Offshoring as Process Innovation

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Industry Dynamics of Offshoring

- Offshoring
  - Labor-market impact: Feenstra & Hanson ('96, '97, '99, '03), Autor et al. ('03), Hsieh & Woo ('05), Feenstra ('10), Ottaviano et al. ('10), Burstein & Vogel ('11), Hummels et al. ('11)
  - Product-market impact: ?
- From product-market perspectives, offshoring is:
  - Cost-reducing investment ("process innovation")
  - Possibly "drastic" (Arrow '62)
  - Location change
- Theory predicts fundamental (yet ambiguous) relationships between:
  - Incentives to offshore
  - Market structure (i.e., how many rivals & where)
- So what?
  - Life & death of firms & industries
  - Job destruction $\in$ creative destruction
- This paper
  - Study strategic industry dynamics of offshoring

This Paper

- Questions
  - How does market structure affect offshoring incentives?
  - How does offshoring shape market structure evolution?
- Model: Dynamic oligopoly with radical process innovation
  - Dynamic game, finite horizon, non-stationary
  - Decision to stay North or go South
  - As more rivals offshore...
    - Competitive pressure on global output price
    - Business stealing from home firms
- Approach: Dynamic & structural
  - Estimate
    1. Demand (global)
    2. Production costs (north & south)
    3. Sunk cost of offshoring (& entry/exit)
  - Why bother?
    - Simultaneous evolution
    - What if no offshoring?
    - Welfare analysis of government interventions (in future)
- Data
  - Universe of Hard Disk Drive makers in the world (1976–98)

Why Study Hard Disk?

- Relevant

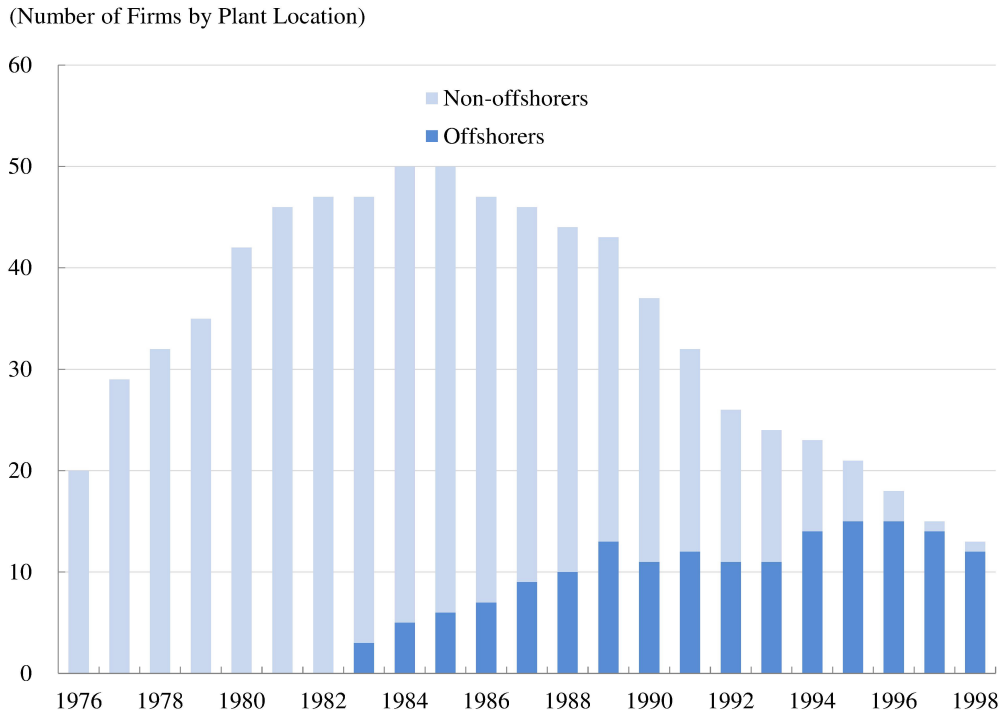


Figure 1: Market Structure and Offshoring

- Feasible
  - Long panel (23 years)
  - Global coverage (178 firms)
  - Details on technology, products, & plant locations

Data (1 of 4): Why Singapore?

- Why not California?
  - Seagate relocated entire assembly from Scotts Valley to Singapore due to the "high cost, marginal quality and poor availability of labor" in US.
  - Co-founder: "We had too many surfers."
- Labor-cost advantage of offshoring

Table 1: Hourly Wage Rate for Manufacturing (US$)

Year	1983	1985	1988	1990	1993	1995
U.S.	8.83	9.54	10.19	10.83	11.74	12.37
Singapore	1.49	2.47	2.67	3.78	5.38	7.33
Malaysia	–	1.41	1.34	1.39	1.74	2.01*
Thailand	0.43	0.54	0.62	1.03	1.25	1.41
Philippines	0.59	0.55	0.74	1.02	1.07	–
Indonesia	0.13	0.3**	0.38	0.60	0.92***	–

Note: Current USD. *, **, and *** indicate data in 1994, 1986, and 1992, respectively.

- No-nonsense government
  - Tax incentives
  - Market-friendly industrial policy
  - Pool of electronics managers, engineers, technicians, & operators.

Data (2 of 4): Entry & Exit

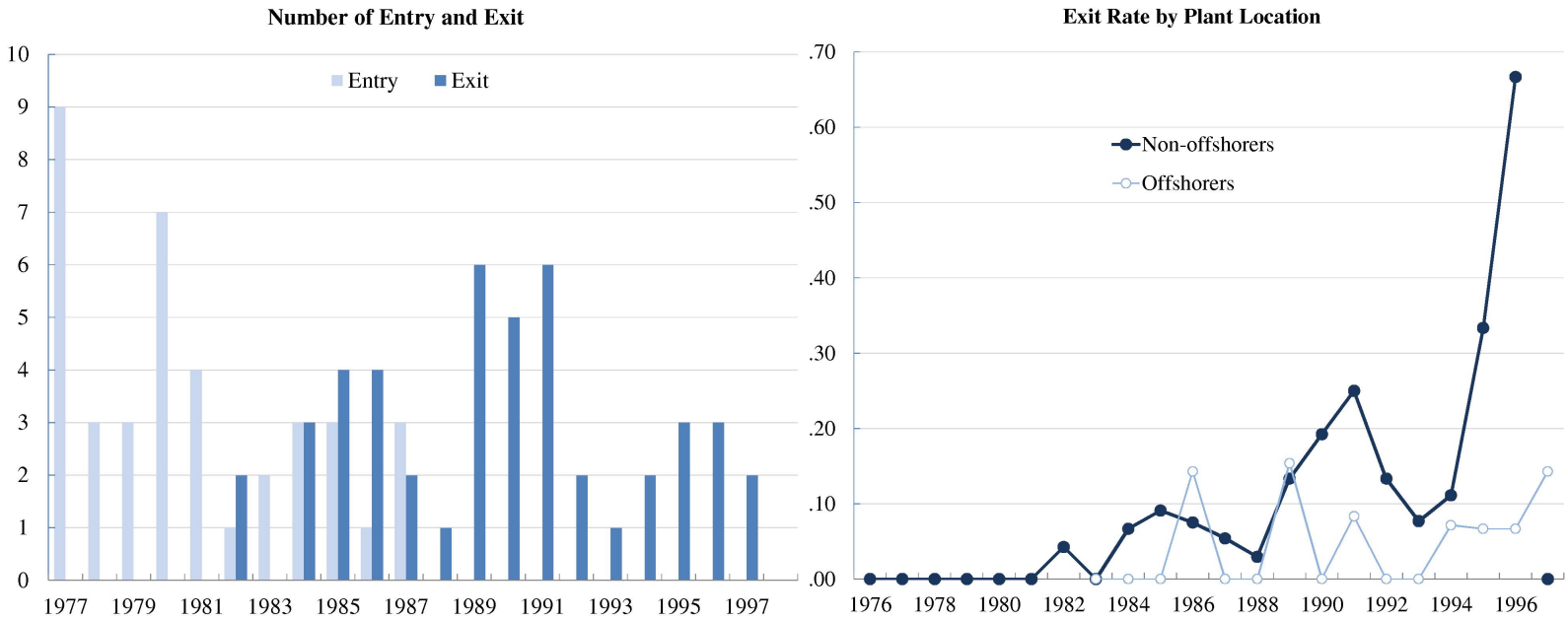


Figure 2: Entry, Exit, and Offshoring

- Massive entry & exit
- Non-offshorers exit more often

Data (3 of 4): Price, Quantity, & Market Share

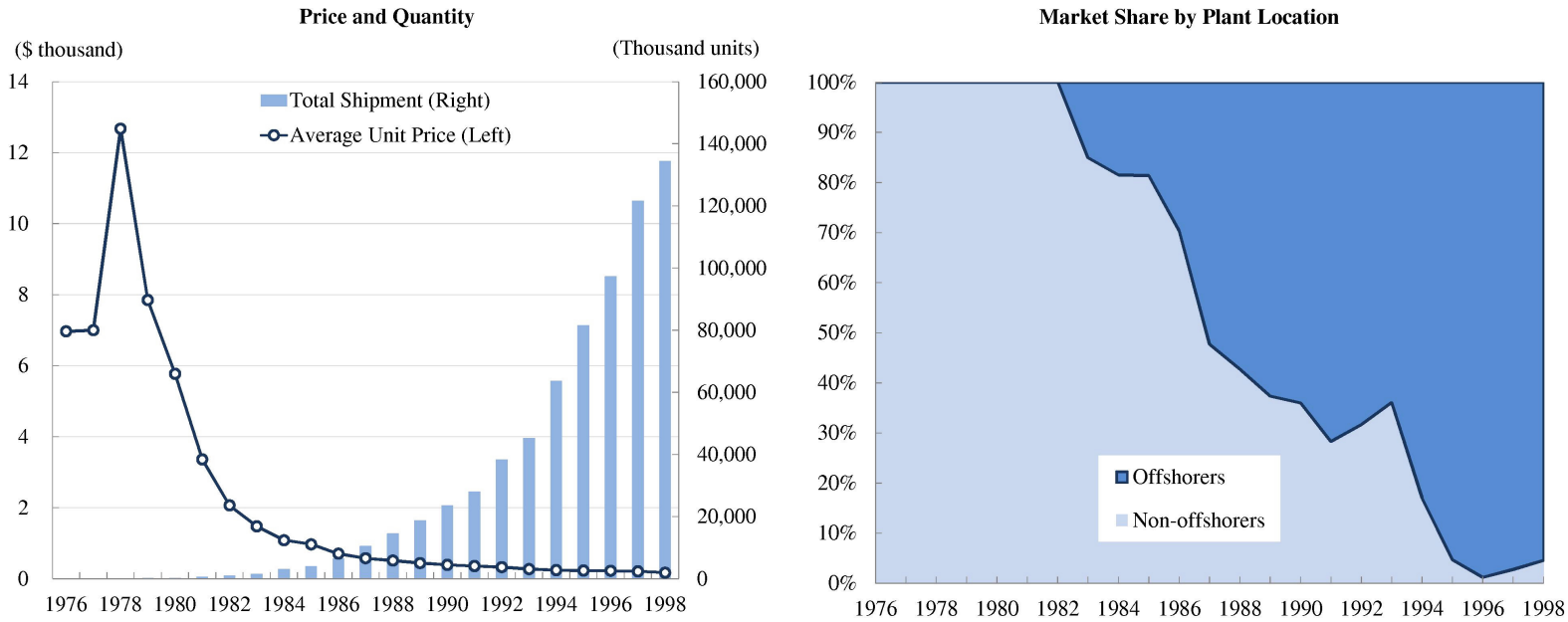


Figure 3: Price, Output, & Market Share

- Falling price
- Rising output
- Growing market share of offshorers

Data (4 of 4): North vs South

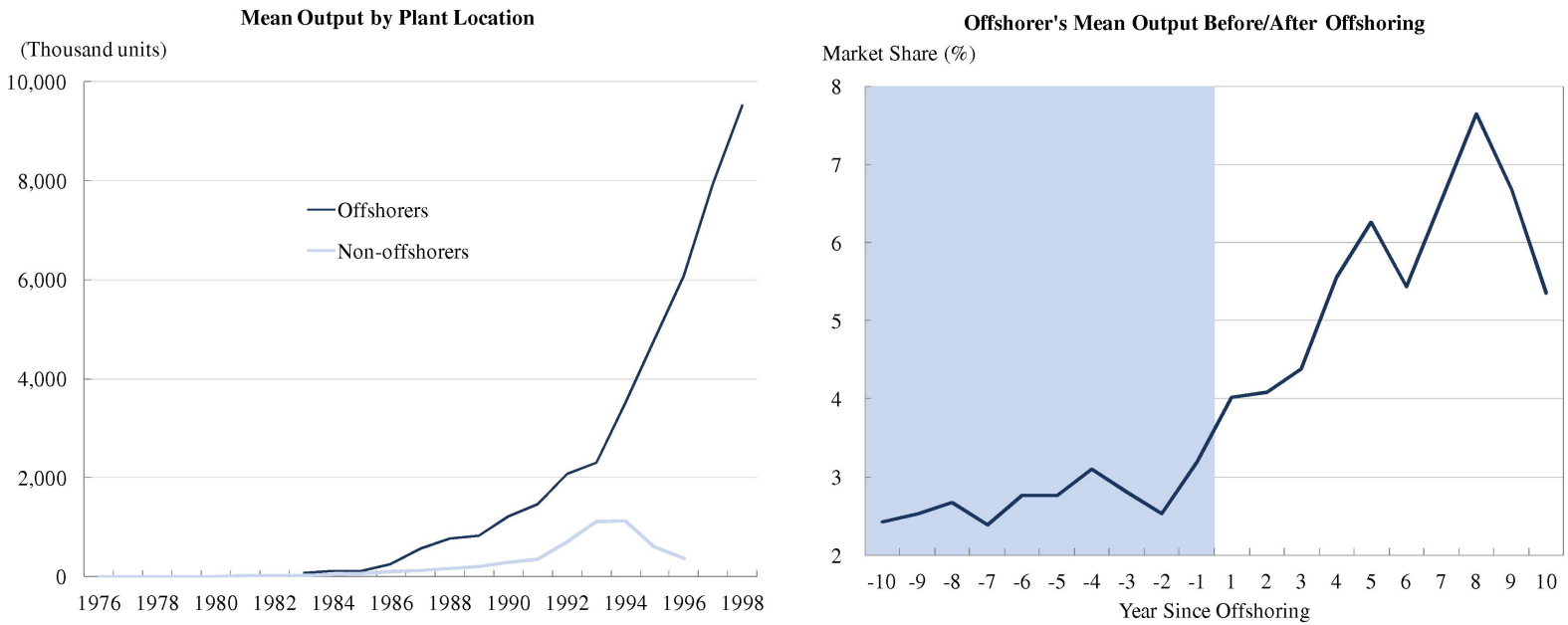
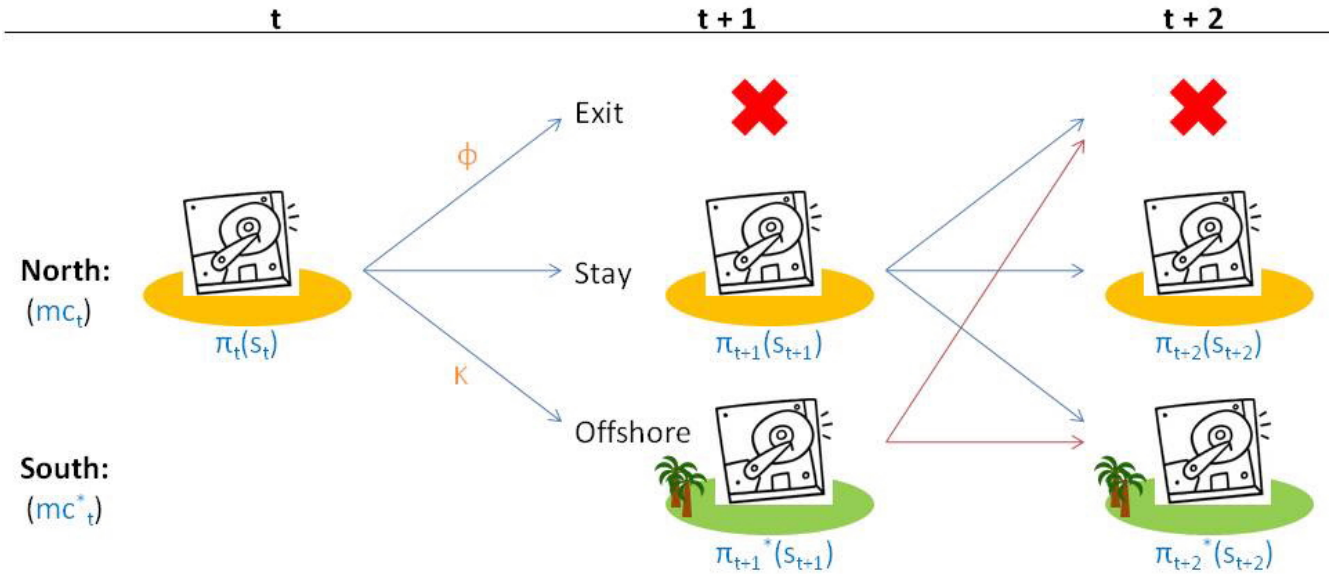


Figure 4: Average Output by Location

- Offshorers sell *more* than non-offshorers
- More output *after* offshoring

Model (1 of 2): Overview

- Dynamic discrete game



- N_t firms in North

$$V_t(s_t) = \pi_t(s_t) + \max \left\{ \begin{array}{c} \phi\beta E\left[V_{t+1}(s_{t+1})|s_t\right] + \varepsilon_{it}^0, \\ \beta E\left[V_{t+1}(s_{t+1})|s_t\right] + \varepsilon_{it}^1, \\ \beta E\left[V_{t+1}^*(s_{t+1})|s_t\right] - \kappa + \varepsilon_{it}^2 \end{array} \right\}$$

- N_t^* firms in South

$$V_t^*(s_t) = \pi_t^*(s_t) + \max \left\{ \begin{array}{c} \phi\beta E\left[V_{t+1}^*(s_{t+1})|s_t\right] + \varepsilon_{it}^0, \\ \beta E\left[V_{t+1}^*(s_{t+1})|s_t\right] + \varepsilon_{it}^1 \end{array} \right\}$$

Model (2 of 2): Timeline

- In each year t
  1. Potential entrants (∞):
     - Observe market structure $s_t = (N_t, N_t^*)$
     - Sequentially decide whether to enter: free entry

$$\max\left\{V_t\left(s_t\right) - \kappa_t^{ent}, 0\right\}$$

     - Actual entrants become active in North
  2. Each active firm i (incumbents + actual entrants):
     - Observes updated s_t & private cost shocks $\left(\varepsilon_{it}^0, \varepsilon_{it}^1, \varepsilon_{it}^2\right)$
     - Decides whether to: $\{exit,\ stay\ North,\ go\ South\}$
     - If already in South, whether to exit
  3. Active firms earn period profits

$$\pi_t^l\left(N_t, N_t^*\right)$$

  4. Decisions implemented & state evolves

Estimation (1 of 4): Demand

- **Steps: (1) demand → (2) supply → (3) dynamics**
  - Industry demand: Differentiated products

$$\ln\left(\frac{ms_{jt}}{ms_{0t}}\right) = \alpha_1 p_{jt} + \alpha_2 g_j + \alpha_3 x_j + \xi_{jt},$$

Model:	Logit		Nested Logit	
Estimation method:	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
Price ($000)	$-.93^{**}$	-3.28^{***}	$-.05$	-1.63^{***}
Nests of Diameters	–	–	$.98^{***}$	$.49^{***}$
Diameter = 3.5-inch	1.75^{***}	$.91^{**}$	2.24^{***}	1.70^{***}
Log Capacity (MB)	.04	1.20^{***}	.08	$.65^{***}$
Adjusted R^2	.50	.27	.80	.67
Num. obs.	405	405	405	405

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

  - IVs for p_{jt}
    - Prices in other region/user (Hausman-Nevo)
    - Num. of product models/firms (Bresnahan-BLP)
    - Years since standard established
    - Unpredictable changes in unobserved quality (Sweeting)

Estimation (2 of 4): Supply

- Cost of production
  - Invert the estimated demand system
  - Firm i's FOC (Cournot with cost=location heterogeneity)

$$q_{it}: \quad P_t + \widehat{\frac{\partial P}{\partial Q}} q_{it} = \widehat{mc_{lt}}$$

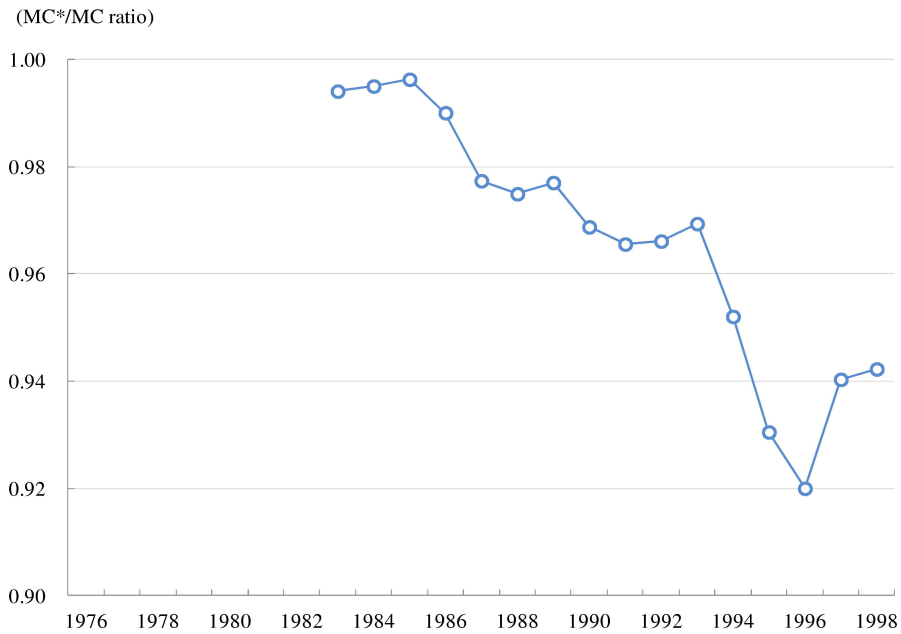


Figure 5: Estimated Cost Advantage of Offshore Production

Estimation (3 of 4): Dynamic Game

- Cost of offshoring (& entry/exit)
  - Algorithm: Nested Fixed Point (c.f., Rust '87)
    1. Try some (κ, ϕ)
    2. Solve for Equilibrium
       - Perfect Bayesian Equilibrium
       - Backward induction, from year 1998
       - For each state-year, find a fixed point of strategies & beliefs
       - Simultaneous-move vs Sequential-move
    3. Pick (κ, ϕ) with maximum likelihood
    4. Free entry: $V_t(N_t, N_t^*) \leqslant \hat{\kappa}_t^{ent} \leqslant V_t(N_t - 1, N_t^*)$
  - Data variation: Time-series of entry/exit/offshoring

Table 2: Estimated Offshoring Cost, Entry Cost, and Sell-off Value

Parameter	Unit	ML Estimate
Sunk Cost of Offshoring (κ)	Billion \$	3.20
Sunk Cost of Entry (κ^{ent})	Billion \$	5.47*
Sell-off Value (ϕ)	Fraction of firm value	.48

Note: * annual average over the sample period.

Estimation (4 of 4): Equilibrium Profits & Values

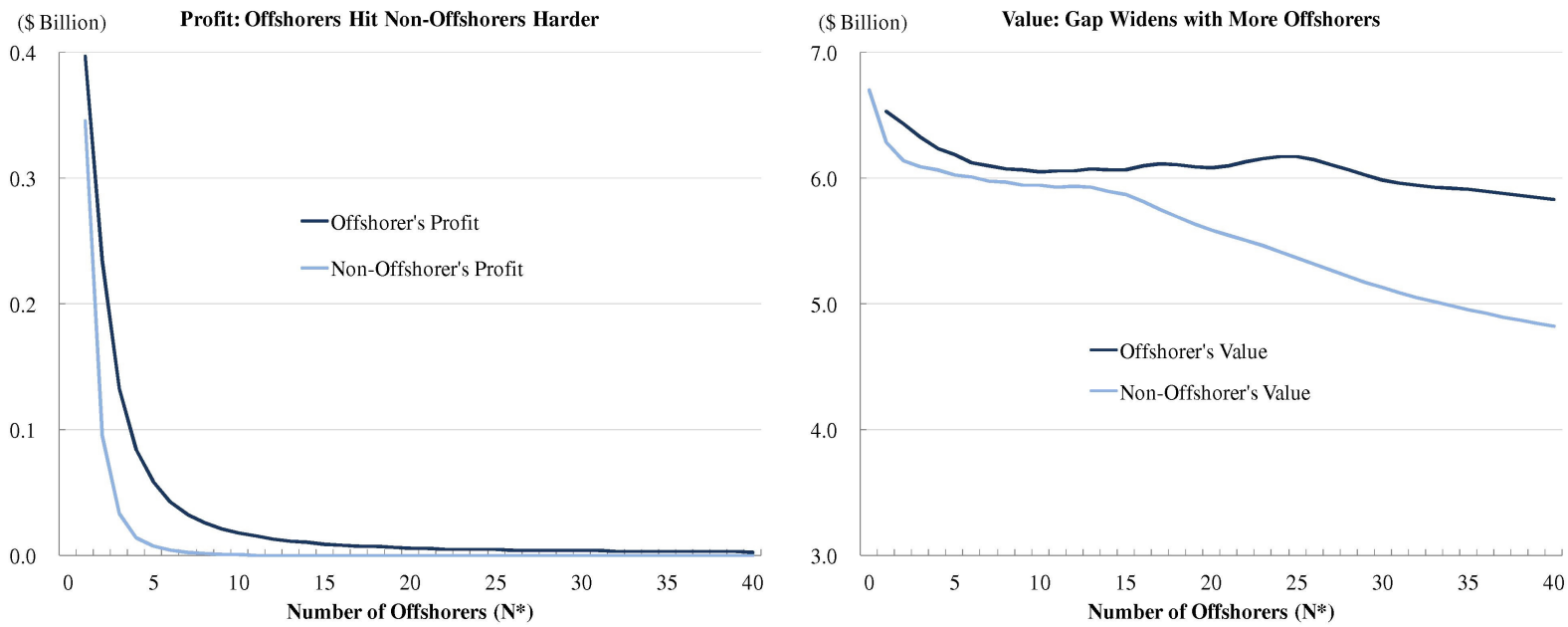
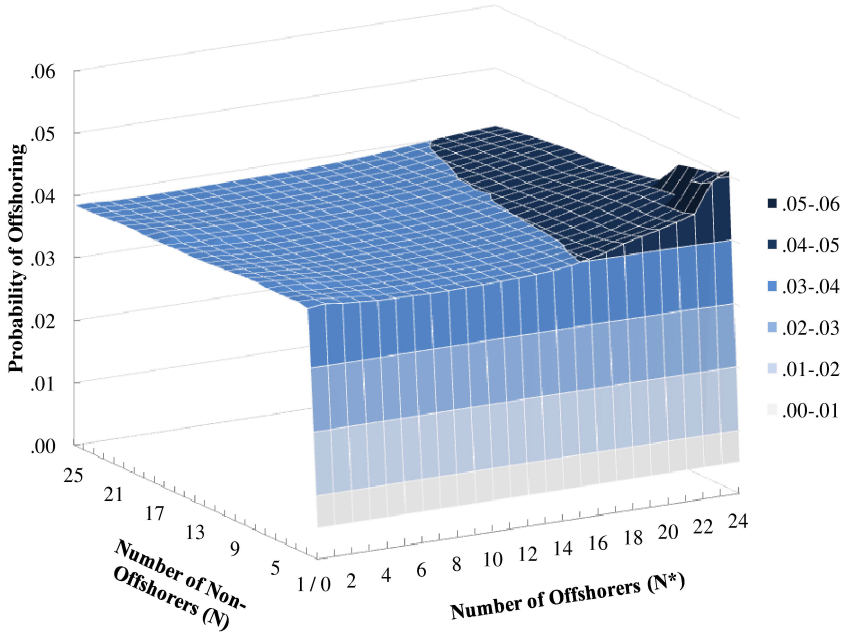


Figure 6: Effects of Market Structure on Profits & Values

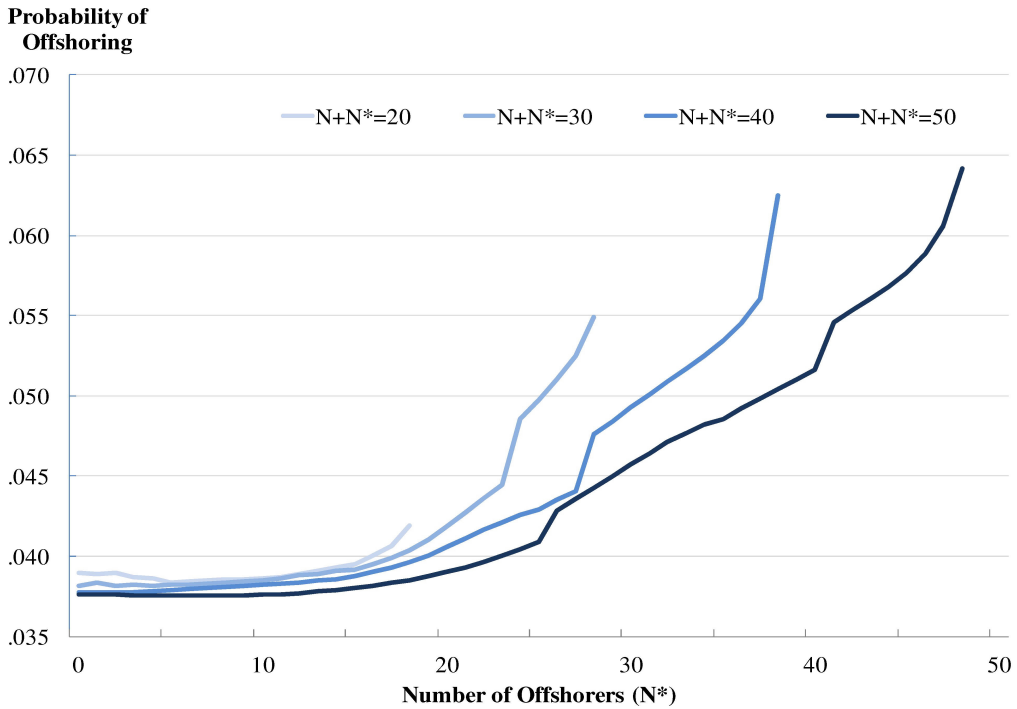
- Profits
  - Drop fast as $N^* \uparrow$ (faster for non-offshorers)
  - Due to $P \downarrow$ & business stealing
- Values
  - Decreasing in $N^* \Longrightarrow \Pr(exit) \uparrow$ in N^*
  - Gap $(V^* - V) \uparrow$ in $N^* \Longrightarrow \Pr(offshore) \uparrow$ in N^*

Finding (1 of 3): How Market Structure Affects Offshoring



- Pr (*offshore*) initially ↑ then ↓ in N
  - "Replacement effect" (Arrow '62) dominates when $N = 1$
  - "Efficiency effect" (Gilbert & Newbery '82) dominates when $N > 1$
- Pr (*offshore*) monotonically ↑ in N^*
  - Disproportionate competitive pressure: "fly or die"
  - Hence Pr (*offshore*) ↑ in N^*/N when $N > 1$

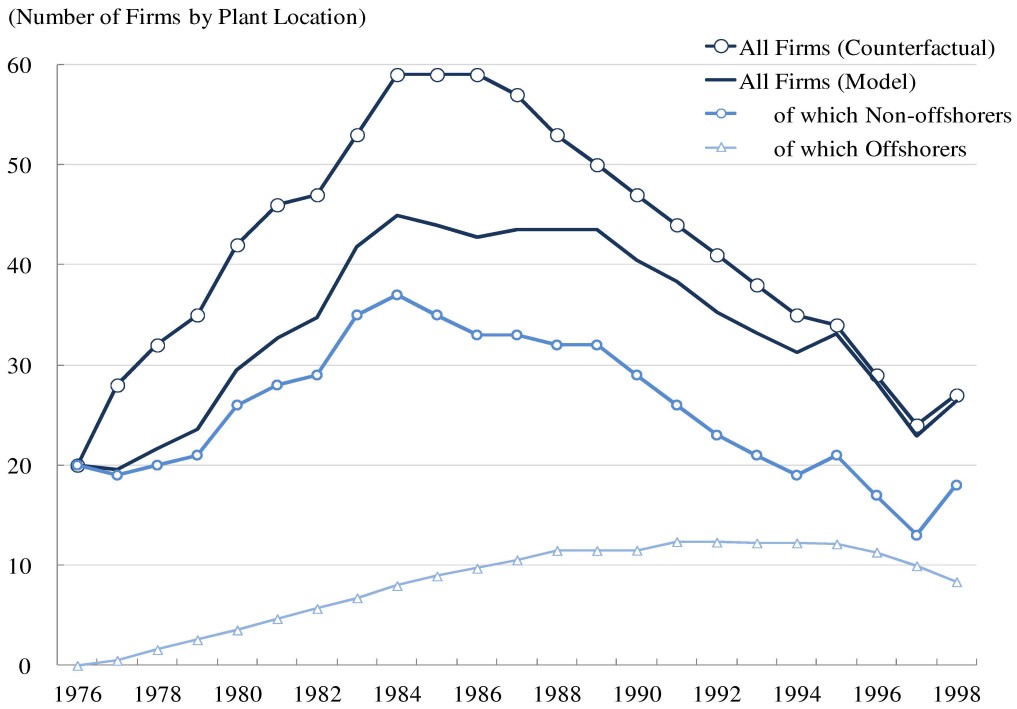
Finding (1 of 3): How Market Structure Affects Offshoring



- How does Pr $(\textit{offshore})$ change with N^*/N?
  - Fix total $\bar{N} = N + N^*$ and vary N^* (& hence N^*/N)
  - Offshoring breeds offshoring

Finding (2 of 3): How Offshoring Shapes Market Structure

- World without Singapore
  - Offshoring cost prohibitively high: $\kappa = 4\hat{\kappa}$



- Relative to "no-offshoring" scenario, the possibility of offshoring:
  - Discourages entry & encourages $N \downarrow$ "fly or die"
  - Accelerates "shake-out" (i.e., mass exits in maturing industry)
  - Yet pro-competitive: $P \downarrow$, $Q \uparrow$, $SW \uparrow$ (due to innovation race)

Finding (3 of 3): Offshoring in Industry Life Cycle

- Incentives to offshore vary with (endogenous) life cycle
  - Initially low ($\because$ still small market)
  - Mid '80s: more ($\because$ demand growth & competitive pressure)
  - Mid '90s: fly or die ($\because$ N^*/N keeps rising)

Table 3: Evolution of Market Structure and Offshoring/Innovation Incentives

Phase	$Pr(offshore)$	$Pr(exit)$	$Entry$	N	N^*	$N+N^*$	N^*/N
I. Early	Low		Many	$\uparrow$	$\uparrow$	$\uparrow$	$\longrightarrow$
II. Middle	Medium		Few	$\downarrow$	$\uparrow$	$\longrightarrow$	$\uparrow$
III. Later	High		None	$\downarrow$	$\longrightarrow$	$\downarrow$	$\uparrow$

Note: Based on estimates and descriptive statistics.

- Is offshoring "drastic" innovation? (Arrow '62)
  - No, in the static sense
  - Yes, in the dynamic & strategic sense

Finding (4 of 3): Anti-Offshoring Policy

- Ban on offshoring
  - Same as "No Singapore" simulation
- Evaluating government interventions
  - Timing matters ($\because$ offshoring incentives change with life cycle phase)
  - Table/Figure, coming soon

Conclusion

- Offshoring as process innovation
  - Offshoring breeds offshoring: strategic complementarity
    - Explains labor-market findings: "displacement from a firm with rising offshoring generates larger and more persistent wage and earnings losses" (Hummels et al. '11)
  - Dynamically pro-competitive & accelerates shake-out
  - Dynamically "drastic" innovation
    - One innovator/offshorer may not drive out others, but
    - Pressure on others to "fly or die"
    - Eventually & collectively "drastic"
- Planner's dilemma
  - Offshoring accelerates itself
  - Timing matters
  - Stop offshoring early?
    - Home industry will die (or survive on expensive life support)
    - Think creative destruction, not just job destruction

Appendix: Persistent Firm Heterogeneity? (1 of 2)

- Firm size dynamics

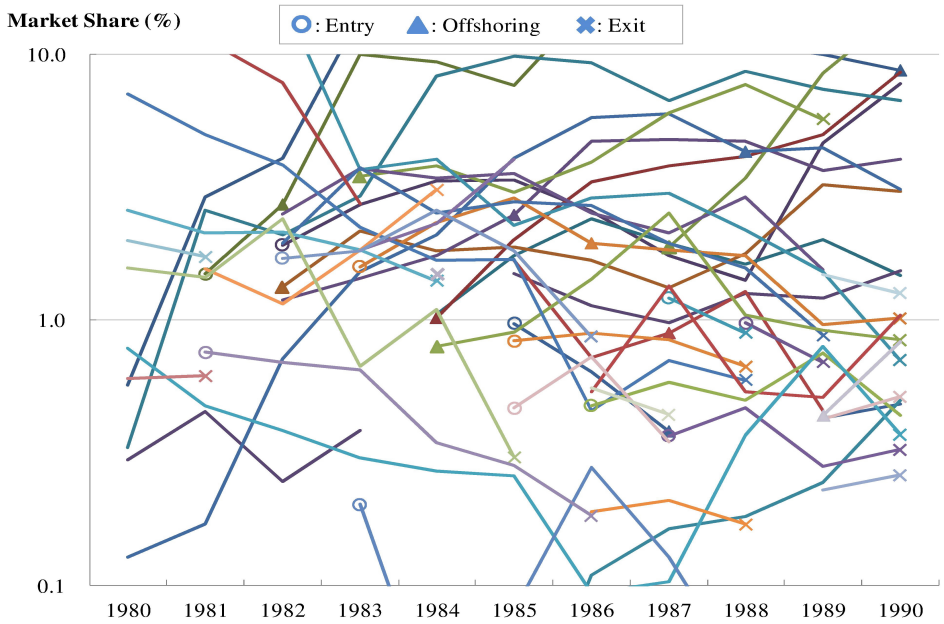


Figure 7: Seemingly Random Patterns of Firm Heterogeneity

Appendix: Persistent Firm Heterogeneity? (2 of 2)

- Self-selection

Table 4: Do Better Firms Self-Select into Offshoring?

Quartile based on 1976–85 market share	Number of Firms	% offshored by 1991	% exited by 1991 (without offshoring)
1st quartile	11	36.4	36.4
2nd quartile	11	27.3	63.6
3rd quartile	11	36.4	36.4
4th quartile	11	18.2	63.6