Competition, Memory and Memoryless Processes, and Innovation Intensity

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Outline

Motivation

- Positive relationship?⇒ Hart (BJE, 1983), and Correa and Ornaghi (JIE, 2014)⇒ *Natural Selection*
- Negative relationship?⇒ Aghion and Howitt (Econometrica, 1992), and Hashmi (REStа, 2013)⇒ *Schumpeterian*
- Non-monotonic relationship?⇒ Aghion et al. (QJE, 2005)⇒ Correa (JAE, 2012)
- Hausman et al. (Econometrica, 1984) and Hall et al. (IEJ, 1986) find that contemporaneous R&D investment depends on previous investment
- Does innovation boost or fall with more competition when innovation follows a memory process?

The Model

- Any industry has two firms, with each firm producing an output, where each unit of output uses γ^{-k_i} units of labor, with $\gamma > 1$ and k_i the technological level of firm i
- An industry can be unleveled with a leader ($k = 1$) and a follower ($k = -1$), or neck-and-neck ($k = 0$), depending on the technology gap (step-by-step model)
- The follower can freely adopt the former leader's technology and thus the leader does not have incentive to innovate
- The follower can also copy the current's leader technology at rate h
- The leader earns monopoly profit π_1
- Neck-and-neck profit π_0 is equivalent to $\pi_1(1-\delta)$, $\forall\delta \in$ [0.5,1], where δ denotes the degree of competition
- A firm i devotes n_i resources to improve its technology k_i, where technology improvement follows a stochastic process which is a function of n

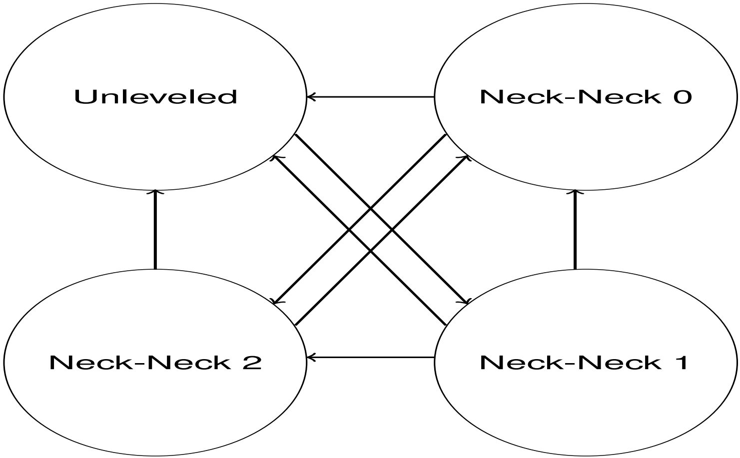
The Model

- If a firm i innovates at time $t - \Delta t$ and its rival j do not, i obtains a knowledge value λ which increases the probability to innovate at t
- If a firm i innovates at time $t - \Delta t$ and so does its rival j, both i and j obtains a knowledge value ϕ which increases the probability to innovate at t
- The knowledge values last for only one period

The Model

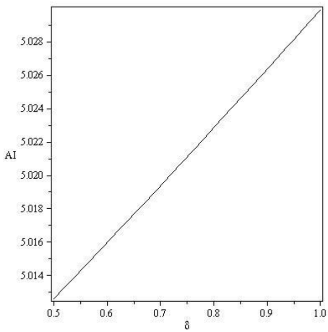
- Industries can be at 4 different states
- Unleveled$\Rightarrow$ one firm as the leader and the other as the follower. The former period state does not matter
- Neck-and-neck 0$\Rightarrow$ leveled firms and both firms failed to innovate in the former period
- Neck-and-neck 1$\Rightarrow$ leveled firms and one firm succeeded to innovate in the former period
- Neck-and-neck 2$\Rightarrow$ leveled firms and both firms succeeded to innovate in the former period

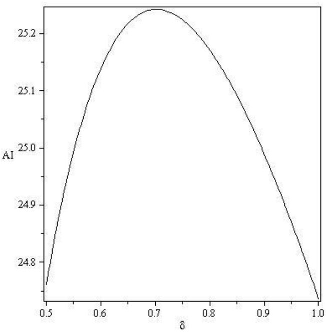
States



Innovation-Competition Relationship

Memory	Memoryless





Data

- Correa and Ornaghi (JIE, 2014) data
- 10,359 U.S. manufacturing firms across 223 industries period 1974-2001

Innovation

$$P_{jt} = \frac{1}{n_{jt}} \sum_{i \in j} P_{it}$$

$$PCI_{jt} = \frac{P_{jt} CI_{jt}}{CI_t}$$

Competition

$$\pi_{it} = \frac{OP_{it} - rK_{it}}{S_{it}}$$

$$c_{jt} = 1 - \frac{1}{n_{jt}} \sum_{i \in j} \pi_{it}$$

Empirical Innovation-Competition Relationship

- $I_{jt} = f(c_{jt}, c_{jt}^2), \forall I_{jt} \in \{P_{jt}, PCI_{jt}\}$
- The first issue is the mutual causality between innovation and competition$\Rightarrow$ using tariff rate growth, Canada first lag tariff rate, Mexico first lag tariff rate, Germany labor productivity and France labor productivity, as instruments, and the control function approach
- The second issue is that a Poisson regression may suffer overdispersion, since sample variance might likely be much larger than sample mean$\Rightarrow$ negative binomial regression
- The third issue, as noted by Allison and Waterman (2002), is that negative binomial with a large number of fixed effects may drive inconsistent estimators$\Rightarrow$ negative binomial random effects

Empirical Innovation-Competition Relationship

Regression Equation

$$I_{jt} = \exp\left\{\beta_0 + \beta_1 c_{jt} + \beta_2 c_{jt}^2 + \zeta \hat{v}_{jt} + \alpha_t + \eta_j + u_{jt}\right\}$$

$$\begin{aligned} H_0 &: \beta_1 = \beta_2 = 0, \\ H_1 &: otherwise. \end{aligned}$$

- Two specifications are performed for each group (memory and memoryless)
- Specification 1 $\Rightarrow$ patents as the innovation variable including instruments
- Specification 2 $\Rightarrow$ citation weighted patents as the innovation variable including instruments

Defining Memory

Sequential Rule

$$P_{jt} = \exp\left\{\lambda_{j0} + \varsigma_j t_j + \sum_{s=1}^{5} \lambda_{js} P_{j,t-s} + \varepsilon_{jt}\right\}$$

$$H_0 \quad : \quad \lambda_{js} = 0$$
$$H_1 \quad : \quad otherwise$$

- $P_{j,t-s}$ denotes the s lag of average patents at industry j
- 77 memory industries⇒ Chemicals and Allied Products (2800), and Aircraft and Parts (3720)
- 146 memoryless industries⇒ Computer and Office Equipment (3570), and Electronic and Other Electrical Equipment (3600)

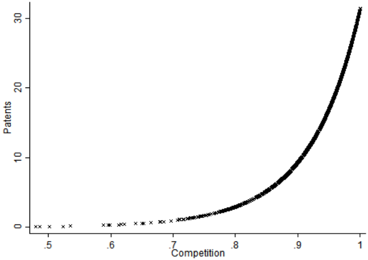
Testing H_0 of Regression Equation

Group	S1	S2
Memory	Rejected [0.0000]	Rejected [0.0000]
Memoryless	Not Rejected [0.1356]	Rejected [0.0165]

Patents Including Instruments (S1)

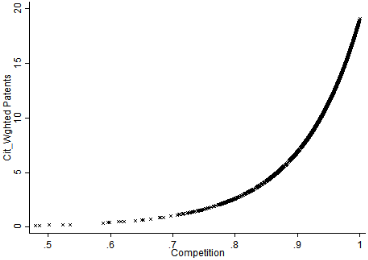
Memory

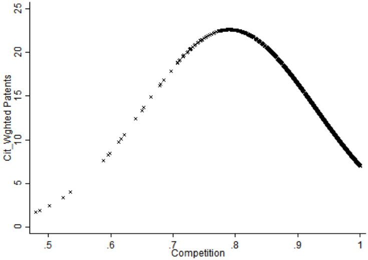
Memoryless



Citations Adjusted Including Instruments (S2)

Memory | Memoryless





Summary

- Positive relationship between innovation and competition when innovation follows a memory process
- Flat patent-competition relationship for memoryless industries
- Inverted-U citation-competition relationship for memoryless industries
- These findings support the idea that one-size does not fit all

Unleveled

Follower who was follower in previous period

- Value function

$$V_{-1}^{-1} = (1 - r\Delta t)\{(n_{-1}^{-1} + h)\Delta t V_0^{-1} + [1 - (n_{-1}^{-1} + h)\Delta t]V_{-1}^{-1}\} - \frac{(n_{-1}^{-1})^2}{2}\Delta t$$

- Bellman equation

$$rV_{-1}^{-1} = (n_{-1}^{-1} + h)(V_0^{-1} - V_{-1}^{-1}) - \frac{(n_{-1}^{-1})^2}{2}$$

Neck-and-Neck 0

Neck-and-neck/Neck-and-neck and Failing

- Value function

$$\begin{aligned} V_0^{0,F} &= \max_{n_0^{0,F}} \Big\{ \pi_0 \Delta t + (1 - r\Delta t) \Big[n_0^{0,F} \Delta t V_1^0 \\ &+ \overline{n}_0^{0,F} \Delta t V_{-1}^0 + (n_0^{0,F} + \overline{n}_0^{0,F}) \Delta t V_0^{0,S} \\ &+ [1 - (2n_0^{0,F} + 2\overline{n}_0^{0,F})\Delta t] V_0^{0,F} \Big] - \frac{(n_0^{0,F})^2}{2} \Delta t \Big\} \end{aligned}$$

- Bellman equation

$$\begin{aligned} rV_0^{0,F} &= \max_{n_0^{0,F}} \Big\{ \pi_0 + n_0^{0,F} (V_1^0 + V_0^{0,S} - 2V_0^{0,F}) \\ &+ \overline{n}_0^{0,F} (V_{-1}^0 + V_0^{0,S} - 2V_0^{0,F}) - \frac{(n_0^{0,F})^2}{2} \end{aligned}$$

(1)

Neck-and-Neck 1

Neck-and-neck/Follower

- Value function

$$V_0^{-1} = \pi_0 \Delta t + (1 - r\Delta t)\{(n_0^{-1} + \lambda)\Delta t V_1 + \overline{n}_0^1 \Delta t V_{-1} + (n_0^{-1} + \lambda + \overline{n}_0^1)\Delta t V_0^{0,S} + [1 - (2n_0^{-1} + 2\lambda + 2\overline{n}_0^1)\Delta t] V_0^{0,F}\} - \frac{(n_0^{-1})^2}{2}\Delta t$$

- Bellman equation

$$rV_0^{-1} = r\Delta t[\pi_0 + (n_0^{-1} + \lambda)(V_1 + V_0^{0,S} - 2V_0^{0,F}) + \overline{n}_0^1(V_{-1} + V_0^{0,S} - 2V_0^{0,F}) - \frac{(n_0^{-1})^2}{2}] + (1 - r\Delta t) r V_0^{0,F}$$

Neck-and-Neck 2

Neck-and-neck/Neck-and-neck and Succeeding

- Value function

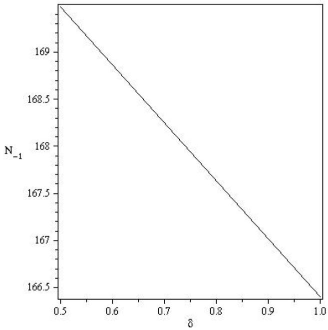
$$\begin{aligned} V_0^{0,S} &= \pi_0 \Delta t + (1 - r\Delta t)\{(n_0^{0,S} + \phi)\Delta t V_1 + (\overline{n}_0^{0,S} + \overline{\phi})\Delta t V_{-1} \\ &+ (n_0^{0,S} + \phi + \overline{n}_0^{0,S} + \overline{\phi})\Delta t V_0^{0,S} \\ &+ [1 - (2n_0^{0,S} + 2\phi + 2\overline{n}_0^{0,S} + 2\overline{\phi})\Delta t] V_0^{0,F}\} - \frac{(n_0^{0,S})^2}{2}\Delta t \end{aligned}$$

- Bellman equation

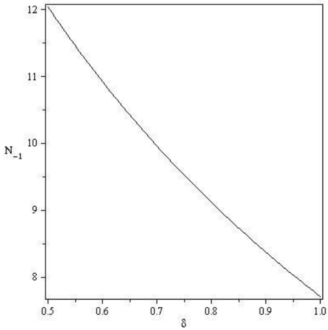
$$\begin{aligned} rV_0^{0,S} &= r\Delta t[\pi_0 + (n_0^{0,S} + \phi)(V_1 + V_0^{0,S} - 2V_0^{0,F}) + (\overline{n}_0^{0,S} + \overline{\phi})(V_{-1} + V_0^{0,S} \\ &- 2V_0^{0,F}) - \frac{(n_0^{0,S})^2}{2}] + (1 - r\Delta t) r V_0^{0,F} \end{aligned}$$

Unleveled Research Intensity

Memory



Memoryless



Neck-and-Neck 2

Cuadro 1: Number of Patents and Citations Matched to Compustat Companies

Year	Patents	Citations	Year	Patents	Citations
1985	22,624	281,093	1996	53,546	947,394
1986	22,909	299,205	1997	64,850	1,073,212
1987	24,384	330,589	1998	66,464	990,483
1988	27,233	369,919	1999	72,106	895,240
1989	29,182	405,128	2000	76,982	697,625
1990	30,240	445,963	2001	76,862	459,160
1991	31,421	486,126	2002	66,553	273,890
1992	33,050	537,206	2003	46,044	114,376
1993	35,363	588,279	2004	23,275	25,361
1994	42,088	720,299	2005	6,149	2,236
1995	53,130	905,360	2006	276	0

Memory Coefficients

	S1	S2
Competition	5.7322	5.2282
	(5.2304)	(5.9390)
Competition Squared	3.3645	2.5996
	(2.8636)	(3.2651)
χ^2-statistic	41.20	25.93
Observations	1,383	1,383
F-statistic	10.50	10.50
Hansen J-statistic	2.03	2.03

Standard errors in parenthesis.

Memoryless Coefficients

	S1	S2
Competition	20.5082	41.9192
	(19.8933)	(22.1176)
Competition Squared	-7.0415	-26.5217
	(10.6161)	(11.9844)
χ^2-statistic	4.00	8.20
Observations	2,354	2,354
F-statistic	10.50	10.50
Hansen J-statistic	2.03	2.03

Standard errors in parenthesis.