International trade and the internal organization of firms: An evolutionary approach

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Evolutionary Game Theory class
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1 Introduction

2 A parametric model

3 General results
Goals

- Build framework for understanding causes and consequences of firms’ internal organization.
- Analyze impact of international trade regime, e.g., rise and decline of Japan 1960-2000.
- Illustrate economic applications of evolutionary games. The paper (coauthored with KC Fung) appeared in JIE in 1996.
Two alternative modes (strategies)

1. Mode A = traditional hierarchy
   - Narrowly defined jobs
   - Buffer inventories
   - Pay for performance
   - Centralized top-down decisions
   - Diffuse public ownership.

2. Mode B = new Japanese mode
   - Job rotation, teams, decisions begin at shop floor
   - “lifetime” employment, seniority-based pay.
   - Just-in-time inventories
   - Keiretsu-owned via cross-holdings.

Intermediate (or mix-n-match) modes are less efficient due to indivisibilities and complements (Milgrom & Roberts, 1990)
Factors affecting fitness

- Environmental factors that advantage B relative to A:
  - demand favors small batch production of many varieties,
  - external shocks are moderate and frequent,
  - workers learn rapidly, and
  - costs of holding inventories are high.

- Increasing returns to B due to:
  - skimming effect: A firms poach most productive young workers
  - network effect: large keiretsu are more effective.

- Decreasing returns to both A and B due to glut effect.
Fitness functions in autarky

Given \( N \geq 2 \) firms, of which \( sN \) employ B mode and \((1 - s)N\) employ A mode, for share \( s \in [0, 1] \).
Fitness \( w_A(s) \) and \( w_B(s) \) are SR Cournot equilibrium profit \( \pi(s, e) \) given \( s, N \) and the environment parameter vector \( e \).

- Set \( FC = 0 \) and constant marginal cost \( c_A \).
- Linear skimming+network effect: B’s have \( MC = c_B - bs > 0 \) where (to avoid trivialities) \( b \in [0, c_B) \) and \( c_A > c_B - b \).
- Linear demand functions with imperfect substitutes capture glut effects, with parameters \( \alpha_A, \alpha_B, \beta, \gamma \).
- So inverse demand for B-output is \( P_B = \alpha_B - \beta X_B - \gamma X_A \), where the \( X \)'s are total outputs from firms in the given mode. Demand for A-output is analogous.
Cournot equilibrium outputs $x_A, x_B$ are quotients of cubic polynomials in the parameters.

Profits are of the form $w_i(s) = \pi_i(s, e) = (x_i)^2\beta$ for $i = A, B$.

For reasonable values of the parameter vector $e$ (which were lost from the caption in the published paper), the fitness functions are graphed in Figure 1.
Cournot fitness functions

Figure:  \( N = ?, c_B = 14, \gamma = 0.98, \ldots \)
Two country extension

- Similar structure in “Foreign” country for production \((N^*, c^*, b^*...\)) and demand \((\alpha_A^*, \alpha_B^*, \beta^*, \gamma^*..\))
- With a little more work, compute foreign and domestic sales of both kinds of firms in both countries in SR Cournot equilibrium.
- These yield profit function differences (“Deltas”) \(\pi_D, \pi_D^*\) graphed in Figures 2, 3a, 3b.
Prohibitive trade barriers \((t \gg 0)\).
No trade barriers, strong glut effects: \( t = 0, \gamma = 0.95 \)
US/Japan parameters: $t = 0, \gamma = 0.98$

Figure: $N = 20, N^* = 10, \alpha = 220, \alpha^* = 110$
Interpretation

- In the US/Japan example, we expect (even absent cost advantages) different modes to go to fixation in the two countries.
- But what if we open free trade in inputs (capital and labor) as well as outputs?
- This would equalize production parameters $c, b$ across the two countries.
- Then the two profit differentials $\pi_D, \pi_D^*$ coincide, and yield the phase portrait in Figure 4.
US/Japan trade in inputs equalizes profit differentials.

Fig. 4: basins of attraction, even in the absence of cost asymmetries or strong glut effects. These diagrams suggest an interesting story about trade between the US and Japan. Begin in autarky, at the point (0,1) in Fig. 2. Note that we are not assuming any cost asymmetries between the two countries; the specialization of Japanese firms in the B mode and US firms in the A mode at (0,1) is purely for historical reasons and is as likely (given the stylized parameters) as any other pattern.

Next, open trade in outputs only. Fig. 3 suggests that the specialization pattern will persist, and indeed be reinforced in that the basin of attraction becomes larger for evolutionary equilibrium (0,1).

Finally, consider a new regime that now allows free (or nearly free) trade in inputs as well as outputs. The new regime will destabilize the existing pattern of specialization. Fig. 4 suggests that the system will evolve towards the highest cost and least efficient state (s,s*) = (0,0). That is, even though the B mode is relatively efficient, it will be completely displaced in the foreign country as well as in the home country.

Is this inefficiency result due to fortuitous parameter values or to details?
The Upshot

An exercise with 3 time scales...

- Begin in autarky with US/Japan parameters, go to EE,
- then drop output trade barriers and go to the new EE,
- and finally drop input trade barriers....
- Then we end up at the EE (0, 0) – the B mode is wiped out, despite its greater efficiency at fixation!
Does that insight survive going beyond the Cournot parametric model?

To investigate, write general properties of a more abstract evolutionary trade model. Still driven by \( \pi_D(s, s^*) \), \( \pi_D^*(s^*, s) \), but these depend on an environmental parameter vector \( Z \) in a general way.

Let \( Z' \subset Z \) be the relevant set where the B- advantage \( \pi_D \) is increasing in \( s \).
Proposition 1. The parameter set $Z'$ can be partitioned into three components, $Z_1$, $Z_2$ and $Z_3$ such that

(a) For all $z \in Z_1$, the state $s = 0$ is the unique NE and is an EE.
(b) For all $z \in Z_2$, the state $s = 1$ is the unique NE and is an EE.
(c) For all $z \in Z_3$ there are three NE: $s = 0$, $s = 1$ and $s = \hat{s}(z)$, where $\hat{s}$ is the unique solution to the equation $\pi_D(s;z) = 0$. The NE $\hat{s}$ is never an EE, but as long as they are distinct from $\hat{s}$, the two endpoint NE are EE whose basins of attraction are separated by $\hat{s}$.
Focus on $Z_3$, and consider two countries

Proposition 2. Let $z,z^* \in Z_3$. In autarky, the four corner states $s = 0, 1$ and $s^* = 0, 1$ are all evolutionary equilibria whose basins of attraction are separated by the vertical line at $\hat{s}(z)$ and the horizontal line at $\hat{s}^*(z^*)$. Given trade in outputs with $(z,z^*) \in Z^\circ$ the states $(0,0)$ and $(1,1)$ are unstable and the remaining EE $(1,0)$ and $(0,1)$ have basins of attraction separated by an unstable saddle path $S$ that lies between the loci $[\pi_D^o = 0]$ and $[\pi_D^{*o} = 0]$. 
Trade in inputs as well as outputs

Proposition 3. Let $\tilde{z} \in Z_3$. Under approximate free trade (AFT) in inputs as well as outputs, the only evolutionary equilibria (EE) are the pure corner states (0,0) and (1,1). Their basins of attraction are separated by a saddle path which may contain an unstable interior Nash equilibrium (NE).
Main result survives on stabilizing B-mode via trade in outputs ... 

yet trade in inputs would destabilize it via transnational network and skimming effects.

Not ready for policy analysis, but points up subtle issues.

Shows problem with optimistic Alchian (1950) view that evolution necessarily supports efficient production.

Same techniques later applied to analyze international environmental policy: cf McGinty and De Vries papers, jointly and separately.