Erasmus University Rotterdam
Department of Applied Economics
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Economics of Innovation

Lecture 4 –
Market structure and innovation

http://www.economics-of-innovation.com

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Lecture date different next week!

- Tuesday instead of Wednesday!
- 10:00 – 12:00 (no break)
  - Sleep a bit longer ☺
- Room T3-21

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Today's agenda

1. Theoretical arguments about market structure and innovation (firm size and market power)
2. Empirical evidence
3. Descriptive model of firm size and R&D intensity (Cohen and Klepper 1992)
4. Policy conclusions

Market structure and innovation

- Present industry structures might influence firm's incentives and abilities to innovate
- Innovation as part of business routine
- Schumpeterian hypotheses (1942):
  1. There is a positive relationship between innovation and monopoly power
  2. Large firms are more than proportionately innovative than small firms
- Highly debated issue! ←→ Contradiction to Schumpeter (1934) – the radically innovative entrepreneur…

Monopoly power and innovation - 1

- Consensus:
  - Anticipation of extraordinary profits from temporary monopoly position creates an incentive to innovate
  - A monopoly position from innovation arises if the firm is able to prevent or at least retard imitation (appropriation)
- Debate:
  - Pro monopoly:
    - Profits can serve as investment pool for future R&D
    - More independent from external financiers, therefore better control over information flows and higher ability to appropriate returns
    - Presence of monopoly stimulates innovation because innovative newcomers to the market can usually capture a part of the monopoly's pie (Romano 1987)

Monopoly power and innovation - 2

- Debate (continued):
  - Contra monopoly:
    - Lethargy and bureaucracy
    - Monopolies have less incentives to innovate than firms in competitive markets (Arrow 1964), but this could change if monopolies have advantages in R&D costs (Segerstrom and Zolnierek 1999)
- Unresolved theoretical debate

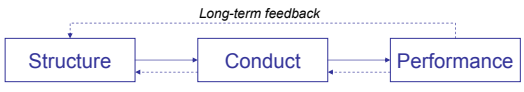
Firm size and innovation

- Advantages of large firms:
  - Economies of scale (R&D, specialists, production and distribution costs)
  - Economies of scope (spillovers, reputation, production costs)
  - Managing risks (portfolio of projects instead of betting everything on one horse)
- Disadvantages of large firms:
  - Bureaucracy and communication problems
  - Staff might be less motivated because their compensation might be less directly linked to corporate performance
  - Lock-in to established technological paradigms (older firms)
- Unresolved theoretical debate

Market structure and innovation

- One of the most researched empirical topics in IO
- Three main problems with empirical research on market structure and innovation:
  1. Causality
  2. Measurement
  3. Functional relationship

Causality



Environment	Behavior	Outcomes / incentives
• Technology • Concentration • Size-class distribution • Entry barriers	• Prices • Quantities • R&D Basic / applied • Innovation Product / process Major / minor Internal / external	• Productivity • Growth • Survival • Cash flow • Market share …

Measurement

- Measures for market structure
  - Concentration ratio (Herfindahl index)
  - Profitability
  - Size class distribution
  - Entry conditions
  - → All are just proxies for market power, no direct measurement
- Measurement of innovation – see lecture 1…
  - Inputs or outputs?
  - No perfect measure exists, various proxies

Functional relationship

- Direct linear relationship between market structure and innovation?
  - Assumed by correlation and OLS analysis that dominate the literature
  - The existing and conflicting evidence suggests that the relationships are in fact more complex
  - Endogeneity usually not controlled for
- Omission of correlated explanatory variables leads to biased results

→ These are tough and challenging conditions for empirical research!

Empirical evidence - 1

- Firm size and innovation
  - Inconclusive findings on firm size and R&D intensity
  - No strong conclusions possible
  - Some evidence for a U-shape relationship
    - Both small and large firms are more R&D intensive than medium-size firms
  - But also some evidence of a threshold effect
    - R&D intensity increases with firm size up to some threshold, thereafter no advantages of large size
  - Many non-random samples used
  - Effect of size varies across industries – usually ignored
    - Small firms more innovative in young industries (*Acs and Audretsch* 1987)

Empirical evidence - 2

- Market power and innovation
  - Earlier studies showed inconclusive evidence
  - Discussion about inverted U-shape since Scherer (1967)
    - Some market concentration enhances incentives to innovate
    - Both pure monopoly and perfect competition have a negative influence on innovation
    - Theoretical motivation for an inverted U-shape exists (e.g. Aghion et. al. 2005)
    - Also, empirical evidence for an inverted U-shape between entry barriers and innovation
    - However, effect of concentration on innovativeness also varies across industries (technological opportunities, maturity of industry, market size and market growth rate…)
    - Information & Communication Technologies (ICT) might change the rules of the game…

Empirical evidence - 3

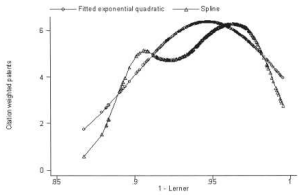


FIGURE II
Innovation and Competition: Exponential Quadratic and the Semiparametric Specifications with Year and Industry Effects
The figure plots a measure of competition on the x-axis against citation-weighted patents on the y-axis. Each point represents an industry-year. The circles show the exponential quadratic curve that is reported in column (2) of Table I. The triangles show a nonparametric spline.

Source: Aghion et. al. 2005. Competition and innovation: An inverted U-shape. *Quarterly Journal of Economics*, May, pp. 701-728.

Current empirical results on market structure and innovation

- Severe measurement problems
- Complex, non-linear relationships
- Differences across industries

→ There is no universally optimal market structure for innovation (but there might be one for every individual industry)

→ Effects vary across industries depending on
  - Technological opportunities
  - Maturity and growth of industry

Firm size and R&D intensity

- Required reading: Cohen and Klepper (1992) - The anatomy of industry R&D intensity distributions, *AER*
  - Closely related to Cohen and Klepper (1992) – The tradeoff between firm size and diversity…, *SBE*
- Main messages:
  - Variation in R&D intensity within and across industry could result from a simple probabilistic process
  - Correlation between market structure & innovation may not be causal
  - Large firms could have advantages in appropriating returns to R&D, and therefore have higher R&D intensity (yet lower R&D productivity)…
  - …but a high number of small firms increases the number of approaches to innovation pursued

R&D intensity distribution - aggregated

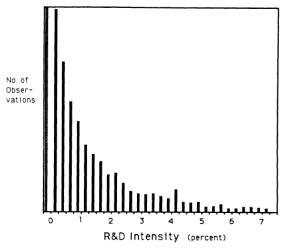
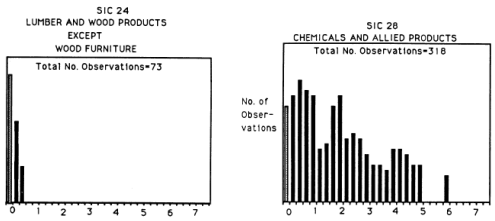


FIGURE 1. R&D INTENSITY (R&D/SALES) DISTRIBUTION FOR ALL BUSINESS UNITS

US Data, 15 industries, 1975-1977, Source: Cohen and Klepper 1992, *AER*

R&D intensity distribution – sector differences



US Data, 2 out of 15 industries, 1975-1977, Source: Cohen and Klepper 1992, *AER*

A model of R&D investment - 1

- Assumptions
  - Different non-competing approaches to innovation (e.g. process vs. product)
  - Firms can conduct various experiments / projects for each approach (i.e. invest more or less money into a given approach)
  - Firm heterogeneity
    - Different R&D capabilities and perceptions, randomly determined permanent characteristic of a firm that hold for each approach
    - Resulting probability to pursue any given approach to innovation is *i.i.d.*
  - No strategic interaction
  - Growth due to innovation is incremental and takes time
    - Ability to appropriate returns from R&D scaled by *ex ante* firm size

A model of R&D investment - 2

Industry variables:

N – total number of different approaches to innovation ($i = 1,\ldots,N$)
J – total number of firms in an industry ($j = 1,\ldots,J$)
p – probability that firm j will have the required expertise to carry out project z_{ij}
g – technological opportunities ($g > 0$)
b – fraction that measures appropriability
d – industry-level parameter that represents appropriability and technology conditions in an industry, $d = bg$
h – price per quality unit that customers are willing to pay

Firm variables:

n_j – number of different approaches pursued by j
z_{ij} – number of experiments of approach i conducted by firm j
r_j – total R&D by firm j, costs of all pursued z_{ij}
q_j – total number of quality units produced by j
s_j - ex ante output of firm j, $s = hq_j$

A model of R&D investment - 3

- Marginal costs of R&D experiment
  - $MC(z_{ij}) = c$ (each additional experiment has the same costs for all approaches)
- Marginal revenue of R&D experiment
  - $MR(z_{ij}) = bgq_j / z_{ij} = ds_j / z_{ij}$ → MR is scaled by *ex ante* output of j, assumed to have diminishing returns with number of experiments conducted
- Firm j that pursues innovation-approach i will conduct a level of experimentation for which
  - $MC(z_{ij}) = MR(z_{ij})$
- R&D intensity of firm j
  - $r_j / s_j = dn_j$

A model of R&D investment - 4

- R&D intensity is a simple multiple of the number of approaches to innovation a firm pursues
  - Whether a firm has the competence for any particular approach was assumed to be randomly given (see next slide)
  - The probability of a firm being competent is assumed to be the same for all firms and all approaches to innovation: *p*
- Average productivity of R&D (e.g. number of patents per $ R&D) could be lower in large firms because they spend more on the margin of each project

A model of R&D investment - 5

- Pursuit of each approach to innovation *i* in firm *j* (n_{ij}) is a Bernoulli trial (yes / no) with p < 0.5
  - R&D intensities across firms are binomially distributed
- Distribution of R&D intensity:

$$E(r_j / s_j) \equiv \mu = dNp$$

$$V(r_j / s_j) \equiv \sigma^2 = d^2 Np(1-p)$$

$$S(r_j / s_j) \equiv (1-2p)N^{-1/2} p^{-1/2} (1-p)^{-1/2}$$

- As *d*, *N*, and *p* rise, the mean and the variance rise, while skewness declines
- Data fit the binomial distribution very well

Advantages of large size

- Large firms have advantages to appropriate gains from R&D if
  - Own output is the preferred appropriation channel (no licensing)
    - Implies that the innovation is more valuable to the innovator than to anyone else (e.g. due to competence, processes, customer knowledge)
  - Successful R&D does not lead to explosive growth
- If so, they spend more on every single approach to innovation and thereby contribute relatively more to technological change (private and social benefit)
  - In *Cohen & Klepper* (1992), this advantage of largeness is assumed and not explained or tested

Advantages of diversity

- Assumptions:
  - Likelihood of a firm pursuing any given approach is independent of size
  - Total number of different approaches is externally given by technology
- Diversity: Total number of different approaches to innovation pursued by firms in an industry

  X – number of firms

  p – probability that firm j pursues approach I

  → Chance an approach is missed $(1-p)^X$ decreases with X

  → Given industry output produced by many small firms diminishes the chance that a beneficial approach to innovation is overlooked

Tradeoff between size and diversity

- There is some theoretically optimal industry structure that balances the social benefits of diversity and large size
- Optimum varies across industries and depends on
  - Vitality of industry technology and number of available opportunities → many opportunities → many (small) firms are good
  - Extent of economies of scale and scope in an industry → mergers are good → advantages of having a few large firms
  - Tension most acute in industries with size advantages and many opportunities
- No known reason why free-market competition should automatically generate the social optimum

Policy conclusions

- Somewhat sobering insights:
  - We know there is likely to be market failure in the provision of R&D
  - We know there is likely to be an optimal market structure, but what is optimal depends on many factors, some of them are not directly observable (e.g. technological opportunities) or subject to debate (e.g. monopolies in network markets)
  - Thus, we are unlikely to know *which particular* structure is optimal in many cases
- Problem seems somewhat alleviated by typical evolutionary pattern of industries
  - Many small firms and opportunities in the early stages
  - Few large firms, focus on process and less on product innovation in more mature stages
  - Large firms can create markets for small firms

Policy conclusions

- How could policy improve the market outcome?
  - Industry-specific policies?
  - Subsidies for new entry?
  - Tax advantages for large / small size?
  - Other unwanted consequences of such policies?
  - Very vague and speculative basis for policy action
- Policies that seem generally beneficial
  - Low entry barriers for entrepreneurship and market entry
    - Opportunity costs
    - Bureaucracy & entry regulations
  - High governmental support for basic R&D and education
  - Appropriate governmental incentives for applied research (IPR, prizes, contests etc.)