world welfare.

Closely related literature

- Singh, N. and X. Vives (1984), "Price and Quantity Competition in a Differentiated Duopoly,“ Rand J of E.
- Qiu, L.D. (1997), "On the Dynamic Efficiency of Bertrand and Cournot Equilibria," JET.
- Symeonidis, G. (2003), "Comparing Cournot and Bertrand equilibria in a differentiated duopoly with product R & D," IJIO.

Related literature (1)

- Welfare comparison: Cournot versus Bertrand (1), Closed economy
  - Statics:
    - Horizontally differentiated duopoly, Singh-Vives (1984)
    - Horizontally differentiated oligopoly, Vives (1985), Hackner (2000)
  - Dynamics: R&D investment – production
    - Horizontally differentiated duopoly with spillover, Qiu (1997), Symeonidis (2003),
    - Vertically differentiated duopoly without spillover, Motta (1993)

Related literature (2)

- Welfare comparison: Cournot versus Bertrand (2), Open economy
- As far as I know, there is no study about this issue in an open economy.

Open economy R&D and trade policy (1)

- Subsidies – R&D investment – production
  - Identical commodities, Qiu-Tao (1998),
  - Horizontally differentiated duopoly, Spencer-Brander (1993),
  - Vertically differentiated duopoly, Zhou-Spencer-Vertinsky (2002), Toshimitsu (2003), Jinji (2003), Jinji-Toshimitsu (2006),

Open economy R&D and trade policy (2)

- Timing or government's ability to commit to policies

  Neary (1991,1994), Leahy-Neary (1996), Neary-Leahy (2000),

- Spillover effects

  omitted

Closed economy Static efficiency: Singh and Vives (1984) shows:

- Superiority of Bertrand competition over Cournot one in the horizontally differentiated duopoly model with linear demand.
  - Consumer surplus and national welfare are higher in the Bertrand equilibrium than in the Cournot equilibrium.
  - Under substitute goods, lower profit of each firm in the Bertrand equilibrium.

Closed economy Dynamic efficiency: Qiu and Symeonidis (1)

- To demonstrate cases of superiority of the Cournot equilibrium, Qiu (1997) and Symeonidis (2003) introduce strong cross-firms spillover effects of R&D into two-stage differentiated duopoly model with the R&D investments stage prior to production stage.
- Under strong cross-firms spillover effects of R&D, Cournot equilibrium can be more efficient.

Closed economy Dynamic efficiency: Qiu and Symeonidis (2)

- Structure of their model
  - the first stage of the game: both firms independently choose R&D investment to maximize net profit.
  - the second stage: firms independently choose outputs or prices to maximize gross profits, given R&D.
  - R&D has cross-firms spillover effects.

Closed economy Dynamic efficiency: Qiu and Symeonidis (3)

- Qiu considers R&D expenditure for process innovation (cost-reducing R&D), and Symeonidis treats that for quality improvement of product.
- They both show that firms invest more in R&D in the Cournot equilibrium than in the Bertrand equilibrium (even without spillover effects). Lower marginal costs or higher quality in Cournot equilibrium.

On spillover effects of R&D investments

- Qiu (1997) and Symeonidis (2003) focus especially on the role of the strong spillover effects of R&D investments, for the Cournot equilibrium to be more efficient dynamically.
- Though spillover effects are practically significant phenomena, in order to investigate some other examples, I assume no spillover effects.

Model Setup: differentiated duopoly with three stages (1)

- Extend Symeonidis (2003) model to the “third-market” framework.
- a model of export subsidy game by the Brander-Spencer of duopoly firms with investments in R&D for quality improvements.
- Differentiated international duopoly,
- three stages, without spillover effects.

Model Setup: differentiated duopoly with three stages (2)

- Modified three-country model, consists of two export countries and one import country.
- One firm in each export country produces differentiated product and exports to and competes in the import country's domestic market in duopoly fashion.
- No consumption for those goods in producing countries and no firm exists in the import country.

Model Setup: order of moves (1)

- In the first stage of the game, both firms independently choose R&D investment (quality) to maximize net profit.
- In the second stage, each government independently chooses its export subsidy to maximize its national welfare given R&D.
- In the third stage, firms independently choose outputs or prices to maximize gross profits, given export subsidies and R&D.

Model Setup: order of moves (2)

- The sub-game perfect equilibrium is obtained by a process of backward induction.
- In this scenario, firms can make commitments in advance to governments.

Setup: Remark on order of moves

- Leahy and Neary (1996)'s explanation, "R&D, like any form of investment, is likely to be chosen before production takes place. Given this temporal sequence, R&D is likely to be chosen before policies such as export subsidies which are intended to affect output. In such circumstances the choice of R&D influences the government's optimal export subsidy and forward-looking firms will exploit this fact."

Formal model (1) : demand

$$\text{utility}: U = a_1 x_1 + a_2 x_2 - \left(\frac{b_1 x_1^2}{u_1^2} + \frac{b_2 x_2^2}{u_2^2} + \frac{k x_1 x_2}{u_1 u_2} \right), \quad 0 < k < 2$$

where, x_i : outputs, u_i : quality

assume symmetry $a_i = b_i = 1$

$$\text{inverse demand}: p_i(x,u) = 1 - \frac{2x_i}{u_i^2} - \frac{k x_j}{u_i u_j},$$

$$\text{ordinary demand}: x_i(p,u) = \frac{\{2(1-p_i)u_i - k(1-p_j)u_j\}u_i}{4-k^2}$$

Formal model (2) : profits

gross profits : $\pi_i = (p_i - c + s_i)x_i$,

where

c : marginal cost,

s_i : export (production, or employment) subsidy

R & D investment : $R_i = R_0 u_i^3, \; R_0 > 0$

net profits : $\Pi_i = \pi_i - R_i$

Formal model (3) : welfare

welfare

import country : $W_h = CS$

export countries : $W_i = \pi_i - s_i x_i$, $i = 1,2$

world welfare : $W = W_h + W_1 + W_2$

net world welfare : $W - (R_1 + R_2)$

$= W_h + (W_1 - R_1) + (W_2 - R_2)$

$= W_h + (\Pi_1 - s_1 x_1) + (\Pi_2 - s_2 x_2)$

Formal model (4) : the third stage, production

given $s=(s_i, s_j), u=(u_i, u_j)$

* Cournot (quantity) competition : $\max_{x_i} \pi_i = (p_i - c + s_i)x_i,$

$$x_i^Q(s,u) = \frac{\{(1-c)(4u_i - ku_j) + 4s_iu_i - ks_ju_j\}u_i}{16-k^2}$$

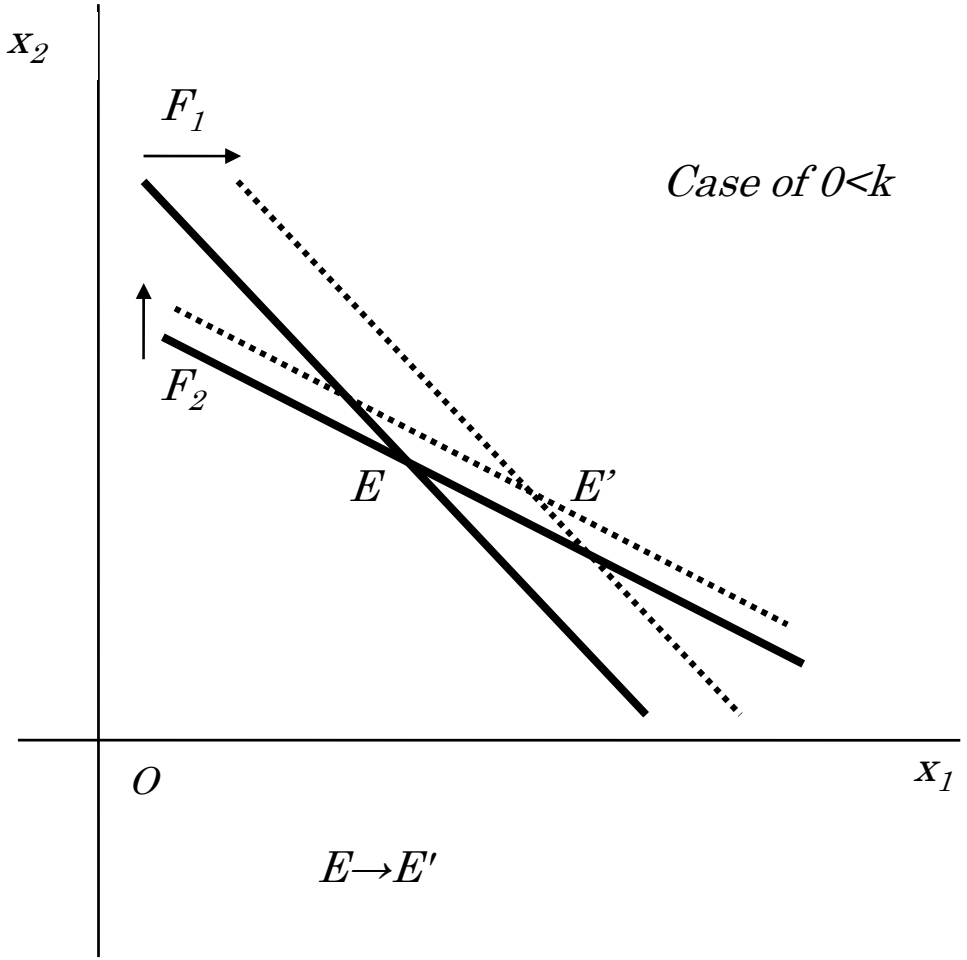
$$\frac{\partial x_i^Q}{\partial s_i} > 0,\ \frac{\partial x_i^Q}{\partial s_j} < 0,\ \frac{\partial x_i^Q}{\partial u_i} > 0,\ \frac{\partial x_i^Q}{\partial u_j} < 0, \quad \rightarrow \underline{\underline{\text{Lemma 1}}}$$

* Bertrand (price) competition : $\max_{p_i} \pi_i = (p_i - c + s_i)x_i,$

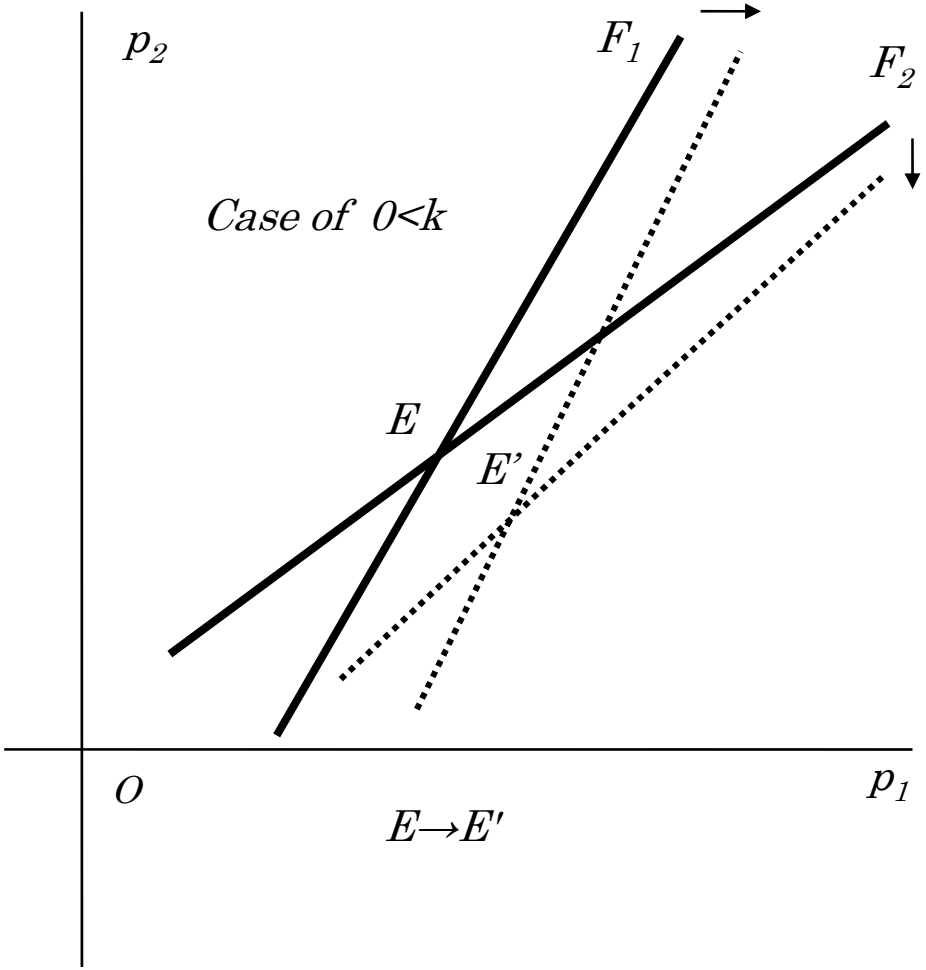
$$p_i^P(s,u) = c + \frac{(1-c)\{(8-k^2)u_i - 2ku_j\} - 8s_iu_i - 2ks_ju_j}{(16-k^2)u_i}$$

$$\frac{\partial p_i^P}{\partial s_i} < 0,\ \frac{\partial p_i^P}{\partial s_j} < 0,\ \frac{\partial p_i^P}{\partial u_i} > 0,\ \frac{\partial p_i^P}{\partial u_j} < 0, \quad \rightarrow \underline{\underline{\text{Lemma 4}}}$$

Cournot outputs, and direct effects of u1: eq. (7) or Lemma 1



Bertrand prices, and direct effects of u1: eq. (34) or Lemma 4



Effects of R&D investment on profit

Implication of Lemma 1 and Lemma 4.

- An increase in R&D investment by a firm has positive direct effect on its profit, but
- positive (negative) strategic effect under Cournot (Bertrand) competition.
- Cournot firms tend to invest more.

Formal model (5) : the second stage, Nash subsidy (export or …)

given $u = (u_i, u_j)$, s_j

∗ Cournot competition : $\max_{s_i} \ \mathrm{W}_i^Q = \pi_i^Q - s_i x_i^Q$,

$$s_i^{QN}(u) = \frac{(1-c)\{(16-k^2)u_i - 4ku_j\}k^2}{D_N u_i} > 0, \quad x_i^{QN}(u) = x_i^Q(s^{QN}(u), u)$$

where $D_N = (16-4k-k^2)(16+4k-k^2) > 0$,

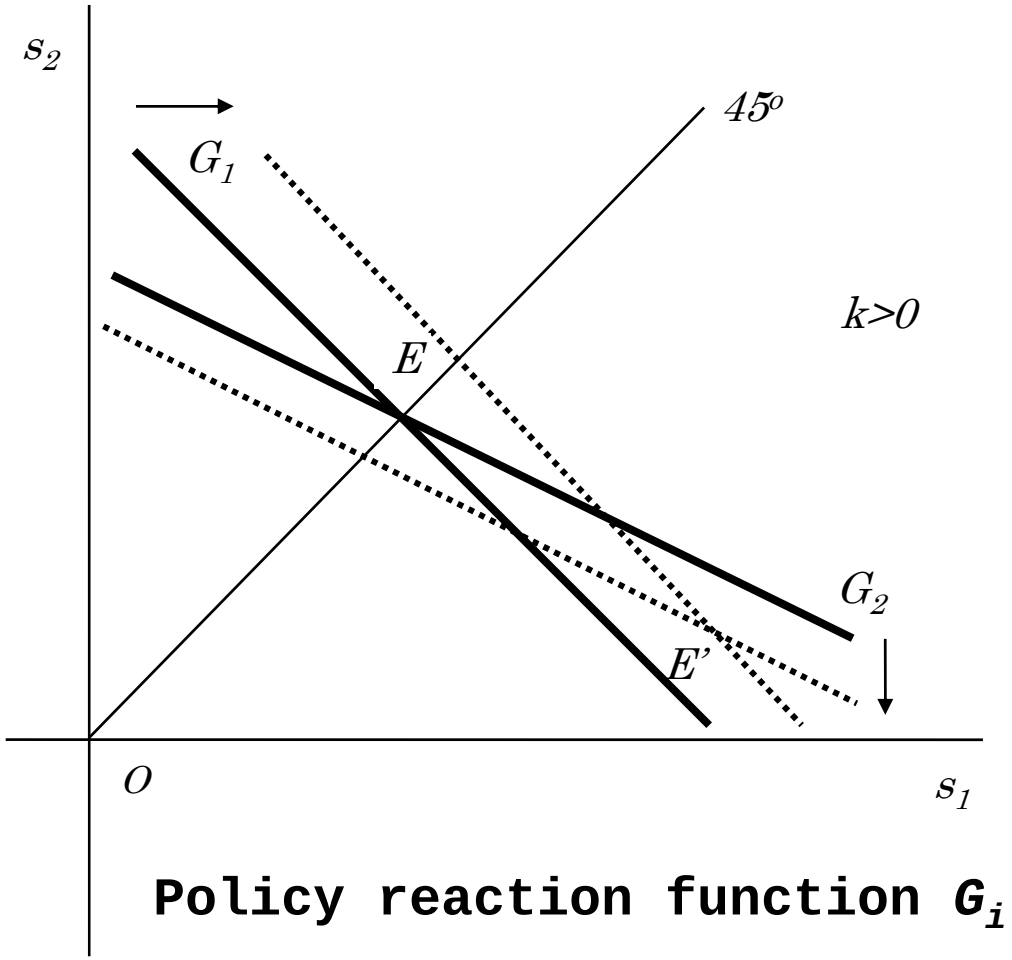
and $\dfrac{\partial s_i^{QN}}{\partial u_i} > 0$, $\dfrac{\partial s_i^{QN}}{\partial u_j} < 0$, $\rightarrow$ Lemma 2

∗ Bertrand competition : $\max_{s_i} \ \mathrm{W}_i^P = \pi_i^P - s_i x_i^P$,

$$s_i^{PN}(u) = -\frac{(1-c)\{2(16-3k^2)u_i - (8-k^2)ku_j\}k^2}{2D_N u_i} < 0,$$

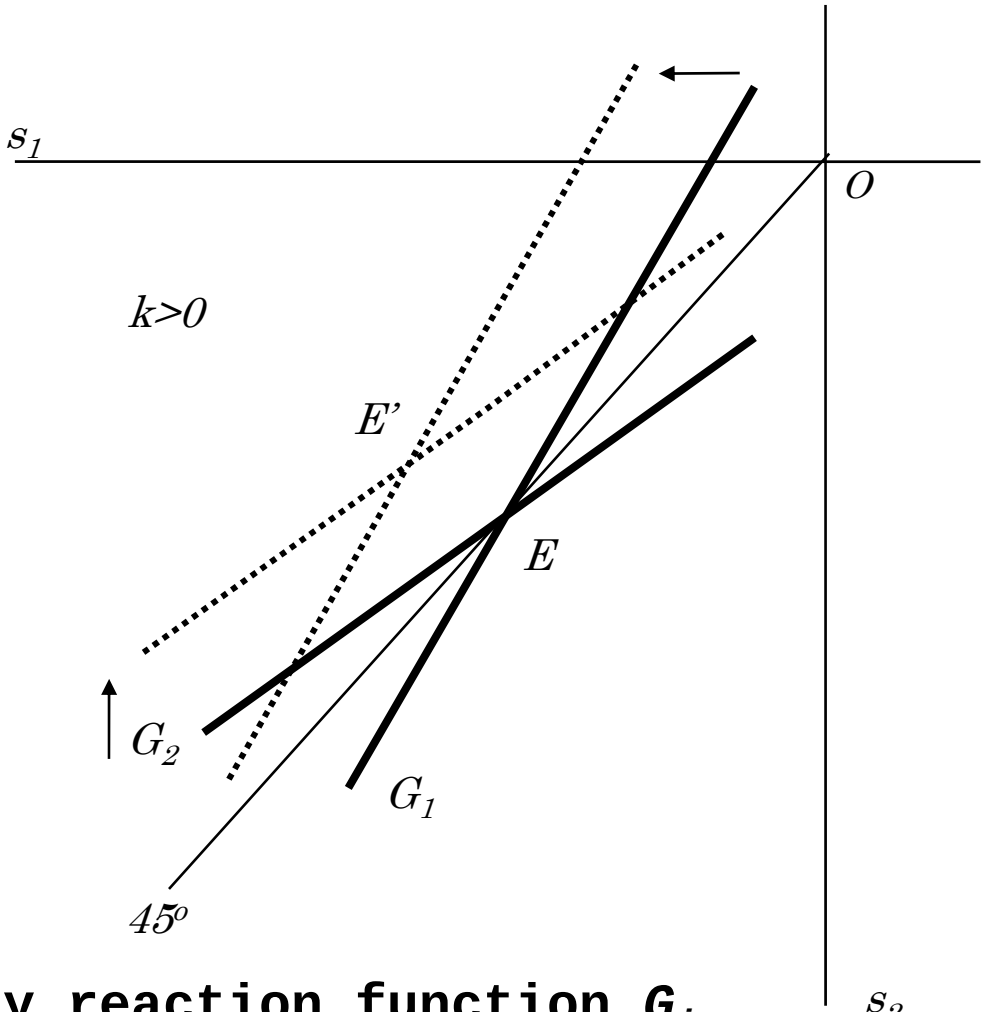
$p_i^{PN}(u) = p_i^P(s^{PN}(u), u)$, and $\dfrac{\partial s_i^{PN}}{\partial u_i} < 0$, $\dfrac{\partial s_i^{PN}}{\partial u_j} > 0$, $\rightarrow$ lemma 5

Lemma 2: Export subsidies under Cournot competition and effects of increases in u_1



Policy reaction function G_i

Lemma 5 : Export subsidies under Bertrand competition and effects of increases in u_1



Policy reaction function G_i

Implications: strategic effects of R&D through export subsidy

- Because Cournot (Bertrand) firms anticipate the second stage positive (negative) subsidy and recognize their ability to influence on export subsidies, they have incentives to invest more (less) under an export subsidy-tax scheme than under free trade in the first stage, to raise subsidy (to cut tax) to themselves.

Formal model (6) : the first stage, R&D investment

$R_i = R_0 u_i^3$, given u_j

* Cournot competition : $\max_{u_i} \ \Pi_i^{QN} = \pi_i^{QN} - R_i$,

Assumption 1C : $0<k<k^* \approx 1.21$

$$u_i^{CN} = \frac{64(16-k^2)(1-c)^2}{3D_N(16+4k-k^2)R_0} > 0, \quad \Rightarrow (s_i^{CN}, x_i^{CN}, p_i^{CN}), \text{ and welfare}$$

* Bertrand competition : $\max_{u_i} \ \Pi_i^{PN} = \pi_i^{PN} - R_i$,

Assumption 1B : $0<k<k^{**} \approx 1.18$

$$u_i^{BN} = \frac{2(16-3k^2)(8-k^2)^2(1-c)^2}{3(2+k)D_N(16-4k-k^2)R_0} > 0, \quad \Rightarrow \quad (s_i^{BN}, x_i^{BN}, p_i^{BN}), \text{ and welfare}$$

Conventional wisdom, free trade benchmark

Lemma 8. Dynamic efficiency under free trade

- Under free trade with substitute goods, without inter firms spillover effects of R&D investment, although Cournot firms invest more in R&D, Bertrand firms still produce more outputs and charge lower prices.

- Welfare of an import country and the world welfare are higher, and welfare in each export country (net profit) is lower in the Bertrand equilibrium.

Lemma 8. Dynamic efficiency under free trade (conventional wisdom, benchmark)

free trade case: $s_i \equiv 0$, symmetric equilibrium

investments : $R_i^{BF} < R_i^{CF}$, $u_i^{BF} < u_i^{CF}$,

outputs and prices: $x_i^{BF} > x_i^{CF}$, $p_i^{BF} < p_i^{CF}$,

import country welfare: $W_h^{BF} > W_h^{CF}$,

export countries welfare: $W_i^{BF} - R_i^{BF} < W_i^{CF} - R_i^{CF}$,

net world welfare:

$$W^{BF} - (R_1^{BF} + R_2^{BF}) > W^{CF} - (R_1^{CF} + R_2^{CF})$$

Our main results : Dynamic efficiency under export subsidies (1)

Like Qiu and Symeonidis :

- Proposition 3.

  (Incentive for R&D): Firms invest more in Cournot competition than in Bertrand one.

$$\text{Dynamic efficiency : investment}$$

$$R_i^{BN} < R_i^{CN}, \quad \text{or} \quad u_i^{BN} < u_i^{CN}$$

Our main results: Dynamic efficiency under export subsidies (2)

- Proposition 4.

  (Outputs and prices): Though Cournot firms produce and supply more than Bertrand firms do, they charge higher prices.

$$\text{Dynamic efficiency : outputs and prices}$$

$$x_i^{BN} < x_i^{CN}, \quad \text{and} \quad p_i^{BN} < p_i^{CN}$$

Our main results : Dynamic efficiency under export subsidies (3)

- Proposition 5. (Welfare):

  (1) The welfare of an import country (consumer's surplus) is higher in the Cournot equilibrium.

  (2) Though the net profit is higher in the Cournot equilibrium, the net welfare of export countries is higher in the Bertrand equilibrium.

  (3) World welfare is higher in the Cournot equilibrium.

Dynamic Efficiency under export subsidies: summary of proposition 5

Dynamic efficiency: welfare

import country welfare: $W_h^{BN} < W_h^{CN}$,

net profits: $\pi_i^{BN} - R_i^{BN} < \pi_i^{CN} - R_i^{CN}$,

export country net welfare: $W_i^{BN} - R_i^{BN} > W_i^{CN} - R_i^{CN}$,

net world welfare: $W^{BN} - (R_1^{BN} + R_2^{BN}) < W^{CN} - (R_1^{CN} + R_2^{CN})$

Intuitions for outputs and welfare ranking reversal : (1)

- To show the intuitions for outputs and welfare ranking reversal, compare the first stage investments and outputs under subsidy policy (superscript CN, BN) with those in a free trade (superscript CF, BF) and those in the first best world welfare maximizing solution (superscript W).

Intuitions for outputs and welfare ranking reversal : (2)

investments: $u_i^{BN} < \underline{u_i^{BF} < u_i^{CF}} < u_i^{CN} < u_i^{W}$,

outputs: $x_i^{BN} < \underline{x_i^{CF} < x_i^{BF}} < x_i^{CN} < x_i^{W}$,

net worldwelfare:

$W^{BN} - 2R_i^{BN} < \underline{W^{CF} - 2R_i^{CF} < W^{BF} - 2R_i^{BF}} < W^{CN} - 2R_i^{CN}$

Summary : more efficient equilibrium without spillover effects

	Free Trade	Nash Export Subsidy
Statics: no R&D investment	Bertrand	Bertrand
Dynamics: with R&D investment	Bertrand	(Conjecture: Bertrand, if governments move first) Cournot, if firms move first.

Summary

- Neither export subsidies nor R&D investments without spillover effects could by itself ensure efficiency of the Cournot equilibrium.
- But the Cournot equilibrium is shown to be more efficient over the Bertrand equilibrium in the sequence equilibrium with an export subsidy and R&D investment without spillover.
- Thus strategic effects through the export subsidy-tax scheme by R&D investments may be more powerful than their possible spillover effects.

Further investigations

- the case of process R&D in addition to quality improvement,
- a more complicated government-only commitment equilibrium, that is, a three-stage game in which, each government can commit to its (R&D subsidy and/or) export subsidy before firms choose investment in the second stage.
- spillover effects of R&D investment,
- asymmetric characteristics of firms within one industry .