Essential Course Notes
EC2212

Industrial Growth and Competition

The Role of Technology in Firm Success, Industry Evolution, and Regional and National Growth

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Syllabus for EC2212

1. The Course

The growth of economies depends on the growth and survival of industries and firms. If you analyze national or multinational economies, industry competition, or company management, it is important to know how industries develop and change. A crucial part of this change, in many industries and for overall economic growth, is continual development of new or improved production methods and products.

This course examines industrial change beginning from the inception of an industry. We pay close attention to technology, which often drives industrial competition. We examine the entry, exit, and growth of firms in individual markets, such as the production of automobiles, shampoo, calculators, penicillin, or software. We study how oligopolies form. We talk about possible national policies and strategies for corporate success. Parts of the story include product variety, economies of scale and scope, advertising and distribution, firm growth by expansion or merger, international trade, and the growth of cities.

Analyzing these issues in practice requires considerable research skills, and the course is designed to give you some of those skills. Half your grade in the course will come from a research project. You will learn ways to collect data, analyze it, and relate your findings to topics in the course. Your experience in the project is useful preparation for third-year dissertations, and also for industry studies carried out in financial firms, consultancies, and corporate management.

This is a half-unit course for second- or third-year economics students. Recommended prerequisites are quantitative methods I and principles of economics. Students with other backgrounds should consult the lecturer before registering. As usual for courses at Royal Holloway, Industrial Growth and Competition should take you about ten hours per week. Your grade is based 50% on the research project, and 50% on an end-of-year exam.

Learning Objectives

In this course, you will learn:

- Ways in which firms change and compete in industries, with a focus on ways related to technological change. Also, ways in which the industries relate to regional, national, and global economic growth.
- Skills useful for research in which you analyze actual firms, markets, or industries.

Schedule

The following is an approximate schedule, divided into ten weeks:

1. Technological Change and Economic Growth
2. Sources of Invention: Small Firms and Innovative Networks
3. Sources of Improvement and Efficiency: Big Firms and Streamlined Structure
4. Evolution of New Industries
5. Turnover of Corporate Leadership
6. Shakeouts
7. Sources of Increasing Returns

8. Product Niches, Patents, Economies of Production Scale, & Other Influences on Dynamics
9. Firm Growth
10. Supporting Economic Growth

Lectures and Seminars

Lectures are for all students simultaneously, and mainly provide a first-pass opportunity to learn the material in the lecture notes. Feel free to ask questions; sometimes you will be asked questions too. Seminars involve fewer students at a time so it is easier to discuss course material and practice with it, and discuss how to handle your ongoing projects. Attendance will be taken at seminars and if you fail to attend more than one seminar, expect to be questioned by your advisor and/or by the department's academic coordinator; in extreme cases students may even be barred from exams for non-attendance! (These attendance policies hold for all courses in the department.) Before each seminar, you absolutely must study all sections of the course notes that pertain to lectures given to date. We will discuss this material and you will be quizzed and put on the spot to answer questions! Studying the course notes should not take long so this should not be a big burden; the other required readings (see below) may be done at any appropriate time. Bring your course notes with you to the seminars. Seminars will involve many kinds of activities, including at one point a game that will help you experience firsthand some of the industry theories in the course.

Projects, Assignments, and Due Dates

You choose, during the first seminar session, a research topic to analyze during the course. Every project will involve collection of some empirical evidence (or simulated data in rare cases), statistical analysis of the evidence, and a write-up with reference to the relevant literature. As the course goes along, I will guide you to go through these processes. You will be part of a team that gathers key information, but ultimately you will do your own analyses and write your own report. You and your team should start reading and gathering relevant information right away. Biweekly assignments will help you prepare the final project report, because each assignment requires you to do a key piece of the project work.

Note the following due dates. Assignments are due in your seminar classes and will be discussed but not be collected; you will tick a sheet indicating whether you have done the assignment. Two copies of the final project report must be handed in to the department office by noon on the last day of the spring term.

28 Jan.	Assignment 1	Team report: literature review about the team's topic
11 Feb.	Assignment 2	Team report: data listing and documentation (data collection required!)
25 Feb.	Assignment 3	Individual report: literature review about your topic
11 Mar.	Assignment 4	Individual report: data analysis
18 Mar.	Assignment 5	Draft version of your final project
28 Mar.	Project Report	Two copies of your final report due by 12:00 noon

Readings

In addition to reading for your project, the main reading is my course notes. The course notes are essentially a draft textbook, which I wrote because there is no textbook that covers the topics of the course. The notes are not as extensive as a fully-developed text, and to flesh out your knowledge you will need to read from further sources.

Further required and optional readings are listed in the course notes. You must look at the required readings to extract the main points, but I don't expect you to read every word. The course notes include self-study questions to direct your reading. The optional further readings are useful if your project relates to a topic, or if you want to learn more. Almost all these readings are in Bedford Library; the course notes tell you where to find them.

Do you want other books about industry economics related to many subjects in the course? Two related texts are Mike Scherer's *Industrial Market Structure and Economic Performance* (Bedford Library 338.758 SCH), an impressive and widely-used compendium of empirical facts and some theoretical models in industry economics, and Mike Scherer's *Industry Structure, Strategy, and Public Policy* (338.973 SCH), which illustrates principles of industry economics with analyses of nine industries. Also useful are Jean Tirole's *The Theory of Industrial Organization* (338.6 TIR), Stephen Martin's *Advanced Industrial Economics* (338 MAR), and David Brewster's *Business Economics: Decision-Making and the Firm* (338.751 BRE).

Project and Assignments

See the Project Guide for information about the course project and assignments.

Two copies of your project report are due in the Economics Department Office by Friday 28 March at 12:00 noon. The department has taken the policy that late assignments receive grades of zero, so it is critical to finish your project well in advance! The project report must be completed by you, not by your team. The report may include sections written by the team as long as the authors are clearly identified; however, expect to receive a grade of zero if you submit only a team-written part of a report. Don't forget to put your name on the front of your report.

2. Quick Reference to Readings

The following codes are used for where you can find each reading:

B Bedford Library main collection.
R Bedford Library, restricted (short) loan section.
O Bedford Library, offprint collection in the restricted (short) loan section.
J Bedford Library, journals shelves.
E Electronic journal collection accessible from the Royal Holloway library web site.
W Web, accessible via the internet at the address specified.
U Available elsewhere in the University of London system (LSE or, in one case, Imperial). Ask the Bedford Library enquiry desk before going, in case you need an official admission document.

Week 1. Technological Change and Economic Growth

Look at These Readings (in order of importance)

Walker, William. "National Innovation Systems: Britain." In Nelson, Richard R., ed. *National Innovation Systems*. New York: Oxford University Press, 1993. Chapter 5, pp. 158-191. **O B R** 338.06 NAT. Gives an overview of industrial innovation in Britain. If you are from another country, the book might have a chapter about your country too.

Yates, Ivan. "An Industrialist's Overview of Manufacturing and Economic Growth." In Yates, Ivan, ed. *Innovation, Investment and Survival of the UK Economy*. London: Royal Academy of Engineering, 1992. Chapter 1, pp. 5-24. **B** check call number in catalog (new addition). Argues the importance of manufacturing industry, and the innovative change that drives its growth, for the UK economy. Useful though at points sloppy (e.g., the triangle drawn on fig. 3 is unnecessary and inappropriate: why should it point at 0 instead of –3 or +0.2?).

Walker, John. "Service Sector Adjustment and the Implications for Manufacturing." In Yates, Ivan, ed. *Innovation, Investment and Survival of the UK Economy*. London: Royal Academy of Engineering, 1992. Chapter 3, pp. 45-51. **B** check call number in catalog; same as above. Presents evidence that service industries are unlikely to provide a strong growth impetus for the UK economy (unless unanticipated growth areas in services can be created through innovative approaches to service industries).

Further Readings

Chandler, Alfred D. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge: Belknap (Harvard University Press), 1977. **B** 338.75 CHA. A monumental document that provided for the first time an integrated history of American industry from the 1700s into the 1900s.

Chandler, Alfred D., Jr. *Scale and Scope*. Cambridge, MA: Harvard University Press, 1990. **B R** 338.644 CHA. Another monumental document, analyzing industrial history in the United States and Europe during the 20th century.

Hounshell, David A. *From the American System to Mass Production, 1800-1932*. Baltimore: Johns Hopkins University Press, 1984. **B** 338.644 HOU.

Landes, David S. *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present*. Cambridge: Cambridge University Press, 1969. **B** 338.94 LAN. The key history of European industrial development from 1700 until shortly after World War II.

Mokyr, Joel. *The Lever of Riches: Technological Creativity and Economic Progress*. Oxford, 1990. **R** 338.06 MOK. A seminal history and analysis of technological advance, mostly in the western world, over more than two millennia; illustrates the fundamental role of technical change in economic growth.

Mowery, David C. and Nathan Rosenberg. *Technology and the Pursuit of Economic Growth*. Cambridge: Cambridge University Press, 1989. **B** 338.06 MOW.

Pratten, Clifford F. "The Manufacture of Pins." *Journal of Economic Literature* 18 (March), 1980, pp. 93-96. **E**.

Rosenberg, Nathan. *Inside the Black Box: Technology and Economics*. Cambridge: Cambridge University Press, 1982. **B** 338.06 ROS. Chapter 1 is an excellent overview of the role of technological progress in economic growth over a long time span.

Scherer, F.M. and David Ross. *Industrial Market Structure and Economic Performance*, 3rd ed. Boston: Houghton-Mifflin, 1990. **R** 338.758 SCH. Chapter 17 considers technological change; focus on the earlier parts of the chapter, pages 613-630 in the book's third edition.

Solow, Robert M. "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics* 39 (August), 1957, pp. 312-320. **O J E**. This paper, which in part led to Solow's Nobel prize, analyzes the extent to which US labor productivity growth from 1909 to 1949 stemmed from increased capital intensity. The answer stunned many economists of the time: capital apparently was of little relevance to productivity growth; technological advances and increased skill of workers apparently contributed over 80% of the labor productivity growth.

von Tunzelmann, G. N. *Technology and Industrial Progress: The Foundations of Economic Growth*. Aldershot, UK: Edward Elgar, 1995. **B** 338.06 VON.

Week 2. Sources of Invention — Small Firms and Innovative Networks

Look at These Readings (in order of importance)

Saxenian, AnnaLee. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, Mass.: Harvard University Press, 1994. **B R** 338.4762 SAX. Argues for the importance of a culture of cooperation and openness in order to make regional agglomerations of firms as beneficial as possible to the firms involved.

Jacobs, Jane. *The Economy of Cities*. New York: Random House, 1969. **B R** 338.091732. Describes regional circumstances that affect innovation by firms, and relates these patterns to the growth and stagnation of cities.

Jewkes, John, David Sawers, and Richard Stillerman. *The Sources of Invention*, 2nd ed. New York: W.W. Norton & Co., 1969. **B** 608.7 JEW. Points out that, among those innovations that take the form of new products, many originate from individuals or small firms.

<u>Further Readings: Importance of Small Firms</u>

Jacobs, Jane. *Cities and the Wealth of Nations: Principles of Economic Life*. 1985. **R** 301.36 JAC.

Schumpeter, Joseph A. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. 1912. Translated from the German by R. Opie, Harvard University Press, 1934. **B** 338.5 SCH. The author became a very controversial leading economist, as you will see from his later book *Capitalism, Socialism, and Democracy* next week. Because this earlier book considers the importance of small firms for creating technological ferment and advance, it is valuable to consider it along with the later book which relatedly argues for the importance of large firms to technological advance.

<u>Further Readings: Agglomerative Networks & Economic Growth</u>

Glaeser, Edward L., Hedi D. Kallal, José A. Scheinkman, Andrei Shleifer. "Growth in Cities." *Journal of Political Economy* 100 (6), 1992, pp. 1126-1152. **E**.

Jaffe, Adam, Manuel Trajtenberg, and Rebecca Henderson. "Geographic Localization of Spillovers as Evidenced by Patent Citations." *Quarterly Journal of Economics*, 108, 1993, pp. 577-98. **E**.

Krugman, Paul. "Increasing Returns and Economic Geography." *Journal of Political Economy* 99 (3), 1991, pp. 483-499. **E**.

<u>Further Readings: Where Firms Get Innovative Ideas</u>

Gibbons, Michael, and Ron Johnston. "The Roles of Science in Technological Innovation." *Research Policy* 3, 1974, pp. 220-242. **U** Imperial College central library, level 3 periodicals 351.85.

Johnston, Ron and Michael Gibbons. "Characteristics of Information Usage in Technological Innovation." *IEEE Transactions on Engineering Management*, EM-22 (1: February), 1975, pp. 27-34. **U** Imperial College central library, level 2 periodicals 62 IEEE.

von Hippel, Eric. *The Sources of Innovation*. Oxford: Oxford University Press, 1988. **R** 338.06 HIP.

Week 3. Sources of Improvement and Efficiency — Big Firms and Streamlined Structure

<u>Look at These Readings (in order of importance)</u>

Cohen, Wesley. "Empirical Studies of Innovative Activity." In Stoneman, Paul, ed., *Handbook of the Economics of Innovation and Technological Change*, Oxford: Basil Blackwell, 1995, pp. 182-264. **O B** 338.06 HAN. A dense review of empirical research on industrial innovation and technological change. Learn the main concepts and points, not the many minute details.

Schumpeter, Joseph. *Capitalism, Socialism, and Democracy*. New York: Harper, 1942. **B R** 320.531 SCH. Examine especially chapters 7 and 8, which contain a core idea that triggered much heated debate and research, because Schumpeter argued that the classical economic focus on highly-competitive markets full of small firms was completely backward from the focus most relevant to understanding the processes of economic growth.

Further Readings

Cohen, Wesley and Steven Klepper. "A Reprise of Size and R&D." *Economic Journal* 106, 1996, pp. 925-951. **O J E**. Argues for a re-interpretation of the evidence on firm size and R&D. Explains how observed empirical patterns, of roughly constant R&D spending per employee for firms of varying sizes and of lower returns to R&D for larger firms, in fact may result from larger firms exploiting R&D possibilities more fully and hence accomplishing more overall innovation than a group of smaller firms that add up to the same size as a large firm would accomplish.

Chandler, Alfred D. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge: Belknap (Harvard University Press), 1977. **B** 338.75 CHA. A monumental document that provided for the first time an integrated history of American industry from the 1700s into the 1900s.

Chandler, Alfred D., Jr. *Scale and Scope*. Cambridge, MA: Harvard University Press, 1990. **B R** 338.644 CHA. Another monumental document, analyzing industrial history in Europe and the United States during the 20th century.

Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, and Sidney G. Winter. "Appropriating the Returns from Industrial Research and Development" (including commentary by Richard Gilbert). *Brookings Papers on Economic Activity* 3, 1987, pp. 783-831. **U** LSE library journals HC101. This paper investigates to what extent firms can "appropriate," or receive, the economic value of their inventions, through patents and other means.

Week 4. Evolution of New Industries

Look at These Readings (in order of importance)

Klepper, Steven, and Elizabeth Graddy. "The Evolution of New Industries and the Determinants of Market Structure." *RAND Journal of Economics* 21 (1: Spring), 1990, pp. 27-44. **O J**. Focus on the first half of the paper, to gain an understanding of some important empirical patterns in the dynamics of product industries.

Hannan, Michael T., and John Freeman. *Organizational Ecology*. Cambridge, Mass.: Harvard University Press, 1989. **R** 338.74 HAN. This book argued for analysis of industries (and other "populations of organizations") using models similar to those in ecology that describe populations of animals; it started a large trend in sociology research that is also pertinent to industry economists. Get the main ideas and a sense of the methods used by the authors.

Geroski, Paul A. *Market Dynamics and Entry*. Oxford: Blackwell, 1991. **R** 338.6 GER. Use chapters 1-3, which give you a sense of the bulk of economic research that has gone on — mostly at an economy-wide level or for very aggregated industry groups rather than for specific products — regarding the entry of new firms.

<u>Further Readings</u>

Audretsch, David B. *Innovation and Industry Evolution*. Cambridge, Mass.: MIT Press, 1995. **B** 338.06 AUD.

Audretsch, David B. "New-Firm Survival and the Technological Regime." *Review of Economics and Statistics* (August), 1991, pp. 441-450. **E**. Audretsch characterizes different industries as belonging to different "technological regimes," with alternative patterns of new-firm survival.

Baldwin, John R. *The Dynamics of Industrial Competition: A North American Perspective*. Cambridge: Cambridge University Press, 1998. **B** 338.70971 BAL.

Carroll, Glenn R., and Michael T. Hannan, eds. *Organizations in Industry: Strategy, Structure, and Selection*. Oxford: Oxford University Press, 1995. **R** 338.74 ORG. This book investigates some organizational ecologists' notions of the dynamics of industries, through a series of industry case studies.

Davis, Steven J., John C. Haltiwanger, and Scott Schuh. *Job Creation and Destruction*. Cambridge, Mass.: MIT Press, 1996. **B** 331.12 DAV. Entry and exit of firms, or their growth or contraction, coincide with the creation and destruction of jobs. The authors analyze these patterns in the US using a new census dataset, and argue for explanations of some important economic patterns.

Gort, Michael, and Steven Klepper. "Time Paths in the Diffusion of Product Innovations." *The Economic Journal*, 92, Sept. 1982, pp. 630-653. **O E**. This paper is a forebear of Klepper and Graddy's paper cited above; the main differences are that this one has a somewhat smaller dataset to work from and a different (one could say less advanced) theoretical model.

Krugman, Paul. "Technological Change in International Trade." In Stoneman, Paul, ed., *Handbook of the Economics of Innovation and Technological Change*, Oxford: Basil Blackwell, 1995, pp. 342-365. **B** 338.06 HAN. This literature review is unusually well-written and hence readable. Section 3 pertains to the product life cycle theory as it has been applied to international trade, and is why I'm suggesting this reading. But the whole article may be of interest.

Porter, Michael E. *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. New York: Free Press, 1980. **B** 338.6048 POR (also **O** chapter 1). Porter, the guru of strategic management, collects important impacts on competitive dynamics and provides a framework to think about them.

Simons, Kenneth L. "Product Market Characteristics and the Industry Life Cycle." Working paper, Royal Holloway, University of London, 2002. Early version at **W** www2.rhul.ac.uk/~uhss021, or ask me for the full updated version. Shows that underlying technological or other characteristics drive industry outcomes systematically. Part of the paper compares the US industries studied by Klepper and Graddy (and previously Gort and Klepper) with the same industries in the UK, to verify the idea that underlying product- or technology-specific traits of industries are prime determinants of the industries' evolutionary processes.

Week 5. Turnover of Corporate Leadership

Look at These Readings

Tushman, Michael L., and Philip Anderson. "Technological Discontinuities and Organizational Environments." *Administrative Science Quarterly* 31, 1986, pp. 439-465. **O**. This paper has generated much interest about how existing producers of a product might have trouble adapting to technological changes in the product or its manufacturing methods, hence allowing new producers a chance to break into the market.

Further Readings

Anderson, Philip and Michael L. Tushman. "Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change." *Administrative Science Quarterly* 35, 1990, pp. 604-633. **O**. In part, this paper argues that technology-related turnover in corporate leadership results from new technologies that require firms to have new "core competencies" — R&D-related skills, personnel, equipment, and organizational and managerial traits.

Christensen, Clayton M., and Richard S. Rosenbloom. "Explaining the Attacker's Advantage: Technological Paradigms, Organizational Dynamics, and the Value Network." *Research Policy* 24 (2), March 1995, pp. 233-257. **O J**. This paper argues that technology-related turnover in corporate leadership may result because companies are blinded by their customers. The desires of customers may not match with the advantages of new technologies, so the companies may not adopt the new technologies. These companies may be surprised that they lose their market because the new technologies have improved and become much better than the old technologies. However, see the article by King and Tucci, which shows that Christensen and Rosenbloom apparently got their results completely wrong.

Foster, Richard N. *Innovation: The Attacker's Advantage*. New York: Summit Books, 1986. **U** LSE Library HD45 F75. A management consultant argues that new firms break into market positions and triumph over incumbents by coming up with innovative new products.

Henderson, Rebecca M. and Kim B. Clark. "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms." *Administrative Science Quarterly* 35, 1990, pp. 9-30. **U** LSE library journals JA1.A3. This paper argues that technology-related turnover in corporate leadership may result because companies are blinded by their mindset about the technology. Scientists, engineers, and managers may be used to how to work with one technology, but a new technology may require a new way of thinking and working that they do not recognize. This problem may occur despite that the company and its employees otherwise have all the right skills and equipment and know-how to pursue the new approach to the industry's technology.

King, Andrew A., and Christopher L. Tucci. "Incumbent Entry into New Market Niches: The Role of Experience and Managerial Choice in the Creation of Dynamic Capabilities." *Management Science* 48 (2), 2002, pp. 171-186. **J**. Christensen and Rosenbloom seem to have gotten the story wrong in the hard disk drive industry: earlier entrants did better than later entrants.

Reinganum, Jennifer F. 1983. "Uncertain Innovation and the Persistence of Monopoly." *American Economic Review* 73(4), 1983, pp. 741-748. **O J**. This classic article develops a simple economic model in which an incumbent and an entrant can try to innovate, reducing their costs when they succeed. For sufficiently drastic innovations, the incumbent has less incentive to innovate than the entrant.

Schnaars, Steven P. *Managing Imitation Strategies: How Later Entrants Seize Markets from Pioneers*. Free Press (Macmillan), 1994. **B** 338.758 SCH. This book describes a large number of cases of specific products to prove that small, late entrants often can seize markets; in many products, the early movers do not necessarily win and later entrants may even have an advantage.

Simons, Kenneth L. "Information Technology and Dynamics of Industry Structure: The UK IT Consulting Industry as a Contemporary Specimen." Working paper, 2002b. **W** www2.rhul.ac.uk/~uhss021. Checks for evidence of whether the internet (and earlier the PC) might yet have caused disruptive technology effects among UK IT consultancies.

Week 6. Shakeouts

Look at These Readings

Klepper, Steven and Kenneth L. Simons. "Technological Extinctions of Industrial Firms: An Inquiry into their Nature and Causes." *Industrial and Corporate Change* 6, 1997, pp. 379-460. **O J**. Investigates four products with extremely severe shakeouts in their numbers of producers, as a means to understand the reasons for shakeouts and how technological change can create highly-concentrated industries.

Further Readings

Phillips, Almarin. *Technology and Market Structure: A Study of the Aircraft Industry*. D.C. Heath, 1971. **U** LSE library HD9711.U5 P55. A classic study of the rich-get-richer phenomenon in industry.

Jovanovic, Boyan, and Glenn M. MacDonald. "The Life Cycle of a Competitive Industry." *Journal of Political Economy*, 102, 1994, pp. 322-347. **O E**. Captures the idea that new technology may contribute to competition and shakeouts.

Klepper, Steven. "Entry, Exit, Growth, and Innovation over the Product Life Cycle." *American Economic Review*, 86, 1996, pp. 562-583. **O J E**. A particularly telling model of shakeouts, this seems to come much closer to empirical fact than other authors' theories have come.

Klepper, Steven and Kenneth L. Simons. "The Making of an Oligopoly: Firm Survival and Technological Change in the Evolution of the U.S. Tire Industry." *Journal of Political Economy*, 108 (4: August), 2000, pp. 728-760. **J E**. Uses rich data from the US tire industry to probe processes of industry evolution and how they involve technological change.

Klepper, Steven and Kenneth L. Simons. "Dominance by Birthright: Entry of Prior Radio Producers and Competitive Ramifications in the U.S. Television Receiver Industry," *Strategic Management Journal*, 21 (10-11: October-November), 2000, pp. 997-1016. **J**. Shows how prior experience can matter to competitive success.

Suárez, Fernando F. and James M. Utterback. "Dominant Designs and the Survival of Firms." *Strategic Management Journal*, 16 (5), June 1995, pp. 415-430. **J**.

Nelson, Richard R. and Sidney G. Winter. 1978. "Forces Generating and Limiting Concentration under Schumpeterian Competition." *Bell Journal of Economics* 9, pp. 524-548. **J**, or see their classic book which contains the same article: Nelson, Richard R. and Sidney G. Winter. *An Evolutionary Theory of Economic Change*. Harvard University Press (Cambridge, Mass.), 1982. **B** 338.09 NEL.

Week 7. Alternative Reasons for Shakeouts and Industry Concentration

Look at These Readings (in order of importance)

Scherer, F.M. and David Ross. *Industrial Market Structure and Economic Performance*, 3rd ed. Boston: Houghton-Mifflin, 1990. **R** 338.758 SCH. Use the section of chapter 4 pertaining to economies of scale and scope (pages 97-141 in the 3rd edition). The evidence suggests that firms and their manufacturing plants face long-run cost curves that involve minimum scales necessary to be efficient. In some industries, plants seem to face diseconomies of scale above some size because of transportation costs and (rarely) other reasons, but the notion of long-run U-shaped cost curves for firms is unproven and is likely pure fiction. Make sure you gain a knowledge of commonly-discussed reasons for advantages or disadvantages to plant size and firm size.

Sutton, John. *Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration*. Cambridge, Mass.: MIT Press, 1991. **B R** 338.6 SUT. This book escapes the problem that theories of market competition and product differentiation generate almost any result depending on the particular assumptions; it does so by predicting *bounds* on the results instead of specific results. It argues that advertising cost spreading and other sources of sunk costs or increasing returns — such as the R&D cost spreading considered earlier in this course — can cause a market to become tightly concentrated among a few producers, whereas markets without these influences need not become tightly concentrated. I suggest you not worry about understanding the mathematical model – which some people argue has drawbacks anyway – but get the notion of bounds and look at how Sutton uses empirical evidence to support his case.

David, Paul. "Clio and the Economics of QWERTY." *American Economic Association Papers and Proceedings* 75 (2), May 1985, pp. 332-337. **O J E**. Illustrates how a particular technology, not necessarily the most efficient technology, can become locked in place as a result of historical accident.

Further Readings

Achi, Zafer, Andrew Doman, Olivier Sibony, Jayant Sinha, Stephan Witt. "The Paradox of Fast Growth Tigers." *McKinsey Quarterly*, (3), 1995, pp. 4-17. **O J**. An easy-reading managerial-audience article on firm growth with increasing returns dynamics.

Arthur, W. Brian. "Competing Technologies, Increasing Returns, and Lock-In by Historical Events." *Economic Journal* 99 (March), 1989, pp. 116-131. **J E**.

Liebowitz, S. J. and Stephen E. Margolis. "The Fable of the Keys." *Journal of Law and Economics* 33 (1: April), 1990, pp. 1-25. **W** http://www.utdallas.edu/~liebowit/

keys1.html. Shows that the QWERTY keyboard seemingly is no worse than Dvorak, to argue that there is little evidence that the technology that gets locked in is of poor quality relative to technologies that don't get locked in.

Week 8. Product Differentiation and Market Niches

Look at These Readings (in order of importance)

Shaw, R.W. "Product Proliferation in Characteristics Space: The UK Fertilizer Industry." *The Journal of Industrial Economics* 31 (1/2: September/December), 1982, pp. 69-91. **O**. Examines the differences between the varieties of fertilizer offered for sale by UK manufacturers, and examines how the varieties changed over time in order to test what theories of product differentiation seem to hold up in practice.

Further Readings

Hannan, Michael T., and John Freeman. *Organizational Ecology*. Cambridge, Mass.: Harvard University Press, 1989. **R** 338.74 HAN. Use chapter 5, which discusses a theory of competition for niches of products with fast versus slow market changes.

Tirole, Jean. *The Theory of Industrial Organization*. Cambridge, Mass: MIT Press, 1988. **O** (chapter 7) **B** 338.6 TIR. Examine chapter 7 to see some common theoretical models of product differentiation, as used in industrial economics. Don't try to learn all the details, but do try to learn the main concepts about how these models portray industries working.

Week 9. Firm Growth

Look at These Readings (in order of importance)

Mansfield, Edwin. "Entry, Gibrat's Law, Innovation, and the Growth of Firms." *American Economic Review* 52 (5), 1962, pp. 1023-1051. **O J E**. This small classic reviews patterns of entry, growth, and innovation in several manufacturing industries.

Dunne, Timothy, Mark J. Roberts, and Larry Samuelson. "The Growth and Failure of U.S. Manufacturing Plants." *Quarterly Journal of Economics* 104 (4: November), 1989, pp. 671-698. **O E**. Reviews how average growth and exit rates vary according to the size and age of plants in the US.

Ijiri, Yuji and Herbert A. Simon. *Skew Distributions and the Sizes of Business Firms.* Amsterdam: North-Holland, 1977. Introduction. **O**. Although Herbert Simon won the Nobel primarily for his work on bounded rationality and human decision making, his work on skew distributions also probably played a part. This book, from which you're only expected to look at the introduction, describes how skew distributions are common in a wide range of phenomena, and shows how some very simple assumptions yield skew distribution results. Notably, random entry combined with random percentage growth independent of firm size yields, in the long run, a skew distribution of firm sizes.

Further Readings

Scherer, F.M. and David Ross, *Industrial Market Structure and Economic Performance*, 3rd ed., Boston: Houghton-Mifflin, 1990. Selected pages on mergers. **R** 338.758 SCH.

Mueller, Dennis C. *Profits in the Long Run*. 1986. **R** 338.516 MUE. Shows evidence that in some markets, certain firms have long-lasting advantages that let them maintain unusually high profits for long periods of time. (By the way, John Sutton has recently formulated an argument against this view, by using a simple depiction of changing size plus evidence on firm size to show that the leading firms maintain high market shares in no more industries than would be expected by random chance; thus the observed long-term profitability might be just firms that were the lucky ones without them having any long-lasting advantage.)

Ravenscraft, David J., and F.M. Scherer. *Mergers, Sell-Offs, and Economic Efficiency*. 1987. **B** 338.83 RAV.

Lichtenberg, Frank R. *Corporate Takeovers and Productivity*. Cambridge, Mass.: MIT Press, 1992. **B** 338.83 LIC.

Sutton, John. *Technology and Market Structure: Theory and History*. Cambridge, MA: MIT Press, 1998. **B** 338 SUT.

Week 10. Firm Technological Success and National Development

Look at These Readings

There are no required readings for week 10.

Further Readings

Sutton, John. “Rich Trades, Scarce Capabilities: Industrial Development Revisited.” *Economic and Social Review* 33 (1), Spring 2002, pp. 1-22.

Lu, Qiwen. *China’s Leap into the Information Age: Innovation and Organization in the Computer Industry*. Oxford: Oxford University Press, 2000. **B** 338.4700164 LU.

Hobday, Michael. *Innovation in East Asia: The Challenge to Japan*. Cheltenham: Edward Elgar, 1995. **B** 338.06095 HOB.

Industrial Growth & Competition

3. Technological Change and Economic Growth (Week 1)

After completing this section of the course, you should understand the great importance of technological change for economic growth:

1. The relation of aggregate growth to technological change. 1. A small (e.g. 2.6%) annual improvement yields great advance over decades or centuries. 2. Solow's measurement of technology contributing to growth. 3. Consumer price indices and hedonic price indices.
2. Gross product per person, compared across countries and time. 1. GWP. 2. Leading countries. 3. Convergence. 4. R&D expenditures nationwide. 5. Military R&D. 6. Why did Britain lose its lead in the industrial revolution?
3. The European Industrial Revolution, as described in *The Unbound Prometheus*. 1. Britain's industrial revolution. 2. The continental surge ahead. 3. Late 1800s to early 1900s.
4. Schumpeter and industrial technology as the source of growth.
5. British national policy and industrial development. 1. Services versus manufacturing. 2. Two strong manufacturing industries. 3. Military industry. 4. Little engineering and science in university education. 5. An anti-engineering culture. 6. Old boy networks. 7. Limited government R&D support.
6. The basic economic growth model. 1. Structure of the model. 2. Growth without technological advance. 3. Growth with technological advance.

Improving Technology Contributes Enormously to Economic Growth.

An example of the importance of technological advance for economic growth is the manufacture of pins. Pins are the subject of Adam Smith's classic analysis of the value of division of labor in his book *The Wealth of Nations*. Yet for reducing the cost of pins, technological advance, not division of labor, has been critical for the modern manufacturing industry. In the 1770s, the average worker produced 4,800 pins per day, but by the 1970s the output per worker per day had risen to 800,000 (despite a decreased number of hours worked). This implies a 2.6% annual growth in productivity, a rate often matched or exceeded by other industries (Pratten, 1980).

Robert Solow won the Nobel prize in large part for showing how important technology is to economic growth. Most economists in past had thought of growth as driven by the accumulation of capital, and by other changes besides technological improvements (e.g. increased division of labor). But, Solow (1957) found that only 12.5% (later corrected to 19%) of measured growth in output per hour worked (in the US economy excluding farms during 1909-1949) could be attributed to increased use of capital equipment. The rest of the productivity gain was attributed to improved production practices and equipment (technological advance in the strict sense) and to increased ability of the labor force (technological advance via the skills of workers).[1]

[1] For a brief summary, see Scherer and Ross (1990, pp. 613-614).

Moreover, the output growth figures used by Solow do not adequately account for technological improvements in the form of new products and improved product quality. It is very difficult to reflect new products in consumer price indexes and some other economic measures, and these measures include few aspects of quality. So, technology seemingly has even more impact on growth than Solow estimated.

To analyze growth, economic output must somehow be compared across different years, despite that the value of money has changed because of inflation. To correct for inflation, economists use a consumer price index. The index compares similar goods in different years, and shows how much prices have changed. For example, if a MacDonald's Big Mac costs £1 in year 1 and £1.50 in year 2, a consumer price index based on Big Mac prices would rise from 100 to 150. Divide a country's economic output by the index in the current year, and multiply by 100, to get figures measured in constant (or "inflation-adjusted") monetary units. Price decreases caused by technological change are also part of the index: if a consumer price index were based solely on the price of computers in the US, the price index would fall 26% per year in 1995-1999, implying a 50% drop in price every two years.[2] Thus from 1997 to 1999 the hypothetical consumer price index could have fallen from 100 to 50. If the same real dollar value of computers were sold in both 1997 and 1999, dividing by the consumer price index (technically, dividing by the consumer price index over 100) would indicate correctly that twice as much output of computers was produced in 1999 compared to 1997.

The problem arises because actual consumer price indexes do not measure the prices of all goods, but only of an established "basket" of goods for which past prices have been available. New kinds of products tend to have the highest rate of price decline, but they are not included in the basket.[3] Therefore, the consumer price index does not fall enough (or grows too quickly) to be able to adjust for the actual amount of price decline among the average good in the economy. Dividing by the consumer price index yields growth figures that are too low. A similar problem arises in terms of the *quality* of products. The consumer price index "basket" includes computers, but the price index does not adjust for the increase in processing power of computers. In part because successive generations of computer chips carry out increasingly rapid computation, the value of computers to users has grown over time. Treating the typical computer of 1999 as being the same as the typical computer of 1997 is misleading. The same problems are true for most goods, because the quality of most goods increases over time. An ideal price index would need to adjust for the quality of goods, measuring not the price per unit of each good, but the price per unit of quality. Quality is exceedingly difficult to measure. If computers double in speed, it is easy to measure the change in speed, but it is not so easy to know how much the average consumer is benefiting from the change in speed. And how can one measure the quality improvement associated with, say, more easy-to-use mouse controls or trackballs built into portable computers? There are attempts to adjust for improved quality of goods, by constructing "hedonic price

[2] The fall in US computer prices was a lesser 12% per year in 1987 to 1994. See US Department of Commerce (2000, p. v).

[3] For one careful analysis of retail price indices and the inclusion merely of new brands, including generic pharmaceuticals, see Berndt, Coburn, and Griliches (1996).

indexes," but consumer price indices have until recently not accounted for quality at all, and now do so in only limited ways.

Economic Growth and Technology: Some Facts

How quickly does economic growth occur? And how quickly does output per worker hour grow? Ignoring some of the problems with the data, consider the gross world product (GWP) after adjusting for inflation. The GWP rose from $4.9 trillion in 1950 to $26.9 trillion in 1995, as measured in constant 1995 US dollars. The GWP per person has risen from $1,925 to $4,733 over the same period. In terms of rates of growth, these figures imply a 1.6% average annual growth rate in world economic output, and a 0.9% average annual growth rate in output per person. Output per worker hour has also grown dramatically, as shown below.

Growth in some nations has been far faster than growth in other nations, with industrialized and newly-industrializing nations such as the US, Japan, the UK, Germany, France, Italy, and Korea having the highest growth rates. Their rapid growth has helped keep these economies booming. Some countries' per capita growth rates have been as high as 3-6% per year, implying a doubling of economic output in only 10 or 5 years![4] Growth rates have also varied over time, and for example economists have been extremely concerned to find the cause of the "slowdown" in productivity growth during the 1970s and 1980s (surprisingly, it has proved extremely difficult to pin down a cause).

Faster growth has enormous benefits for an economy over a period of time! Suppose that government agencies, such as the British Monopolies and Mergers Commission or the US Federal Trade Commission, can crack down on anti-competitive practices to reduce prices by 10%, on average, for an economy. (This sort of government policy has been followed in Britain and the US during the 1900s, although the percentage price reduction that has resulted would be difficult to estimate.) In contrast, government policies that increase the productivity growth rate from 3.0 to 3.5% would yield just as strong an improvement in prices within 20 years, and an increase from 3.0 to 4.0% would yield the same improvement in 10.6 years. Twice the improvement results in 40 or 21.2 years, etc. Thus, especially over periods of multiple decades, improving productivity growth rates can be much more valuable than reducing anti-competitive practices.

Growth in economic output per worker hour – that is, growth in labor productivity – is shown in table 3.1. The table records the percentage annual growth in GDP per worker hour for sixteen industrial countries over periods of 10-16 years from 1870 to 1979. A number of patterns are apparent in the table. First, there are substantial differences between countries among their rates of labor productivity growth. Comparing countries in the last (1970-1979) time period, productivity growth rates range from 1.83% to 5.03% per year. And there are large numbers of less-industrialized countries, not included in the table, that had far lower growth rates. Second, within individual countries there are substantial differences across time. Taking the UK as an example, productivity growth rates in the periods given ranged from 0.87% to 3.56% per year, depending on the time period. Third, "convergence" tended to occur among this group of leading industrial nations. Countries that already had high productivity (such as the US, Canada, and Australia) had relatively low productivity growth rates, and countries that had lower

[4] See Barro and Sala-i-Martin (1995, pp. 330-381) for data on national and regional growth rates.

productivity had relatively high productivity growth rates, leading to convergence in labor productivity over time. Thus, amongst these industrialized countries, the less-

Table 3.1. Growth Rates (% per year) of GDP per Worker Hour in Sixteen Industrial Countries, 1870-1979

	1870-80	1880-90	1890-00	1900-13	1913-29	1929-38	1938-50	1950-60	1960-70	1970-79
Australia	1.82	0.37	-0.80	1.01	1.49	0.88	2.20	2.76	2.22	2.83
Austria	1.50	1.98	1.93	1.50	0.72	0.21	1.61	5.69	5.90	4.32
Belgium	1.84	1.36	0.93	0.90	1.79	1.01	1.14	3.14	4.88	4.88
Canada	2.19	1.23	1.70	2.70	1.21	0.00	5.36	3.09	2.72	1.83
Denmark	1.47	1.95	1.90	2.21	2.57	0.43	1.23	2.97	4.90	3.06
Finland	1.29	1.14	3.36	2.42	1.95	1.89	2.10	3.96	6.37	2.60
France	2.32	0.90	2.02	1.82	2.34	2.83	0.75	4.39	5.38	4.09
Germany	1.50	2.15	2.42	1.41	1.40	2.34	-0.40	6.64	5.29	4.50
Italy	0.22	0.43	1.20	2.35	1.92	2.96	0.56	4.27	6.69	3.91
Japan	1.87	1.72	2.11	1.88	3.42	3.41	-3.20	5.57	9.96	5.03
Netherl.	1.44	1.26	0.98	1.07	2.44	-0.10	1.93	3.33	4.93	4.06
Norway	1.39	1.96	1.17	2.02	2.78	2.61	1.88	4.03	4.52	3.66
Sweden	1.76	1.95	2.70	2.62	2.40	2.66	3.43	3.43	4.79	2.55
Switzerl.	1.59	1.37	1.47	1.26	3.18	1.01	1.52	2.98	3.69	1.91
U.K.	1.63	1.20	1.24	0.90	1.44	0.87	2.21	2.19	3.56	2.77
U.S.	2.28	1.86	1.96	1.98	2.39	0.74	4.03	2.41	2.51	1.92

Source: Williamson (1991).

productive countries tended to catch up and gain a productivity more like that of the more-productive countries. However, convergence often has not occurred among less-industrialized countries; I only showed you the patterns among highly industrialized countries.

Productivity growth stems in large part from spending on R&D and other engineering improvements. Available figures are very imperfect, because it is difficult to measure R&D: many sorts of R&D and related engineering work are never recorded in corporate financial statistics. But the figures give a rough idea of the trends. In the early 1960s, the US and UK spent about 2.5-2.7% of GDP on R&D, whereas France, West Germany, and Japan spent less than 1.5% of GDP on R&D. By the mid-1970s through the mid-1980s, however, all five nations were spending around 2.5% of GDP on R&D (with France a bit lower, usually below 2%). However, much of the spending in the US and UK was on military or "defense" R&D, which may not benefit the economy as much as nonmilitary R&D. West Germany and Japan were the biggest spenders on nonmilitary R&D, with the US and UK nearly as low spenders as France after subtracting away the military-related R&D spending. So, the figures are definitely an undercount, but they tell us that many leading nations have increased R&D spending over time, catching up with the US and the UK, and that much of US and UK R&D has been in the (less economically beneficial) military category.

Differences between countries allowed industries to become efficient much more rapidly in some nations than in others. In this regard, for example, one might ask why Britain lost its leadership in terms of productivity and economic power in the late 1800s and early 1900s, despite that it took the lead in the industrial revolution of the 1800s. Why did its industries improve so much less quickly that they were bettered by industries in the US and Germany? The reasons are multiple and difficult to pin down, but various researchers have tried. Mowery and Rosenberg (1989), for example, attribute the fallback to three factors: the slow pace at which British firms adopted modern, hierarchical corporate structures; the country's minimal financial support for technical and managerial education and minimal encouragement of university-industry linkages; and the lack of curtailment of British cartels. Adoption of new corporate structures is a social innovation, an organizational technological change that seemingly did yield both higher productivity and higher rates of other kinds of technological progress. Education has been and remains fundamental for workers to have skills used in innovative progress, and university-industry linkages have been particularly important in launching some industries such as the early German chemical and dyestuffs industries. Cartel-busting reduces price which yields short-term benefits as discussed above, although cartels sometimes retarded innovation so getting rid of cartels might have yielded more innovation. A fuller understanding of Britain's leadership in the industrial revolution, and its subsequent loss of leadership, requires more detailed attention to its industries.

The Unbound Prometheus

David Landes (1969), in his book *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present*, relates in detail how and why specific British industries fared relative to their continental European counterparts. This book is the key history of European industrial development from 1700 until shortly after World War II. The book first describes the Industrial

Revolution in Britain, then the much slower Industrial Revolution in Continental Europe. Next it describes the "second industrial revolution" of the late 1800s and early 1900s, in which the German economy grew rapidly and the British economy fell behind relative to the growth of other nations. Then it goes on to the interwar years, and finally to the post-1945 period. This section summarizes the book through its chapter on the second industrial revolution, excluding the period from 1914 on.

Chapter 2: "The Industrial Revolution in Britain."

The themes of British industrialization might be outlined in either of two ways. First, the development of industry can be set in its broader social context, showing how this context influenced industrial development and in turn how the industrial advances helped to transform society. Second, the development of industry can be understood through a series of examples, showing the products and technologies involved and hence how the processes of production were transformed through the Industrial Revolution.

The British Industrial Revolution is a story of how "change begat change" (p. 2), not merely in the sense of new technology building upon old, but in terms of "a large complex of economic, social, political, and cultural changes, which have reciprocally influenced the rate and course of technological development" (p. 5). Many historians have debated what characteristics of Britain enabled it to undergo a sustained industrial revolution before such a revolution occurred in any other country. Landes' arguments, including the ones presented here, are by no means the end of the debate.[5] But it seems safe to summarize by saying that the economic and social milieu of Britain around the turn of the eighteenth century made possible a sustained industrial revolution. Britain was probably the world's most advanced economy at the time. It had a relatively open economy, without the trade barriers and business-limiting social customs that prevailed in continental Europe. A large labor force was available in nearby Ireland and Scotland and elsewhere, and during the Industrial Revolution there was a large influx of workers from these regions (p. 116). Britain had an advanced system of banks and bank credit (pp. 74-76). Many of these enabling characteristics did not remain static during the industrial revolution, but grew throughout. The banking system gradually expanded. Political power initially held by the landed wealthy was gradually taken over by the new class of manufacturers. Cities and towns grew up around the new manufacturing centers such as Lancashire and the Midlands (pp. 51-52, 122). A new transportation infrastructure was installed at an exponentially increasing pace (pp. 46-47). Distribution structures widened. The educational system expanded, and the government took on new functions. The Industrial Revolution resulted, not through any one leap but by a gradual transformation, in an economic transformation. Labor and resources moved from agriculture to industry. Many workers lost the work that had been their livelihoods, and, Landes claims, a widening gap developed between the rich and the poor (p. 7). Yet enough people had money to buy commodity goods, beyond just necessities, to create the demand that, perhaps more than supply, made possible continuing industrial growth (pp. 77-80). Also, growing exports to nations around the world reinforced the large demand for standardized commodity products, produced with a mind toward large quantities as opposed to high quality (p. 53). Hiring became, more so than in the past, based upon

[5] For more on Britain's leadership in the industrial revolution, see among other sources Mokyr (1990).

people's skills rather than upon who knew whom (pp. 9-10). Labor became increasingly specialized (pp. 119-120). Perhaps most important, a new system of production, the "factory system," developed in which workers served as "hands," relatively unskilled laborers who performed tasks assigned to them by their managers (pp. 114-123). The factory system made possible a rationalization of labor, including careful design of workplace layouts and organization; in a later era such rationalization would lead to the assembly line (p. 2). As to the contribution of the new factory system to the revolution of industry, Landes writes,

> [T]he contribution of factory industry to the economy was out of proportion to its share of total production. Thus the factory promoted a higher rate of investment, hence of growth, than other forms of manufacture. (p. 121)

Landes apparently views the development of the factory system as a central transformation that enabled the rapid "change begat change" growth of the British Industrial Revolution.

If this revolution is analyzed in terms of the exemplary products and technologies that made it happen, four such products and technologies stand out. These are textiles, iron, the steam engine (and the coal that fueled it), and chemicals. Textile manufacturing was transformed initially for cotton textiles. While the wool industry was larger (p. 82), and while the first transforming inventions were designed for wool (p. 84), cotton production could be mechanized more easily because of its easier-to-handle plant fibers, and because for cotton the supply of raw material was more elastic (p. 83). The textile industry became a first example of the new factory system. The iron and steel industry greatly increased in productivity through advances in manufacturing methods. These technological improvements did not entail a transformation to the factory system, because the pace of human workers was driven more by human decisions than by the pace of machinery. The technological improvements in iron production came mostly from gradual advances. These advances had to do with adaptation of existing smelting and refining techniques to new ores and fuels, changes in furnace design to economize on the amount of fuel used, reduction of waste of metal, and increases in production volumes (pp. 89-95). The iron industry was fueled by coal, and digging ever-deeper into the ground to get more coal led to problems with water flooding the mines (pp. 96-97). To solve this problem, steam engines were put to use, and thus began the development of a technology that eventually came into use throughout many kinds of industry (pp. 100-104). Steam engines diffused gradually as the technology developed; for example water power continued to be used for a long time in the woolen textiles industry, because water wheels provided smoother power than did steam engines (p. 104). Development of the steam engine required revolutions in metallurgy and the construction of precision machinery (pp. 103-104). The chemical industry grew up largely in response to the needs of other manufacturing industries, notably, textiles, soap, and glass (p. 108). In the chemicals industry, "one compound leads to another" (p. 109), and continual technological advance occurred as manufacturers tried to create new chemicals in place of old ones whose properties were not ideal. More in the chemical industry than in other industries, scientific research drove technological advance, although the research tended to be trial-and-error in contrast to today's rational chemical science (pp. 113-114). These products and technologies were the most outstanding of the period of British industrialization.

Of the changes that took place in Britain during the 1700s and early 1800s, what themes are most important? Landes summarizes the developments of the Industrial Revolution with three "material changes" that he sees at the heart of the Revolution. The first is the substitution of machines for handiwork. The second is the development of steam power. And the third is the improvement in getting and working raw materials, in particular, metals and chemicals. While these themes cannot tell the whole story of the industrial revolution, certainly they were inextricably enmeshed in the "change begat change" processes of the British Industrial Revolution.

Chapters 3-4: "Continental Emulation" and "Closing the Gap."

The Industrial Revolution was a long time in coming to Continental Europe, but when it came, it came swiftly. In the late 1700s and especially the early 1800s, the manufacturing techniques of Britain began to diffuse into the Continent, but by 1850 the Continent still had not achieved the industrial transformation seen in Britain. From 1850 to 1873, however, Continental Europe experienced its own rapid industrial transformation, bringing it into the same industrial league as Britain, though not quite making it an economic equal.

In the 1700s, Western Europe had the social and economic ingredients needed for an industrial transformation, but the social and economic milieus still could use improvement. Western Europe was quite developed economically and culturally, though not so much as Britain (p. 125). And its politics and cultures slowed down the area in becoming more centralized (p. 125) and more open to the idea of profit-making industry. But its industries initially were small and fairly independent, spread geographically across the Continent and the countrysides (p. 133). Worse, both the domestic industries and the exporters began to be smothered by inexpensive imports from Britain (p. 138). This pressure not only confined producers to local markets, but gave them scale disadvantages with the latest large-scale equipment. A series of wars beginning with the French Revolution set back technical advance in the Continent, destroyed capital, and gave Britain more time to advance still farther technologically (pp. 142-147). In relation to Britain, producers on the Continent were left in a poorer competitive position, and at the end of the wars were reluctant to invest in expensive best-practice production technologies (pp. 145-147). At least the wars accomplished one gain: they brought a new sense of freedom, which would help to make possible industrial development (pp. 144-145). Transfer of British equipment and production techniques to Europe was very slow as of 1800 (pp. 139-142), but throughout the 1800s the influx of technology, artisans, and equipment increased. British law forbade emigration of artisans until 1825 and export of the most valuable technology (e.g. major textile inventions) until 1842, but nonetheless artisans and technology leaked out (p. 148). A shortage of skilled mechanics in Continental Europe was remedied by transmission of skills from British immigrant workers to European workers and thence to other European workers (pp. 147-151). Schools, fact-finding missions, and technical advice and assistance, all mainly provided by governments, also assisted in the diffusion of British manufacturing methods (pp. 150-151). In addition to technology diffusion, transportation improvements assisted the development of the Continental economy. Road, river, and canal travel increased in frequency, speed, and vehicle size (p. 153). Railroads were important not for any immediate revolutionary decrease in transportation costs (some key rail connections were not made until the 1850s and 1860s), but because they stimulated industrial growth (p. 153). They created a great demand for iron and other raw materials, and they required people to work these materials into the relevant parts. Gradually, it became easier to get credit for investment, partly because of an infusion of funds from investors in Britain (pp. 154-158). These changes led to some limited transformations of the Continental industries by 1850.

The story of the transformation of these industries is best told through a discussion of the industries. A cotton textile industry grew up that was more technologically progressive than in the past, and to a much lesser extent the same happened in the woolens industry, but neither compared to Britain either in its state of technology or in its overall volume of production (pp. 158-174). The heavy industries of iron and coal were the leading industrial sector to drive the Continental economic growth (p. 174). Cheap ore and coal in some regions, combined with high transport costs, gave an advantage to local manufacturers and helped to remove competition from Britain (p. 174). The industries saw a considerable diffusion of new manufacturing techniques, but also, with little competitive pressure to enforce low-cost manufacture, many manufacturers simply expanded their use of old techniques (p. 175). Improvements in the iron industry came from a shift to mineral fuel (coal) instead of plant fuels, and from improvements in the construction and operation of plant and equipment (pp. 175-180). Higher fuel costs than in Britain stimulated technological innovations that had not yet occurred in Britain, but the British iron industry still used larger equipment and achieved lower costs (p. 180). Steam engines in the 1700s almost all came from Britain, but by the 1820s a Continental industry developed first in France and then in Belgium. An emphasis on fuel economy led to faster technological advance than in Britain (pp. 181-182), and the Continental industry did more “improvisation,” and hence came up with more inventive ideas, than the British industry (p. 184). However, production quantities were low and there was no standardization of the finished goods (p. 183). Production of steam engines and other machines was driven by demand from at first mining and metallurgy and then the construction of the railroads (p. 184). But most Continental manufacturers relied on water power rather than steam power (p. 182). The chemicals industry in Continental Europe was small, in part because of the small demand from textile manufacturers (p. 185). The small demand, combined with high transportation costs for both raw materials and output resulted in small-scale, high-cost production (p. 185). Thus, the transformation of Continental industry by 1850 was limited.

Continental Europe was still about a generation behind British industrial methods (p. 187). As a result, it was more rural; in 1851, about half of the English and Welsh population lived in towns, but only about a quarter of the French and German population (p. 187). Industry was dispersed throughout the countryside, first to take advantage of rivers for water power, and second to support the metallurgy and mining industries which had to be close to the sources of their raw materials (p. 188). The old putting-out method of work increased with the proliferation of cheap materials and with a ready supply of cheap rural labor (pp. 188-190). In the Continent, as opposed to Britain, labor unrest and a revolution by the underclass were seen as reasonably likely, factory owners felt a responsibility for the welfare of their workers, and governments intervened (especially in France) to regulate hiring and firing (pp. 190-192). The biggest transformation was yet to come.

Between about 1850 and 1873, rapid economic changes took place on the Continent. Key industrial indicators such as railroad mileage and steam-power capacity grew at an average rate of about 5-10% per year (pp. 193-194). There were many stimuli to this rapid growth (pp. 196-210). First, there was a temporary break with social traditions that had hindered industrial development, and Western Europe experienced entrepreneurial freedom (pp. 196, 200). Laws were passed to allow the easy formation of companies and to otherwise smooth economic processes (pp. 197-199). International trade was eased by the elimination or reduction of traffic restrictions and levies for waterway traffic, a simplification of profligate varieties of currency, and treaties which lowered tariffs (pp. 199-200). The final key railroad links were finally installed. The railroads decreased transportation costs, and hence they increased competitive pressure between regions and helped to force producers to become efficient (pp. 196-197, 201-202). New coal beds were brought into production, and new raw materials were imported (guano for fertilizer, wool and hides, vegetable oils for producing soap and candles, sulfides, and pyrites) (pp. 202-204). An increased money supply made it easier for entrepreneurs to get loans (pp. 204-205). In what Landes calls the “financial revolution” of the 1800s, demand for and supply of banking services increased (pp. 205-210). Small tradesmen and people from rural areas entered the money market for the first time (p. 206). And larger, richer investment banks grew up to seek out large investors; these banks were especially useful where there were many opportunities for investment but few sources of funds, as in Germany (pp. 206-210). These stimuli resulted in important changes in Continental industry.

Important industrial advances occurred, along with production by every-larger firms and a new regionalization of industry. The textile manufacturing industry finally mechanized (pp. 211-215). The iron and steel industries completed their conversion from vegetable to mineral fuels (pp. 215-219). Steam power came into widespread use (pp. 220-221). The scale and concentration of industrial production increased steadily, particularly in the heavy industries such as iron (pp. 222-225). And industries relocated and manufacturing centers grew up, often near the sources of raw materials or at convenient rail locations (pp. 226-228). By 1873, most industries in Continental Europe had still not achieved the same technological status as comparable industries in Britain, but they were much closer, and the Continental economy had completed a revolutionary step forward.

Chapter 5: “Short Breath and Second Wind.”

Landes addresses specific growth industries and technologies that were key determinants of the new balance of European industrial competitiveness emerging from the second industrial revolution. Developments in steel, chemicals, and electrical power helped to drive a shift in relative industrial power away from Britain and toward Germany. This is not to say that the stories of these industries entirely explains this shift in national competitive advantage. But these industrial developments are a key to understanding the overarching reasons for the shift in industrial competitiveness.

Steel, a variety of iron, had been produced for centuries, but as of the mid-1800s most production was of other types of iron (pp. 251-254). Steel had advantages over these other types. It was (and is) stronger, more plastic, harder, and, in many ways, more easily worked (p. 251). But it was also difficult to produce, so its high cost limited its application mainly to small, high-cost items such as watches and to weapons (pp. 251-254). Two technological advances that cut costs radically, the Bessemer and Siemens-Martin processes, came in the 1850s and 1860s (pp. 255-257). However, since these methods were only useful with non-phosphoric ores, and since non-phosphoric ores were rare in Europe, use of these techniques grew slowly. In 1878-1879, Thomas and Gilchrist devised a method to put limestone into the molten iron, resulting in a slag which formed by the combination of the limestone with any phosphorous in the ore (pp. 257-259). The slag could be drawn off, leaving the metal free of phosphorous. For the first time, the phosphorous-rich ores of Europe could be used to efficiently produce steel. The result was a rapid rise in steel production, largely replacing wrought iron by around 1900. Germany developed a competitive advantage over Britain in the industry. Britain, with its different ores, tended to use the Siemens-Martin process, which placed it on a somewhat different technological front from the Continent (p. 262). On the Continent, continual innovation led to a high-quality product, while British steel remained irregular in quality (p. 263). German firms integrated blast furnaces with smelting operations and in turn with rolling, but in Britain these operations remained separate, so the German firms gained cost advantages over British producers (p. 263). Automation also reduced costs, especially in Germany (pp. 265-268). Germany developed much larger steel plants than Britain, with for example blast furnaces that were two-thirds larger than British furnaces in 1910, and firms that were four times larger on average around 1900 (pp. 263-265). Landes writes, “The whole situation was self-reinforcing” (p. 263). Over the period 1870-1914, the British lost their leadership in steel to Germany.

Similar developments occurred in chemicals. Of the chemical industries in the period, two involved key technological advances and played major roles in overall economic development. The first industry is alkalis. Demand for alkalis grew rapidly, as they were used in the manufacture of textiles, soap, and paper (p. 270). From 1852 to 1878, output in Britain, initially the leading producer of alkalis, tripled (p. 270). But production of alkalis was expensive because it required an expensive ingredient, ammonia (p. 271). It was clear that it should be possible to recover ammonia from the production process, and much work had been done to try to devise a method of recovery, but not until the early 1860s was the problem solved by Ernest Solvay (pp. 271-272). The process took a decade to perfect, but by the mid-1870s it began to be used in Continental Europe, and resulted in soda (alkali) that could undersell soda from the British industry by about 20%, mostly because of lower materials costs (p. 272). The new technique spread rapidly in France and Germany (p. 272). But Britain lagged behind. British producers had large investments in their existing Leblanc soda industry, and they did not want to abandon these investments (p. 272). They managed to cut costs while using existing equipment, among other ways by introducing more efficient equipment and by recovering and selling chlorine as a by-product (p. 272). In the 1890s, though, new electrolytic production methods, used mainly in the US and Germany, competed with the British industry and made it less profitable, and profits were hurt still more by growing foreign protectionism (pp. 272-273). For the first time since the beginning of the Industrial Revolution, output in the British industry decreased (p. 273). German output rose at the same time (p. 273). By 1920, Britain’s Leblanc soda industry was shut down (p. 273).

The second chemical industry is organic compounds. Germany and Britain both did the initial theoretical and experimental groundwork for this industry throughout the 1800s (p. 274). At first, Britain, and to some extent France, led the industry (p. 275). British manufacturers had the advantage of a good location for supply of raw materials, and the French benefited from a large demand because of that country's "emphasis on highly coloured, imaginatively designed fabrics" (p. 275). Again, though, Britain lost its industrial dominance. British firms had to compete against the strong science and enterprise present in Germany, and in a "spiral of decline" the British were outcompeted in cost by the Germans and venture capital was scared away from the British industry (p. 275). In France, a costly patent war in the 1860s ruined many firms. German dyestuffs production was small as of the late 1860s, but by the late 1870s German firms had about half the world market, and by 1900 about 90%. In practical terms, the German influence in the market was even higher, because German firms had subsidiaries and affiliates in other countries. Switzerland managed to carve out niches of the dyestuffs market by concentrating on tints requiring especially careful production, by helping customers with the latest technical advice for dyeing, and by importing raw chemicals and intermediates from nearby Germany (and perhaps France also) (p. 276). Germany's new lead in dyestuffs gave it yet another industry to help it rise to economic preeminence.

The new electrical power industry also assisted in this rise to preeminence. Around 1880-1900, central power generation and electrical power networks developed (p. 285). Initially, incandescent lighting provided a demand for electrical power, but lighting was soon surpassed by industrial uses of electricity: railway traction, electro-chemistry, electro-metallurgy, and electric motors (pp. 287-288). The first public power station in Europe was built in 1881 at Godalming, England (p. 285). Initially, a patchwork of different standards sprang up, and especially in Britain the individual power networks were costly to interconnect (p. 285). The Germans took the lead in large-scale electrical generation, at first using waste heat from blast furnaces (pp. 286-287). Larger scale gave production economies and meant a smoother demand since more users (and more diverse users) were involved (p. 286). Germany again started late, but quickly developed as the industry leader, in part because of its "technical excellence" and "rational organization" (pp. 289-290). Not only did the German steel industry assist in the development of large-scale power generation, and the German chemical industry assist in creating demand, but also the availability of electrical power led to a transformation of the factory and further economic growth (p. 288). Electricity made possible more home and shop industries and small plants. In addition, new uses for electricity and cheaper power led to new economic investment. Thus the German experience of electrical power generation illustrates how one industrial development led to another in the burgeoning of the German economy during the second industrial revolution.

In addition to this story of industrial development, other themes are relevant to explaining the advance of Germany and the decline of Britain during the "second industrial revolution." It is very well to say that Britain got onto a downward spiral, and Germany onto an upward one, but what other influences were involved, and most importantly, how did the spirals get started? One can only speculate on the reasons, and Landes (pp. 326-358) does just that. Here are many of his speculations, with a bit of my own commentary. Britain was developing its service sector at the expense of manufacturing (pp. 329-330), presumably because demand shifted to services as people's incomes increased. The service industries did not have the same potential for efficiency improvements as did manufacturing industries. There may have been some resistance to changing manufacturing methods because of "interrelatedness," the way a whole economic structure grows up to support and rely upon each method (pp. 334-335). Perhaps the owners of British firms were relatively complacent, since they were merely the well-off grandchildren of the people who created Britain's Industrial Revolution (pp. 336-337). Apparently, though, at least some British manufacturers reacted with imagination and vigor to foreign competition just before World War I (p. 338). British industry may have grown less competitive inside the country (pp. 338-339) and hence, with less threat of failure, had less incentive to innovate and become more efficient. A scarcity of skilled workers, engineers, and scientists, in part caused by poor attendance in Britain's schools, might have contributed to Britain's downslide relative to Germany (pp. 339-348). Indeed, this would explain why Germany managed so readily to take the lead at scientific innovations important in the development of industry. Britain's relative scarcity of skills and knowledge contributed to an inadequate supply of venture capital (pp. 348-354). The scarcity of skills and knowledge also could have contributed to Britain's slow progress in adopting methods of standardization, compared to Germany's rapid progress (pp. 315-317). In summary, a great many possible reasons are available to explain why the spiral advance of Germany and decline of Britain got started, but there is no clear right answer. The point is simply that Britain exchanged its economic lead with the US, Germany, and other parts of the Continent through the process of the second industrial revolution, and industries and technologies including steel, chemicals, and electricity were essential to the transformation.

Joseph Schumpeter and the Schumpeterian Hypothesis

Joseph Schumpeter, in the 1940s, likewise pointed to the importance of productivity growth and new products in driving economic advance, and argued that the traditional focus on reducing anti-competitive practices was misplaced. In fact, he went even further, and argued that large firms and monopolies (by which he also meant oligopolies) are the primary source of rapid economic progress! By trying to stop anti-competitive practices, Schumpeter argued, economists and governments were irreparably damaging the economy! Economic growth and the creation of new products were supposedly being harmed by governments limiting the power of monopolists. If Schumpeter was right, we could have been living today in a world with much cheaper prices, and far more new and useful technologies than exist, if past governments had been supportive of large corporations and monopolies. (Schumpeter's arguments appeared in chapters 7-8 of his book *Capitalism, Socialism, and Democracy*.)

Was Schumpeter right? Yes and no. Judging from the best available evidence to date, it seems that large firms are best for innovation in some situations and small firms are best in others. To characterize crudely, part 2 of this course will address situations for which small firms are either better or okay, and part 3 will address situations for which large firms are better.

Some of Schumpeter's notions were labeled "the Schumpeterian hypothesis" by other economists. In particular, the Schumpeterian hypothesis is that larger firms are better at producing innovations than small firms. Specifically, the hypothesis is often defined by empirical researchers in terms of a firm's amount of successful innovation per unit of its size. For example, a researcher might measure a firm's number of patents in a year divided by its number of employees, or count the innovative changes appearing in the firm's products and divide by its capital value. The researchers then test the so-called Schumpeterian hypothesis by seeing whether large firms tend to have higher values than small firms of (R&D output) / (firm size).

British Industry and Technological Progress

Britain, like other countries, has some traits that support rapid technological progress, and other traits that harm progress. The chapter assigned to you by William Walker (1993) makes several conclusions, as listed below.[6] [Possible policy conclusions, my own rather than Walker's, are noted in brackets.]

1. Britain in past had strong manufacturing industries, but by the 1900s it had begun to cede much of its international leadership to other nations. It remains strong in service industry, but not so strong in manufacturing. [Unless the British government expects to be able to depend on service industries to sustain its economy and international trade in future, successful ways of improving Britain's manufacturing industries – to the extent they can be found – would be useful. Service industries may turn out to be a quite productive economic sector in future, but a better understanding is needed of how much and how productivity growth can be achieved, as compared to manufacturing.]
2. Britain has strengths in a few manufacturing industries, including pharmaceuticals and military aerospace.
3. Large percentages of UK government budgets have been devoted to the military, and this has benefited Britain's arms industry, including aerospace. However, channeling funds and top researchers into the relatively secretive arms industry may have damaged other British industries, which benefit from neither substantial spin-off innovations nor the top-notch researchers who have been sucked up by the arms industry. [Reallocate government funds appropriately, paying for researchers to work in other, more commercially productive industries or in universities, rather than in arms industry. This might be done through incentive schemes to firms, tax breaks, funded R&D centers, or increased funding to research grant schemes. Ideally, find a way to do this that does not compromise national security needs, perhaps in part by funding industries or R&D areas that can benefit key technologies that relate to the nation's ability to continue economically should war break out, or by funding technology areas in which skills might eventually prove critical.[7]]
4. University education has recently been providing adequate skills for many careers, but few students in Britain gain the skills needed for engineering work or for applied sciences – other nations train many more such students as a percentage of their student-age populations. Thus, there is a shortage of computer programmers, electrical engineers, industrial engineers, etc. [Target additional funding to

[6] See other chapters in the same book for similar analyses of other nations.

[7] The government's recent moves to privatize much of its military R&D may greatly diminish information exchange flows with US military R&D laboratories, because British R&D personnel (as opposed to bureaucrats with less direct knowledge of technologies) will be in private companies with which the US military limits information exchange to retain US firms' competitiveness.

educational programs that train these sorts of people, at least as long as there are not substantial percentages of people with these skills who are unable to find jobs when they enter the workforce. Woo greater student interest especially at pre-university educational levels, to give students relevant skills and motivation.]

5. There is a British culture that looks down on engineers and up on bankers and literati. This discourages youths from pursuing engineering careers, relative to other nations where engineering is seen as valuable to society, intelligent, creative, and a sign of personal eminence. [Politicians should change their mindsets and seize opportunities to project a new and better image of engineering through speeches, education, funding opportunities, national museums, etc.]
6. British politics has a large old-boy network of Oxbridge graduates who are stuck in the mindset that bankers and literati are good, while engineers with greasy overalls are bad. Government has been relatively supportive of some industries such as financial services, but the lack of politicians' understanding of manufacturing industry needs has led to poor government support for most manufacturing industry. [Government should consult industry representatives more closely about policy (I'm not addressing unions here) and try to be supportive.]
7. Government funding for R&D has been modest compared to other leading industrial nations, and has been quite low in non-military sectors. [Put more money into appropriate non-military R&D in Britain, through grants, research institutes, funding of universities, or other means.]

The Basic Model of Economic Growth

A large sub-field of macroeconomics analyzes economic growth. Growth models for countries or the world almost always fit the form:

$$y = A(t) \times f(k),$$

where y is the amount produced per person, A(t) is a productivity measure that increases over time, $f(\bullet)$ is a production function, and k is the amount of capital per person. It is commonly assumed that the production function $f(\bullet)$ involves decreasing returns to scale; suppose this is the case.

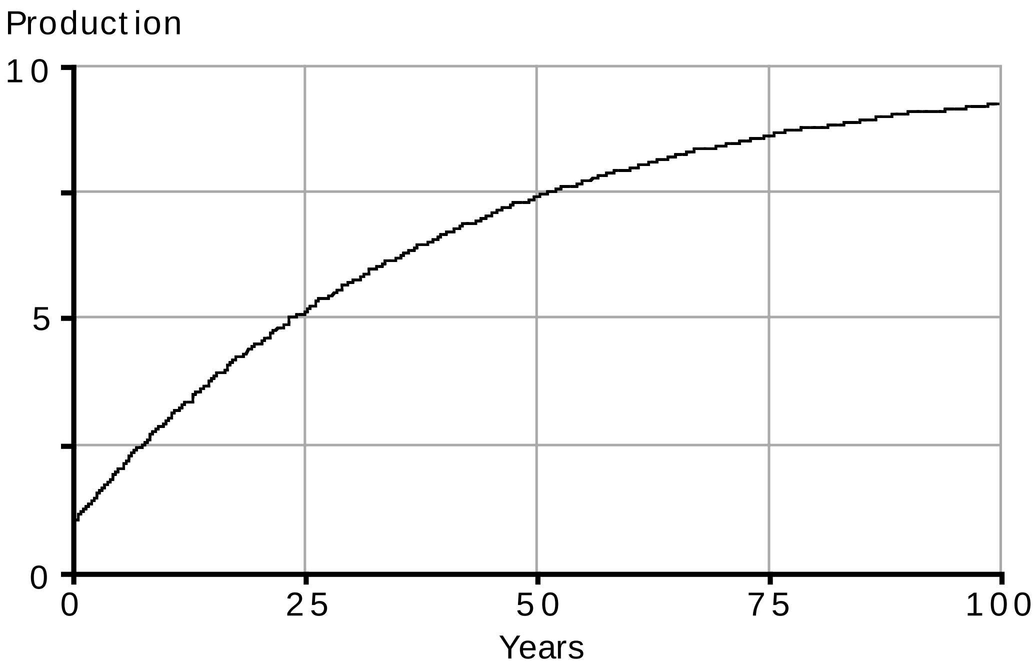
The amount of capital per person changes over time because of (a) "depreciation" of machinery, buildings, and other goods when it wears out or breaks down; (b) investment in new capital to be used for future production; and (c) change in the number of people. Assume the number of people remains constant. An equation for the change in capital per person then might be:

$$\frac{dk}{dt} = (1 - h)y - \delta k,$$

where h is the fraction of production that is consumed and δ is the fraction of capital that depreciates per year.[8]

[8] Note how the units of measurement are consistent. k is measured as a dollar value of goods, so dk/dt is measured as a dollar value of goods per year. 1 and h are dimensionless, so (1-h) is dimensionless, but y is measured as a dollar value of goods per year; hence (1-h) times y is measured as a dollar value of goods per year. δ is measured in units of "per year," so δ times k is measured as a dollar value of goods per year. Hence the left-hand side, and the terms added together on the right-hand side, have identical units of measurement. Were the units of measure not identical, there would clearly be something wrong with the equation.

Figure 3.1. Production over Time in Growth Model with No Productivity Growth



Now, to understand a key fact about the results of the model, consider how the model economy would develop if the production function $f(\bullet)$ took the form $k^{0.5}$, k started out at 1 at the beginning of year 0, half of production were invested (h = 0.5), and capital depreciated at a (continuous) rate of 5% per year (δ = 0.05).

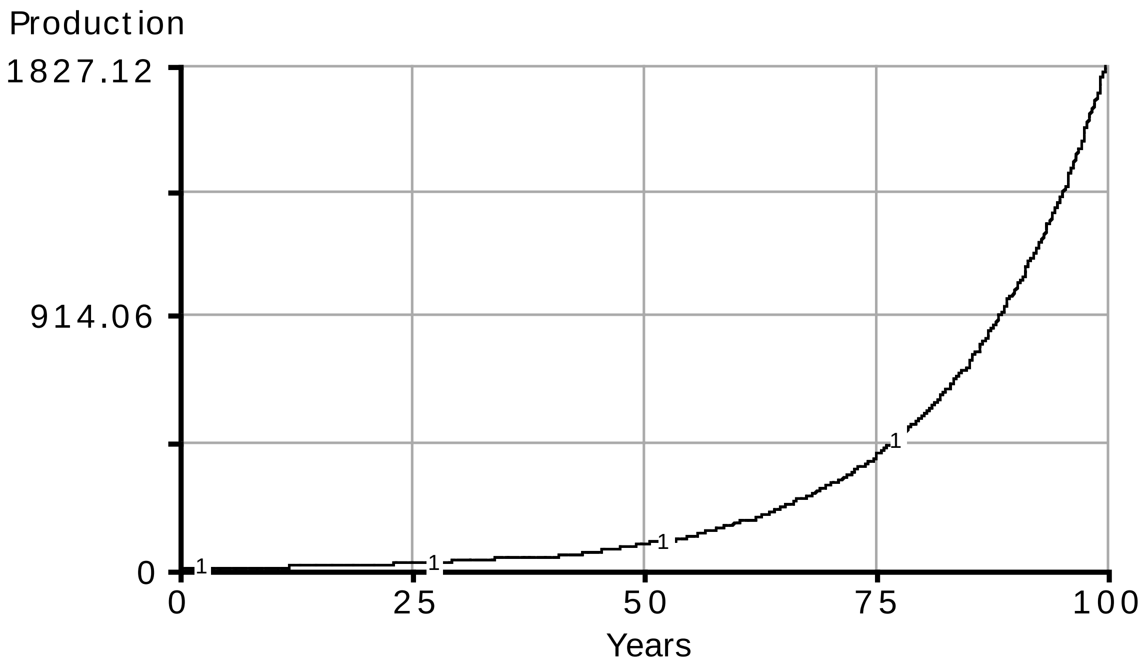
Consider first the case in which there is no technological progress, so that A(t) = 1 for all t. It is easy to compute the results of the model by computer. I have done so (using a program called Stella to facilitate the process; if you so desire you can use this program at the Royal Holloway Computer Center – look in the Economics directory of programs). Figure 3.1 shows the resulting amount of production over time.

After a short time, the decreasing returns to the production process cause annual gains in production to grow less. Nonetheless, there is a great increase in amount produced over the 100-year time span shown in the graph: output rises by more than nine times, and it is heading toward an equilibrium level ten times the initial amount of output. Consumers can consume much more over time, and hence (it is generally presumed in such models) grow happier.

What if there is ongoing productivity growth? Consider a growth rate of 3% per year, so that A(t) = exp(0.03×t). As seen earlier in this chapter, this productivity growth rate has been typical for developed countries in the 1900s. How much does the productivity growth matter to production?

Figure 3.2 shows a graph of production versus time similar to the one just presented. In just 18.6 years, production exceeds the equilibrium of 10 that would result without productivity growth. And production continues to shoot up thereafter. After 100 years, production has grown by a multiple of 1,827! As you can tell, productivity change is enormously important to economic growth in the basic macroeconomic growth model.

Figure 3.2. Production over Time in Growth Model with 3% Annual Productivity Growth



Conclusion

Technological advance, broadly defined, has been the primary source of economic growth. To stimulate economic growth, therefore, the most promising policies are any means that yield greater rates of technological progress. There are many means to such innovation, and this chapter has touched on several, including: transfer of skills between nations, education, social attitudes that support innovation, and national R&D funds. In the end what matters of course is the productivity improvements within the myriad companies (and government and nonprofit organizations) that compose a productive economy. The coming sections of the course will have much to say about how these companies operate in their respective industries, and how competition affects and is affected by technological change.

Study Guide

Terms to Know

Robert Solow
consumer price index
inflation-adjusted
hedonic price index
convergence
The Unbound Prometheus
Joseph Schumpeter
Capitalism, Socialism, and Democracy
depreciation

Key Reading with Questions

Walker, William. "National Innovation Systems: Britain." In Nelson, Richard R., ed. *National Innovation Systems*. New York: Oxford University Press, 1993. Chapter 5, pp. 158-191. **O B R** 338.06 NAT. Gives an overview of industrial innovation in Britain. If you are from another country, the book might have a chapter about your country too.

1. After Britain's industrial revolution, why might the country have lost its industrial leadership and begun an economic decline? Describe the three explanations that Walker mentions.

2. How important is manufacturing in the British economy? First, explain with reference to specific percentages of GDP or employment. How does this compare with other countries? Second, Walker seems to imply that manufacturing is especially important for the country's future. What reasons might he have for saying so? Are there other reasons for or against this idea?

3. What are the main sectors of manufacturing in Britain, and (as of a decade ago) what fraction of national production did they constitute? Which of these sectors were the biggest exporters? To what extent were they under British ownership versus ownership by people or companies outside Britain? Be specific.

4. Table 5.6 in W. Walker's paper gives you some idea of the distribution of (US) patents granted to firms in different UK manufacturing sectors. For example, whatever percentage of patents are granted to UK chemicals manufacturers (the table doesn't indicate what the percentage is), the percentage is only about half as much as that among UK aerospace firms. In contrast, the percentage of patents granted to Japanese chemicals manufacturers is about five times the percentage granted to Japanese aerospace manufacturers. This seems to suggest that the aerospace industry is much more important in the UK economy than in the Japanese economy. What other differences are there between the UK and other countries?

5. How did UK R&D in 1986, as a percentage of GNP, compare with that in other countries? How did government R&D spending per person compare? What has been the trend over time in R&D spending? On what have the R&D funds been spent?

6. What weaknesses does W. Walker identify in Britain's innovation system? What changes does he recommend for government policies?

Yates, Ivan. "An Industrialist's Overview of Manufacturing and Economic Growth." In Yates, Ivan, ed. *Innovation, Investment and Survival of the UK Economy*. London: Royal Academy of Engineering, 1992. Chapter 1, pp. 5-24. **B** check call number in catalog (new addition). Argues the importance of manufacturing industry, and the innovative change that drives its growth, for the UK economy. Useful though at points sloppy (e.g., the triangle drawn on fig. 3 is unnecessary and inappropriate: why should it point at 0 instead of –3 or +0.2?).

1. How important is manufacturing to the UK economy, and to the economies of other nations?

2. Why does Yates think that Britain's manufacturing sector is below its optimal size?

3. Is R&D funding high or low in the UK compared to France, Germany, Japan, and the US?

4. How does Britain's annual value added per employee compare with that of other nations?

5. Why does Yates think that there is "short-termism" in UK R&D investment?

Walker, John. "Service Sector Adjustment and the Implications for Manufacturing." In Yates, Ivan, ed. *Innovation, Investment and Survival of the UK Economy*. London: Royal Academy of Engineering, 1992. Chapter 3, pp. 45-51. **B** check call number in catalog; same as above. Presents evidence that service industries are unlikely to provide a strong growth impetus for the UK economy (unless unanticipated growth areas in services can be created through innovative approaches to service industries).

1. What two arguments are commonly invoked for why the UK does not need a strong manufacturing industry?

2. How does J. Walker refute the first of these arguments?

3. How does J. Walker refute the second of these arguments?

4. What does J. Walker argue can be done to help the manufacturing sector propel economic growth in the UK?

Further Readings

Chandler, Alfred D. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge: Belknap (Harvard University Press), 1977. **B** 338.75 CHA. A monumental document that provided for the first time an integrated history of American industry from the 1700s into the 1900s.

Chandler, Alfred D., Jr. *Scale and Scope*. Cambridge, MA: Harvard University Press, 1990. **B R** 338.644 CHA. Another monumental document, analyzing industrial history in the United States and Europe during the 20th century.

Hounshell, David A. *From the American System to Mass Production, 1800-1932*. Baltimore: Johns Hopkins University Press, 1984. **B** 338.644 HOU.

Landes, David S. *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present*. Cambridge: Cambridge

University Press, 1969. **B** 338.94 LAN. The key history of European industrial development from 1700 until shortly after World War II.

Mokyr, Joel. *The Lever of Riches: Technological Creativity and Economic Progress*. Oxford, 1990. **R** 338.06 MOK. A seminal history and analysis of technological advance, mostly in the western world, over more than two millennia; illustrates the fundamental role of technical change in economic growth.

Mowery, David C. and Nathan Rosenberg. *Technology and the Pursuit of Economic Growth*. Cambridge: Cambridge University Press, 1989. **B** 338.06 MOW.

Pratten, Clifford F. "The Manufacture of Pins." *Journal of Economic Literature* 18 (March), 1980, pp. 93-96. **E**.

Rosenberg, Nathan. *Inside the Black Box: Technology and Economics*. Cambridge: Cambridge University Press, 1982. **B** 338.06 ROS. Chapter 1 is an excellent overview of the role of technological progress in economic growth over a long time span.

Scherer, F.M. and David Ross. *Industrial Market Structure and Economic Performance,* 3rd ed. Boston: Houghton-Mifflin, 1990. **R** 338.758 SCH. Chapter 17 considers technological change; focus on the earlier parts of the chapter, pages 613-630 in the book's third edition.

Solow, Robert M. "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics* 39 (August), 1957, pp. 312-320. **O J E**. This paper, which in part led to Solow's Nobel prize, analyzes the extent to which US labor productivity growth from 1909 to 1949 stemmed from increased capital intensity. The answer stunned many economists of the time: capital apparently was of little relevance to productivity growth; technological advances and increased skill of workers apparently contributed over 80% of the labor productivity growth.

von Tunzelmann, G. N. *Technology and Industrial Progress: The Foundations of Economic Growth*. Aldershot, UK: Edward Elgar, 1995. **B** 338.06 VON.

4. Sources of Invention: Small Firms and Innovative Networks (Week 2)

As economists, we'd like to find ways to (1) encourage the creation of new products, (2) improve the features and quality of existing products, and (3) reduce costs of production. As part of finding ways to spur technological improvement, it helps to know some of the determinants of invention and innovation:

1. Firm size: Do large or small firms innovate more? Why?
2. Individuals who create innovations: Do inventions and improvements come from people within a firm? Or do they come from customers, suppliers, or outside inventors? What types of inventions/improvements come from which people?
3. Regional agglomerations of firms: How does the local community around a firm affect that firm's innovative success?

Just as firm size, individuals, and regional traits affect the amount and type of invention and innovation, so do successful invention and innovation affect the sizes of firms, the character of individuals, and the fortunes of regions. An important example is how innovative success or failure may result in the growth or stagnation of whole regions, as analyzed by Jane Jacobs (1969) in her book *The Economy of Cities*.[9]

After completing this section of the course, you should understand the above basic influences on innovation or invention in firms, and you should understand Jane Jacobs' main point about the role of innovative ideas in affecting the growth of cities. An exception is firm size, which will be covered mostly in week 3.

Firm Size

Studies of innovation by firms have checked to see whether small or large firms innovate more. Some of the conclusions we'll discuss next week, but for this week note that:

1. Lots of issues are more important than size in determining which firms innovate more.
   a) The industry in which firms participate. Suppose you compare the aerospace industry versus the soft drinks industry. It's no surprise that aerospace firms have bigger R&D budgets, in absolute terms or as a percent of sales or profits, than soft drink firms.
   b) The culture of the firm, how it's organized, and the skills of people in the firm. Some firms have a belief in being technology leaders, while others pay more attention to costs or marketing. Some firms involve factory workers in coming up

[9] It is easy to imagine the effects of innovation and invention on firm sizes and on individuals' characters. Firms that succeed as innovators may expand. Individual inventors whose ideas are commercialized may become wealthy and skilled and invent more (as with Thomas Edison, who harnessed his profits to fund a laboratory full of workers who steadily developed further inventions), or may instead spend decades in unsuccessful legal battles to try to capture some of the profits from their inventions (as with John Sheehan, whose MIT laboratory developed synthetic methods to make and modify penicillin).

with ideas to improve the production line, while others separate the jobs of their engineering staff and line workers. Some firms have executives, scientists, and engineers with the necessary skills to succeed with a technology; others don't.

2. Consider firms in the same industry with similar culture, organization, and employee skills. Among these firms, large size seems beneficial for some types of innovation:
   a) Firms with large market shares seemingly have the advantage for the many incremental changes that improve a product and reduce its manufacturing cost. (We'll discuss this next week.)
   b) Small firms, however, are relatively free of bureaucratic problems and incentive problems that may get in the way of major inventions. The managers of large firms are often charged with blocking important inventions that have little to do with a firm's existing products or markets, or especially those that would replace the firm's existing products, because they want to focus on what the firm already does.
3. In a classic book entitled *The Sources of Invention*, Jewkes, Sawers, and Stillerman (1959) discussed some of the issues that help to determine which firms and individuals are the sources of invention. They considered only major new products, not incremental improvements in technology. Through a series of case histories, they pointed out that major inventions come from many sources – large firms, small firms, and individuals. Thus, they argued, it would be wrong to think that large firms are necessary for invention to occur.
4. Often, the term invention is used to mean the initial creation or discovery of an idea, while innovation is used to mean the commercialization of the idea. In practice, the innovation part of the work almost always requires far more money, and far more work by scientists and engineers, than the initial invention. For example, the discovery of penicillin by an individual – Alexander Fleming in 1928 – did not lead to a commercial product until a massive development program during World War II, when thousands of scientists and engineers came up with viable, affordable production methods. Large firms, not small firms or independent inventors, made commercial production of penicillin a success.[10] Large firms seemingly dominate commercial innovation more than initial invention. And the large firms, not the initial inventors, generally make most or all of the profit.

Individuals who Create Innovations

The ideas for an invention or innovation often come from outside the firm that puts the innovation into practice. Thus, a firm's contacts with customers and suppliers, and its openness to ideas from those sources, may influence its rate of innovation. Also, of course, the specific individuals involved in companies help determine how successful a company can be at innovation.

- Johnston and Gibbons (1975), and later von Hippel (1988), analyzed the sources of innovation (and invention), and found that often the ideas for innovations came not from the company that put the innovations into products, but from customers or suppliers of the company.

[10] A government laboratory, the Northern Regional Research Laboratory in Peoria, Illinois, also played an important role in early development of penicillin production methods.

- An important concept in theories of industry concentration is that of heterogeneity between firms. The term heterogeneity simply means differences, which could involve differences in size, research skills, managerial capabilities, etc. Some theories assume that heterogeneity in terms of the capabilities of managers and of engineers / researchers remains fixed over time -- that is, a rating could be assigned to each firm when it starts up, telling how good that firm is in terms of the capability of its personnel, and the rating remains over time. Such fixed heterogeneity of personnel can explain some interesting facts about industrial competition, as we'll discuss later.

Regional Agglomerations of Firms

A regional agglomeration occurs when firms locate near each other. Agglomerations might have many advantages for the success of companies at R&D and at competition more generally. Nearness by itself, however, may not guarantee an advantage. In a fascinating analysis of two high-tech areas involving electronics industries, AnnaLee Saxenian (1994) contrasts Silicon Valley with the Route 128 area near Boston, in the process showing some of the characteristics that seem to be necessary for regional agglomeration to give an advantage. Saxenian points out the following differences between the two region's cultures:

1. Openness and interchange of ideas among engineers and managers in Silicon Valley (SV), versus very little interaction around Boston.
2. Normality of rapid job-change in SV, versus job change taken as a danger sign about a potential employee around Boston.
3. Readily available start-up money, especially from previously successful entrepreneurs, in SV, versus difficulty of obtaining loans from conservative Boston banks. Close involvement and assistance from SV investors. Past failures not a barrier to getting start-up money in SV. Targeted (to a particular technology area) venture capital firms in SV.
4. Close links between university research and educational programs in SV, versus more distant university-corporate relationships around Boston.
5. Firms in SV working closely with local government and volunteering executives' time to try to resolve regional problems, versus more combative and political corporate-government relations in the Boston area.
6. Even willingness of firms in SV to let startups use computers overnight when the owning firm doesn't need to use them, or for competitors across the street to loan each other lab equipment when special needs arose; this didn't happen in the Boston area.

Thus, in all these ways, Silicon Valley had a culture that encourage openness, communication, and interchange, whereas the Boston area did not. It is this culture of openness, communication, and interchange to which Saxenian attributes Silicon Valley's success.

The Economy of Cities

Jane Jacobs (1969), in her book *The Economy of Cities*, describes agglomeration economies related to innovation. She argues that cities with diverse economies may tend to grow, whereas cities focused primarily on a single industry may stagnate if the single industry ceases to grow or collapses. In her view, diverse economies have more ability to spin off new kinds of business when profit opportunities exist. For example, Silicon Valley may have been an especially likely and supportive environment for spin-off of new businesses, because the diversity of businesses there made available so many different skills, ideas, interests, and resources needed to start many different types of new businesses. Diversity of knowledge and assets allows people to come up with new business approaches. In contrast, if almost all firms in a city were specialized in, say, cotton spinning and weaving, then it may be very hard to create new kinds of non-cotton business when the UK cotton industry becomes unable to compete with producers in other nations.

What evidence is there in favor of this view?

1. Two key types of case study evidence are in Jacobs' book. First, Jacobs counters the theory of agricultural primacy with stories of how ancient cities developed before the growth of sophisticated agriculture. According to the theory of agricultural primacy, it is only once agricultural improvements made enough excess food available that part of the population could live in cities and perform non-agricultural trades. But Jacobs argues that agglomeration economies, related to ongoing innovation, made cities form early, and even that with interchange of goods and techniques from distant lands, cities were the sources of major improvements in agriculture. Second and more importantly, Jacobs discusses cities in Britain such as Manchester, Birmingham, and London and how they fit with her theory.
2. Empirical studies by Glaeser et al. (1992) and Jaffe et al. (1993), among others, analyze city growth/stagnation and technological change, and find support for Jacobs' view. (Empirical articles related to agglomeration economies in specific industries also provide indirect evidence for and against Jacobs' view.)

Study Guide

Terms to Know

invention (comes up with the initial idea)
innovation (… turns the initial idea into a marketable product, feature, or method)
radical / major invention (establishes a new product)
incremental innovation (… improves an existing product or reduces costs)
product innovation (creates a product or improves an existing product)
process innovation (… improves manufacturing methods)
heterogeneity
agglomeration

Key Readings with Questions

Saxenian, AnnaLee. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, Mass.: Harvard University Press, 1994. **B R** 338.4762 SAX. Argues for the importance of a culture of cooperation and openness in order to make regional agglomerations of firms as beneficial as possible to the firms involved.

1. Why might geographic agglomeration help companies that are located near each other?

2. Why did geographic agglomeration help electronics companies in California's Silicon Valley area more than it helped companies in Boston's Route 128 area? List Saxenian's reasons.

3. Based on Saxenian's findings, what policies could you use as a company executive to encourage the prosperity of your company? Why might you have trouble achieving policies that help your company because of agglomeration? What competitive disadvantages might you suffer?

4. Based on Saxenian's findings, what policies might you use as a regional planner? And what policies might you use as a university executive officer? Why?

Jacobs, Jane. *The Economy of Cities*. New York: Random House, 1969. **B R** 338.091732. Describes regional circumstances that affect innovation by firms, and relates these patterns to the growth and stagnation of cities.

1. What is the main point that Jacobs makes about why cities grow or stagnate?

2. What are Jacobs' main reasons for thinking that cities grow or stagnate this way?

3. If you were a city planner and you believed Jacobs' arguments, what could you do to ensure that your city's economy remained healthy? Explain why your policies would make sense on the basis of Jacobs' logic.

Jewkes, John, David Sawers, and Richard Stillerman. *The Sources of Invention*, 2nd ed. New York: W.W. Norton & Co., 1969. **B** 608.7 JEW. Points out that, among those innovations that take the form of new products, many originate from individuals or small firms.

1. What is the main point of the book?

2. What evidence do the authors use to make this point?

3. Do the authors talk about (a) who comes up with the idea of an invention, or (b) who develops it as a product? In the context of the rest of what you learned in the course, why might this distinction matter?

Further Readings

<u>Importance of Small Firms</u>

Jacobs, Jane. *Cities and the Wealth of Nations: Principles of Economic Life*. 1985. **R** 301.36 JAC.

Schumpeter, Joseph A. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. 1912. Translated from the German by R. Opie, Harvard University Press, 1934. **B** 338.5 SCH. The author became a very controversial leading economist, as you will see from his later book *Capitalism, Socialism, and Democracy* next week. Because this earlier book considers the importance of small firms for creating technological ferment and advance, it is valuable to consider it along with the later book which relatedly argues for the importance of large firms to technological advance.

Agglomerative Networks & Economic Growth

Glaeser, Edward L., Hedi D. Kallal, José A. Scheinkman, Andrei Shleifer. "Growth in Cities." *Journal of Political Economy* 100 (6), 1992, pp. 1126-1152. **E**.

Jaffe, Adam, Manuel Trajtenberg, and Rebecca Henderson. "Geographic Localization of Spillovers as Evidenced by Patent Citations." *Quarterly Journal of Economics*, 108, 1993, pp. 577-98. **E**.

Krugman, Paul. "Increasing Returns and Economic Geography." *Journal of Political Economy* 99 (3), 1991, pp. 483-499. **E**.

Where Firms Get Innovative Ideas

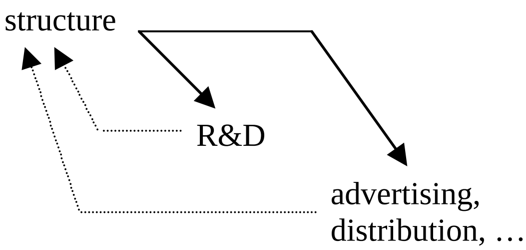
Gibbons, Michael, and Ron Johnston. "The Roles of Science in Technological Innovation." *Research Policy* 3, 1974, pp. 220-242. **U** Imperial College central library, level 3 periodicals 351.85.

Johnston, Ron and Michael Gibbons. "Characteristics of Information Usage in Technological Innovation." *IEEE Transactions on Engineering Management*, EM-22 (1: February), 1975, pp. 27-34. **U** Imperial College central library, level 2 periodicals 62 IEEE.

von Hippel, Eric. *The Sources of Innovation*. Oxford: Oxford University Press, 1988. **R** 338.06 HIP.

5. Sources of Invention: Big Firms & Streamlined Structure, Improvement & Efficiency (Week 3)

Section III of the course continues to address how the structure of an industry – the sizes and other characteristics of its firms – affects R&D in the industry. The following three sections of the course will examine how R&D, and other factors, affect structure.



After completing this section, you should:

1. Understand the relevance of issues including technological opportunity, demand, appropriability, and absorptive capacity for determining amounts of innovation.
2. Know the results of empirical research on the so-called "Schumpeterian hypothesis" about firm size, industry concentration, and innovation. These results have been widely interpreted as suggesting that small firms are better or no worse innovators than large firms.
3. Be able to explain the assumptions behind a cost-spreading model of firm size and R&D.
4. Be able to explain why this model predicts exactly the empirical results that have emerged about the "Schumpeterian hypothesis," yet it implies that large firms are in a sense better innovators, are as a result more competitive, and are better for society.
5. Be able to step back and think about when small versus large firms are better, based on the assumptions that go into the cost-spreading theory.

You should also make some attempt to master the mathematics used in the cost-spreading model. This will stretch your skills, in a way useful for other economic theories.

Firm Size and R&D

Why might bigger or smaller firms tend to do more R&D? To begin answering the question, consider some of the factors that affect how much R&D a firm does:

1. Technological opportunity. In different industries or product markets, there are different amounts of opportunity to create important new technologies. For example, there seems to be more technological opportunity today in the biotechnology or software industries than in the cloth manufacturing industries. Technological opportunity is sometimes known as a "technology push" factor.

2. Demand for technology. Regardless of technological opportunity, progress may slow when there is little economic demand for a technology. For example, with the switch from horse and carriage travel to automobile travel, the development of new patents related to horseshoes plummeted. (A horseshoe is a U-shaped metal bar nailed to the bottom of horses' hooves, so that the hooves don't wear out.) People's willingness to pay for a new technology is sometimes known as a "demand pull" factor.
3. Appropriability. Can firms "appropriate" the monetary returns to R&D? Webster's dictionary definition of "appropriate":

   verb: 1. "… to claim or use as by an exclusive right…"

   2. "To set apart for, or assign to, a particular person or use, in exclusion of all others…"

   If patent rights are strong, both small and large firms should be able to appropriate the returns to R&D, i.e. capture the profits that could come from the inventions and innovations created during the R&D. If patent rights are weak, either (1) other firms copy the invention or innovation; (2) other firms develop minor variations of the new technology and patent the variations instead, thus "patenting around" another firm's patent and continuing down the path of development; or (3) large firms with strong investments in the technology can maintain dominance by having large numbers of patents and copyrights, and by defending them legally, so that new firms are kept out of the market and find it impractical to develop new technologies.
4. Availability of financing. Do firms have enough money to fund R&D?
5. Absorptive capacity. Do firms have the capacity to "absorb" information about new technologies developed in other firms or by academic researchers? The extent to which a firm has the relevant R&D personnel and other resources needed to absorb new technologies from outside the firm is called its "absorptive capacity."
6. Incentives from cost-spreading. Consider two firms, producing 100 and 10,000 automobiles per year respectively. Suppose a project to design a new production machine, thus cutting production cost per car by £1, costs £10,000. For the smaller firm, the project would not be worthwhile, because it would take 100 years of producing 100 cars per year to pay back the development cost of £10,000. But for the large firm, the project pays for itself in one year, and in future years saves £10,000 per year. Thus, the fixed cost of R&D may be spread over the number of units sold, giving an advantage to larger firms.
7. … [There are lots of other possible influences on the rate of innovation.]

In addition to which firms do more R&D, with empirical data it helps to ask why some firms may seem to do more R&D. In particular, a firm's "propensity to patent", or relatedly its potential to publish the results of R&D, influences how much it seems to do R&D. In some industries, firms need to patent a lot, whereas in other industries it makes more sense to keep R&D results secret. Also, different firms may have managers who are more or less keen on patenting or restrictive about publishing.

Larger firms tend to have more incentives than smaller firms to improve and streamline existing technologies. Hence, large firms often pursue large numbers of minor improvements to products and manufacturing processes. If an invention comes from smaller firms, commercialization (or "innovation") still takes a lot of effort, which may be carried out with help from larger firms.

Empirical Findings about Firm Size, Industry Concentration, and R&D

The Schumpeterian hypothesis, remember, is that in some sense larger firms and monopolies are better than small firms as a source of innovation and invention. In practice, to test the hypothesis, economists have usually found some measures of R&D spending or R&D output and of firm size, computed (R&D spending or output) / (firm size) for each firm, and compared the resulting figures. The notion is that, if the hypothesis is right, the values of [(R&D spending or output) / (firm size)] should be bigger for larger firms. The name "R&D intensity" is used to mean (R&D spending) / (firm size), since firms with higher values are in a sense doing research and development more intensively.

Many empirical studies were carried out in which data on the sizes and R&D spending of firms, along with data on industry concentration, were used to test the Schumpeterian hypothesis. Not surprisingly, these studies found that bigger firms tend to have bigger R&D budgets and more R&D results (such as patents). The real question they posed was, however, whether R&D intensity increases with firm size.

It turns out that R&D intensity varies a lot from company to company for reasons that seem to have little relation with size. Specifically, most of the variance in companies' R&D/size measures can be attributed to variables other than size. Characteristics of particular industries, such as the nature of the technology and its appropriability, explain much of the variance. And for other reasons, individual firms have enormous differences in R&D intensity that cannot be explained by their sizes.

Examining what little relationship remains between R&D intensity and firm size, R&D intensity seems roughly unrelated with size: specifically, above a low threshold in size, R&D intensity seems to be roughly constant regardless of firm size.

Similarly, in more concentrated industries (which typically have bigger firms), there tend to be higher R&D budgets, but there is little relationship between industry concentration and R&D <u>intensity</u>, and R&D intensity seems roughly unrelated with industry concentration. (There was a slight upside-down U-shape found in the relationship; this pattern has become known as "Scherer's inverted-U" after its discoverer Mike Scherer. But this pattern is not very strong.)

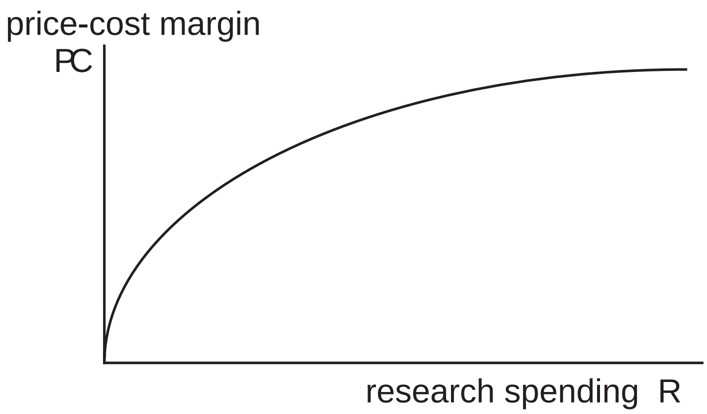
Finally, it was found that the R&D <u>output</u> of firms per unit of size actually seems to <u>decline</u> with firm size! For example, the number of patents produced each year per employee in a company or per £ spent on research actually seems to be <u>smaller</u> in the bigger companies! Thus, it seemed, perhaps the bigger companies are actually less efficient than the smaller companies!

With this sort of empirical evidence, many researchers took the view that Schumpeter's notions were wrong, and small companies are better sources of R&D. Even people who had originally been champions of the Schumpeterian view (such as Mike Scherer) seemed to adopt this view. But, surprisingly, there are reasons to think this view is wrong, at least for many kinds of technological advance. One reason comes in the form of a theoretical model of R&D cost-spreading.

R&D Cost-Spreading – A Model that Explains the Empirical Patterns

The empirical tests of how innovation patterns vary with firm size and with industry concentration have often been interpreted as suggesting that Schumpeter was wrong. However, this is not the only possible interpretation. Cohen and Klepper (1996) argue that indeed, the patterns observed between firm size and R&D, and also between firm size and R&D productivity, may be exactly what one should expect if large firms indeed pursue R&D more intensively than smaller firms. While Schumpeter was vague about just how and why the large firms were to be most innovative, the Schumpeterian hypothesis may be much closer to the truth than most economists have believed.[11]

The following model and discussion is adapted from that presented by Cohen and Klepper. Suppose that a firm spends an amount of money R on research ($R \geq 0$). (The term "research" as used here is intended to mean R&D in general, thus including development activities and production line engineering as well as fundamental research.) Research allows it to lower its unit production cost, to charge a higher price for its higher-quality product, or both. Therefore, research increases its price-cost margin, PC = price - cost. (The higher the price-cost margin, the more profit the firm makes per unit produced.) Firms do the most promising research first and the least promising research last, so that the first research project done yields the biggest increase in PC.[12] Thus, the relationship between PC and the firm's research spending takes a form such as that illustrated below.



Stated mathematically, these assumptions imply that:

$$PC'(R) > 0 \qquad PC''(R) < 0$$

If this is gobbledygook to you, read the "Interpreting Derivatives" section in the chapter "Mathematical Skills Related to the Text," before going on.

If the firm will produce and sell Q units of its product, it makes a profit of

$$\Pi = PC(R) * Q - R.$$

For an introduction to Greek letters such as Π, read the "Greek Letters" section in the chapter "Mathematical Skills Related to the Text."

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[11] Indeed, Cohen and Klepper's argument serves as a cautionary reminder. Simply examining empirical evidence and interpreting it to mean what it seems by surface appearance to mean, without thinking through just what underlying processes may be involved, gives a danger of making a completely wrong interpretation. Evidence cannot be interpreted without a theory, and if no theory is explicitly invoked, then implicitly the theory assumed is that the only processes with a substantial effect on the empirical findings are the processes that are assumed from surface appearances. Just as economic models developed with insufficient attention to real-world facts are usually wrong, so empirical facts interpreted without reference to an underlying theory often yield incorrect interpretations.

[12] More generally, the model can be framed in terms of expected increases in PC. The expected increase, E(PC), resulting from research is defined roughly speaking as the average increase that could occur.

That is, the firm's profit equals its price times the number of units it produces, minus its per-unit cost times the number of units it produces, minus the amount of money it spends on research.

Two key assumptions have been made above:

1. Research results cannot be sold to other producers. (If they could be, the profit from such sales would have to be included in the profit equation.)
2. Output Q is a fixed constant.

The first assumption states that the "returns" to research are not "appropriable" except through the firm's own sales. "Returns" to research means the total profits that the inventor and all other firms using the invention get because of the invention. "Appropriability" describes an inventor's (or an inventing firm's) ability to capture these profits. In reality, is this assumption realistic? For most industries, it is a quite good approximation. Firms typically can "invent around" their competitors' patents, thus coming up with alternative innovations and patents rather than paying competitors for rights to use patents. Sometimes firms manage to force others to pay royalties, but there is a long history of involved lawsuits in which firms demanding royalties for patents can have their patents ruled invalid, or can be forced to settle out of court for relatively small amounts of money. Firms that demand anything more than a tiny royalty payment are prime targets for other firms to come up with alternative inventions. In many industries, such as the US automobile industry of the early 1900s, patent pools are established so that every firm in the industry has the right to use any technology invented by any producer. Such patent pools have the advantage of avoiding excessive lawsuits and also help to reduce the amount of duplicative research. The kinds of patents that have proved most defensible are new chemicals and drugs, because there is often no way to "invent around" a patented chemical formula. Thus, assumption 1 is for most industries quite realistic, though it is not appropriate for some industries such as new chemicals and drugs.

The second assumption says that output Q is a fixed constant. For example, if output of the firm today is q_{today}, then perhaps future output is $Q = k * q_{today}$. This assumption says that the firm is limited in how much it can expand in the time before it sells the product. Is this assumption reasonable? It is very unusual compared to the assumptions of most theoretical models in industry economics, because such models typically assume that firms can choose to produce any amount of output. But realistically, firms cannot instantly adjust their size to produce whatever amount of output management pleases. Increasing size requires that capital expenditures be raised to meet the costs of expansion, and it leads to a broad range of problems related to production engineering; shipping; purchase, construction, and renovation of buildings; and hiring and training of employees. The typical rapidly-expanding firm, judging from company histories, is hard-pressed to deal with these sorts of helter-skelter changes. And even as the personnel involved would be too hard-pressed to deal with all the attendant problems at an excessive rate of expansion, new personnel with the skills needed to help with the expansion are often difficult to hire and in any case generally require large amounts of their time and of existing personnel's time in order to do their jobs effectively. Thus, treating Q as a fixed constant seems a reasonable first approximation.

Based on the simple model that has been discussed, it is possible to show that profit-maximizing firms generate exactly the empirical patterns we have seen.[13] Moreover, the model implies that society is better off with large firms than with smaller firms, that large firms go farther in the pursuit of research, and that large firms are more able competitors. The discussion below will address the following three points in turn:

1. Larger firms do more research than smaller firms.
   But, larger firms do not necessarily do more research per unit of firm size.
2. Larger firms achieve a greater PC (i.e., increase in price and decrease in cost) from their research than smaller firms. Thus, society is better off with larger firms, because they produce better goods more cheaply than smaller firms.
   Also, those larger firms are better competitors than smaller firms; they achieve greater profit per unit of output.
3. The research results (in terms of an increase in PC) per unit of research are less for larger firms. Thus, larger firms seem to accomplish less for every dollar they spend on R&D. But this is a good thing — it means they do the relatively low-value research too, instead of focusing exclusively on the very promising research as small firms do.

These points will be both discussed and proved mathematically.

You should learn to understand the mathematical proofs well enough to do them yourself, as they involve fundamental skills that economists (and economics students) should have. Before going on, read the "Computing Derivatives" and "Maximizing a Function" sections of the appendix.

Before seeing the proof of points 1-3, consider how much research a profit-maximizing firm chooses to do. At the profit maximum, the firm chooses to do the amount of research R for which $\frac{d\Pi}{dR} = 0$. So,

$$\frac{d\Pi}{dR} = PC'(R)\ Q - 1 = 0.$$

$$\text{I.e., } PC'(R) = \frac{1}{Q}.$$

To show that this yields the maximum profit, not the minimum profit, it must be the case that $\frac{d^2\Pi}{dR^2} < 0$.

$$\frac{d^2\Pi}{dR^2} = PC''(R)\ Q < 0 \qquad \text{because } PC''(R) < 0 \text{ and } Q > 0.$$

So, choosing the amount of research R that sets $PC'(R)$ equal to 1/Q indeed yields the maximum profit.

[13] While of course no real firm can be expected to be truly profit-maximizing, in the way profit maximization is used here, it seems a reasonable approximation within existing industries. (For research that would create entirely new industries, one might argue that the potential outcomes of the research are particularly difficult to estimate, hence making it difficult for firms to optimize the amounts of such research they carry out. Even so, the variation in research budgets with firm size would surely follow a similar pattern to that observed in existing industries, though perhaps with greater random variation.) The managers of a firm that expends far more or less on R&D than the optimal amount generally perceive their error quickly, because the huge expenses involved tend to lead to much consideration of the prospects for outcomes of the R&D. And furthermore, even if they should want to do so, small firms rarely have budgets to pursue amounts of research comparable to that of large firms.

The first point made above is that (a) larger firms do more research than smaller firms, but (b) larger firms do not necessarily do more research per unit of firm size.

A. If larger firms do more research than smaller firms, then it must be the case that $\frac{dR}{dQ} > 0$. That is, the amount of research done by firms must increase with their size (where size is represented by their amount of output Q).

Proof: From the profit-maximizing condition, you know that $PC'(R) = \frac{1}{Q}$. Taking the *total* derivative of both sides (using derivative rule 8 on the left-hand side and rule 5 on the right-hand side) *with respect to Q* tells you that

$$PC''(R)\,\frac{dR}{dQ} = \frac{-1}{Q^2}.$$

Rearranging by dividing both sides by $PC''(R)$ tells you that

$$\frac{dR}{dQ} = \frac{-1}{Q^2} * \frac{1}{PC''(R)}.$$

Since $Q > 0$ and $PC''(R) < 0$ (as assumed at the beginning), multiplying together the -1 divided by a positive number divided by a negative number tells you that $\frac{dR}{dQ}$ has to be a positive number. That is, $\frac{dR}{dQ} > 0$. QED.[14]

B. If larger firms don't necessarily do more research per unit of firm size, then it must be the case that $\frac{d(R/Q)}{dQ}$ is not unambiguously greater than zero. That is, the amount of research done per unit of firm size need not increase or decrease with firm size.

Proof: If $PC(R) = k \log(R)$, that is, if it just happens to be the case that the graph of PC versus R takes exactly a form given by a constant times the logarithm of R, then $PC'(R) = k / R$, so the profit-maximizing condition states that

$$\frac{k}{R} = \frac{1}{Q}.$$

Using this, you can see that $R = k\,Q$, so that $R / Q = k$. Taking the derivative with respect to Q, you get

$$\frac{d(R/Q)}{dQ} = 0.$$

In other words, in this special case, R&D per unit of firm size is exactly the same for all firms.

With other possible forms of PC(R), such as 1 - exp(-R), smaller firms do more R&D per unit of firm size. And I am sure that for other forms of PC(R), larger firms do more R&D per unit of firm size, though I haven't written out an example or a proof yet (if you come up with one, let me know).

[14]QED is a way of concluding mathematical proofs that essentially means, "Hah; I told you so."

The second point made above is: (a) Larger firms achieve a greater PC (i.e., increase in price and decrease in cost) from their research than smaller firms. Thus, society is better off with larger firms, because they produce better goods more cheaply than smaller firms. (b) Also, those larger firms are better competitors than smaller firms; they achieve greater profit per unit of output.

A. For larger firms to achieve a greater PC than smaller firms, it is simply necessary that they do more research than smaller firms. This is because $PC'(R) > 0$; that is, the price-cost margin only goes up with the amount of R&D a firm carries out. And you know from point 1a that larger firms do indeed carry out more research than smaller firms.

B. Consider two firms, a smaller firm and a larger firm, with outputs $Q_{smaller}$ and Q_{larger}. Their amounts of research and profit will be represented similarly, by $R_{smaller}$, R_{larger}, $\Pi_{smaller}$, and Π_{larger}. If the larger firm did not maximize its profit but instead only did the same amount of research, $R_{smaller}$, as a profit-maximizing smaller firm, even so the larger firm would still achieve the greater amount of profit per unit of output. The profits per unit of output for the two firms would then be:

$$\Pi_{smaller} / Q_{smaller} = [PC(R_{smaller}) * Q_{smaller} - R_{smaller}] / Q_{smaller}$$
$$= PC(R_{smaller}) - R_{smaller} / Q_{smaller}$$
$$\Pi_{nm,larger} / Q_{larger} = [PC(R_{smaller}) * Q_{larger} - R_{smaller}] / Q_{larger}$$
$$= PC(R_{smaller}) - R_{smaller} / Q_{larger}$$

Here, the subscript "nm" on the variable $\Pi_{nm,larger}$ indicates a non-maximizing amount of profit. The only difference in profit per unit is that the larger firm saves more money by dividing its research cost by a greater amount.

A profit-maximizing larger firm can do much better. Choosing a larger amount of research spending ($R_{larger} > R_{smaller}$), as you know from point 1a (which was found for profit-maximizing firms), lets the larger firm increase its profit. Since this causes Π_{larger} to be greater than $\Pi_{nm,larger}$, and since Q_{larger} is a constant, $\Pi_{larger} / Q_{larger}$ is even greater than $\Pi_{nm,larger} / Q_{larger}$.

The third point made above is that research results, in terms of an increase in PC per unit of research, are less for larger firms. Thus, larger firms seem to accomplish less for every dollar they spend on R&D. This is a good thing, since it means they do the relatively low-value research too, as well as focusing on the very promising research as small firms do.

- From the graph shown earlier, it is easy to see that $[PC(R) – PC(0)] / R$ is lower for larger amounts of research. Mathematically, this property follows from the assumptions that $PC'(R) > 0$ but $PC''(R) < 0$; it is a property of any concave increasing function.

Thus, it is possible to prove mathematically that the empirical patterns of R&D and firm size are just what one should expect if large firms are the best loci for society's innovation. Contrary to common interpretations of these patterns, larger firms may be both more competitively able and better for society. For a country's producers to fare well against international competition, according to this model, they must be comparable in size to, or larger than, their foreign competitors. And more importantly, for society in general, the rapid technological improvement brought by large firms cannot be equaled by their smaller brethren.

These conclusions have depended upon assumptions that mean they do not apply to certain kinds of industries. If firms can appropriate returns to innovation, as chemical and drug firms do with defensible patents, or if firms can rapidly expand to any amount of output, as multi-product chemical firms might do for some new products, then small firms would be expected to have the same incentive as large firms to do R&D. There may be other reasons why larger firms may have the upper hand at R&D, for example economies of scope in the research of chemical and drug firms, but the so-called “R&D cost-spreading” argument given here does not apply.

Another issue not addressed yet is diversity. All firms in this model were assumed to pursue exactly the same sorts R&D. And in practice, manufacturers producing similar products do seem to carry out duplicative R&D. But, oligopolistic firms may be limited in their desire to develop radical changes in a product technology, given their “cushy” established position and their investment in the established technology. Perhaps, then, society would be better off to have a combination of large firms and some mechanism that guarantees continued innovativeness with radical inventive ideas. For example, a nation could establish a small percentage-of-sales corporate and import tax to pay for research grants for university and corporate researchers with successful R&D proposals.

Study Guide

Terms to Know

industry structure
technological opportunity
technology push
demand pull
appropriability
patenting around
absorptive capacity
R&D cost-spreading
propensity to patent
R&D intensity
(Scherer’s) inverted-U

Key Readings with Questions

Cohen, Wesley. “Empirical Studies of Innovative Activity.” In Stoneman, Paul, ed., *Handbook of the Economics of Innovation and Technological Change*, Oxford: Basil Blackwell, 1995, pp. 182-264. **O B** 338.06 HAN. A dense review of empirical research on industrial innovation and technological change. Learn the main concepts and points, not the many minute details.

1. Based on Cohen's paper, how do firm size and innovation seem to be related? Describe the major research findings. Sum up the major arguments for and against the Schumpeterian hypothesis.

2. Based on Cohen's paper, how do market concentration and innovation seem to be related? Describe the major research findings. Does this have any more to say about the Schumpeterian hypothesis?

3. Pick one feature described in Cohen's section 3, on how the characteristics of firms affect their innovative activities. Explain what this feature is and how it is supposed to affect innovation by firms. If there is empirical evidence on the matter, describe what the evidence has to say.

4. What are demand-pull and technology-push? What does Cohen mean when he says, "The consensus... is that the Marshallian scissors cuts with two blades." (p. 212)?

5. What is technological opportunity? How does it matter? How does technological opportunity change over time, in general and within a given industry?

6. What is appropriability? Why might the profits from innovations be appropriable or not? How does the nature of appropriability vary from one industry to another?

Schumpeter, Joseph. *Capitalism, Socialism, and Democracy*. New York: Harper, 1942. **B R** 320.531 SCH. Examine especially chapters 7 and 8, which contain a core idea that triggered much heated debate and research, because Schumpeter argued that the classical economic focus on highly-competitive markets full of small firms was completely backward from the focus most relevant to understanding the processes of economic growth.

1. What does Schumpeter argue in *Capitalism, Socialism, and Democracy*, and why did it attract so much attention among economists?

2. List the specific reasons Schumpeter gave for why the largest firms and monopolies are supposedly more innovative than other firms.

3. Argue against Schumpeter and demolish his work. Form your argument in four parts: (A) Make the case that his reasons for larger / more monopolistic firms being innovative are just plain wrong. (B) Claim that the evidence is against him, and bring lots of examples (and numbers, if you have them) to bear against him. (C) Express every other good argument you can think of to make your case. Try to layer your arguments, e.g., "even if the reader does not agree with the argument I have just made, then here is another argument which also proves beyond a doubt that Schumpeter is wrong.... And even if the reader does not agree with this argument, there are yet more reasons to know that Schumpeter is wrong." (D) Explain why, therefore, the world of small firms competing with each other á la Adam Smith is the best way for industries to be.

Make sure you construct your argument with an additional paragraph at the beginning that captures the reader's interest and introduces the point. And make sure your argument ends in a conclusive statement that ties together all of your arguments.

4. Argue against your essay of question 3 and demolish your own work. Go about this in three parts: (A) Briefly review the evidence and arguments that might work in your favor to demolish your former essay. (B) Lay out, on paper or in your mind in a way you won't lose track, the broad outlines of your argument to demolish your former case. (C) Grab your pen and dash out all those arguments into a coherent essay that demolishes your former case (as before, make sure to begin and end your essay appropriately).

It might help to pretend you are in a class exam from years past, and you have a half-hour to complete this task after which your paper must be handed in and graded by a merciless English teacher.

Further Readings

Cohen, Wesley and Steven Klepper. "A Reprise of Size and R&D." *Economic Journal* 106, 1996, pp. 925-951. **O J E**. Argues for a re-interpretation of the evidence on firm size and R&D. Explains how observed empirical patterns, of roughly constant R&D spending per employee for firms of varying sizes and of lower returns to R&D for larger firms, in fact may result from larger firms exploiting R&D possibilities more fully and hence accomplishing more overall innovation than a group of smaller firms that add up to the same size as a large firm would accomplish.

Chandler, Alfred D. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge: Belknap (Harvard University Press), 1977. **B** 338.75 CHA. A monumental document that provided for the first time an integrated history of American industry from the 1700s into the 1900s.

Chandler, Alfred D., Jr. *Scale and Scope*. Cambridge, MA: Harvard University Press, 1990. **B R** 338.644 CHA. Another monumental document, analyzing industrial history in Europe and the United States during the 20th century.

Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, and Sidney G. Winter. "Appropriating the Returns from Industrial Research and Development" (including commentary by Richard Gilbert). *Brookings Papers on Economic Activity* 3, 1987, pp. 783-831. **U** LSE library journals HC101. This paper investigates to what extent firms can "appropriate," or receive, the economic value of their inventions, through patents and other means.

6. Evolution of New Industries
(Week 4)

This chapter introduces the industry evolutionary processes discussed in the next four chapters. After completing this part of the course, you should:

1. Understand that commonly-used industry data at the 2-digit and 4-digit SIC levels are too aggregated to see many important competitive patterns.
2. Have an initial knowledge of some common industry evolution processes, and how they relate to patterns of entry, exit, and the presence or lack of early-mover advantages.

Types of Competitive Evolution

This course focuses on competitive processes that operate within industries at the product level, or simply within "products." Industries can be defined more or less narrowly, and often are categorized using Standard Industrial Classification (SIC) codes. SIC codes were developed by national statistical agencies to organize the data they collect. The codes also are often used to organize directories of company information. At the broadest level, SIC codes define different industries using a 1-digit number, classifying all companies in an economy into one of up to 9 different industries using the numbers 1-9. Extra numerical digits can be added thereafter to classify industries in increasing detail. National statistical data tend to be available to researchers at 1-, 2-, or 4-digit levels.[15] Unfortunately, the 4-digit level tends to be quite aggregated in terms of individual products. For example, 4-digit industries using US SIC codes include all types of motor vehicles classed together, or all types of prepackaged software classed together. Competitive dynamics of the sort discussed in this course take place at a much narrower level of industry, such as automobiles, motorcycles, or trucks; word processors, computer games, or drawing software. Looking at data using 4-digit SIC level industries can be misleading! Aggregating individual product markets can cover up patterns such as "shakeouts" and "turnover in corporate leadership," discussed in the next two sections of the course, thus giving the false impression that competition is relatively constant and mundane. Competition, however, is more rich and complex when analyzed at the more relevant level of individual products.[16]

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[15] At more detailed levels, the data must be kept secret for confidentiality reasons. Selected researchers can use the data at national statistical offices, either by being employed there or by special agreements subject to legal restrictions, and using these data it has been possible to carry out some of the more important studies in macroeconomics, industry economics, and labor economics.

[16] Definitions of product markets are used differently depending on researchers' purposes. Microeconomists generally define product markets to pertain to goods, regions, and buyers for whom the price of an identical good is identical for all the buyers. Antitrust authorities generally consider markets in terms of the ability of oligopolies to influence prices. Business strategists consider markets in terms of relevant strategic concerns, and market definition may depend on the business or competitive issues analyzed. Geroski (1998) contrasts these three viewpoints in a recent article. In this course, the relevant groups of products, technologies, regions, and buyers depends on the topic analyzed. Shakeouts and turnover of corporate leadership occur within products that serve (fairly) identical needs, and they may be analyzed at national or international levels with somewhat different conclusions. Market niches, in contrast, restrict competition

What patterns do competitive processes follow at the level of individual products? In general, different product industries follow different patterns. Attempts by industry economists to find patterns that transcend all or most industries have met with only limited success, uncovering a few robust empirical patterns without necessarily explaining why those patterns arise (Schmalensee, 1989). A new approach, however, seems likely to work much better. A few common patterns seem to play out over time across most product industries. By grouping product industries according to the competitive patterns that occur in them, it should be possible to categorize most products into a few types. Each type involves different competitive processes. Each competitive process is a dynamic process, and occurs typically over some number of decades. In different alternative processes, leading companies do or do not benefit from a spiral of advantage that helps secure their competitive position, small firms or startups can or can not take advantage of major technological changes to wrest leading market shares from incumbents, and the market is or is not divided into many parts or "niches" between which there is relatively little competition. Eventually, it is hoped, these alternative processes can be traced to their ultimate causes in terms of characteristics of the product, its technology, and its consumers. Chapters 7 and 8 of the course notes consider patterns involving corporate leadership turnover and shakeouts respectively, chapter 9 elaborates on forces that may yield shakeouts, and chapter 10 considers the effect of market niches on competitive processes. One important force in all product industries is the growth of firms, and chapter 11 discusses firm growth through internal investment and merger.

A First Comparison of Some Industry Evolutionary Patterns

To gain a sense of different competitive dynamics, one useful measure is how the number of companies changes over time. This is by no means the only relevant measure! Also important are the changing sizes of firms and the distribution of market shares (and hence industry concentration), the changing extent to which product differentiation matters and the effect of product differentiation on prices, the changing nature of consumer demand, the changing technological strengths of firms and their innovation, and other issues such as entry, exit, advertising, distribution networks, and technology licensing agreements. Nonetheless, the number of firms is one important measure – for example it is often thought that with more firms there are more diverse approaches to technological improvement and hence more benefits for consumers, and industries with few firms tend to be quite concentrated in terms of market shares. Changes in the number of firms will also be an important theme in upcoming chapters.

Figure 6.1 provides a preview by exhibiting diverse patterns in how the number of firms changes over time, across a range of narrowly-defined product manufacturing industries. The figure also provides a sense of how such patterns compare between countries, since data for both the US and the UK are exhibited. The data shown were collected from a variety of trade registers and have varying levels of error. Some data are quite clean (as for tires in the US), while others have problems such as lack of clarity in product definition (phonograph records). For most of the products, data are available

between producers in different market segments only when there is a substantial degree of separation between the characteristics of products demanded. Theories related to technological core competency of companies, and advantages of experience in related product markets, involve notions of advantages of scope that may span multiple products while remaining within one or more technology types.

from near the inception of the product market, although in a few products such as typewriters the product market began before 1900 and data for the earlier years have not been obtained. For further information on the data, see Simons (2002a).

From inspection of the graphs, you can see that one common pattern is an initial gradual increase in the number of producers followed by a sharp decrease or “shakeout” in the number of producers. Some industries such as tires appear to have experienced very severe shakeouts, while others such as phonograph records appear to have experienced less shakeout or perhaps no shakeout at all in one or the other country. Thus shakeouts are not universal, although most industries (narrowly-defined product industries, that is) that have existed for some number of decades have experienced at least some degree of shakeout.

What might account for these differences in the evolution of firm numbers, and how are they related to the evolution of other industry characteristics that matter such as concentration and technological change? The next chapters will help understand these questions. A common underlying cause of shakeouts will be suggested in chapter 8, and the theory of shakeouts described there will be shown to fit better than other theories with the available evidence. Three reasons why shakeouts might not occur are: (1) technology (or possibly distribution networks and other aspects of industry competition) may have little role to play, (2) technology (or etc.) may differ in industries with shakeouts versus other industries where corporate leadership turnover may occur and may replenish the number of firms (see chapter 7), or (3) product differentiation may mean that firms in an “industry” in fact are not in competition with each other so that competition cannot drive down the number of firms (see chapter 10).

Finally, note that not only do both countries experience a similar range of patterns, but moreover the patterns are similar between matched pairs of industries across the two countries. The timing of the peak number of producers and the severity of decrease in the number of producers is similar, with a large and statistically significant correlation, across countries (Simons, 2002a). This suggests that common underlying technology- or market-traits and dynamic competitive processes have yielded common competitive dynamics across the two countries. The dynamic patterns occurring in industries appear not to be merely a matter of chance, but to be a matter of systematic underlying processes. The next chapters will analyze some of the key processes.

Figure 6.1. Number of Manufacturers versus Time of Various US and UK Products

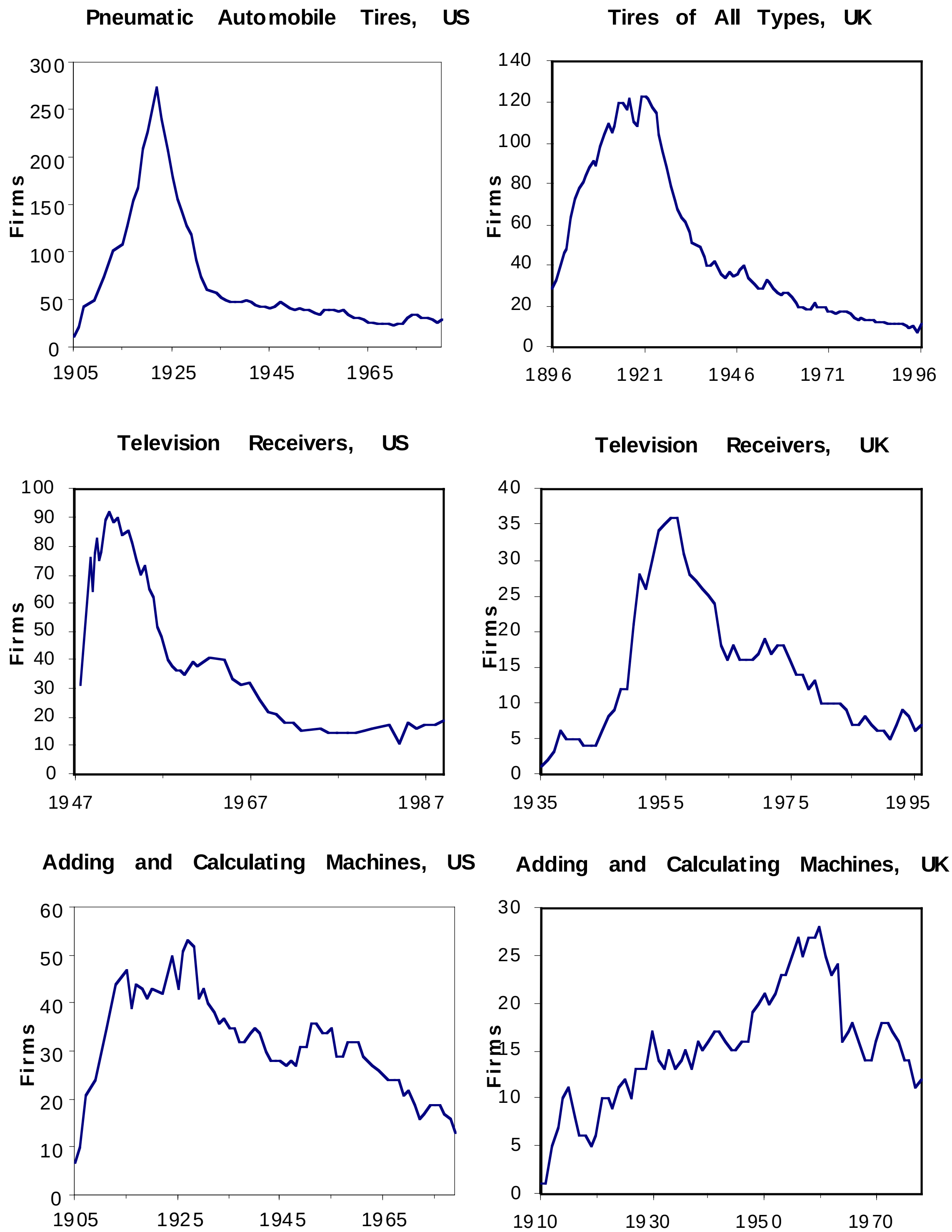


Figure 6.1 continued.

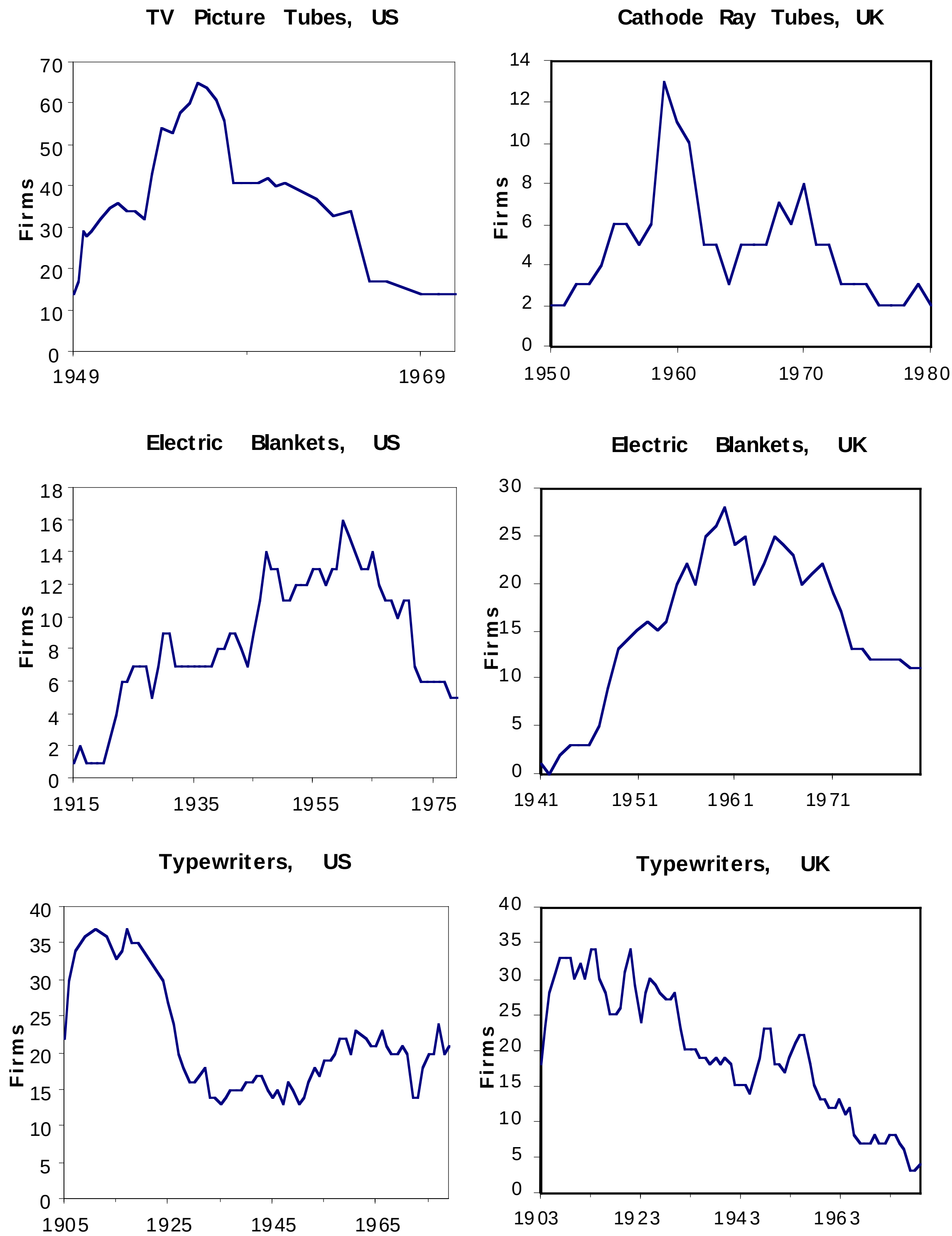
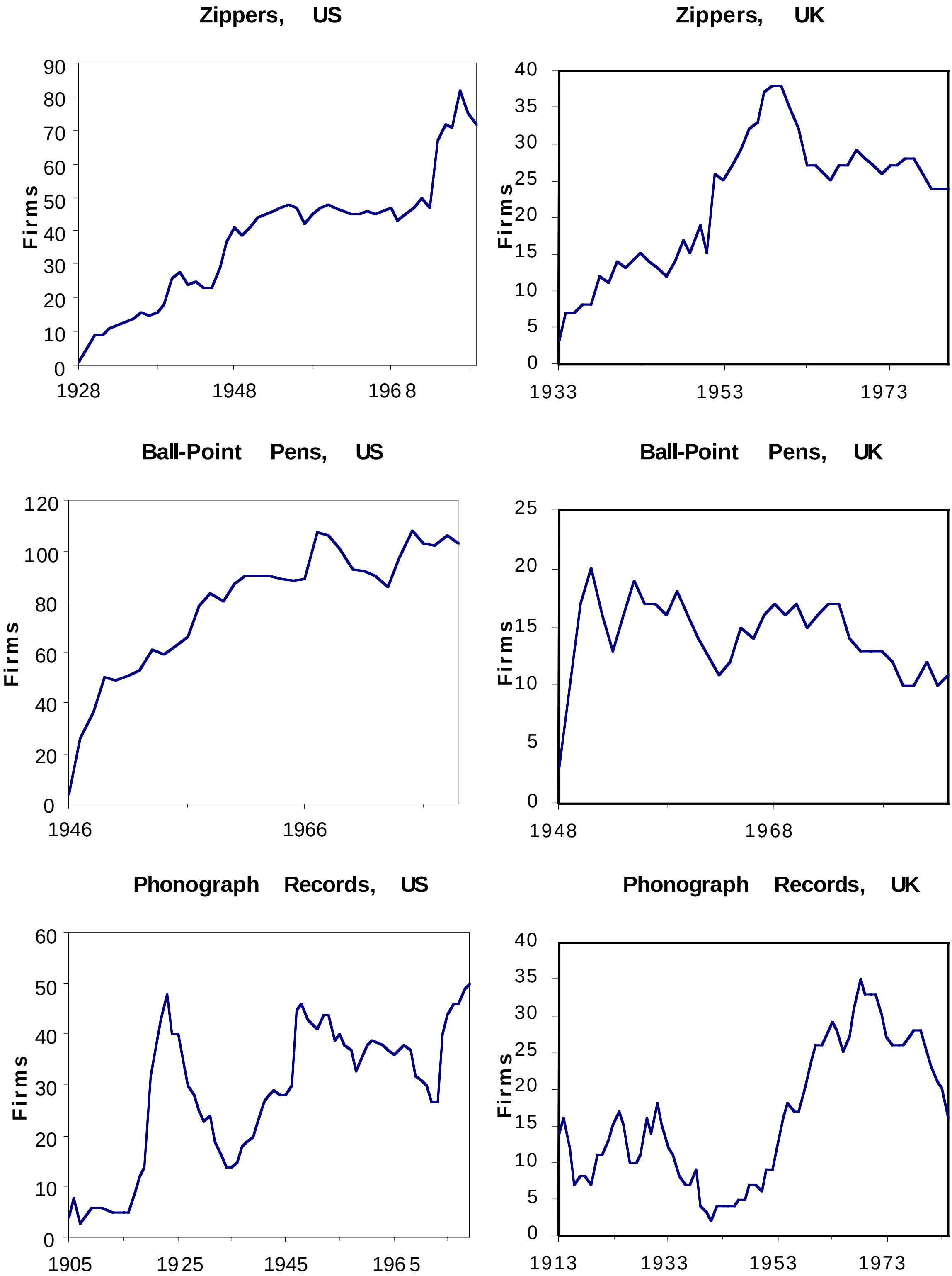


Figure 6.1 continued.



Study Guide

Terms to Know

industry
product
Standard Industrial Classification (SIC) codes
4-digit SIC codes

Key Readings with Questions

Klepper, Steven, and Elizabeth Graddy. "The Evolution of New Industries and the Determinants of Market Structure." *RAND Journal of Economics* 21 (1: Spring), 1990, pp. 27-44. **O J**. Focus on the first half of the paper, to gain an understanding of some important empirical patterns in the dynamics of product industries.

1. What empirical phenomenon do Klepper and Graddy describe? How common is it? How strong is it? Does it seem to be more common, or stronger, in some industries or time periods than in others?

Hannan, Michael T., and John Freeman. *Organizational Ecology*. Cambridge, Mass.: Harvard University Press, 1989. **R** 338.74 HAN. This book argued for analysis of industries (and other "populations of organizations") using models similar to those in ecology that describe populations of animals; it started a large trend in sociology research that is also pertinent to industry economists. Get the main ideas and a sense of the methods used by the authors.

1. What model do Hannan and Freeman use to describe how the number of organizations in a population (e.g., the number of companies in an industry) changes over time? Write down the mathematical equation they use, and explain roughly why they use it. Explain what they mean by legitimacy and competition, and how those concepts relate to the model.

2. The authors do statistical studies of particular populations of organizations to analyze patterns of entry and exit. What populations do they study? What do they conclude?

Geroski, Paul A. *Market Dynamics and Entry*. Oxford: Blackwell, 1991. **R** 338.6 GER. Use chapters 1-3, which give you a sense of the bulk of economic research that has gone on — mostly at an economy-wide level or for very aggregated industry groups rather than for specific products — regarding the entry of new firms.

1. In the UK, about how many businesses start up each year, and about how many shut down? What are the comparable figures in the US? Be sure to distinguish between figures that apply to the country as a whole, and figures that apply only to certain industries (e.g. the 87 three-digit industries discussed by Geroski on page 12).

2. Does more or less entry of new businesses occur when the economy is doing well or badly? I.e., can entry be called pro-cyclical or counter-cyclical? And in specific number terms, how much does the health of the economy seem to matter?

3. How important are most entrants? About what percentages of entrants are of what size? What does Geroski mean by "entry penetration"? What evidence does he have to say (p. 18) that "the 'bark' made by the large number of entrants that appear each year far exceeds their 'bite.'"? Thus, he seems to find that there is a revolving door of entry: small firms revolve into business through the revolving doors, but they rarely make it inside to the lobby where the big firms are making money; instead they just revolve outside (and out of business) again through the revolving door. Do the conclusions seem to change when one looks at data that span many countries?

4. Explain the difference between gross entry and net entry.

5. How long do companies typically survive in the UK, before they go out of business? Do larger companies seem to survive longer or shorter, relative to smaller companies (describe the evidence)?

6. Geroski's evidence pertains almost entirely to very broad industries, such as pharmaceuticals or antibiotics rather than penicillin, or automotive vehicles and parts rather than windshield-wiper manufacturers or final automobile manufacturers. If one looked at narrowly-defined industries such as penicillin, windshield wipers, or automobiles (excluding parts), do you suppose the conclusions would change? Why or why not? If narrowly-defined industries behave as found by Klepper & Graddy and Klepper & Simons, what patterns would one observe when many such industries are aggregated into one broad industry?

Further Readings

Audretsch, David B. *Innovation and Industry Evolution*. Cambridge, Mass.: MIT Press, 1995. **B** 338.06 AUD.

Audretsch, David B. "New-Firm Survival and the Technological Regime." *Review of Economics and Statistics* (August), 1991, pp. 441-450. **E**. Audretsch characterizes different industries as belonging to different "technological regimes," with alternative patterns of new-firm survival.

Baldwin, John R. *The Dynamics of Industrial Competition: A North American Perspective*. Cambridge: Cambridge University Press, 1998. **B** 338.70971 BAL.

Carroll, Glenn R., and Michael T. Hannan, eds. *Organizations in Industry: Strategy, Structure, and Selection*. Oxford: Oxford University Press, 1995. **R** 338.74 ORG. This book investigates some organizational ecologists' notions of the dynamics of industries, through a series of industry case studies.

Davis, Steven J., John C. Haltiwanger, and Scott Schuh. *Job Creation and Destruction*. Cambridge, Mass.: MIT Press, 1996. **B** 331.12 DAV. Entry and exit of firms, or their growth or contraction, coincide with the creation and destruction of jobs. The authors analyze these patterns in the US using a new census dataset, and argue for explanations of some important economic patterns.

Gort, Michael, and Steven Klepper. "Time Paths in the Diffusion of Product Innovations." *The Economic Journal*, 92, Sept. 1982, pp. 630-653. **O E**. This paper is a forebear of Klepper and Graddy's paper cited above; the main differences are that this one has a somewhat smaller dataset to work from and a different (one could say less advanced) theoretical model.

Krugman, Paul. "Technological Change in International Trade." In Stoneman, Paul, ed., *Handbook of the Economics of Innovation and Technological Change*, Oxford: Basil Blackwell, 1995, pp. 342-365. **B** 338.06 HAN. This literature review is unusually well-written and hence readable. Section 3 pertains to the product life cycle theory as it has been applied to international trade, and is why I'm suggesting this reading. But the whole article may be of interest.

Porter, Michael E. *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. New York: Free Press, 1980. **B** 338.6048 POR (also **O** chapter 1). Porter, the guru of strategic management, collects important impacts on competitive dynamics and provides a framework to think about them.

Simons, Kenneth L. "Product Market Characteristics and the Industry Life Cycle." Working paper, Royal Holloway, University of London, 2002. Early version at **W** www2.rhul.ac.uk/~uhss021, or ask me for the full updated version. Shows that underlying technological or other characteristics drive industry outcomes systematically. Part of the paper compares the US industries studied by Klepper and Graddy (and previously Gort and Klepper) with the same industries in the UK, to verify the idea that underlying product- or technology-specific traits of industries are prime determinants of the industries' evolutionary processes.

7. Turnover of Corporate Leadership (Week 5)

One common process in the dynamics of product markets involves turnover of corporate leadership. Existing or "incumbent" market leaders may lose their large market shares when new or small firms surpass them by using better products or other advantages. The most common explanation for corporate leadership turnover involves technological change: the new leaders, but not incumbents, successfully use technological changes to take over the leading market shares. The times of such major technological change may be marked by the entry of new firms and exit of unsuccessful firms.

After completing this section of the course, with its required readings, you should:

1. Understand what is meant by corporate leadership turnover.
2. Be able to describe at least several examples of corporate leadership turnover, and how they relate to relevant technological changes.
3. Explain the three groups of industry patterns that Tushman and Anderson argue correspond to corporate leadership turnover caused by technological changes.
4. Explain at least the following theories of why incumbents lose their market leadership to new firms: Tushman and Anderson theory based on core competencies, Henderson and Clark's theory based on R&D mindsets and organization, and Christensen and Rosenbloom's theory involving customer demand.
5. Discuss corporate strategies that may help incumbents to prevent leadership turnover, as well as strategies that may help entrants to become market leaders.

Examples

Examples of corporate leadership turnover are listed in table 7.1. The examples are drawn from a series of articles and books in which the authors analyze the phenomenon of leadership turnover or broader competitive processes. Some of the examples were developed with limited factual evidence, so further research could help to clarify their validity. Consider the manufacture of cement, for which existing kilns with fires underneath were improved based on two innovations that occurred at about the same time. First, rotating kilns were used in place of existing fixed kilns, and second, coal dust was sprayed mechanically and burned underneath the kilns to provide a more even distribution of heat. Tushman and Anderson (1986) argue that the new technologies were substantially different from the old and led to the replacement of leading producers with new firms. In their original article and a later one (Anderson and Tushman, 1990), they make similar arguments for other new technologies in cement, microcomputers, and (container and flat) glass. Other authors have made similar claims either as part of articles analyzing the process of leadership turnover or in broader studies of industries such as electronic switches or calculators. And Schnaars (1994) documents further examples in a book analyzing how later entrants may take over markets from the leading incumbents. All the examples mentioned here come from the US, since the phenomenon apparently has received little study for other countries, although it would seem that similar patterns should occur in any capitalist economy.

Table 7.1. Examples of Corporate Leadership Turnover in the US

product	new technology	date
cement	rotary kiln & coal dust	c1892
	suspension preheating	1972
minicomputers	solid state & integrated circuitry	1960s
container glass	semiautomation	1893
	Owens machine	1903
flat glass	drawing machines	1917
	continuous forming	1923
	float glass	1963
aligners for semiconductor manufacturing	proximity (vs. contact) aligners	
	scanner (vs. proximity) aligners	
	step & repeat (vs. scanner) aligners	
hard disk drives	8-inch (vs. 14-inch)	
	5.25-inch (vs. 8-inch)	
	3.5-inch (vs. 5.25-inch)	
electronic switches	transistor (vs. vacuum tube)	
calculators	electronic (vs. mechanical) calculators	

Sources: Tushman and Anderson (1986), Anderson and Tushman (1990), Henderson and Clark (1990), Christensen and Rosenbloom (1995), Majumdar (1982), Schnaars (1994).

Detecting and Analyzing Corporate Leadership Turnover

How can one detect and analyze corporate leadership turnover? Tushman and Anderson (1986) suggest a number of methods. A first approach is to identify whether new or old firms constitute the bulk of firms that introduce a new innovation. For example, consider the use of powdered coal for making cement. Of the five innovators that appear to have been the first US firms to use powdered coal in cement manufacture, 4 of the 5 were new innovators, and only 1 of 5 was an incumbent, according to Tushman and Anderson (1986). The extremely high proportion of new firms among the innovators (80%) suggests that incumbents either could not or would not take advantage of the new technology as readily as new firms. Thus, if reliable data can be obtained about which firms were first to use an important new technology, the data provide a test of whether old firms were lax at adopting the technology and hence might lose their positions of leadership or be forced out of business. Ideally the market shares of the incumbent innovators would be examined as well, to determine whether they were leading firms. However, when market share data are unavailable (as is usually the case), examining whether firms are new or old still provides a useful test.

A second approach focuses on the "era of ferment" that the new technologies are likely to introduce. With new product or process technology as well as old technology, diversity of types of the product or of manufacturing techniques is likely to increase. This increased diversity should remain temporarily, until the new technology and the firms that use it outcompete the old. In addition to increased diversity, the improvement to the product or reduction in cost (cost reduction presumably yields at least some price reduction) should increase demand for the product, so unit sales should grow. In particular, sales should grow more quickly than from the usual trends (sales may grow perpetually even without technological advance as the number of consumers grow, consumers gain more money to spend, etc.). And finally, sales growth should become harder to forecast. With the reasons for growth in sales hinging on new product traits and lower costs, forecasters have little information to use to help determine buyers' reactions to these changes, so errors in published forecasts should become greater on average during an era of ferment.

A third approach uses industry-wide data on entry, exit, and market share of firms. After the new technology is introduced, entry should occur by firms taking advantage of the new technology, and thereafter exit should rise as some firms are forced out of the market. (Tushman and Anderson, contrary to my depiction, suggest that the entry/exit ratio should rise, rather than entry rising earlier and exit later. However, their suggestion is casual, and entry preceding exit would seem to fit more appropriately with their story.) In terms of market shares, they should become more dispersed as the new market leaders take over market share from incumbent leaders. So dispersion in market shares should rise temporarily, and at least many of the firms with leading market shares should lose their leading positions to new or formerly small firms.

Why Does Leadership Turnover Occur?

Why should turnover in corporate leadership occur? In particular, given that incumbent firms presumably would like to retain their market leadership, why do they lose their dominant positions to new or small firms? And is this switch of leadership likely to occur for <u>any</u> inattentive or poorly managed firms regardless of the nature of the product and its associated technology, or are some products and technologies more prone to corporate leadership turnover than others? At least four theories have been advanced to explain why incumbent firms would lose their market dominance:

1. New technology makes obsolete firms' previous <u>core competencies</u>. For example, makers of mechanical calculators had considerable expertise at creating precision arithmetical machinery made of cogs, gears, levers, and springs, but little or no skill at making similar machines with electronic components instead of mechanical parts. The switch in technology may matter because (1a) incumbents do not have the necessary skills and resources to use and manage the new technology even if they have the desire to do so, or (1b) incumbents' managers do not realize that the new technology is important even if they have the necessary skills and resources to use it. Theory 1 is suggested by Tushman and Anderson (1986) and Anderson and Tushman (1990).
2. Firms are blinded by prior technological views and organizational filters. Given the way R&D employees are used to thinking about the technology, and given the way a company and its employees are used to gathering and organizing information about new technological ideas, the firm becomes stuck with an old approach. Its personnel, and in a sense the whole organization, are stuck in a mindset that is soon to be outdated, and they cannot grasp the concepts behind the new technology. Theory 2 is suggested by Henderson and Clark (1990) in an analysis of competition in semiconductor manufacturing alignment equipment.
3. Firms are blinded by their customers. Firms are used to providing for the needs of an existing group of customers, and they may not pay attention to new markets that involve new (and often seemingly smaller) groups of customers. Suppose that other firms meet the needs of these customers, and the technology that best meets

the needs of the new customers (perhaps unexpectedly) turns out to yield much more rapid improvements than using the existing technology, so that the new technology used for the new group of customers ends up taking over the market that had been served by the original technology! Then the companies that used the new technology to serve the new customers end up taking over the market of the original incumbent firms. Theory 3 is suggested by Christensen and Rosenbloom (1995) in an analysis of competition in the hard disk drive industry.

4. Differing incentives may have differential effects on incumbents versus new firms, so that new firms are more likely to break into new markets and incumbents are more likely to stick with existing markets. If the new markets turn out to replace the existing markets, perhaps because the new technology turns out to be better, then the new firms may take over the market from incumbents. R&D cost spreading could explain why large incumbents firms would innovate most for existing markets, whereas for new markets incumbents might have no more incentive to innovate than new firms. Theory 4 is suggested speculatively at the end of Klepper and Simons's (1997) analysis of extinctions of industrial firms.

It is unclear how often these different reasons for loss of leadership occur in practice. Even the validity of the individual theories for the industries in which the theories were developed rests on very little factual evidence. Further research is necessary to resolve the reasons.

Does Leadership Turnover Occur?

Christensen and Rosenbloom's (1995) study of the hard disk drive gained a lot of interest in management strategy research, and Christensen went on to write a top-selling business book on the subject. Unfortunately, their analysis of the hard disk drive industry appears to be misleading, perhaps dead wrong. King and Tucci (2002) used the same data source studied by Christensen and Rosenbloom to do another, very thorough study of the hard disk drive industry. They were shocked to find that the evidence gave quite the opposite conclusion from Christensen and Rosenbloom's conclusion! In their paper is a politic statement that their statement holds for one kind of analysis whereas Christensen and Rosenbloom used another; I haven't spoken with either set of authors to disentangle quite what this statement means. Christensen and Rosenbloom seem to have at least done a shoddy analysis of the facts. It seems the hard disk drive industry is not, after all, a compelling example of corporate leadership turnover.[17]

However, reasonably compelling evidence of leadership turnover does seem to exist in other industries. Technology-driven corporate leadership turnover is for real, but it remains to be seen just how common this phenomenon really is. The answer may be, major leadership turnover is less common than many people have argued, notably less than management consultants (including Christensen) who earn money by advising firms about the issue. More careful scientific research is needed to better understand this important matter.

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[17] Similarly, Simons (2002b) shows that in the UK computer consultancy industry, the personal computer and the internet did not cause disruptive competitive effects. He also points out reasons why the personal computer and the internet are frequently likely to have only limited disruptive competitive effects. This contrasts with arguments by Hobijn and Jovanovic (2001) for the PC and, for example, Evans and Wurster (2001) for the internet.

Possible Firm Strategies

Given that turnover in corporate leadership occurs, one might wonder how to prevent it (for incumbent firms that would like to retain their hold on the market) or how to take advantage of it successfully (for firms that would like to take over the market). Schnaars (1994) suggests relevant strategies at the end of his book *Managing Imitation Strategies*. For incumbents who wish to defend their markets against newcomers, he suggests:

1. Sell out. While the company is doing very well and hence is worth a lot of money in terms of its share prices or potential value to investors, sell the company. If competitors then take over the market, you're still rich and the new buyers are poor.
2. License your technology and set up joint ventures. Perhaps you can arrange a mutually agreeable plan with a large firm that has some advantages in related markets and technologies, thus (a) helping to keep that firm from being your competitor, and (b) strengthening your advantage against other competitors. Also, licensing widely at reasonable charges can keep your competitors happy so they don't try to challenge your legal rights to the technology or develop alternative technologies.
3. Fight off copycats. Do this in several ways: 3a. Use legal measures, based on copyrights and patents, to secure your position and harass competitors with lawsuits. 3b. Introduce low-end generic products to preclude competitors breaking into the low-price high-volume market and perhaps advancing more rapidly as a result. (Here, Schnaars is vague, suggesting that an alternative strategy might be to focus on the high-price end of the market.) 3c. Perpetually innovate. Remain a leader in technology, so that competitors do not surpass you. 3d. Create a proprietary standard. Get your technology "locked in," just as technologies like the VHS video system and the Windows computer operating system have become proprietary standards that benefit certain companies.

For new firms, or for large existing firms who have not yet entered a market, Schnaars suggests that profitable opportunities may exist to copy a product and enter the market. The opportunities for imitation are greatest, he suggests, when:

1. Small firms have pioneered the new market. Beat them while they're still weak.
2. Patents are absent or can be circumvented. You might: (2a) Show that previous patents or use of technology preceded the date when firms applied for patents, and thus their patents have no legal validity. (2b) Come up with an alternative design for the same purpose as a patent, thus getting around ("patenting around") the patent. (2c) Use your previous patents defensively and offensively, to protect your position and to challenge the rights of incumbents to produce their goods.
3. Related experience in other products or technology give you an advantage. Use the relevant skills of your engineers and scientists, your distribution channels, your brand image with consumers, and other advantages.
4. New market segments can be created. Open up the new market segment in addition to the existing market, thus vastly expanding your sales over that of competitors. Be creative at identifying relevant market segments.

Firms that choose to imitate can follow a number of strategies that, Schnaars argues, can help them succeed:

1. Anticipate unlikely threats. You are an unlikely threat when you break into someone else's market, and there are probably unforeseen threats facing you too. Brainstorm for possible threats and dangerous situations you might not have considered, and perhaps plan how to preempt or react to these situations.
2. Do concurrent R&D. Remain a leader in technology, so that competitors do not surpass you.
3. Challenge the pioneer(s), your competitors, through whatever legal and regulatory means are possible. For example, you might point out to federal agencies that approve drugs (and perhaps even to the public) that a competitor's drug could have a potential harmful effect.
4. Enter quickly after a substantial market has formed, but do not worry about entering early in terms of time or order of entry. Early entry may be irrelevant if, because of the tiny market and its nascent stage, the form of the product is still evolving and little of the product is being sold. But once the market becomes big, relatively early entry may be important.
5. Don't copy too closely. If your product is too similar to that of competitors, you may expose yourself to lawsuits on the basis of patents or copyrights held by the competitors.
6. Give continuity to consumers, not too much change. You may have a radically new and better version of the product, but if customers don't want to switch to your version because it is too different from what they're used to, then you won't get many customers.

These competitive strategies may not seem very nice, and certainly anti-trust lawsuits (such as those pending now for Microsoft and Intel, plus past suits that have led to the breakup of businesses such as General Motors' bus business) provide some cause for caution and attention to ethics. But the world of business can at times be a cutthroat world, and it is unwise to ignore these sorts of competitive concerns and strategies.

Technological and Non-Technological Causes of Turnover

Although the reasons discussed above for corporate leadership turnover have all involved technological change, it is important to recognize that leadership turnover may occur for non-technological reasons as well. For example, new companies may target new markets that had been overlooked by incumbents. In the UK, Golden Wonder became the major producer of potato crisps after it targeted women, children, and families as the end consumers, instead of targeting men in bars as the previous market leader, Smith's, had done. In the US, Bic took over the market for ball-point pens by introducing inexpensive throw-away pens instead of the high-priced stylish pens that had been produced by incumbents. Both Golden Wonder and Bic succeeded in part because of technical innovation, but redefinition of the market was key to their success.

Study Guide

Terms to Know

turnover of corporate leadership
incumbent
Tushman and Anderson

era of ferment
diversity of product / manufacturing techniques
sales growth forecasting
dispersion in market shares
core competency
prior technological views
organizational filters
blinded by customers
Schnaars
Managing Imitation Strategies
sell out
licensing
copyrights
generic products
locked in
imitation
patenting around

Key Readings with Questions

Tushman, Michael L., and Philip Anderson. "Technological Discontinuities and Organizational Environments." *Administrative Science Quarterly* 31, 1986, pp. 439-465. **O**. This paper has generated much interest about how existing producers of a product might have trouble adapting to technological changes in the product or its manufacturing methods, hence allowing new producers a chance to break into the market.

1. What phenomenon do the authors describe?

2. The authors examine data from several industries. Which industries do they study? And in which of the industries, at what dates specifically, do they observe apparent turnover of corporate leadership? How specifically do they tell when turnover of corporate leadership seems to have occurred?

3. What empirical tests do they use to examine whether their theory makes sense? Why? What are the authors' conclusions from the empirical tests?

4. For what reasons do Tushman and Anderson seem to think that turnover of corporate leadership occurs? Why don't incumbent firms do something to keep the market instead of letting new entrants take over the business? ("Incumbent firms" means firms that are already in the industry.)

Further Readings

Anderson, Philip and Michael L. Tushman. "Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change." *Administrative Science Quarterly* 35, 1990, pp. 604-633. **O**. In part, this paper argues that technology-related turnover in corporate leadership results from new technologies that

require firms to have new "core competencies" — R&D-related skills, personnel, equipment, and organizational and managerial traits.

Christensen, Clayton M., and Richard S. Rosenbloom. "Explaining the Attacker's Advantage: Technological Paradigms, Organizational Dynamics, and the Value Network." *Research Policy* 24 (2), March 1995, pp. 233-257. **O J**. This paper argues that technology-related turnover in corporate leadership may result because companies are blinded by their customers. The desires of customers may not match with the advantages of new technologies, so the companies may not adopt the new technologies. These companies may be surprised that they lose their market because the new technologies have improved and become much better than the old technologies. However, see the article by King and Tucci, which shows that Christensen and Rosenbloom apparently got their results completely wrong.

Foster, Richard N. *Innovation: The Attacker's Advantage*. New York: Summit Books, 1986. **U** LSE Library HD45 F75. A management consultant argues that new firms break into market positions and triumph over incumbents by coming up with innovative new products.

Henderson, Rebecca M. and Kim B. Clark. "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms." *Administrative Science Quarterly* 35, 1990, pp. 9-30. **U** LSE library journals JA1.A3. This paper argues that technology-related turnover in corporate leadership may result because companies are blinded by their mindset about the technology. Scientists, engineers, and managers may be used to how to work with one technology, but a new technology may require a new way of thinking and working that they do not recognize. This problem may occur despite that the company and its employees otherwise have all the right skills and equipment and know-how to pursue the new approach to the industry's technology.

King, Andrew A., and Christopher L. Tucci. "Incumbent Entry into New Market Niches: The Role of Experience and Managerial Choice in the Creation of Dynamic Capabilities." *Management Science* 48 (2), 2002, pp. 171-186. **J**. Christensen and Rosenbloom seem to have gotten the story wrong in the hard disk drive industry: earlier entrants did better than later entrants.

Reinganum, Jennifer F. 1983. "Uncertain Innovation and the Persistence of Monopoly." *American Economic Review* 73(4), 1983, pp. 741-748. **O J**. This classic article develops a simple economic model in which an incumbent and an entrant can try to innovate, reducing their costs when they succeed. For sufficiently drastic innovations, the incumbent has less incentive to innovate than the entrant.

Schnaars, Steven P. *Managing Imitation Strategies: How Later Entrants Seize Markets from Pioneers*. Free Press (Macmillan), 1994. **B** 338.758 SCH. This book describes a large number of cases of specific products to prove that small, late entrants often can seize markets; in many products, the early movers do not necessarily win and later entrants may even have an advantage.

Simons, Kenneth L. "Information Technology and Dynamics of Industry Structure: The UK IT Consulting Industry as a Contemporary Specimen." Working paper, 2002. **W** www2.rhul.ac.uk/~uhss021. Checks for evidence of whether the internet (and earlier the PC) might yet have caused disruptive technology effects among UK IT consultancies.

8. Shakeouts (Week 6)

A second common process in the dynamics of product markets is industry shakeouts. In many products, the number of producers has been shown to increase over time following the introduction of a new type of product, reach a peak, and then drop off. Judging from a sample of US products studied by Gort and Klepper (1982), with revised data analyzed by Klepper and Graddy (1990), most products that have been around for at least several decades have had some degree of shakeout in their number of manufacturers. In some cases, the shakeouts can be quite severe, with a decrease of 80-90% or more in the number of firms. Not surprisingly, industries with severe shakeouts tend to become quite concentrated, which suggests that an understanding of shakeouts can help us understand why and how the market shares in industries sometimes become quite concentrated.[18] Shakeouts happen despite expansion of industry output; hence, they are not (generally) the result of markets drying up.

After completing this section of the course with its required reading, you should know:

1. What an industry shakeout is.
2. How common industry shakeouts are.
3. Typical patterns over time of price and industry-wide production, in industries with shakeouts.
4. Be able to explain the theory of shakeouts discussed in this chapter.
5. Know what the theory predicts about survival curves for cohorts of entrants from different times, and why.
6. Know how actual survival curves look for cohorts of entrants from different times in industries with severe shakeouts.
7. How typical survival curves look for cohorts of entrants from different times in industries with little or no shakeouts.
8. Empirical evidence regarding the theory of shakeouts discussed in this chapter.

Prevalence

Table 8.1 conveys a sense of how strong shakeouts typically may be. In conjunction with Klepper, I refined Gort and Klepper and Klepper and Graddy's sample. Errors in the original data have been corrected, and the table is limited to products that (a) seem to have particularly valid data and (b) attain at least 40 firms (to reduce random noise) at the peak.

As can be seen from the table, judging from the data sample, it appears that most products for which at least several decades of data are available have experienced at least some amount of shakeout. Twelve of the 28 products in the table had at least a 50% drop in number of manufacturers from the year with the peak number of firms to the year with the lowest number of firms thereafter. Some products, however, do not appear to

[18] This understanding could also lead to improved understanding about the advantages and benefits of concentration and about appropriate market policy.

experience substantial shakeouts. For example, despite having been produced for many decades, ballpoint pens and phonograph records do not appear to have had substantial shakeouts.

Table 8.1. Degree of Shakeout in a Sample of US Manufactured Products

Product	Severity of Shakeout	First Year in Sample	Year of Peak # Firms
DDT	90%	1945	1952
Tires, Pneum. Auto	90%	1905 (1896)	1922
Television Receivers	89%	1948	1949
Saccharin	78%	1905	1918
Windshield Wiper Mechanisms	76%	1911	1925
Electric Shavers	74%	1936	1938
TV Picture Tubes	74%	1949	1956
Adding Machines	70%	1905	1927
Radio Transmitters	70%	1922	1962
Penicillin	67%	1943	1952
Freezers	64%	1944	1954
Paints, with Rubber	53%	1933	1966
Radar	49%	1945	1962
Gyroscopes	43%	1913	1970
Artificial Xmas Tree	26%	1924	1965
Photocopiers	26%	1939	1968
Styrene	26%	1937	1980
Shampoo	17%	1905	1949
Cryogenic Tanks	16%	1960	1977
Piezo Crystals	13%	1935	1963
Zippers	12%	1928	1977
Ballpoint Pens	4%	1946	1975
Microfilm Readers	2%	1939	1978
Heat Pumps	0	1953	1979
Lasers	0	1962	1979
Phonograph Records	0	1905	1979
Recording Tapes	0	1951	1979
Gas Turbines	0	1940	1979

Source: K. Simons's analysis of data collected from industrial trade registers.

Causes

Why do shakeouts occur? One strategy to answer this question is to choose products that had particularly severe shakeouts and then to learn about those industries. This is augmented by other strategies, such as using existing theories about shakeouts to guide an analysis of any patterns the theories predict should or should not occur in industries with shakeouts. For example, one pattern commonly predicted by theories is that the annual probability of exit among surviving firms should rise during a shakeout, as the rise in exit is often expected to be much of the reason for the shakeout.

To analyze the causes of shakeouts, Klepper and I used a sample of four products that had severe shakeouts and for which it was possible to gather large amounts of data over periods covering a substantial time span. All four products are US manufactured products. The figures on the next page plus one show the number of firms, entry, and exit in each product. Examine first the bottom panel of each figure. The number of firms in each product rises to a peak before dropping off substantially. The percentage drop in number of producers was 97%, 90%, 89%, and 67% respectively in automobiles, tires, television sets, and penicillin.[19] The dotted and solid lines in the bottom panel of each figure represent entry and exit respectively (all figures are in terms of number of entrances or exits per year). In each case, entry is high during the early years of an industry, but then falls dramatically, reaching annual amounts near zero.[20] Exit in each product is greater when there are more firms, which is not surprising since more firms are available to be able to exit. More interesting to examine is how the probability of exit changed over time. The top panel of each graph shows the percentage of surviving firms that ceased production of the product during each year. The dotted line shows the actual data. The solid line is a five-year moving average, making it easier to see patterns in the data. Surprisingly, the exit rates shown in the top panel of each graph do not generally rise substantially during the shakeout. Except in tires, the annual probability of exit among randomly-selected surviving firms appears to have remained roughly the same as before. In tires, the exit rate does seem have risen substantially during the time of the shakeout in the industry, which coincides with several types of increased competition including a tire price war through mail-order catalogs and other outlets. The exit rate does seem to fall somewhat during later years in at least the automobile, tire, and TV set industries. Thus, a key conclusion from these graphs is that the shakeouts seemed to have occurred not because the chances of exit rose, but because (a) entry dropped off almost to zero, and (b) exit continued as before. With no new entry to make up for the substantial amounts of exit going on in each industry, the number of firms began to drop off. The drop-off continued in each product for more than two decades (more than four decades in automobiles and tires), so whatever the reasons, they seem to have persisted for long periods of time. Each product never recovered anything near its initial number of manufacturers, and each product ended up with a highly concentrated market structure.

In each of the four products, the market expanded over time in terms of total unit production. Prices fell dramatically from a combination of reduced production cost and increased output (yielding lower-price points on a competitive demand curve). The figures on the next page plus one, drawn from Klepper and Simons (1993), show these patterns in price and output. The changes in output and price could be quite dramatic; penicillin prices even fell to less than one thousandth of the original price.

A Theory of Shakeouts

As a next step in understanding why shakeouts happen, it helps to have a theoretical model in mind. Therefore, I turn now to a theory of industry shakeouts. For simplicity, I focus on a single theory that seems to fit most closely with factual evidence. Other theories are discussed by Klepper and Simons (1993, 1997), along with a discussion of what aspects of each theory match with evidence presented by the authors.

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[19] Moreover, the shakeout in the number of penicillin manufacturers was much more severe among manufacturers of penicillin G, the most standard type of penicillin, rather than newer varieties of the drug that were useful for treating different diseases. See the section on product differentiation and market niches.

[20] Entry in the penicillin industry rose in the 1980s, when new firms entered the market producing some of the more lucrative, newer types of penicillin.

Figure 8.1. Number of Producers, Entry, and Exit in the Four Products

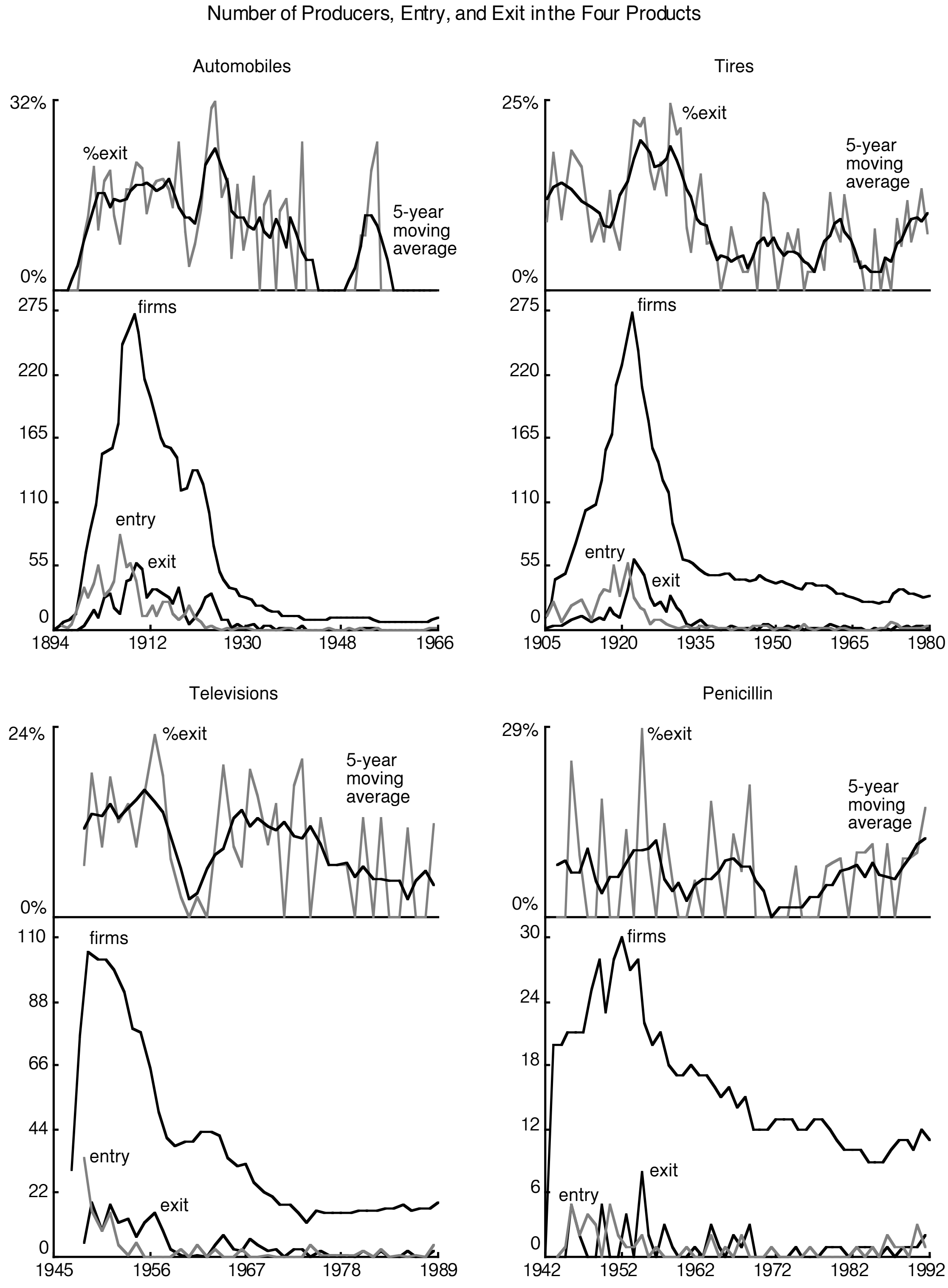
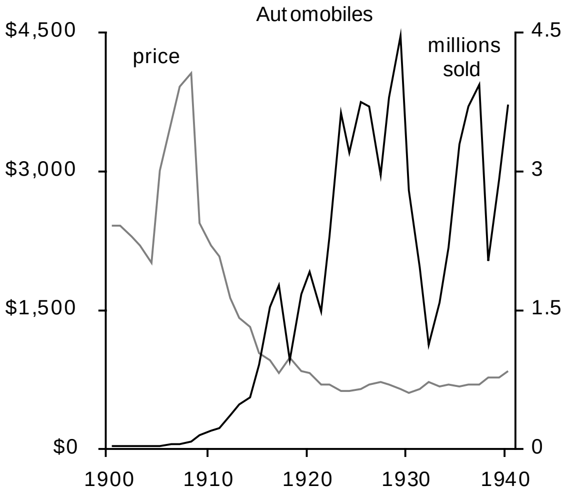
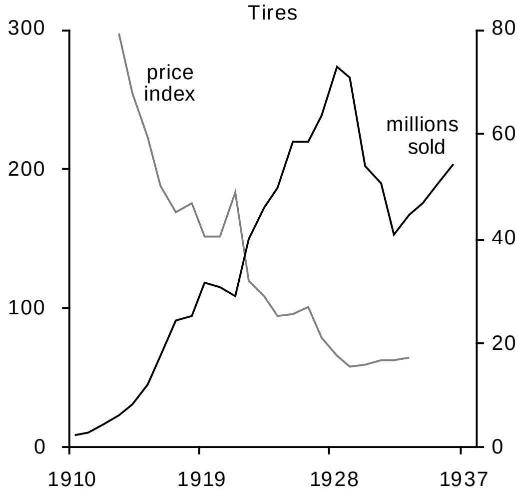


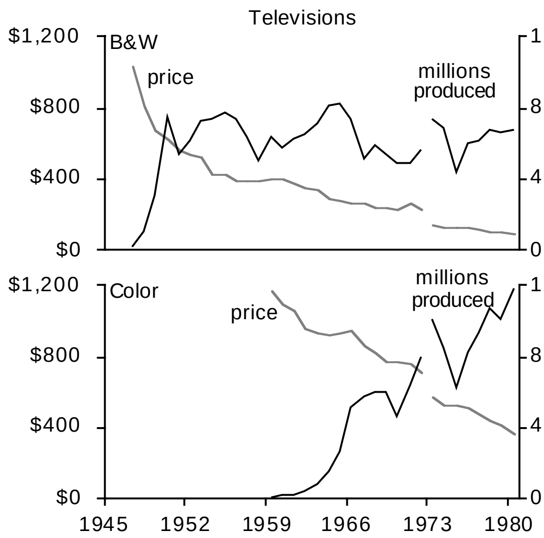
Figure 8.2. Price and Output in the Four Products



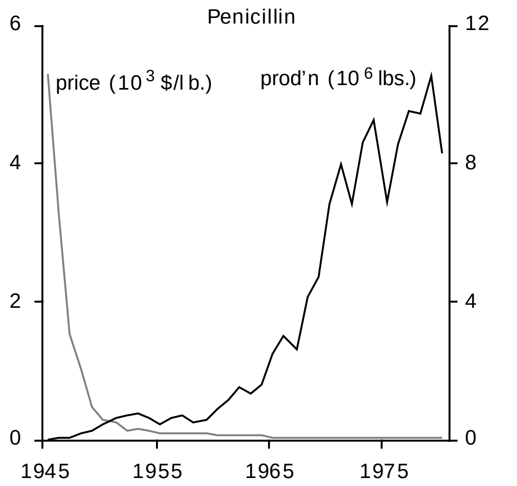
Unit factory sales in millions and real wholesale prices in 1924 dollars (using the CPI as a deflator). Source: Thomas [1965, pp. 321-2].



Unit sales in millions and real wholesale US price indices, set to 100 in 1926. Sources: Gaffey [1940, pp. 51 and 54], Carlsmith [1935, p. 117].

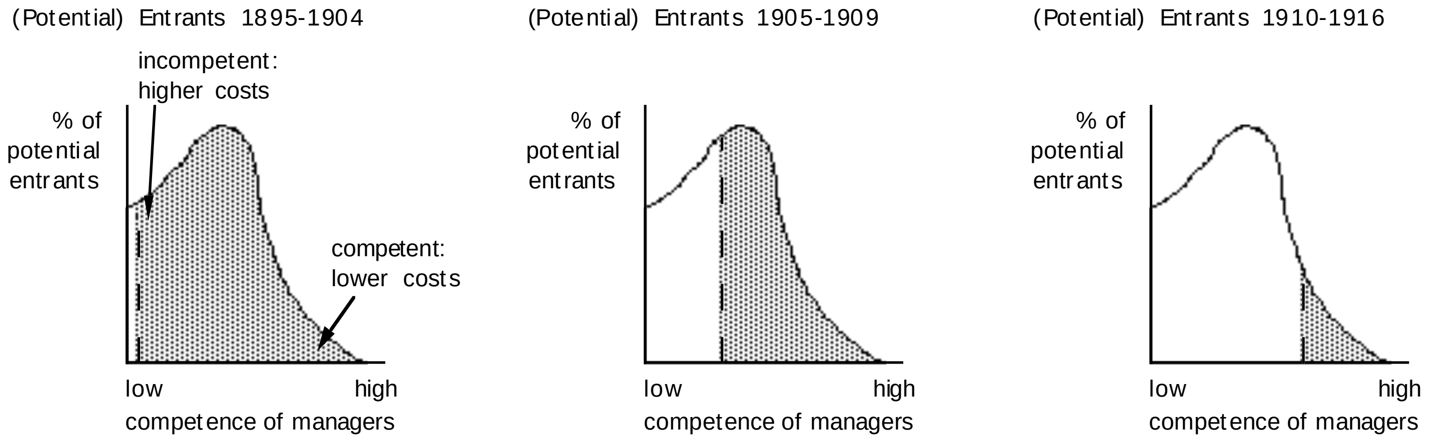


Unit production and real prices in 1980 dollars of black & white and color television sets. Before 1973, US-made sets only; later, imports are included. Prices were calculated as value of production divided by units produced, with the CPI as a deflator. 1959-1962 color data are based on sales rather than production. Source: *Television Factbook* [1991, pp. C-329 and C-332-3].



Production in millions of pounds and estimated average real price per pound in 1950 dollars. Sources: Production from *Synthetic Organic Chemicals*, 1945-1955, Salaices [1989]. Production for 1945-1947 was estimated assuming 0.7 billion Oxford units per pound (Federal Trade Commission [1958, p. 355]). Prices computed using *Synthetic Organic Chemicals*, 1945-1980, and deflated using the CPI.

Figure 8.3. One Theory (that Seems to Fit with Facts) About Shakeouts



(By mid-1920s, entry becomes impossible.)

	How big are firms that entered in 1895-1904?	How big... entered in 1905-1909?	How big... entered in 1910-1916?
circa 1904	small		
circa 1909	medium (but 80% have exited)	small	
circa 1916	large (but 90% have exited)	medium (but 80% have exited)	small

Firms always enter at small sizes.
As time goes on, surviving firms grow.
At any point in time, earlier entrants are larger than later entrants.

Size <u>and</u> competence reduce a firm's costs. Because of survival of the fittest, firms in each group are forced out until only competent early entrants remain.

The model discussed here is based loosely on two papers by Klepper (1996, 1998). I intentionally ignore some features of the earlier model that are not essential to such a model and that do not always fit with the evidence. Also, I intentionally generalize the approach taken by Klepper to encompass a range of size-related advantages of firms and a range of reasons for varying competency of personnel among different firms. For a formal mathematical treatment, consult the papers by Klepper.

Figure 8.3 illustrates the theory. Over time, entrepreneurs and other individuals and firms gain the necessary expertise and interests to be able to enter an industry as producers. This people and firms could choose to enter the industry as producers, and hence they are called “potential entrants.” Consider for example the US automobile industry, where commercial production began at about the year 1895. The top left of the figure describes potential entrants in the years 1895-1904. The managers of the potential entrants have a range of skills and abilities, so that some of them are extremely competent at designing and building cars, and at managing a company more generally, while others have far less competence. This is shown on the graph as a distribution, with managerial competence ranging from low to high along the bottom axis, and with the density function (percentage of firms) appearing on the vertical axis. Even the least-competent potential entrant could choose to enter if desired. The exact shape of the competence distribution is arbitrary, but the results discussed here hold regardless of the shape.

Potential entrants choose to enter if they expect they can make a profit in the industry. They know the price at the current point in time, and they also know (at least roughly) the level of manufacturing cost and product quality they expect (on average) to be able to achieve by doing a given amount of research. Thus, they know their expected profit from entering production. (In practice they probably do not know exactly, but at least they can guess roughly how they are likely to fare. Surveys of actual entrepreneurs seem to indicate they are generally overconfident, but taking this into account in the model would not alter the general conclusions.) Since manufacturing cost and product quality depend on managers’ competence, more competent entrants have a greater expected profit than less-competent entrants. As a result, extremely incompetent potential entrants choose not to enter, while competent potential entrants do enter. This is shown in the graph by a dashed vertical line. Potential entrants to the left of the line are not competent enough to enter profitably, and therefore choose not to enter, while potential entrants to the right of the line are competent enough and do enter. The entrants all make a profit initially, with the most competent entrants making the greatest profit.

Over time, more firms enter the industry, and incumbent firms expand. As a result, the total industry output rises, causing the price (per unit of quality) to fall. To show that shakeouts and related patterns can happen even with a constant demand curve, the demand curve is assumed to be constant. Similarly, the distribution of new potential entrants at each point in time is assumed to remain the same over time. The falling price makes it harder and harder for new entrants to make a profit in the industry. Examine the next two graphs at the top of the page. They indicate that the same distribution of competence applies to potential entrants in the periods 1905-1909 and 1910-1916 (however the number of potential entrants is not shown on the graph and may differ over time). In these later periods, potential entrants must be increasingly competent in order to enter profitably, and hence the dashed line is farther to the right in the 1905-1909 graph and even farther in the 1910-1916 graph. Eventually, the price falls sufficiently that even the most competent potential entrants cannot profitably enter, and entry ceases entirely. In this example, the comment to the right indicates that entry ceases entirely by the mid-1920s.

At their times of entry, all firms start out small. Over time, they choose to expand production. The rate of expansion is limited because it costs money to expand, and the expansion costs are assumed to be convex, that is, the expansion costs grow more and more rapidly as the rate of expansion increases. Firms choose amounts of expansion necessary to maximize their profits. The earliest entrants start out small circa 1904, but by circa 1909 the surviving early entrants have grown to a medium size, and by circa 1916 the survivors have grown to a large size. In contrast, entrants in the second group (1905-1909) are small just after they entered, circa 1909, and are medium-sized circa 1916. The third group of entrants, in 1910-1916, are still small circa 1916. Therefore, by 1916, there is a range of different sizes among surviving firms. The earliest entrants are large, the middle group of entrants is medium-sized, and the last group of firms (which just entered) is small.

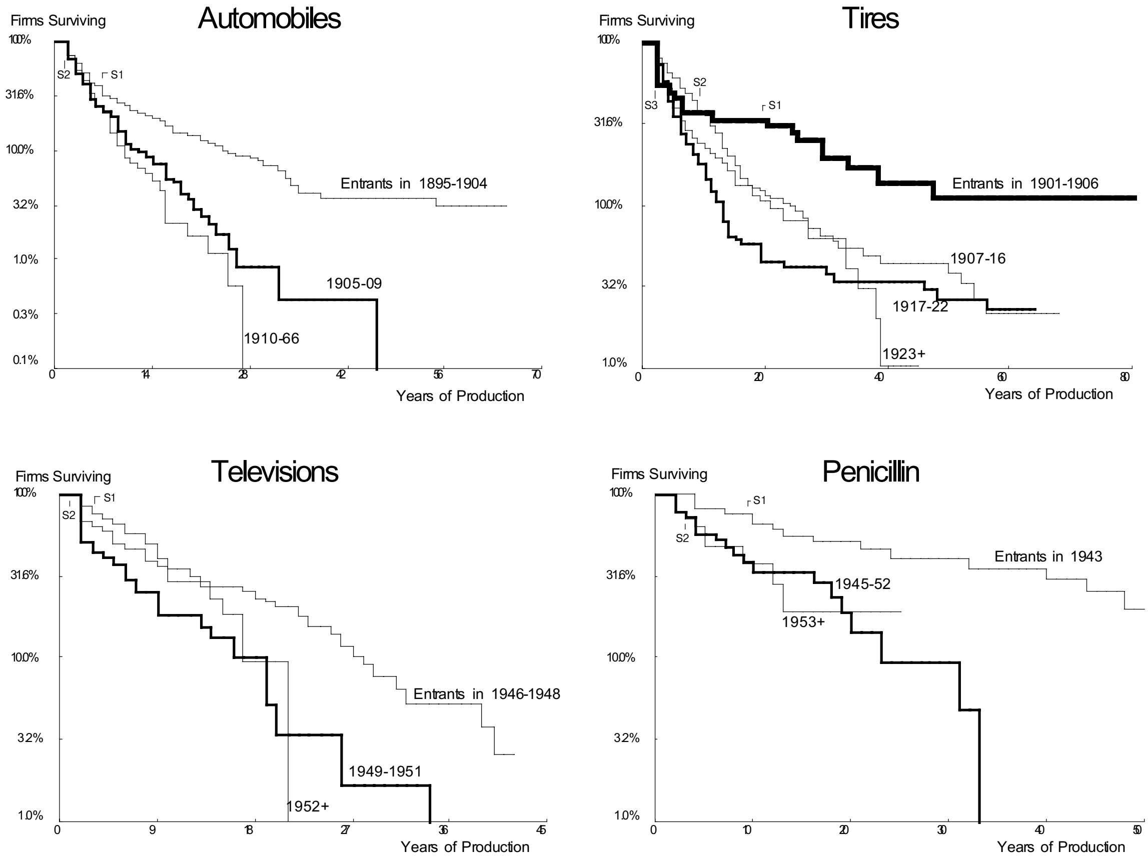
In addition to competence, size also gives firms an advantage. The advantage may exist for many reasons, one of which is R&D cost-spreading (discussed earlier in the course). Therefore, firms that are both large <u>and</u> highly competent are able to achieve lower costs and better product quality than other firms. As expansion and entry continue to drive up total industry output, and hence drive down the price (per unit of quality), competition becomes increasingly fierce. Unless firms are able to reduce costs and improve quality sufficiently, they become unable to remain profitable given the decreasing price. Gradually the smallest and least capable firms are forced out of the market. Note that the relatively small size of later entrants gives them a disadvantage. Once prices fall sufficiently, even the most competent later entrants eventually cannot compete, and all of the later entrants are driven to extinction. By a similar process, eventually even the most competent entrants in the middle entry cohort can no longer make a profit. Thus the cohorts are driven to extinction in reverse order of entry. Eventually, only the most competent early entrants are left dominating the market.

Note that, once firms have been in the market for many years, their rates of exit differ dramatically according to time of entry. Among the earliest entrants, some firms manage to survive and dominate the industry. In contrast, later entrants are driven to extinction. Therefore, at old "ages" (years of participation in the industry), the probabilities of exit are especially high for late entrants, but relatively low for early entrants. In contrast, the theory predicts that at young ages the probabilities of exit should not depend so much on time of entry. While late entrants are at a disadvantage because of their smaller sizes relative to earlier entrants, they also have an advantage in that only the more competent potential entrants enter during late entry periods. The disadvantage of size tends to be counteracted by the advantage of competence, helping to equalize the probabilities of exit at young ages. Thus, the <u>heterogeneity</u> (differences) in potential entrants' and firms' capabilities has an important effect on survival rates at young ages. The contrasting effects of entry time on survival at young versus old ages is an important prediction of the theory and distinguishes it clearly from other shakeout theories that yield opposite predictions.

Actual Survival Patterns

The figures on the next page examine actual survival patterns of entrants at different times. The four figures pertain to automobiles, tires, television sets, and penicillin respectively. The vertical axis of each graph indicates the percentage of

Figure 8.4. Survival over Time in the Four Products



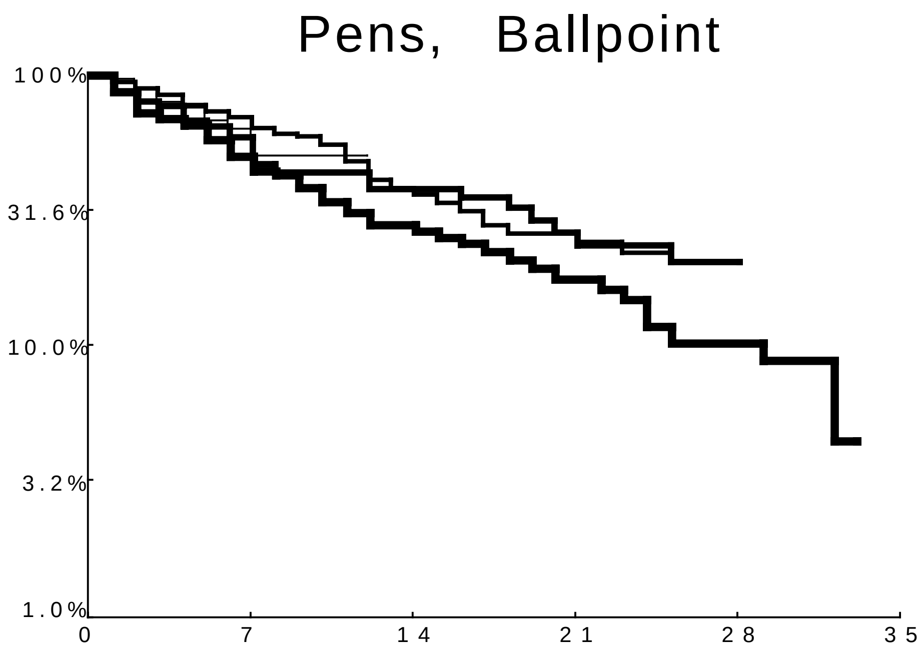
Source: Author's analysis of data from multiple sources; see Simons (1995).

firms surviving. The horizontal axis indicates the age of firms, in terms of the number of years for which production of automobiles had continued. In each graph, firms are divided into three or four cohorts or groups. Earlier entrants are indicated using thicker lines, and later entrants using thinner lines. Dates of entry are indicated beside each line. Because the vertical axis on each graph is logarithmic, going from 100% to 10% to 1% (and to 0.1% in automobiles), a rate of exit can be read from each graph as thenegative of the slope of a line on the graph. Thus, a straight line drawn on the graph would imply a constant exit rate. The denotations S1, S2, and S3 denote the average age of each cohort of entrants at the time each shakeout began, for cohorts that entered before the shakeout began. These denotations facilitate comparison of the probabilities of exit before and after each shakeout began.

Examine the slopes of the graphs – the exit rates – at young ages for each cohort in each product. At young ages, the exit rates are similar for all cohorts, except in penicillin where the earliest entrants have the lowest chances of exit at young ages. At older ages, in all cases the exit rates of the earliest entrants diverges dramatically from the exit rate of later entrants. The later cohorts of entrants in automobiles and televisions are driven to extinction, approximately in reverse order of entry. In tires, a similar pattern is apparent, except that a few later-entering firms manage to survive in the long term; and even among the long-lasting late entrants none of them gained substantial market shares or became very important producers in the industry. In penicillin, the late entrants also seem to have been driven to extinction, except that a few entrants from the late 1960s (which is part of the 1953+ cohort) were still producing at the date from which data are most recently available. Thus, in all the products, the early entrants seem by old ages to have gained a substantial advantage in terms of lower probabilities of exit, and except in penicillin no advantage appeared at young ages. These data fit closely with the theory, and they differ dramatically from patterns apparent in other products, such as ballpoint pens or shampoo, that experienced little or no shakeouts. The figures on the next page show comparable survival curves for US manufacturers of ballpoint pens and shampoo. For these non-shakeout products, the survival curves of early and late entrants are similar at all ages, and in fact if anything the earliest cohort seems to have had a slightly higher rate of exit compared to later entrants in the ballpoint pen industry.

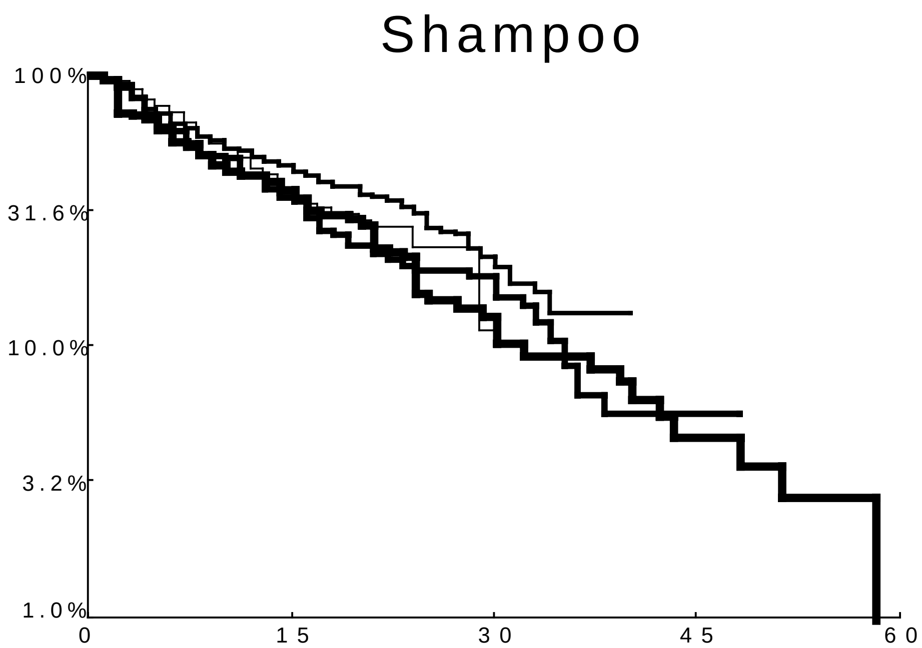
Finally, consider the source of the apparent advantage enjoyed by some of the earliest entrants into each product industry. Many reasons could exist why earlier entrants had an advantage. However, there is reason to think that R&D cost-spreading, or some similar R&D-related advantage to size, had an important role. All four products had enormous rates of technological advance, increasing product quality and lowering costs. And it turns out that the largest firms led in the great majority of improvements to the products and to manufacturing methods, leaving other firms trailing with regard to quality and cost. Consider counts of major innovations by manufacturers of each product, as analyzed by Klepper and Simons (1997) based on sources of innovations data that could be gathered. In automobiles, the top two producers were responsible together for 43% of such product innovations, and 95% of process innovations, after the year 1902. In tires, the top four firms were responsible for 98% of product innovations and, to the extent data are available, all of the process innovations. The top five TV producers were responsible for 84% of product innovations and nearly all substantial process innovations. And the top four penicillin producers were responsible for all of the major product innovations and, to the extent data are available, seem to have led at process innovation. It appears that the leading firms dominated innovation in each product, and that smaller firms were simply unable to sustain research programs of the magnitude necessary to remain leaders in cost and quality. The results of their R&D programs are apparent in their better products and, to the extent data are available, lower manufacturing costs.

Figure 8.5. Survival in Manufacture of Ballpoint Pens



Source: Author's analysis of data from *Thomas' Register of American Manufacturers*; see Simons (1995). The cohorts are 1946-1950 (thickest line), 1951-1954, 1955-1967, and 1968-1979 (thinnest line).

Figure 8.6. Survival in Manufacture of Shampoo



Source: Author's analysis of data from *Thomas' Register of American Manufacturers*; see Simons (1995). The cohorts are 1905-1926 (thickest line), 1927-1939, 1940-1949, and 1950-1979 (thinnest line).

Summary of Evidence Regarding the Theory

Klepper and Simons (1997, 1999) analyzed products with severe shakeouts to probe the causes of shakeouts. They collected evidence for the four US industries discussed earlier: automobiles, tires, televisions, and penicillin. The evidence they collected suggests that the theory described above explains shakeouts quite well. Of course, some aspects of the evolution of these industries are not explained by the theory, as discussed below. Consider first the evidence in support of the theory:

1. Industry output continued to grow dramatically during the shakeouts. So, the shakeouts did not result from markets drying up.
2. Entry dropped to negligible levels at some point, within a few years after the shakeouts began in tires, TVs, and penicillin, and 10-15 years later in automobiles. So, entry declined as this theory and most theories of shakeouts predict.
3. Exit continued over long periods, with the number of firms falling throughout multiple decades in each product. So, the shakeouts were not simply the consequence of some short-term change.
4. Overall rates of exit did not systematically rise at the times of the shakeouts.[21] So, the shakeouts do not seem to have resulted from some process that caused a temporary jump in the chances of exit; rather, a more continual process seems to have been at work.
5. Survival curves for cohorts of entrants from different times show similar rates of exit across cohorts at very young ages (except in penicillin where the US government discouraged less-able firms from entering the earliest cohort). [By age I mean years of production in the relevant market.] So, at young ages the rising ability requirement for entrants seems to counter any disadvantages associated with size or age, confirming theoretical predictions of what would happen if both factors are at work.
6. Survival curves for cohorts of entrants from different times show diverging rates of exit across cohorts at older ages. In all products, some earlier entrants come to dominate the market, while later entrants have much higher exit rates. Indeed, in all products except tires, literally all the later entrants are driven out of the market by the time they reach fairly old ages.
7. One theory has been that a major invention leads to a shakeout, as firms must adapt the new technology to their product or manufacturing process if they are to remain competitive. Successful adopters of the technology gain lower costs and expand, while unsuccessful firms are forced to exit to avoid having their expected profits fall below zero. Klepper and Simons collect data on innovations and their impacts and show that the major innovations did not cluster around the times of the shakeouts, and that when innovations did occur around these times they did not have the competitive ramifications to be able by themselves to have caused the shakeouts. So, individual major innovations do not seem to have triggered the shakeouts.
8. Another theory has been that the emergence of a dominant product design leads to a shakeout, as firms must switch from competing based on innovative product designs to competing by producing the standardized product at the lowest possible cost. The transition yields a rise in exit as firms must adapt to the new

[21] Overall rates of exit rose in tires, and there is evidence of a possible slight rise in penicillin, but in automobiles and televisions the rate of exit remained constant.

technological regime, while entry falls because new product features can no longer serve as a basis for entry. Klepper and Simons used data on product versus product innovation and quality and cost indicators to analyze technological progress over time, and found that the shift from product to process innovation predicted by the theory did not occur at the times of the shakeouts. Moreover, key features of eventual product designs did not emerge until well after each shakeout began. So, dominant designs do not seem to have triggered the shakeouts.

9. The leading firms dominated at innovation, giving them leadership in cost and product quality.[22] So, the evidence fits what would be expected if leading firms' dominance stemmed from R&D.
10. Progressive technological accumulation ("learning") may also have been relevant, but its competitive relevance was limited by the often rapid diffusion of key technologies.
11. Economies of production scale do not seem to have been the source of concentration, as firms tended to employ multiple identical machines.[23]
12. Patent rights did not give firms dominant positions that kept other firms out of the market. In automobiles and televisions, patent pools legally guaranteed the right of firms to share each other's patents. In the few cases where firms tried to use patents to deny access to critical technology, other firms generally invented around the relevant patents, eventually outcompeting the firm that tried to deny access.[24]
13. Few imports reached the US in the years studied for each product, and there was little impact of producers from other nations setting up production in the US, at least over the first decade of each shakeout.[25]
14. For further evidence in support of the theory, see the papers by Klepper and Simons.

The theory does not explain some patterns of evolution in the four products:

15. The rate of exit rose at the time the shakeout began in tires (and maybe penicillin slightly), and this concurrent rise in the rate of exit is not explained by the theory. In tires the rise in the exit rate – though not the falloff in entry – has been attributed by historians mainly to a price war that began when discount catalog retailing chains started selling tires. This finding suggests that the rate of exit may sometimes rise at the time of a shakeout, or at any time, for reasons not described by the theory.
16. The number of firms stabilized or even rose, beginning at some time long after each shakeout began, in all the products. The theory by itself, in contrast, suggests the shakeout would continue indefinitely. One might speculate that the

[22] Their leadership in terms of innovation even substantially exceeded their market shares except for automobiles product innovation.

[23] In automobiles scale might have mattered, but even considering the oft-discussed body presses, bodies were available from third-party suppliers and even major firms such as Ford continued to outsource much of their body production.

[24] The exception was semisynthetic types of penicillin, created after 1958, which treated different kinds of diseases than the earlier "natural" penicillins. Dividing the penicillin market up by types, the natural penicillin market experienced a much more severe shakeout than the penicillin market overall, while newer types of semisynthetic penicillin were tightly controlled by patents and experienced little or no shakeout.

[25] Only in televisions was there much impact of international competition during the years studied – eventually all the US producers either ceased production or sold their television manufacturing to firms based in other countries, mainly Japan – but non-US firms had little impact for the first decade of the shakeout.

advantages to R&D weaken in many products following many decades of improvement to the product and its manufacturing methods. Alternatively, as in penicillin, later entrants might get into new niche markets that are sheltered from competition in the main market.

17. A small number of US-based firms entered in the later years of each product. These firms had tiny market shares and/or participated in niche markets different from the original market.
18. In three of the four products (all except penicillin), there was a gradual shift toward a more standardized product. Thus dominant product designs often develop over extended periods of time.
19. For further industry patterns not explained by the theory, see the papers by Klepper and Simons.

Technological and Non-Technological Causes of Shakeouts

Shakeouts need not only occur in products for which technological advance is so extreme and R&D cost-spreading provides an advantage to firm size. Advantages to size or age can stem from other sources such as advertising cost-spreading, brand reputation, and distribution networks. Sutton argues in his analysis of food products industries that concentration resulted from advertising cost-spreading, and that R&D is unlikely to have played a major role. Indeed, shakeouts are apparent in data on food product industries collected by a fellow student in your course.

Study Guide

Terms to Know

shakeout
Klepper
cohort
heterogeneity
dominant design

Key Readings with Questions

Klepper, Steven and Kenneth L. Simons. "Technological Extinctions of Industrial Firms: An Inquiry into their Nature and Causes." *Industrial and Corporate Change* 6, 1997, pp. 379-460. **O J**. Investigates four products with extremely severe shakeouts in their numbers of producers, as a means to understand the reasons for shakeouts and how technological change can create highly-concentrated industries.

1. What products do Klepper and Simons examine and why? In what eras were these products produced? Do shakeouts seem to occur because of contracting demand?

2. An early-mover advantage seems to exist in the products with severe shakeouts researched by Klepper and Simons. What does this mean? How is this advantage seen to exist? What does it mean for late entrants, and is it worthwhile for a firm to enter late in the industry if it knows it almost certainly won't last long?

3. List all the possible reasons you can think of why earlier entrants might have a competitive advantage. Which seem more likely to be important, in your own view? How could you gather evidence, and what kinds of evidence might you gather, to test the relative importance of these different possible sources of advantage?

Further Readings

Phillips, Almarin. *Technology and Market Structure: A Study of the Aircraft Industry*. D.C. Heath, 1971. **U** LSE library HD9711.U5 P55. A classic study of the rich-get-richer phenomenon in industry.

Jovanovic, Boyan, and Glenn M. MacDonald. “The Life Cycle of a Competitive Industry.” *Journal of Political Economy*, 102, 1994, pp. 322-347. **O E**. Captures the idea that new technology may contribute to competition and shakeouts.

Klepper, Steven. “Entry, Exit, Growth, and Innovation over the Product Life Cycle.” *American Economic Review*, 86, 1996, pp. 562-583. **O J E**. A particularly telling model of shakeouts, this seems to come much closer to empirical fact than other authors’ theories have come.

Klepper, Steven and Kenneth L. Simons. “The Making of an Oligopoly: Firm Survival and Technological Change in the Evolution of the U.S. Tire Industry.” *Journal of Political Economy*, 108 (4: August), 2000, pp. 728-760. **J E**. Uses rich data from the US tire industry to probe processes of industry evolution and how they involve technological change.

Klepper, Steven and Kenneth L. Simons. “Dominance by Birthright: Entry of Prior Radio Producers and Competitive Ramifications in the U.S. Television Receiver Industry,” *Strategic Management Journal*, 21 (10-11: October-November), 2000, pp. 997-1016. **J**. Shows how prior experience can matter to competitive success.

Suárez, Fernando F. and James M. Utterback. “Dominant Designs and the Survival of Firms.” *Strategic Management Journal*, 16 (5), June 1995, pp. 415-430. **J**.

Nelson, Richard R. and Sidney G. Winter. 1978. “Forces Generating and Limiting Concentration under Schumpeterian Competition.” *Bell Journal of Economics* 9, pp. 524-548. **J**, or see their classic book which contains the same article: Nelson, Richard R. and Sidney G. Winter. *An Evolutionary Theory of Economic Change*. Harvard University Press (Cambridge, Mass.), 1982. **B** 338.09 NEL.

9. Alternative Reasons for Shakeouts and Industry Concentration (Week 7)

Earlier, this course focused on one source of advantage to large firms – R&D cost spreading – that can help explain why a few early entrants come to dominate in industries with shakeouts. This section of the course describes other reasons why large firms may experience an advantage, leading possibly to shakeout and concentration of market shares. Alternative reasons include economies of scale in production machinery or methods, progressive cost reduction by some firms before other firms reduce their manufacturing costs, lock-in of one firm's technology or network competition that leads customers to choose one firm's technology, advertising cost spreading, and sunk costs of entry.

After completing this section of the course and its required readings, you should be able to explain the following concepts:

1. First-mover advantage and early-mover advantage.
2. Minimum efficient production scale.
3. Alternative shapes of production cost curves.
4. Experience (or learning) curves.
5. Lock-in of technologies.
6. Network economies.
7. Advertising cost spreading.
8. Sunk costs.
9. Sutton's bounds on industry concentration, and why concentration has a higher bound when advertising (or R&D) cost spreading is relevant.

Reasons for Advantages to Large Firms / Early Entrants

Any of these reasons can give successful early entrants some sort of advantage in the market. The most advantage may accrue to the very first firm to enter a market, in which case the firms is said to have a first-mover advantage. Or, because of randomness in the capabilities of firms that enter and in how they fare in the market, the firms with the best competitive advantage may be some of many firms that entered relatively early, in which case the advantaged firms (or all the early entrants put together) are said to have an early-mover advantage. People often use the term "first-mover advantage" when they mean "early-mover advantage," but please don't confuse the two terms yourself.

Economies of scale in production occur when firms' unit production costs fall as output rises because of advantages of larger machinery or larger plants. Typically unit production costs fall and then eventually level off above a so-called minimum efficient scale. The steel industry is a classic example of economies of production scale, and in the mid-1970s had a minimum efficient scale of perhaps 4-12 million tons of steel per year, or 3-8% of 1967 US demand (Scherer and Ross, 1990, pp. 102-103, 115). In practice, economies of production scale have not been found to have much relation to measures of market concentration, suggesting that scale economies in practice generally are not the reason for actual industry concentration (Bain 1956, Scherer et al. 1975).

Theoretical economic models often make assumptions about the shape of marginal production cost curves. For example, one plausible assumption that is sometimes made is that marginal production costs decline up to minimum efficient scale and remain constant thereafter. Another assumption often made is that marginal cost curves are U-shaped or convex, but given available evidence for long-run cost curves this assumption appears to be incorrect; be wary of theoretical arguments that rely on U-shaped or convex long-run firm cost curves. Let C(Q) be the marginal cost of production as a function of the quantity produced. Increasing returns to scale occur when C falls as Q increases, so that $C'(Q) < 0$. This gives firms lower marginal costs, and lower average costs, as output increases. Constant returns to scale occur when C remains constant as Q increases, so that $C'(Q) = 0$. Decreasing returns to scale, which seem almost never to happen for long-run marginal cost curves, occur when C increases as Q increases, so that $C'(Q) > 0$. The rate of change of C'(Q) is C''(Q), so that C' rises with Q if C'' is positive, C' remains constant if C'' is zero, and C' decreases with Q if C'' is negative. If it were the case that $C'(Q) < 0$ and $C''(Q) < 0$, marginal costs would fall as Q increases (since $C' < 0$) and they would fall at a greater and greater rate (since $C'' < 0$, causing C' to be a bigger and bigger negative number as Q increases); this would probably not be realistic. More realistic would be the assumption that $C'(Q) < 0$ and $C''(Q) > 0$, so that marginal costs fall as Q increases (since C' is a negative number) but they fall less and less quickly (since the positive value of C'' adds to the negative number C' bringing it closer to zero, so that the change in marginal cost as output increases could eventually approach zero).

Progressive cost reduction occurs when a firm's manufacturing costs decline over time. Specifically, researchers have often characterized costs as declining as a function of cumulative output to date. Thus, if a firm has produced n-1 units of the product in past, its cost of producing the n^{th} unit might be D(n). The function D(n) traces out a decreasing curve when graphed. Such a cost reduction curve is often called an experience curve or learning curve. They might occur for many different reasons. The term "learning" suggests that workers on the plant floor learn to do their jobs more rapidly and efficiently, but in practice progressive cost reduction usually seems to stem from other sources such as continual engineering improvements to production methods and machinery.

Lock-in of a technology occurs when the technology becomes a standard that all producers use. The standard may exist because customers (or possibly firms) demand it or because industry committees or government require it. Consider for example the layout of keys on a typewriter or on a computer keyboard. Almost certainly you use a keyboard beginning "QWERTY" in the top row of letters. This key layout emerged in the late 1800s, when typewriters used metal bars to press ink onto the page each time the user pressed a key.[26] At first companies used different

[26] Why was the keyboard laid out this way? One myth has been that the metal type bars would easily run into each other and get stuck, jamming the typewriter, if users typed too quickly, and that therefore the QWERTY keyboard arrangement was chosen to keep commonly used letters far apart from each other. This explanation is wrong. For example, "er" and "re" are the most frequently used pairs of letters in English, but they are placed next to each other on the keyboard; similarly the most commonly used letters in English are not particularly far apart on the keyboard. Another theory, that the keoboard was arranged to be able to spell out TYPEWRITER quickly and impress customers, also seems strange because although all the necessary keys are in the first row of letters, it would have been faster to type alternate letters on different hands, in which case every other letter should be on opposite sides of the keyboard. Nor does the key layout correspond to the order of letters used in a printer's tray. Adler (1997, p. 61) concludes, after reviewing these and other theories, "[I]t seems likely that most of the letters were simply arranged at random in the order they were extracted from a box…. [T]here were so

keyboard layouts. But as more and more typists trained to use the QWERTY layout, and as more and more users acquired typewriters using the QWERTY keyboard, it increasingly made sense for companies to buy QWERTY typewriters and for typists to learn to type with the QWERTY keyboard. QWERTY became a *de facto* standard for typewriter keyboards. It is not clear that the QWERTY keyboard is the best arrangement, and indeed more recent typing methods are available, such as the so-called Dvorjak keyboard layout, or finger holes in which users move multiple fingers side-to-side in different directions to indicate different letters. In some cases, more recent standards may be better, but there is a high cost to companies and typists that switch away from the standard that everyone else uses, tending to hamper the switch to new and better methods. Indeed, Paul David and other writers about lock-in have argued that technologies other than the best tend to become locked-in, although apparently no evidence exists to support this claim – in particular David's argument that the Dvorjak keyboard is inherently better than QWERTY was based on misleading evidence; see Liebowitz and Margolis (1990).

Lock-in in some cases gives much of the market value to one company and takes it away from other companies, as happened when the VHS standard for videocassette records won out over the competing Betamax standard. With stores carrying more VHS movies, consumers had an incentive to buy VHS video machines, and with consumers having VHS machines, video stores had an incentive to stock films in VHS format. The locked-in VHS format has lower recording quality than Betamax, but offers longer recording times (the longer recording times were especially important in the early years of videos, as they allowed full recording of a film or sports event on a single tape). A similar lock-in process has led to market dominance by Sony in video game machines that attach to televisions.

Lock-in often involves network economies, in which the "network" of people or companies using a standard gives benefits ("economies") to each person or company in the network. For example, users of the Microsoft Word word processor benefit from the network of other users with whom they can readily exchange documents and who can help each other understand how to use the program.

Advertising cost-spreading can operate much like R&D cost-spreading. Companies choose national advertising budgets, and advertising affects consumers' willingness to buy. If there are decreasing marginal returns to advertising, as was assumed for R&D, companies with larger outputs will choose to spend more on advertising and will achieve lower price-cost margins. You can work out the mathematics identically to the earlier model of R&D cost-spreading, but substituting advertising in place of R&D. The earlier model assumes that growth in firm size is limited. Sutton (1991), in his book *Sunk Costs and Market Structure*, develops a steady-state model in which he assumes that firms can grow to any size they desire, but the number of firms is limited because only a few firms can be large enough to remain profitable given that advertising cost-spreading gives an advantage to the largest firms.[27] In his model, firms pay a sunk cost in order to establish their advertising reputation.

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many more important things to worry about, such as whether the project would even succeed in getting off the ground."

[27] In Sutton's model with advertising cost spreading, you might expect that only one firm could exist, because if one firm is responsible for the entire market output, it will have a lower cost than two firms each with half the market output, so that whichever firm becomes larger can outcompete the other firm. Whether this is predicted to happen depends on the nature of competition between firms. Under Bertrand competition, prices must be driven as low as possible, leaving only one firm which supplies

Sunk costs can take many forms, but all involve investing a substantial sum of money that must be paid before a firm is able to produce a product. In the case of advertising, the sunk cost involves establishing a reputation with consumers. Other sunk costs involve paying for (a) plant and equipment required to achieve a minimum acceptable production scale, (b) R&D, or (c) approval by government regulatory agencies. Because sunk costs come in discrete chunks, it is possible for a limited number of firms to enter an industry and remain profitable. Perhaps two firms could profitably enter an industry, but entry by a third firm would reduce the profits of all firms below zero. If the third firm is profit-maximizing, it will choose not to enter, leaving two firms that each earn positive profits.

How Assumptions Affect Conclusions in Models of Industry Competition

Analysis of competition in industries is complicated by the fact that different conclusions can result depending upon the assumptions put into a model. This is especially true for two of the main themes of past research in industry economics, (a) the nature of competition (in particular to what extent firms can receive the benefits of collusion either intentionally or unintentionally), and (b) product differentiation. The models are generally based on simple static assumptions, rather than focusing on the dynamics of industries, and they are usually developed without much attention to empirical evidence. Basic competitive models include those of monopoly, Cournot competition (firms choose quantities), and Bertrand competition (firms choose prices). Product differentiation models vary according to the "space" over which firms can differentiate, such as a line segment (as for soft drink sellers located along a beach), a circle, a plane, the surface of a sphere, etc. The space can represent different product characteristics, such as the speed of a car, the color of wallpaper, or the sweetness and crunchiness of breakfast cereal. Product differentiation models also vary according to the number of firms allowed to participate and the specific ways in which their competition affects each other. In general, the predictions of models depend on the nature of competition and the characteristics of product differentiation assumed in the models, and the outcomes predicted by the models vary enormously depending on the assumptions.

Bounds on Predicted Industry Concentration

John Sutton's *Sunk Costs and Market Structure* is highly regarded by industry economists for his elegant treatment of how, despite the huge variation in predictions resulting from these different assumptions, some characteristics of industry competition might be predictable. He develops a model (which stems from joint work with Avner Shaked) in which an industry either does or does not have opportunities for advertising cost-spreading. He allows for a great range of possible forms of competition and product differentiation, and shows that market concentration may be more or less depending on the form of competition or differentiation. However, he points out, if advertising cost-spreading matters, then there is a lower bound on how concentrated an industry can be – the industry must be at least as concentrated as a predictable lower bound. This conclusion is illustrated in Figure 9.1. Thus, his model predicts that advertising cost-spreading can lead to concentrated industries, much as Klepper's model of shakeouts predicts eventual market concentration as (in part) a

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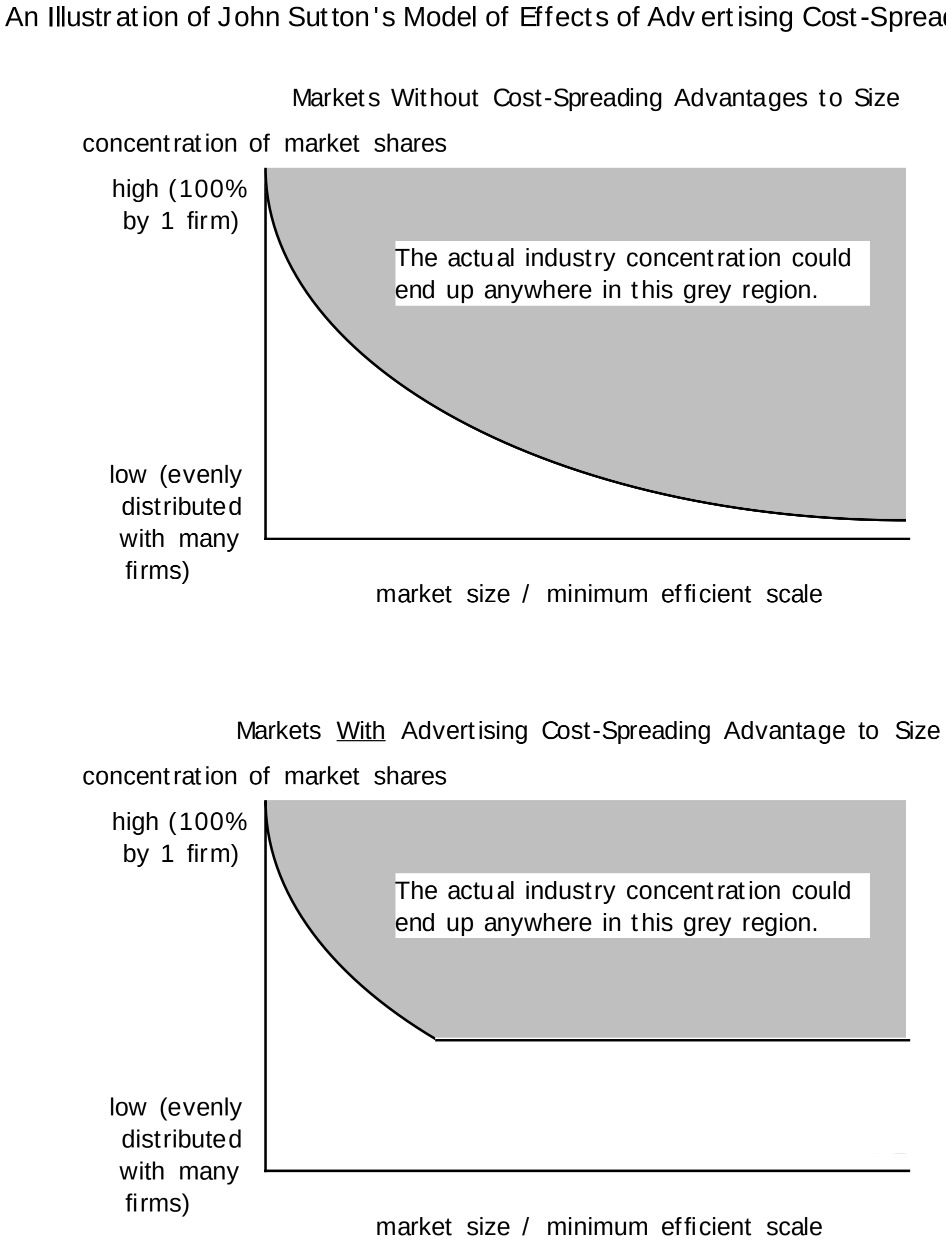
the whole market at a price equal to average manufacturing cost, and which therefore does not make any profit. But under other types of competition, such as Cournot competition, multiple firms may share the market, with each firm being less efficient than would be possible were it to expand.

result of R&D cost-spreading. Sutton's model does not describe the dynamics of change, however; it only predicts whether an industry must end up concentrated in the long run. Thus it differs from Klepper's model, which is intended primarily to explain the dynamics of competition and which explains the eventual concentration as a result of an ongoing process.

Figure 9.1. Illustration of Sutton's Model of Effects of Advertising Cost-Spreading



Study Guide

Terms to Know

economies of scale	experience curve
minimum efficient scale	learning curve
marginal cost of production	lock-in
increasing returns to scale	QWERTY
constant returns to scale	network economies
decreasing returns to scale	advertising cost-spreading
progressive cost reduction	sunk cost
first-mover advantage	Bertrand competition
early-mover advantage	product differentiation
monopoly	Sutton
Cournot competition	*Sunk Costs and Market Structure*

Key Readings with Questions

Scherer, F.M. and David Ross. *Industrial Market Structure and Economic Performance*, 3rd ed. Boston: Houghton-Mifflin, 1990. **R** 338.758 SCH. Use the section of chapter 4 pertaining to economies of scale and scope (pages 97-141 in the 3rd edition). The evidence suggests that firms and their manufacturing plants face long-run cost curves that involve minimum scales necessary to be efficient. In some industries, plants seem to face diseconomies of scale above some size because of transportation costs and (rarely) other reasons, but the notion of long-run U-shaped cost curves for firms is unproven and is likely pure fiction. Make sure you gain a knowledge of commonly-discussed reasons for advantages or disadvantages to plant size and firm size.

1. Draw two graphs, one showing economies of scale and economies of scope, the other showing economies of scale and *dis*economies of scope. Provide examples of situations in which each graph could be correct.

2. Think of at least a dozen distinct reasons why companies' cost, or labor requirements per unit of output, might go down over time on a so-called "learning curve." If you were working as a consultant for Boeing's Wichita plant when it built its B-29 bombers, how could you measure the relative importance of these different reasons?

3. In what industries are transportation costs likely to be especially important? Do the existence of transportation costs cause economies of scale, or diseconomies of scale? Draw example total and marginal cost curves for companies in an industry with high transportation costs, and for companies in an industry with low transportation costs. Write down a mathematical equation that could fit the general shape of each cost curve.

4. What approaches might one use to measure economies of *production* scale? Explain using an example how you would go about each approach.

5. How important, in practice, do minimum efficient scales of production seem to be? Provide an answer in specific, concrete terms, using some actual numbers.

5. On one sheet of paper, write at the top "Advantages of Large Size," and on another, write at the top "Disadvantages of Large Size." Brainstorm and write down every reason you can think of (however wild it might be) for large companies to have competitive advantages or disadvantages.

6. If a company in the industry you're studying hired you as a consultant, how might you test to see, in that industry, whether the advantages to being large outweigh the disadvantages, or vice versa? How would you resolve the company's question to find out how important are the various possible sources of advantage or disadvantage (as laid out in your answer to question 5), and what kinds of information would you collect in order to answer the question?

7. How might advertising yield economies of scale and scope? What evidence does the book use, and how, to get at whether or not these reasons are important?

— To answer questions 8 and 9, you will need to read the remainder of chapter 4 in the *Industrial Market Structure and Economic Performance*. —

8. "Gibrat's law" proposes that in a given year, the percentage growth or contraction of a firm's size is a randomly chosen number that has nothing to do with how big the company is. If Gibrat's law is right, even with no economies of scale, industries will still become very concentrated over time. Why? If this is true, does it have to be the case that chance alone determines corporate success, and there is nothing companies can do to make themselves more successful? Why or why not?

9. Have government policies affected economies of scale or scope? Explain.

Sutton, John. *Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration.* Cambridge, Mass.: MIT Press, 1991. **B R** 338.6 SUT. This book escapes the problem that theories of market competition and product differentiation generate almost any result depending on the particular assumptions; it does so by predicting *bounds* on the results instead of specific results. It argues that advertising cost spreading and other sources of sunk costs or increasing returns — such as the R&D cost spreading considered earlier in this course — can cause a market to become tightly concentrated among a few producers, whereas markets without these influences need not become tightly concentrated. I suggest you not worry about understanding the mathematical model – which some people argue has drawbacks anyway – but get the notion of bounds and look at how Sutton uses empirical evidence to support his case.

1. What are the differences between Cournot and Bertrand competition? (Recall what you did from Tirole's book.) How do you think real firms compete?

2. In what way does Sutton analyze a continuum ranging from a monopoly to Cournot competition to Bertrand competition?

3. What does Sutton mean when he says that, in models in which “firms are permitted to produce more than one product..., multiple equilibria are endemic” (p. 40)?

4. Explain the meaning of both graphs in Sutton’s Figure 2.4 (p. 42).

5. What is a sunk cost (p. 46)?

6. Sutton considers a wide range of ways that industries might be (p. 47). Describe this range.

– You may wish to skip Sutton’s sections 3.2 through 3.5, if you are short on time. –

7. From Sutton’s section 3.6 (pp. 77-81), explain Figure 3.9.

8. Why could advertising cost-spreading lead to the pattern shown by the solid line in Figure 3.9? Specifically, why wouldn’t there be lots of companies (and hence low concentration) — even though total industry sales may be gigantic — in advertising-intensive industries?

9. What industries does Sutton analyze, in what countries (pp. 84-90)? Why?

10. How does Sutton measure market size and concentration (pp. 90-91)?

11. How does Sutton measure setup costs (pp. 93-99)?

12. Explain the point of Figure 5.4 (p. 118), which shows two graphs, for industries that aren’t and are advertising-intensive.

David, Paul. “Clio and the Economics of QWERTY.” *American Economic Association Papers and Proceedings* 75 (2), May 1985, pp. 332-337. **O J E**. Illustrates how a particular technology, not necessarily the most efficient technology, can become locked in place as a result of historical accident.

1. Recount from your memory the history of the QWERTY keyboard. Why is it argued not to be the ideal keyboard design? (The article by Liebowitz and Margolis below presents compelling evidence that Paul David is wrong about its inefficiency.) How did it come to be the standard? Why don’t people just switch to a better design?

2. What does Paul David mean by the terms “path-dependent,” “historical accidents,” and “lock-in”?

Further Readings

Achi, Zafer, Andrew Doman, Olivier Sibony, Jayant Sinha, Stephan Witt. “The Paradox of Fast Growth Tigers.” *McKinsey Quarterly*, (3), 1995, pp. 4-17. **O J**. An easy-reading managerial-audience article on firm growth with increasing returns dynamics.

Arthur, W. Brian. “Competing Technologies, Increasing Returns, and Lock-In by Historical Events.” *Economic Journal* 99 (March), 1989, pp. 116-131. **J E**.

Liebowitz, S. J. and Stephen E. Margolis. "The Fable of the Keys." *Journal of Law and Economics* 33 (1: April), 1990, pp. 1-25. **W** http://www.utdallas.edu/~liebowit/keys1.html. Shows that the QWERTY keyboard seemingly is no worse than Dvorak, to argue that there is little evidence that the technology that gets locked in is of poor quality relative to technologies that don't get locked in.

10. Product Differentiation and Market Niches (Week 8)

In practice when you analyze competition in industries, it is rarely the case that industries for which you obtain information will have a single type of product (of possibly varying quality) produced by all firms.[28] Rather, different products will be available to meet the needs of different groups of consumers. Therefore, it may be important to consider the effects of product differentiation on competition.

After completing this section of the course, you should be able to:

1. Explain the three reasons discussed below for how product differentiation matters for competition and industry analyses.
2. Explain the concept of market niches.
3. Discuss product differentiation in the US penicillin and UK fertilizer industries, including how each industry fits with the above concepts regarding product differentiation.

How Product Differentiation Matters for Competition and Industry Analyses

Product differentiation matters to competition and to industry analyses for at least three reasons:

1. Competition takes place primarily at the level of product industries. Specifically, shakeouts and turnover of corporate leadership should be expected to occur among firms providing products that meet the same (or at least similar) needs for the same (at least partly the same) group of consumers. By aggregating these product industries, you change the patterns you might expect to see. For example, suppose you analyze the motor vehicle industry, combining together the automobile, truck, bus, and motorcycle industries as well as all the industries producing parts for such vehicles. Although shakeouts and early-mover advantages occurred for at least the automobile and bus industries, the data for the whole motor vehicle industry may not necessarily show much of a shakeout nor much early-mover advantage. Also, the aggregated data obscure the times when shakeouts occurred in each product, the differing extent to which there was an early-mover advantage, etc. A similar issue would be arise when analyzing the whole of the electronics industry versus individual sub-markets of the industry.
2. Having a substantially different product from the products of other firms can provide some degree of protection from competition with those other firms. For example, sports car makers may be nearly unaffected by a major firm reducing its price for a low-cost family car, whereas other makers of low-cost family cars would experience greater competition.
3. Advantages to size (or to other characteristics of firms) may span multiple niches or multiple product markets. For example, economies of scope in the production process imply that the costs of producing one product decrease when substantial amounts of another product are produced. Similarly, R&D work may be relevant to multiple products or their manufacturing processes, and brand reputation may benefit a firm for all the different products it sells.

[28] Variations of quality of a product are known as vertical product differentiation, whereas variations to match different consumers' tastes are known as horizontal product differentiation.

Market Niches Defined

Market niches are natural differences in the market according to major differences in product differentiation that could fit consumer demands. For example, it might be said that the market for automobiles has market niches for family-size cars, sports cars, luxury cars, and off-road vehicles. Each sub-market of the automobile industry is somewhat independent of the others in terms of consumer demand and competition.

Examples of Product Differentiation and its Effects

Two examples of product differentiation are Klepper and Simons' (1997) data on US penicillin producers and Shaw's (1982) analysis of the UK fertilizer industry. In penicillin, the so-called "natural" penicillin varieties, especially penicillin G, were commodity products with fierce competition as prices plummeted over time. In contrast, most of the "semisynthetic" penicillin varieties, introduced after new techniques were pioneered circa 1958, were patented and closely held, and prices for semisynthetic penicillins were much higher than for natural penicillins. Table 10.1 lists US penicillin manufacturers from 1948 to 1993 for which the types of penicillin manufactured could be determined. The table shows for each type of penicillin the firms that made that type and their dates of production. Penicillin G and the natural penicillins in general (G, O, and V in the table) experienced a sharp shakeout in their numbers of manufacturers.

With the advent of the semisynthetics, a few of the major natural penicillin producers also began to produce semisynthetic varieties, along with some new firms which entered semisynthetic production. Beecham from the UK (which had been licensing some firms) eventually entered US production also. While patents remained in force, the number of firms in semisynthetic markets remained small. A few more firms entered after patent expiration.[29]

Thus, firms that innovated in the development and patenting of new types of penicillin were able to reap the substantial profits associated with these new market niches. The US penicillin industry is also an example of how a shakeout may impact manufacturers in part of the market, while in other market segments firms are unaffected by competition. Indeed, the different types of penicillin were useful for treating different diseases, so the advent of new types generally did not take away sales from old types – although other antibiotics were competitors – and unit sales continued to grow over time in each major market segment.

In UK fertilizers as analyzed by Shaw (1982), firms typically produced multiple kinds of fertilizers. It makes sense to define the product space in simplified form as having two dimensions, (1) nitrogen and (2) potassium and phosphorous. Firms had multiple products at different points in the product characteristics space, which is the space over which products were differentiated. (A product characteristics space might take on different forms in different cases. For soft drink sellers locating at different places along a beach, the space would be a line segment representing locations on the beach. In this case the product characteristics space is a

[29] Some of the semisynthetic producers eventually began some natural penicillin production. The two types of production were closely related, so this pattern suggests that, decades after the introduction of penicillin, the semisynthetic producers were able to achieve competitive costs in natural penicillin production. (Natural production is, roughly, a step in the production process for semisynthetic penicillin.)

Table 10.1. Penicillin Types and Their Manufacturers, 1948-1993

Penicillin G†	[Innovation dated as 1942 by Achilladelis]
	Abbott 1948-1964
	Baker 1948-1952
	Bristol 1948-1959, 1961, 1974, 1977, 1981-1983
	Commercial Solvents 1948-1959
	Cutter 1948-1954
	Heyden 1948-1953
	Hoffman LaRoche 1948-1949
	Lederle 1948-1949, 1954-1955
	Lilly 1948-1969, 1972, 1976-1981
	Merck 1948-1986
	Pfizer 1948-1992
	Schenley 1948-1953
	Squibb 1948-1982
	X 1948-1953, Upjohn 1954-1957
	Wyeth 1948-1993
	U.S. Rubber 1949
	Monsanto 1954
	Penick, S.B. 1954-1955
Penicillin O	X 1951-1953, Upjohn 1954-1964, 1966
	Pfizer 1968-1975
Penicillin V†	*Lilly 1955-1990
	Abbott 1956-1974
	Wyeth 1956-1976, 1983-1985
	Bristol 1958, 1970-1985, 1987, 1989-1993
	Squibb 1968-1976
	Pfizer 1976-1988
	[*Also developed by Glaxo (UK).]
Phenethicillin†	*Bristol 1959-1975
	Pfizer 1960-1965, 1967-1971
	Squibb 1960-1961, 1963-1964
	Wyeth 1962-1966
	[*Also developed by Beecham (UK).]
Ampicillin†	Bristol 1963-1993
	Wyeth 1966-1993
	*Beecham 1968-1990
	Squibb 1968-1976
	Trade Enterprises 1971-1981
	Biocraft 1972-1993
	Kanasco 1986-1992
NEP penicillin	Merck 1963
Methicillin	Bristol 1961-1985
	Beecham 1972-1982
	Wyeth 1991

Table 10.1 (contined)

Oxacillin	Bristol 1961-1985
	Beecham 1969-1992
	Biocraft 1979-1992
Cloxacillin	Bristol 1964-1985
	Beecham 1968-1993
	Biocraft 1980-1988, 1990-1993
	Kanasco 1991-1992
Nafcillin	Wyeth 1964-1990
	Beecham 1975-1976, 1984-1988, 1990-1991
	Bristol 1975-1977, 1979-1985, 1987
Dicloxacillin	Bristol 1966-1979, 1981-1985
	Beecham 1968-1992
	Wyeth 1968, 1970-1975, 1977-1989
	Biocraft 1983-1993
	Kanasco 1990, 1992
Hetacillin	Bristol 1966-1979, 1981-1991
Carbenicillin†	[Innovation dated as 1969 by Achilladelis]
	*Beecham 1970-1985, 1987, 1989††
	*Pfizer 1972-1986, 1988
	Biocraft 1986
Amoxicillin	Beecham 1973-1993
	Biocraft 1976-1993
	Bristol 1977-1993
	Trade Enterprises 1978-1979
	Wyeth 1980-1985
	Kanasco 1986-1992
Ticarcillin	Beecham 1976-1993
Azlocillin†	[*Developed 1978 by Bayer (Germany)]
Cyclacillin	Wyeth 1978-1985
	Bristol 1984-1985
	Biocraft 1986, 1988
Epicillin	Trade Enterprises 1978-1982
	Kanasco 1986
Piperacillin	Bristol 1982-1993
Amdinocillin†	[*Developed 1984 by Roche (Switzerland)]
Sulbactam†	[*Developed 1986 by Pfizer]
Floxacillin	Beecham 1989††

*Innovating firm.
†Major innovation according to Achilladelis (1993).
X Identity of producer kept confidential in *Synthetic Organic Chemicals*.
††Beecham may have continued production of carbenicillin and floxacillin after 1989. After 1987, *Synthetic Organic Chemicals* does not specify all of the semisynthetic penicillins produced solely by Beecham.
Sources: *Synthetic Organic Chemicals*, FTC (1958), and Achilladelis (1993).
Reprinted based on Klepper and Simons (1997).

square in which firms choose percentage concentrations of (1) nitrogen and (2) potassium and phosphorous.

Competitively, firms did not spread out across this two-dimensional space as some theories would imply – instead they clumped together, with almost identical products sold by multiple firms. Some theories would also suggest that leapfrogging behavior might occur over time, jumping over each other's positions to move to more advantageous places (given their competitors' current locations) in product characteristics space. Over time, there was no leapfrogging in product characteristics space. More concentrated fertilizers did become available over time, and when one firm would introduce a more concentrated variety, this was quickly (within a few years) matched by competitors.

Thus, in the UK fertilizer industry, while products were differentiated, this does not seem to have had much competitive impact. Unlike in penicillin, new forms of fertilizers were not radically new products with protected market niches. It is in industries where different firms participate in different niches that product differentiation can make a big competitive difference. And it is where the creation of new, protected product niches depends on the development of new technologies that technology has the most major impact through product differentiation. In other industries such as automobiles, firms' products are affected by continual innovation, causing an increase in quality but not generating a new market niche, at least not a niche that will be separated for long from that of other firms. Innovation creates new market niches only in some industries, and not all innovation results in new market niches.

Study Guide

Terms to Know

economies of scope
market niche
product characteristics space
leapfrogging

Key Readings with Questions

Shaw, R.W. "Product Proliferation in Characteristics Space: The UK Fertilizer Industry." *The Journal of Industrial Economics* 31 (1/2: September/December), 1982, pp. 69-91. **O**. Examines the differences between the varieties of fertilizer offered for sale by UK manufacturers, and examines how the varieties changed over time in order to test what theories of product differentiation seem to hold up in practice.

1. What is Shaw's paper about?

2. Describe the theories of product differentiation that he comments on.

3. What are Shaw's conclusions with regard to these theories of product differentiation?

Further Reading

Hannan, Michael T., and John Freeman. *Organizational Ecology*. Cambridge, Mass.: Harvard University Press, 1989. **R** 338.74 HAN. Use chapter 5, which discusses a theory of competition for niches of products with fast versus slow market changes.

Tirole, Jean. *The Theory of Industrial Organization*. Cambridge, Mass: MIT Press, 1988. **O** (chapter 7) **B** 338.6 TIR. Examine chapter 7 to see some common theoretical models of product differentiation, as used in industrial economics. Don't try to learn all the details, but do try to learn the main concepts about how these models portray industries working.

11. Firm Growth
(Week 9)

After completing this chapter and its required readings, you should be familiar with the following issues:

1. Limits to firm growth rates in Penrose's theory of firm growth.
2. Gibrat's "Law."
3. The approximate firm size distribution in the US tire manufacturing industry, as it changed over time.
4. How growth rates of US manufacturing plants have varied with plant size and age, and how the figures are affected by the inclusion or exclusion of exiting plants.
5. The skew distribution of sizes of firms and of other phenomena.

The Myth of the U-Shaped Long-Run Firm Cost Curve

Economic models have often used the simple, mathematically convenient assumption of the U-shaped long-run firm cost curve. That is, the marginal cost of an additional unit produced by the firm is assumed to vary with the size of the firm, falling at small sizes, but rising again at large sizes.[30] Figure 11.1 illustrates this assumption as it is often shown in introductory microeconomics texts. The bottom axis in the figure is the quantity produced, and the vertical axis is the unit cost of production. Two types of unit costs are shown in the figure, the marginal cost of producing an additional unit, and the average cost of production. In the example given by the figure, a firm that produces 48 units has the lowest possible *marginal* cost, of $4 per each additional unit produced. The U-shape of the marginal cost curve implies a U-shaped average cost curve as well. In the example, a firm that produces 73 units has the lowest possible average cost of $95 per unit.

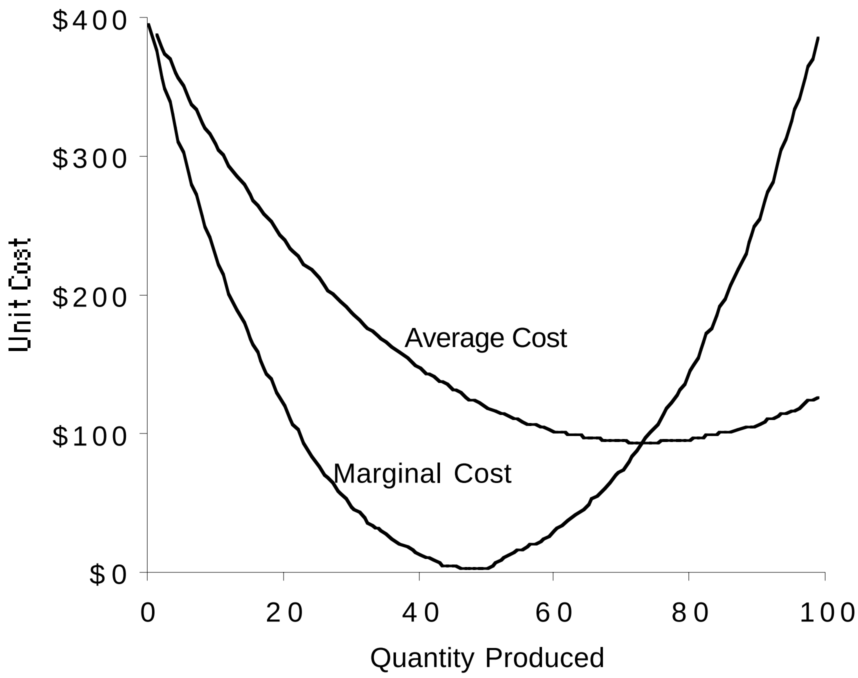
U-shaped cost curves are a convenient assumption because firms can be assumed to locate at the bottom of the U: specifically, they can be assumed to choose a quantity of output such that they have the lowest possible average cost of production. If all firms have identical long-run cost curves, and if any number of firms can enter production, then competition forces firms to locate at the bottom of the U in average cost, because the firms set prices at (or near in some competitive models) their average cost of production. Thus all firms have identical outputs, with quantity chosen to coincide with the bottom of the U in the average cost curve, and price equal to (or near) the lowest possible average cost. This is the long-run outcome in the sense that it is what happens after firms enter and adjust their production capacities.

Unfortunately, this convenient assumption is generally wrong. Real long-run marginal and average firm cost curves seem not to be U-shaped, but to decline or flatten out with continual increases in output. You can sense a problem with the assumption by reflecting on the following facts:

- Giant firms like Microsoft, Sony, and IBM manage to survive and do fine, over a lengthy period of time (no firm succeeds forever), despite their enormous size.
- Even if management did impose excessive inefficiencies for large firms, they could (and sometimes do) break up into divisions managed like separate firms.

[30] Specifically, the marginal cost curve typically is assumed to be convex, falling initially, but then rising without bound.

Figure 11.1. U-Shaped Marginal and Average Cost Curves



- The firms in a given industry virtually never have identical sizes, even many decades after the start of the industry. Despite having had a long time to adjust, including to gain technology and streamline management to make their cost curve as good as possible, somehow actual firms are not converging on the bottom of a hypothetical U-shaped best cost curve.
- Regional U-shaped cost curves for plants or branches do not yield U-shaped costs for firms, because firms may own many plants or branches. Thus even though concrete plants face U-shaped cost curves because of the high cost of shipping wet concrete, an overall concrete firm may own many plants and have steadily decreasing marginal costs.

Nobel prizewinner Hebert Simon, in the introduction to his book *Skew Distributions and the Sizes of Business Firms* with Yuji Ijiri (Ijiri and Simon, 1977), points out how the bulk of economists have been unwilling to eschew the misleading assumption of U-shaped long-run firm costs. In some models the assumption of U-shaped costs may be of minor importance and may aid in making a valid point, but in many models this erroneous assumption may yield misleading conclusions and damaging policy suggestions. Clearly a more appropriate working assumption is needed for what determines firm size.

Major Theories of Firm Growth

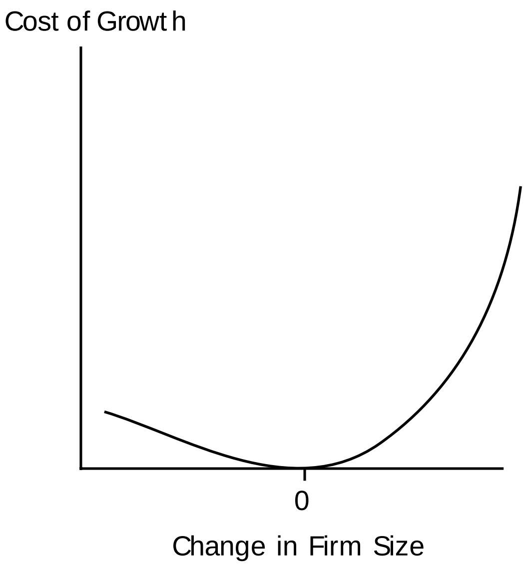
In this section we shall be concerned not with the initial sizes of firms, but with the growth of firms over time. The initial sizes of firms presumably are determined by practical matters including immediate demand, resources in hand, and financing, at the time a company is founded and as experienced by the people who founded the company. Once the initial size of a firm has been determined, the growth rate of the firm determines its size at each point in time. In explaining patterns in firms' (internal) growth, two views have been especially prevalent. The first view pertains to the costs of growth, and the second to the empirical distribution of actual growth rates.

The first view, pertaining to costs of growth, dates back at least to Edith Penrose's book *The Theory of the Growth of the Firm*. Unlike static models in which firms choose an equilibrium amount of output, Penrose's theory has no equilibrium amount of output. Firms may always have reasons to grow or contract. Instead of focusing on the size of firms, the theory focused on firms' rates of growth. The theory emphasizes limits to growth rates of firms, so that firms cannot expand or contract as rapidly as they might ideally prefer. Penrose points out two main limits to growth rates: (1) managerial limits and (2) training of new employees. Even hard-working managers only have limited time to spend, and even if they had cash on hand to hire masses of consultants to assist, they could not do an effective job of expansion beyond some practical upper limit. The managers need to make sure that new parts of the company function adequately, and that they interact effectively with existing parts of the company. Training of new employees also takes considerable time on the part of existing staff. If a company hires new employees too quickly, quality and service may drop because the new employees take time to gain the right skills for the job and old employees spend a lot of time showing the new employees what to do.

Penrose's theory thus conveys the notion of convex costs of growth, used earlier in Klepper's theory of shakeouts. This notion can be embodied formally in a model as a component of cost, $G(\Delta Q)$, where ΔQ is the change in firm size and G is convex and U-shaped with $G(0) = 0$. (Note that convexity of G implies $G'>0$ and $G''>0$ for $\Delta Q > 0$.) Figure 11.2 illustrates this notion as a U-shaped cost with respect to *growth* rather than quantity; of course this cost is only one component of the firm's cost. The change in firm size may be 0, negative (for a contracting firm), or positive.

The second view about growth rates is to model the distribution of growth rates without worrying about why firms grow more or less. Alternatively, empirical variables that are correlated with growth can be identified, with tabular analyses or regressions showing how the mean growth rate or the distribution of growth rates vary with characteristics such as size, age of the firm, nationality, industry, and other traits.

Figure 11.2. U-Shaped Cost of Growth



The starting point to analyze the distribution of growth rates is Gibrat's law. Gibrat's law is not a theory because it just assumes a mathematical formula without explanation, and it is not a law either because it does not fit perfectly with the data. It is, however, a useful point of comparison for thinking about firm growth rates. Gibrat's law simply states that firms of any size have exactly the same probability distribution for their percentage growth rate. For example, according to Gibrat's law, firms with 10 employees and firms with 10,000 employees have exactly the same probability to grow by 50% or more in a given year. As will be seen in the next sections, Gibrat's law is not exactly right. It is furthest from being right for small, new companies (and even more so for plants or branches) in particular product markets. But among large multiproduct companies, such as the leading US companies recorded in the annual *Fortune* 500 list, Gibrat's law is very close to being correct.

Empirical Patterns in Product Industries

Growth within a product industry is different from growth in multiple industries. Large modern firms participate in many industries, and they can grow and change over time by entering new markets and leaving old ones. When considering competition in a particular industry, however, you often want to consider only growth within the industry. Growth within an industry is obviously limited in some ways – once a passenger bus manufacturer gains a 100% share of passenger bus production, it is difficult for the firm to expand its passenger bus business further. (Some related expansion is possible: It may be able to expand internationally, to create greater demand in its home market, or to grow in related industries.)

Table 11.1 shows the distribution of firm sizes, as measured by capitalization in contemporaneous US dollars, for US tire manufacturers from 1909 through 1964. All surviving manufacturers are shown, and each column tells the number of firms in a given year that had a particular size. Size 4A is the largest, and denotes firms with at least $1 million of capitalization. The following size categories are increasingly smaller, with size F representing the smallest category of $2,500-5,000. The X column gives the number of firms of unknown size; size X producers appear to have been generally very small. The size data pertain to the size of the whole company, not just its tire manufacturing business, but in the sample tires tended to be the largest part of the business, so that firm sizes give a good approximation to sizes of firms' units dealing with tire production specifically. The shaded cells indicate the median size producer in each year, among firms of known size. As you can see, following an initial dip in firm sizes driven by small entrants in the early 1910s, the sizes of surviving producers rose dramatically over time.

Table 11.1 does not show whether surviving firms grew over time, or whether the firms that survived happened to be larger firms. Both influences on the size distribution turn out to be relevant: successful firms grew over time, and larger firms were more likely to survive. Survival is perhaps the more dominant influence. Table 11.2 examines all firms that were size 4A producers in 1930, to see whether they were always so large or whether they grew over time. As the table indicates, most of them started out with at least $1 million of capitalization, although at least a quarter of them grew to that size after starting out in much smaller size categories. Table 11.3 examines all firms that were size B producers in 1915, to see how they changed size over time. The bulk of them remained at the same size, but the firms that managed to survive for a decade or more were mostly firms that expanded quite dramatically.

Table 11.1. Evolving Size Distribution in US Tire Manufacturing

Year	4A	3A	2A	A	B	C	D	E	F	X	Total
1909	5		3	7	6	1	6		1	14	43
1914	13	9	18	13	18	7	13	11	7	26	135
1919	35	24	17	40	25	18	12	8	3	47	229
1924	44	28	24	42	16	19	4	3	1	46	227
1929	38	19	15	23	11	7				24	137
1934	35	10	10	12	7	3				11	88
1939	34	7	5	8	2	5				4	65
1944	24	7	4	7	1	2				6	51
1949	20	9	3	3	1	2				5	43
1954	17	6	3	3	1	3				6	39
1959	15	4	2	2	1	1				2	27
1964	5		1							1	7

Note: The table shows the number of US tire manufacturers by size, every five years from 1909 through 1964. The largest firms are on the left side ("4A") and the smallest on the right ("F"). The column labeled "X" gives the number of firms for which size information is not available. A blank cell denotes zero firms. Firms' size classes are determined according to the amount of capital they had. The classes are as follows:

4A........over	$1,000,000	D........over	$10,000
3A........over	500,000	E........over	5,000
2A........over	200,000	F........over	2,500
A........over	100,000	G........over	1,000
B........over	50,000	H........over	500
C........over	25,000	X........No information	

Classes G and H are excluded from the above table, because no manufacturers were listed as having those sizes. Data were collected by the author using annual editions of *Thomas' Register of American Manufacturers*.

Table 11.2. Evolving Size Distribution in US Tire Manufacturing, 4A Firms in 1930

Year	4A	3A	2A	A	B	C	D	E	F	X	Total
1909	3		1	1	1		1			1	8
1914	7	2	6	3	1						19
1919	16	3	3	1	2						25
1924	24	2	2		1					2	31
1929	36										36
1934	32										32
1939	24										24
1944	17	1									18
1949	13										13
1954	13										13
1959	12										12
1964	13										13

Note: The table shows the thirty-six tire manufacturers that were "4A" firms in 1930. This table shows how their sizes evolved over time. A blank cell denotes zero firms. Size classes are the same as in the previous table.

Table 11.3. Evolving Size Distribution in US Tire Manufacturing, B Firms in 1915

Year	4A	3A	2A	A	B	C	D	E	F	X	Total
1909					3						3
1914					16	1		1			18
1919		2			9						11
1924	1	2	3		2						8
1929			3		1						4
1934			3		1						4
1939	1		1								2
1944	1		1								2
1949	1		1								2
1954	1		1								2
1959	1		1								2
1964	1		1								2

Note: The table shows the twenty-three tire manufacturers which were "B" firms in 1915. This table shows how their sizes evolved over time. A blank cell denotes zero firms. Size classes are the same as in previous tables.

Empirical Patterns for Firms/Plants in Multiple Industries

If you consider firms participating across many industries, growth patterns might be expected to differ, given that size is not limited by the size of a particular product market. Whether that is true remains to be seen in future empirical work, but at least we can examine patterns of growth rates among firms and plants in multiple industries. A lot of work has been done looking at such growth rates, often using data collected by government censuses of manufacturers.

What do the data show? Among surviving firms, growth rates decline both with age and with size. The same pattern is true among plants (factory sites) belonging to various firms. Exit is also related to age and size, with the oldest and largest firms/plants having the lowest rates of exit. If firms/plants that exit are counted as having -100% growth rates (given that their size in the next year is in some sense zero), these empirical patterns are less strong and among some age/size classes even appear to be reversed. Table 11.4 shows these patterns among a sample of plants, using US census data that include most US manufacturing plants.

Herbert Simon, working with colleagues Ijiri and Bonini, examined growth among Fortune 500 firms (Ijiri and Simon, 1977). They started with a basic model of growth following rules similar to Gibrat's law. Under these very simple assumptions, it is possible to show (in their case through some fairly complex mathematics) that a skew distribution of firm sizes results: firms end up with different sizes, and most firms are relatively small while a tiny fraction of firms have much larger sizes. As you look farther to the right at the extreme tail of very large sizes, the number of firms at those sizes gets increasingly miniscule. Simon and his co-authors went through a series of steps that made the model more realistic, and showed that predictions of the model fit increasingly well with size patterns among Fortune 500 firms as the model is made more realistic.

Firm sizes are by no means the only measure that follows a skew distribution pattern. City population sizes, the number of times different words appear in books, and many other phenomena have skew distributions. A similar process, such as that proposed by Simon and his colleague, may underlie all these situations.

Table 11.4. Growth and Exit among US Manufacturing Plants

Average Five-Year Growth Rates among Surviving Plants

	Plant Size (# of employees)				
Age (years)	5-19	20-49	50-99	100-249	250+
1-5	61%	30%	19%	13%	7%
6-10	34%	14%	7%	1%	-1%
11-15	31%	6%	-1%	-2%	-2%

Average Five-Year Exit Rates

	Plant Size (# of employees)				
Age (years)	5-19	20-49	50-99	100-249	250+
1-5	41%	40%	39%	33%	23%
6-10	35%	27%	28%	25%	16%
11-15	30%	21%	23%	21%	13%

Average Five-Year Growth Rates, with Exit = -100% Growth

	Plant Size (# of employees)				
Age (years)	5-19	20-49	50-99	100-249	250+
1-5	-6%	-22%	-28%	-24%	-18%
6-10	-13%	-17%	-23%	-24%	-17%
11-15	-9%	-16%	-24%	-22%	-15%

Source: Dunne, Roberts, and Samuelson (1989).

Study Guide

Terms to Know

U-shaped long-run firm cost curves
Edith Penrose
The Theory of the Growth of the Firm
limits to firm growth rates
Gibrat's law
Herbert Simon
skew distribution

Key Readings with Questions

Mansfield, Edwin. "Entry, Gibrat's Law, Innovation, and the Growth of Firms." *American Economic Review* 52 (5), 1962, pp. 1023-1051. **O J E**. This small classic reviews patterns of entry, growth, and innovation in several manufacturing industries.

1. What issues does Mansfield analyze?

2. What conclusions does Mansfield reach?

Dunne, Timothy, Mark J. Roberts, and Larry Samuelson. “The Growth and Failure of U.S. Manufacturing Plants.” *Quarterly Journal of Economics* 104 (4: November), 1989, pp. 671-698. **O E**. Reviews how average growth and exit rates vary according to the size and age of plants in the US.

1. What issues do Dunne, Roberts, and Samuelson address?

2. What conclusions do they reach?

Ijiri, Yuji and Herbert A. Simon. *Skew Distributions and the Sizes of Business Firms*. Amsterdam: North-Holland, 1977. Introduction. **O**. Although Herbert Simon won the Nobel primarily for his work on bounded rationality and human decision making, his work on skew distributions also probably played a part. This book, from which you’re only expected to look at the introduction, describes how skew distributions are common in a wide range of phenomena, and shows how some very simple assumptions yield skew distribution results. Notably, random entry combined with random percentage growth independent of firm size yields, in the long run, a skew distribution of firm sizes.

1. What empirical regularity do Ijiri and Simon focus on?

2. Why do they think it is interesting to examine this empirical regularity?

3. What could cause this regularity?

4. Why do Ijiri and Simon think that firm sizes can be better explained by their theory than by “classical” theories of firm size?

5. In what sense do Ijiri and Simon “proceed by successive approximations”? That is, as they introduce successive changes to their model of firm growth, what changes do they introduce?

Further Reading

Scherer, F.M. and David Ross, *Industrial Market Structure and Economic Performance*, 3rd ed., Boston: Houghton-Mifflin, 1990. Selected pages on mergers. **R** 338.758 SCH.

Mueller, Dennis C. *Profits in the Long Run*. 1986. **R** 338.516 MUE. Shows evidence that in some markets, certain firms have long-lasting advantages that let them maintain unusually high profits for long periods of time. (By the way, John Sutton has recently formulated an argument against this view, by using a simple depiction of changing size plus evidence on firm size to show that the leading firms maintain high market shares in no more industries than would be expected by

random chance; thus the observed long-term profitability might be just firms that were the lucky ones without them having any long-lasting advantage.)

Ravenscraft, David J., and F.M. Scherer. *Mergers, Sell-Offs, and Economic Efficiency*. 1987. **B** 338.83 RAV.

Lichtenberg, Frank R. *Corporate Takeovers and Productivity.* Cambridge, Mass.: MIT Press, 1992. **B** 338.83 LIC.

12. Firm Technological Success and National Development (Week 10)

The first part of the course, in weeks 1-2, dealt with the broader impacts of technological change on regional and national growth. Weeks 2-3 examined how the structure of industries – the sizes, numbers, and locations of firms – affects technological change. Weeks 4-7 then spent even more time on the reverse part of the process – how technological change affects common competitive processes in industries. To understand the competitive processes involved, weeks 8-9 dealt with related issues concerning product differentiation and firm growth. Week 10, the final week of the course, ties together perspectives ranging from the levels of the individual firm and its industry to the level of a whole nation. The focus is on how national governments have sought to aid the success of firms and industries in order to aid entire nations' economies.

After completing this chapter and its associated lecture, you should be familiar with the following issues:

1. Linear versus leapfrog technology development models.
2. How catching-up of firms technologically might be viewed in terms of firms' quality and efficiency of firms, and benchmarking as a way to measure the requirements of catching up.
3. Some approaches to national technology policy.

Linear versus Leapfrog Models of Technology Development

Technology development models for developing countries have fallen into two broad classes: linear versus leapfrog views. The successful <u>linear</u> approach is illustrated by the experience of Korea's Anam Industrial, the world's largest semiconductor packaging company. As Hobday (1995) characterizes based on interviews with senior staff, Anam went through successive phases of linear technology growth. Anam began packaging computer chips into plastic and ceramic cases in 1968-1980 with considerable help from US clients, which provided machinery, engineering assistance, product design information, and materials. By 1980-1985, the firm set up greater in-house process engineering, again aided by US companies such as Texas Instruments. With its new Engineering R&D Department, in the late 1980s into the 1990s Anam increasingly took charge of incremental process engineering and began to develop its own new approaches for production processes and designs for semiconductor packages. The gradual technology diffusion into Anam, followed by steady growth in in-house engineering capabilities, helped Anam to reach US $1.8 billion of export sales by 1992.

The successful <u>leapfrogging</u> approach, in contrast, promises to allow firms rapidly to become internationally competitive. The chief designer of an internationally successful Chinese language printing system, developed by Founder of China, put it this way:

> In high-tech areas, there are big lags between our country and advanced countries. Many new ideas and methods originate abroad…. However, we should not be satisfied with merely catching up because this would not come up with competitive products. It was inevitable that we would catch up for quite a long time. However, it was possible to leap forward based on our indigenous innovative capabilities. (Quoted in Lu, 2000, p. 132)

Founder succeeded at leapfrogging ahead of its potential competitors, indeed taking on the role of a pioneer in the industry. If Founder had caught up more slowly, it likely would have failed, or at least been constrained by lack of funds, in the face of intense competition versus firms from the US, UK, and Japan. Founder was able to succeed at leapfrogging because an opportunity existed for a disruptive new technology with sizeable potential market demand, and because it entered quickly and developed the leading-edge technology in the field.

Whether linear or leapfrog approaches can best succeed depends on the industry in question and the kinds of technological change ongoing. Where ongoing technological changes reinforce the strengths of incumbent firms, the leapfrog approach typically would require a daunting effort far too expensive to be worthwhile. Instead, market niches are often available to make a profit in some part of the industry, perhaps aided by low labor costs, national incentive schemes, or advantageous geography. Catching-up firms in lower-income countries may become loci of technology transfer, spurring growth as for Anam Industrial. Where ongoing technological changes are disruptive or create entirely novel markets, opportunities exist for firms to take a lead in pioneering new technologies.[31] In lower-income countries, pockets of specialized knowledge and skill may provide the crucial head start to succeed at developing an internationally competitive version of the new technology. Founder, for example, benefited from early university research as well as unusual access to talented engineering graduate students at China's leading university. Financial investments for new firm development, when directed according to these principles, need not be large and can be arranged in ad-hoc ways so long as the firm retains the right incentives and freedoms.

Catching Up in the Face of International Competition

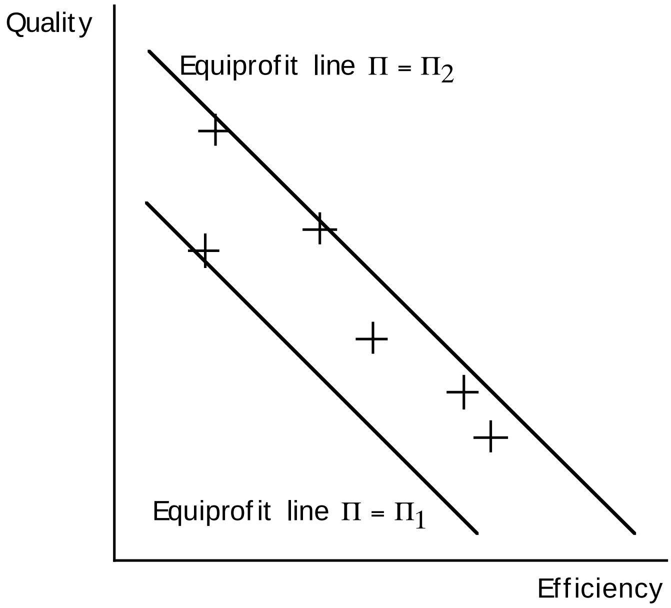
To varying degrees, firms compete against international competitors.[32] Protectionism in the form of tariffs, predatory pricing laws, national politics, and other means may keep competitors at bay only to some degree. Firms must be able to provide a good enough product at a low enough cost that they are at least as competitive as their international competitors can be after coping with the protectionist barrier. And if firms are to be able to compete internationally, they must be competitive enough that they no longer need a protectionist barrier in order to survive.

To illustrate this point, consider an industry with firms making a product in a home-country. Different firms labelled i = 1 to N have different levels of efficiency (the inverse of unit cost) and quality. Firms have a range of per-unit profitability levels, indicated by the symbol Π. If competition within the home-country is weak (competition may be weaker in the early decades of an industry's history and if firms' strategies are relatively cooperative with each other), then the difference between the most profitable and least profitable firms can be large. If competition is severe, then the least profitable firm must be nearly as profitable as the most profitable firm in order to survive. Figure 10.1 illustrates the concept. In the figure, the vertical axis indicates quality and the horizontal axis indicates efficiency. Firms are indicated using + symbols, with the position of each + indicating the firm's quality and

[31] Recall that disruptive technologies may lead to corporate leadership turnover.

[32] This section is inspired by a related talk given by John Sutton at the 2001 meetings of the European Association for Research in Industrial Economics, published as Sutton (2002).

Figure 12.1. Firm Positions and Profits in Quality-Efficiency Space



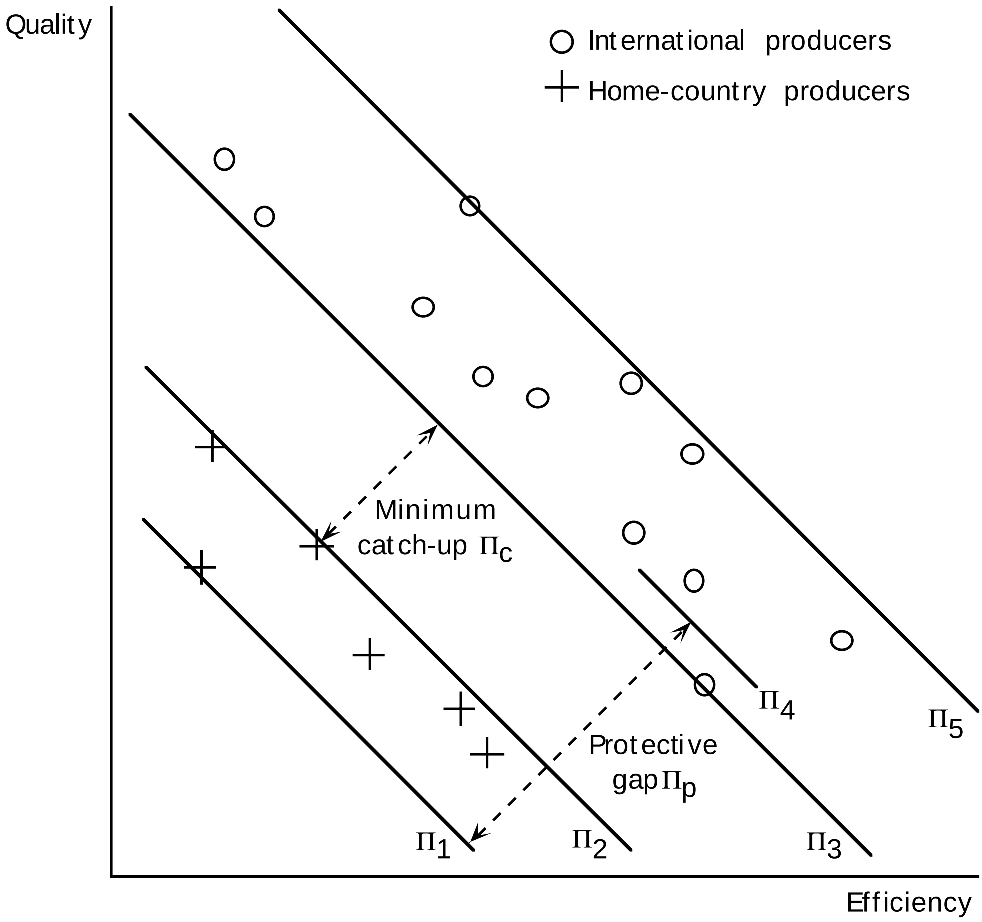
efficiency. The higher are a firm's quality and efficiency, the greater its profitability. Of course, firms with greater quality and efficiency, to the upper right of the diagram, have greater profitability. The sloping lines inside the diagram are equiprofit curves, with all firms on the line having the same profits. The upper equiprofit curve corresponds to a profitability of Π_2, and the lower equiprofit curve corresponds to a profitability of Π_1=0, with $\Pi_2 > \Pi_1$. The difference, $\Pi_2 - \Pi_1$, indicates how competitive is the industry; a more competitive industry has a smaller value of $\Pi_2 - \Pi_1$. The companies with the best technology in the country are at the equiprofit line where $\Pi=\Pi_2$.

In this discussion, it is supposed that the home-country firms currently survive only because of the protectionist trade barriers. International firms with greater quality and efficiency exist, but they must pay a protectionist fee of Π_p for each unit they sell in the home country (Π_p may consist of a tariff and/or other kinds of costs). Among home-country firms, the least profitable firms, which are barely able to survive, must be able to compete with international competitors. Suppose the worst international competitors have sufficient quality and efficiency to yield them profitability Π_3 (> Π_1) if they were producing within the home country. However, they must pay the protectionist fee and hence, when selling goods in the home country, have an actual profitability of $\Pi_3 - \Pi_p$. If $\Pi_3 - \Pi_p < 0$ then they cannot sell the product at all, and only firms with greater quality and efficiency can sell the product. Let Π_4 ($\geq \Pi_3$) be such that $\Pi_4 - \Pi_p = 0$, such that firms at equiprofit line Π_4 are barely willing to sell to the home country.[33]

This situation is illustrated in Figure 10.2. The quality and efficiency levels of international and home-country producers are indicated using o symbols for international producers and + symbols for home-country producers. As before, profit levels are indicated according to the profitability an *in-country* producer would have,

[33] It may be necessary, however, for the home country to set its tariffs such that $\Pi_4 \leq \Pi_3$ if international firms are to be induced to sell within the country, since with limited quantities produced the international firms may prefer to sell to other more profitable markets.

Figure 12.2. International and Home-Country Producers in Quality-Efficiency Space



selling the product in-country, if it had the specified quality and efficiency levels. Because the home-country producers are assumed to be bad at quality and efficiency, there is a gap between even the best home-country producers and the worst international producers. This gap, denoted Π_c, is the minimum catch-up necessary for the best home-country producers to be able to sell their product on the international market. That is, to be internationally competitive, they must improve their quality and/or efficiency enough to move them from curve Π_2 to at least curve $\Pi_2 + \Pi_c = \Pi_3$.

Firms that seek to catch up must aim for a moving target. The rising quality and efficiency of international firms, as well as any other changes in competitiveness, mean that curve Π_3 shifts toward the upper right over time. Thus, when a firm benchmarks its abilities relative to competitors to see how much it needs to improve to be internationally competitive, it is important for it to realize that the competitors will be getting better too.[34]

Benchmarking is a serious business. It is the task undertaken by firms to see how their quality and efficiency compare with other firms. Products and processes may be compared to see how much a low-technology firm lags behind higher-technology firms, with many very specific aspects compared. Once benchmarking has been completed, firms can consider which aspects of the product and process are within their means to improve substantially. If a firm can afford to improve its

[34] Of course, the saving grace of firms in low-technology countries may often be low – and perhaps falling – labor costs relative to other countries, helping to improve efficiency in the low-technology countries.

product and process such that it moves to the upper right of (the new) curve Π_3, then it can become a profitable international producer. The process of benchmarking is in part fits within the definition of absorptive capacity, as benchmarking uses information about other firms to help find fruitful ways to make improvements in the product and process (benchmarking thus can help spur the diffusion of technology). However, benchmarking also is an attempt to determine quantitative measures of gains that might be made. These quantitative measures can be used to aid decisions about what technology areas are worthwhile for investment, as well as whether investments have a reasonable chance of taking firms to internationally competitive levels of technology.[35]

National Technology Policy

Nations have tried various policies to help their industries become competitive and thus aid the national economy. In various cases, national governments have tried to pick key technologies or industries as focal points and invest huge amounts of national funds into these industries. Often prestigious industries such as semiconductors are chosen, with little regard for whether the choice was appropriate. Now, with the worldwide glut in semiconductor production following from apparent national over-investment, analysts tend to label semiconductors as an example of why nations should not pick key technologies as a focus for industrial activity.

An alternative approach is for a government to allocate funds to broad technology areas, allowing a substantial government agency to disburse those funds to industry projects that seem especially worthy. In the US, the Advanced Technology Program channels funds to promising industrial projects that are developing new technology. Japan's Ministry of International Trade and Industry, or "MITI" (now called the Ministry of Economy, Trade, and Industry, "METI") became renowned for its attempts not only to manage particular areas of technology development, but also to manage other aspects of firms' development and their international trade.[36] And it is commonplace for governments to have a range of other agencies that fund technology development: in the UK, government research councils provide universities with competitive research funds to spur research nationwide, with projects part-funded by industry given favorable consideration.

Technology is largely a social good, since individuals firms usually capture only a small part of the returns to invention and innovation. Firms do not have the financial incentive to do a socially optimal amount of R&D, and hence firms naturally tend to underinvest in R&D. To help generate more appropriate levels of R&D

[35] In many industries there may be little chance of catching up to leading international competitors. In the television receiver manufacturing industry, for example, US and UK producers met a similar fate in the face of international competition. Despite substantial investments by some of the US firms (notably Zenith) and despite eventual high labor costs in Japan, the technological lead of Japanese and other international firms proved overwhelming. The Japanese firms consistently led US producers by 1-2 generations in the development of integrated electronic circuitry, which made TV sets more reliable and cheaper to manufacture; UK firms seemingly lagged at least as much as their US brethren. Eventually literally all of the original US and UK producers of TV sets either exited or sold out to their international competitors.

[36] While it is clear that MITI has not always operated effectively, nonetheless the government funding involved in MITI, Nippon Telephone and Telegraph, the Ministry of Education, and other government activities has helped to move forward the competitive abilities of Japanese firms and the skill and technology bases of Japanese scientists and engineers. For a careful analysis of MITI's inefficiencies in major electronics projects, see Callon (1995). Johnson (1982), however, argues that MITI was important to Japan's growth in the period through 1975.

investment, government funding of science helps develop technology that may benefit all people in all nations. In some cases, such as the Advanced Technology Program and MITI, the funding is aimed at building the expertise of firms within a country, which may help the country's producers gain in size and technology leadership. As a result, in some industries – roughly, in industries with shakeouts and without corporate leadership turnover – the technology investments provided at a national level may be rewarded by lasting economic success, causing the nation's producers to become entrenched as the leading international firms in those industries. In either case, national or international funding of technology development can have substantial net social benefits.[37] Nations and the world benefit from investments in technology.

Study Guide

Terms to Know

linear technology development
technology leapfrogging
benchmarking
technology policy
MITI
Advanced Technology Program

Key Readings with Questions

There are no required readings for week 10.

Further Reading

Sutton, John. "Rich Trades, Scarce Capabilities: Industrial Development Revisited." *Economic and Social Review* 33 (1), Spring 2002, pp. 1-22.

Lu, Qiwen. *China's Leap into the Information Age: Innovation and Organization in the Computer Industry*. Oxford: Oxford University Press, 2000. **B** 338.4700164 LU.

Hobday, Michael. *Innovation in East Asia: The Challenge to Japan*. Cheltenham: Edward Elgar, 1995. **B** 338.06095 HOB.

[37] Harmful impacts of technology, such as the use of new weapons of war and global climate change, have to date seemingly been substantially less than the beneficial impacts of technology. But that is a subject for other pages than these.

Educational Tools

13. Mathematical Skills Related to the Text

Interpreting Derivatives

When you read about an economic theory, you might see:

$$PC'(R) > 0 \qquad PC''(R) < 0$$

The above line is read, “PC-prime of R is greater than zero, and PC-double prime of R is less than zero.” The prime and double-prime are compact ways in which people write first and second derivatives. The “(R)” just serves as a reminder that PC (or its first or second derivative) may have different values depending on what R is. Thus, the expressions are equivalent to:

$$\frac{dPC(R)}{dR} > 0 \qquad \frac{d}{dR}\left[\frac{dPC(R)}{dR}\right] < 0$$

A derivative is a slope. It tells you how quickly one variable changes as a second variable increases. So the first expression says that if you draw a graph of PC versus R, such as the above graph, the slope is everywhere greater than zero (i.e., the slope is everywhere positive). As more money R is spent, the price-cost margin PC increases. The second expression involves the derivative of the derivative, or the slope of the slope. In the graph above, the slope starts out very steep, but gets less and less steep. Thus, the slope is decreasing, so the slope of the slope is a negative number. This simply reflects the assumption that firms first do research that promises a high gain for each research dollar spent, and only later do research that promises relatively low gain. This is known as an assumption of “decreasing marginal returns to R&D.”

Greek Letters

Economists and other scientists often use Greek letters to represent variables. For example, the Greek letter Π, pronounced “pi” (as in “apple pie”), is generally used to represent a firm’s profit. Here is the Greek alphabet, in lower- and upper-case letters:

α, A	alpha	ι, I	iota	ρ, P	rho
β, B	beta	κ, K	kappa	σ, Σ	sigma
γ, Γ	gamma	λ, Λ	lambda	τ, T	tau
δ, Δ	delta	μ, M	mu	υ, Y	upsilon
ε, E	epsilon	ν, N	nu	φ, Φ	phi
ζ, Z	zeta	ξ, Ξ	xi (“zi”/“ksi”)	χ, X	chi
η, H	eta	ο, O	omicron	ψ, Ψ	psi
θ, Θ	theta	π, Π	pi	ω, Ω	omega

Computing Derivatives

When you compute the derivative of Π with respect to R, $\frac{d\Pi}{dR}$, start with the formula Π = PC(R) * Q - R, shown earlier. The derivative of two items summed together is simply the sum of the derivatives of the two items. Thus,

$$\frac{d\Pi}{dR} = \frac{d}{dR}[PC(R) * Q] + \frac{d}{dR}[-R].$$

Then to take the derivative of the first item, remember that Q is a constant. The derivative of a constant times anything is equal to the constant multiplied by the derivative of the anything. Thus,

$$\frac{d}{dR}[PC(R) * Q] = Q * \frac{d}{dR}[PC(R)] = Q * PC'(R) = PC'(R) * Q.$$

(Recall that $PC'(R)$ is a way of writing the derivative of PC(R) with respect to R, and means the same thing.) The derivative of the second item works similarly, but you also use the fact that the derivative of a variable (such as R) with respect to itself is 1. (I.e., if you plotted R versus R on a graph, the slope would be 1 everywhere.) Thus,

$$\frac{d}{dR}[-R] = \frac{d}{dR}[-1 * R] = -1 * \frac{d}{dR}[R] = -1 * 1 = -1.$$

Combining the two items, you get

$$\frac{d\Pi}{dR} = PC'(R) * Q + (-1) = PC'(R)\ Q - 1.$$

(When two variables are placed next to each other, it means that they are multiplied together.) This is exactly the result found in the main text. If you set this result equal to zero, then rearrange, you get $PC'(R) = \frac{1}{Q}$.

The second derivative, $\frac{d^2\Pi}{dR^2}$, is the derivative of the first derivative. So it is

$$\frac{d^2\Pi}{dR^2} = \frac{d}{dR}\left[\frac{d\Pi}{dR}\right] = \frac{d}{dR}[PC'(R)\ Q - 1] = \frac{d}{dR}[PC'(R)\ Q] + \frac{d}{dR}[-1].$$

$$= PC''(R)\ Q + 0 = PC''(R)\ Q$$

Here, you take the derivative just like you did above, but also using the fact that the derivative of any constant number, in this case -1, is always 0.

Practice computing these derivatives, covering up the solution while you compute, until you can do them quickly and easily. You should know the following rules for derivatives, most of which were used above. These rules are expressed using x rather than R; in fact, any letter or even a whole name for a variable can be substituted in place of the x's. The letter k below means any constant number (such as -1, or 3, or Q above.) The A(x) and B(x) can be replaced by absolutely anything.

1. $\frac{d}{dx}[A(x) + B(x)] = \frac{d}{dx}[A(x)] + \frac{d}{dx}[B(x)].$
2. $\frac{d}{dx}[k] = 0.$
3. $\frac{d}{dx}[kA(x)] = k * \frac{d}{dx}[A(x)].$
4. $\frac{d}{dx}[A(x) * B(x)] = A(x) * \frac{d}{dx}[B(x)] + \frac{d}{dx}[A(x)] * B(x).$
5. $\frac{d}{dx}[x^n] = nx^{n-1}.$ Here, n is any constant number.

   A special case is $\frac{d}{dx}[x] = \frac{d}{dx}[x^1] = 1x^0 = 1 * 1 = 1$. To see this, note that x^n is x multiplied by itself n times (and $x^{-n} = 1/x^n$), and that $x^0 = 1$ except when x = 0 (0^0 is "undefined," that is, it's some number but you don't know what it is).

6. $\frac{d}{dx}\left[\exp(x)\right] = \exp(x)$.

   Note that exp(x) means e^x, i.e. e raised to the power x, and "e" is a number, approximately 2.71828, with infinitely many digits.

7. $\frac{d}{dx}\left[\log(x)\right] = \frac{1}{x}$.

   Note that log(x), or the "logarithm of x," answers the question "the number e raised to what power equals x?" It is the opposite of exp(x), so that exp(log(x)) = x, or log(exp(x)) = x.

8. $\frac{d}{dx}\left[A(B(x))\right] = \frac{d}{dB}\left[A(B(x))\right] * \frac{d}{dx}\left[B(x)\right]$.

   This last one is called the "chain rule." It is simpler than it looks, and very powerful. For example, suppose someone asks you what's the derivative of $\exp(x^n)$. Let A(.) be the exp(.), and let B(x) be x^n. Then

   $$\frac{d}{dB}\left[A(B)\right] = \frac{d}{dB}\left[\exp(B)\right] = \exp(B) = \exp(x^n)\text{, and}$$
   $$\frac{d}{dx}\left[B(x)\right] = \frac{d}{dx}\left[x^n\right] = nx^{n-1}.$$

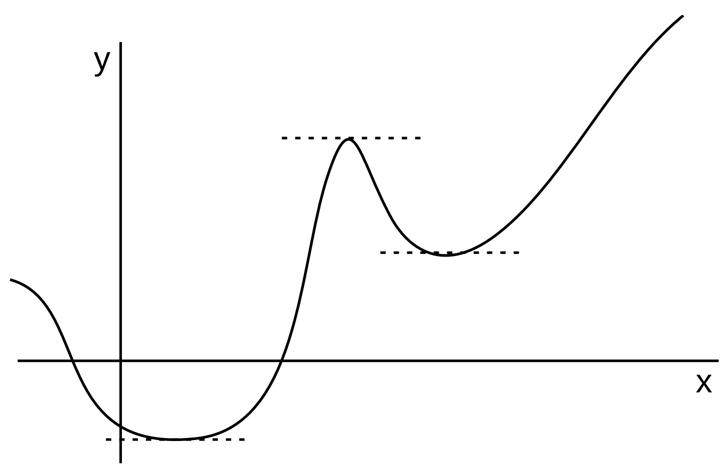
   Plugging these two parts into the formula tells you that

   $$\frac{d}{dx}\left[\exp(x^n)\right] = \exp(x^n) * nx^{n-1}.$$

   By successively applying the chain rule, you can even take the derivatives of things like A(B(C(D(x)))).

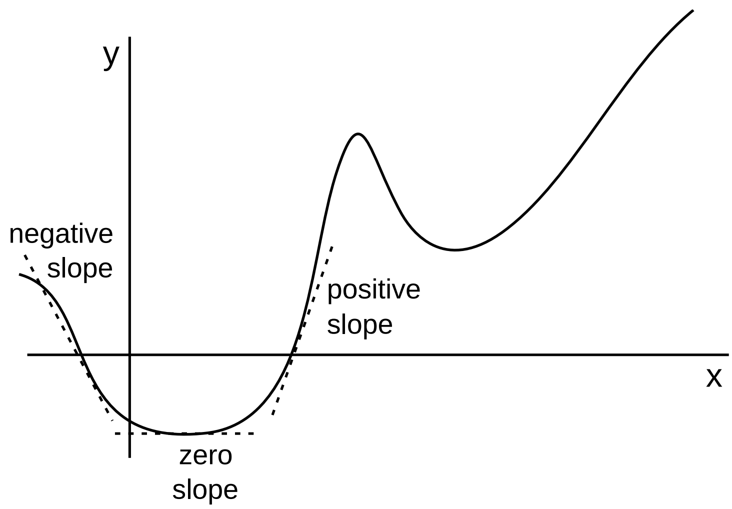
Maximizing a Function

Once you are used to using derivatives, you can use them to find the high and low points of a function. For example, consider the function graphed below.



At the high and low points of the function, as indicated by the dashed lines, the slope of the function is zero. Since a derivative is the same as a slope, if you take the derivative of y(x) with respect to x, than set it equal to zero, that tells you where the high and low points are. All you have to do is solve the resulting equation for x, and you will find out all the values of x that have high and low points. Note that if one side of the function increases or decreases forever, that side will never have a slope that equals zero, so you have to check you're not missing this critical fact! (For example, if y represented profit and as x increased y increased infinitely, the profit-maximizing decision is an infinitely large value of x (or, just as large as a firm could be in practice).

If you find a value of x that has a zero slope, how can you tell whether it is a minimum or a maximum? One way is to solve for the second derivative, that is, the derivative of what you found the first time you took the derivative, or the slope of the slope. If the second derivative is negative when you plug in the value of x that corresponds to the point, the point yields a maximum; if the second derivative it positive, the point yields a minimum. You can see this from the illustration below. Around the part of the graph where there is a minimum, the slope starts out more negative, then becomes zero, then becomes positive. Thus, the slope is increasing, so the slope of the slope — the second derivative — is positive.



A high point or low point that is one of many such points is often called a "local maximum" or "local minimum." The highest part of the function is called the "global maximum," and the lowest part is called the "global minimum."

14. Course Quiz

This quiz is for your own use, to help you study for the course and ensure that you have covered major topics. This is a multiple-choice quiz, unlike the essay exam at the end of the year.

Write your answers below. The correct answers are attached at the end of the quiz. Do not look at the answers until you have made a serious attempt at all the questions!

Answers:

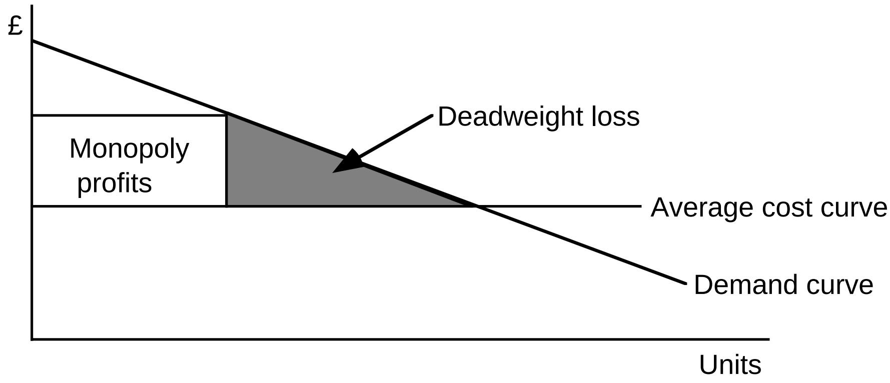
1. _____	11. ___
2. _____	12. ___
3. _____	13. ___
4. _____	14. ___
5. _____	15. ___
6. _____	16. ___
7. _____	17. ___
8. _____	18. ___
9. _____	19. ___
10. ___	20. ___

Quiz Questions

1. Which of the following is true:
   A. Britain gained its international economic leadership in the 1900s.
   B. Britain became Europe's largest oil producer in the 1950s.
   C. In Britain, compared to France, pharmaceutical firms are responsible for a smaller percentage of the patents created by all the country's firms.
   D. Engineers generally have a higher social status in Britain than in Germany.
   E. Military research absorbs the efforts of many of Britain's best engineers.

2. Jane Jacobs has argued that:
   A. Improvements in agriculture caused the formation of cities.
   B. Cities can be sources of innovation which spurs economic growth.
   C. Too much focus of an economy on one industry can cause stagnation.
   D. A and B.
   E. B and C.

3. In the electronics industry of Silicon Valley, compared to the same industry in the Boston area:
   A. Venture capital has been more easily available to start new companies.
   B. Engineers and corporate executives have exchanged information more freely.
   C. Employees have switched jobs more frequently.
   D. All of the above.
   E. None of the above.



4. According to Schumpeter's *Capitalism, Socialism, and Democracy*, the above graphical analysis is misleading because:

A. Monopolies are natural in many industries, and hence must be tolerated.
B. Dynamic changes in price and quality due to technological advance yield far greater economic gains than those that can be achieved through static efficiency.
C. Large companies have more efficient managerial structures than small companies.
D. The analysis is measured in monetary terms rather than in utiles; since a rich person may have ten times as much money to spend as a poor person, the rich person implicitly gets counted ten times as much, which is unfair to the poor person.
E. Monopolists encourage the formation of startup companies.

5. Research that purports to test the Schumpeterian hypothesis found that

A. R&D spending decreases with firm size.
B. R&D spending increases with firm size.
C. R&D intensity decreases with firm size.
D. R&D intensity increases with firm size.
E. None of the above.

6. In the context of R&D and innovation, "appropriability" means:

A. The ability to capture profits resulting from an invention or innovation.
B. The ability of other firms to copy an invention or innovation.
C. The importance of an invention or innovation.
D. How well an invention or innovation meets the needs for which it was designed.
E. The tendency of an invention or innovation to lead to more inventions or innovations.

7. In a recent reinterpretation of the evidence on the Schumpeterian hypothesis, Cohen and Klepper argued that the evidence may indicate an R&D-related advantage to larger firms, in which in some ways larger firms are best for the economy. They argued that

A. Large firms have better managers.
B. There are economies of scale in R&D, so that the cost or quality improvement per each dollar spent on R&D is higher for larger-scale R&D.
C. The cost of R&D per unit of output is smaller for firms that produce more output, and as a result, large firms have an incentive to do more R&D than small firms.
D. The greater market power of large firms lets them affect politics to their benefit.
E. None of the above.

8. In models of industries, if the unrealistic assumption about U-shaped long-run cost curves is dropped, which of the following assumption(s) can be used instead in order to determine firms' sizes:

A. When firms first produce the product, they produce a small amount Q_0 (say, Q_0 = 100 units per year).
B. Firms' growth over time is limited, because of a cost of growth, $G(Q_t - Q_{t-1})$, where $G > 0$ and $G' > 0$ for $Q_t - Q_{t-1} > 0$. For example: $G(Q) = £100 * ([Q_t - Q_{t-1}] / 10 \text{ units per year})^2$.
C. Firms maximize their profits.
D. All of the above can be used together to determine firms' sizes, but any one assumption is insufficient.
E. None of the above.

9. Which of the following statements is <u>wrong</u>:

A. Sometimes market leaders in particular product markets have lost their leadership to new entrants.
B. In the manufacture of "photolithographic alignment equipment" used to make semiconductors, firms that had the highest market share in one type of equipment often did not have the highest market share in newer types of equipment.
C. In cement manufacturing in the US, it has been claimed that a new type of kiln, used to manufacture the cement, was developed around the time when a change in market leadership occurred.
D. Turnover of corporate leadership has been found to occur most when market growth is least.
E. Technological discontinuities have been associated with difficulty in forecasting market growth, according to a paper by Tushman and Anderson.

10. Which of the following explanations has not been proposed (at least not in our course) to explain why leading producers of a product may lose their leadership:
A. Firms are blinded by attention to the needs of their existing customer base.
B. Firms are blinded by the past experiences of their researchers or engineers.
C. Firms' past research and development work causes them to move into new products and abandon the old.
D. Firms' past technological competencies are of limited relevance when major new technologies begin to be used for the product or its manufacturing methods.
E. None of the above.

11. Shakeouts in the number of firms manufacturing a product:
A. Typically occur while the number of units produced continues to increase.
B. Seem to have occurred, to some degree, in most products that have been produced for at least several decades.
C. Sometimes involve a decrease of more than 75% in the number of producers.
D. All of the above.
E. None of the above.

12. Shakeouts in the US automobile, tire, television, and penicillin industries appear to have occurred because
A. Demand for the products dropped off.
B. A major change in technology caused an increase in minimum efficient scale.
C. A dominant design forced firms to adapt to new product characteristics.
D. A dominant design forced firms to become suddenly more proficient at manufacturing methods, or be out-competed.
E. Some early entrants gained an advantage that grew over time, eventually giving the other firms a severe competitive disadvantage.

13. Nearly all the major innovations in the US automobile, tire, television, and penicillin industries were developed by
A. The smallest firms.
B. The largest firms.
C. Suppliers that did not manufacture the final product.
D. The smallest firms as well as some suppliers.
E. The largest firms as well as some suppliers.

14. The QWERTY keyboard has been used by Paul David as an example of
   A. Lock-in of the best available technology.
   B. Lock-in of an inferior technology.
   C. The cause of a shakeout.
   D. How a new technology allows an entrant to take over market leadership from an incumbent firm.
   E. How a new technology allows an incumbent firm to become a monopolist.

15. John Sutton, in his book *Sunk Costs and Market Structure*, compares industry concentration versus market size / setup cost in food industries in Europe and North America. He
   A. Considers a range of different kinds of inter-firm competition, from monopoly to Cournot competition to Bertrand competition.
   B. Considers a range of different kinds of product differentiation patterns.
   C. Argues that national advertising costs sometimes make an industry much more concentrated than it would otherwise be.
   D. All of the above.
   E. None of the above.

16. In answering an end-of-year exam question about the penicillin industry — specifically, about what some statistical evidence from the industry can tell you about competitive processes — which of the following strategies is likely to win the highest mark from an examiner:
   A. Explain that there is not evidence to draw conclusions; better evidence is needed.
   B. Say that you are going to discuss what happened in the penicillin industry, then discuss what happened, then point out that the penicillin industry is likely to be big in the future.
   C. Say that the evidence shows that the earliest types of penicillin experienced a shakeout in which some early entrants dominated in the long run, but later types of penicillin apparently were dominated by new entrants; explain how the evidence proves the point; then sum up by explaining what you showed and why it is important for understanding industries in general.
   D. Explain that in many industries there are important patterns of change over time. Describe common patterns of change. Describe theories of why these patterns of change occur. Point out that there are ways to analyze statistical evidence about industries. Show how the ways to analyze evidence can tell you whether theories are right or wrong. Say that these same methods could be applied to the penicillin industry data.
   E. Just leave the answer blank.

17. Suppose you test whether early entrants in UK automobile manufacturing had higher 10-year survival rates than later entrants. Suppose you find the following results in Stata:

```
           | tenyear
      early|        0          1 |     Total
-----------+----------------------+----------
         0 |       88          4 |        92
         1 |       55         15 |        70
-----------+----------------------+----------
      Total|      143         19 |       162

           Fisher's exact =                 0.001
   1-sided Fisher's exact =                 0.001

4 / 92   =  0.04
15 / 70  =  0.21
```

These results prove beyond any doubt that:

A. Later entrants had 1/1000 the chance of early entrants to survive at least ten years.
B. Later entrants had a 4% chance of surviving at least ten years, versus a 21% chance for early entrants.
C. If later entrants had the same chance as early entrants of surviving at least ten years, then there would be only a 1/1000 chance of seeing a disparity of at least this much between early entrants' and later entrants' survival rates.
D. Later entrants had the same chance as early entrants of surviving at least ten years.
E. Later entrants had a greater chance than early entrants of surviving at least ten years.

18. A common reason for using logarithmic numbers (100%, 10%, 1%, etc.) on the vertical scale of a survival plot, rather than linear numbers (100%, 50%, 0%) is:

A. Because statistical programs usually make graphs this way.
B. To be able to see how exit rates (probabilities of exit per year) changed over time.
C. To be able to compare different cohorts of entrants.
D. To draw attention to the vertical axis.
E. To confuse people seeing the graph.

19. To collect data on the number of companies that produced a product and their dates of survival over the past five decades, likely sources of information are:

A. Trade registers, such as Kelly's Directory, which can be found in Guildhall Library.
B. Old telephone books, which can be found in the British Telecomm Archives.
C. Lists, sometimes found in trade magazines, of firms producing the product.
D. All of the above.
E. None of the above.

20. Which of the following is a standard format for how to include an article in your list of references at the end of your project report:

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E. 1982. Shaw, R.W. "Product Proliferation in Characteristics Space: The UK Fertilizer Industry." *The Journal of Industrial Economics* 31 (1/2: September/December), pp. 69-91.

Answers:

1. E   2. E   3. D   4. B   5. B   6. A   7. C   8. D   9. D   10. C   11. D
12. E   13. E   14. B   15. D   16. C   17. C   18. B   19. D   20. A

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