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Research Paper Abstracts
as of Dec. 2009

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Papers in Progress (Full Written Version Exists) or Under Submission

1. "Product Market Characteristics and the Industry Life Cycle," 46pp.

Abstract: Economists have long sought to understand how product-specific traits drive industry outcomes, but the conclusions that could be drawn have been limited by shortage of dynamic competitive theories and empirical fact. The paper draws on a theoretical model in which technological opportunity drives industry evolution, fueling a spiral of advantage that allows a few firms to dominate in the long run in specific types of markets. The theory has distinctive implications that can be tested using a new type of long-period, cross-sectional, cross-national industry data on narrowly-defined product markets. To meet these extremely demanding empirical requirements, the paper marshals novel data that span many decades for 18 matched industries in the US and the UK.

Several new and important empirical results emerge from the tests. Previous work had found that static industry concentration levels are similar in matched industries across countries, but moreover the entire process by which industries evolve to their static outcomes turns out to occur similarly for the same industry in the two different countries. Some industries have strong shakeouts in firm numbers and others not, confirming the heavily-cited findings of Gort and Klepper (1982), which had not yet been verified using alternative data. In industries with shakeouts entry eventually nearly ceases, but in industries without shakeouts entry remains high. Even in industries with strong shakeouts there is not necessarily a rise in firms' rate of exit coincident with the shakeout, adding to confirmation that shakeouts are not driven by single technological events. The theory and evidence explain why early mover advantage has been observed sporadically in industries, showing it is tied up with the spiral of firm advantage that yields shakeouts, so that only in industries with substantial shakeouts do early movers experience low exit rates relative to incumbents.

The evidence corroborates the idea that technology is the usual driving force behind these typical inter-industry outcomes. Patents on technologies for the existing product and its manufacturing methods (excluding technologies that yield alternative products) act as a proxy for firm-specific innovation. Leading early entrants dominate these patents in industries with substantial shakeouts, and patenting enhances survival mainly in industries with shakeouts. Thus in most industries, within-firm technological innovation seems to drive alternative industry competitive dynamics, through a spiral of firm advantage in industries with high opportunity for product improvement and process innovation.

2. "On the Theory of Product Market Characteristics and the Industry Life Cycle," 51pp.

Abstract: Does industry competition depend largely on product-specific traits? If so, what traits matter how? A model is developed in which the nature of technological opportunities in an industry affects industry evolution over long periods following the inception of a product. Continuous-time firm decisions dictated by optimal control theory provide a mathematical basis for proofs of inter-firm differences and industry outcomes. Analysis of the model shows that, with firms optimizing discounted profit streams by choosing entry, exit, growth, and research spending, alternative industry dynamics arise depending on the degree of relevant technological opportunity. The theory provides an explanation for why some industries experience shakeouts and concentration while others do not, and matches with rich empirical findings reported in a companion paper.

3. "Two Roads to Riches: The (In)Frequency of Strongly Disruptive Technological Change," 40pp.

Abstract: The frequency with which radical technological changes disrupt industry competition is an open question. The present paper develops an upper-bound estimate of the frequency of "strong" disruptive technological changes within defined product industries. This estimate is obtained by searching not for subjectively-defined radical technological changes, as past studies have done for particular industries, but for objectively-defined effects of radical technological changes on firm entry and survival patterns. Strong disruptive technological changes are defined as those that lead to replacement of (at least some) incumbent firms by new entrants, and hence imply detectable patterns in firm entry and exit. Data spanning many decades and 47 product-level industries, detailing firm entry and exit in each industry, are used to assess the frequency of disruptive entry and exit patterns and hence to bound the frequency of strong disruptive technological change within industries. Periods of strong disruption turn out to occur in the data approximately as often as would be expected given random fluctuations of entry and exit. Hence strong disruptive technological change within industries appears to be a rare phenomenon. Assuming that disruptive technological changes are in fact frequent, this suggests that disruptive technological changes typically are not associated with Schumpeterian surges in entry and exit.

4. "Information Technology and Dynamics of Industry Structure: The UK IT Consulting Industry as a Contemporary Specimen," 31pp.

Abstract: The personal computer and the internet are often considered to have disruptive competitive impacts. Should managers and policy makers consequently plan for disruption that gives new firms an edge? What adoption and use policies are appropriate for PC- and internet-related technologies? This paper probes these questions, using the UK IT consulting industry as a test case for disruptive impacts of the PC and the internet.

Findings regarding the entry, exit, growth, and technology-related areas of business for new entrants and incumbents over a period of three decades suggest that the PC and the internet did not have such a disruptive effect on market structure by the year 2001. Recent entrants were relatively likely to apply the PC and the internet to areas of business, but this neither enhanced their growth nor reduced their exit. The industry's trade literature suggests several reasons why the PC and the internet are unlikely to disrupt competition in any industry, as well as apparently sensible patterns in the adoption and use of PC- and internet-related technologies.

5. "News Media as a Channel of Environmental Information Disclosure: Evidence from an EGARCH Approach," 33pp., with Ran Zhang (primary author) and David I. Stern.

Abstract: This paper incorporates EGARCH modeling in a financial event study relating firm value to negative environmental news. News media provide informal information channels unlike formal government disclosure programs. This paper improves on previous studies by using a larger sample than most studies, treating heteroskedasticity in the disturbance term with a hybrid method that allows EGARCH, and comparing stock market reactions across industries and event types. Both standard and hybrid methods reveal reductions in firms' stock market valuations by on average 1.2% in response to negative environmental events. Significant negative market reactions to environmental news arise for all industry groups and event types analyzed. Accidents and complaints yield 2.0% mean reductions in stock market value, versus later lawsuits and court decisions with 1.5% and 0.8% reductions respectively. Firms in traditional polluting industries are most affected. These stock market impacts suggest that informal environmental information channels may financially incentivize firms' self-regulation.

6. "Technology Benchmarks for Sustained Economic Growth," 51pp.

Abstract: An economic growth theory model is developed in which worldwide economic and population growth is optimistically allowed to be increasing in current population-and-economy size, but degradation of environmental quality can cause eventual population-and-economic collapse. The existence of an environmental technology time path that guarantees sustained growth ($dY/dt \geq 0$) is proven. This time path is labeled a technology benchmark, a path of environmental technology in use that society must achieve to ensure against population-and-economic collapse. The World3 global simulation model, developed by an interdisciplinary team of scientists to analyze global growth and its relation to environmental issues, is used to derive

estimates of the requisite time path for several key technologies. The estimated time paths are compared with available information on actual rates of technological change. Such technology benchmarks could serve as measurable goals for national and international policy.

7. "Technology Requirements for Population and Economic Growth," 19pp.

Abstract: The Limits to Growth debates of the 1970s raised the issue of whether (and how much) population and economic growth is feasible. The first major global model, World3, was attacked as being unrealistic, and the initial attention it received largely faded within a few years. Unfortunately, key issues raised by the World3 model have been left unaddressed. Indeed, the bulk of criticisms of the model were misplaced or factually incorrect. I address anew how criticisms considered by economists and others can be accounted for in the model, and show that accounting for the criticisms does not alter policy recommendations based on the model. In-depth sensitivity analyses show that the policy recommendations are highly robust to parameter changes. Next, I use the model to estimate technological targets. The technological targets serve as benchmark goals in order to ensure that given amounts of population and industrial growth can be supported. The benchmarks based on the World3 model are crude approximations. More refined technology targets, currently being developed in continuing research, are based on a range of alternative models and assumptions about food, water, energy, material, and other requirements of population and industry. Such technology targets set goals that world society apparently must achieve in order to ensure that desired levels of population and economic growth can be supported.

8. "Assessing the Effects of Ownership Change on Careers: New Evidence from Matched Employer-Employee Data," 36pp., with Donald S. Siegel and Tomas Lindstrom.

Abstract: Changes in corporate ownership, via merger, acquisition, or divestiture, could influence career paths for workers. Although there have been several papers on the employment and wage effects of mergers and acquisitions, the unit of analysis in such studies is typically the plant or firm. In contrast, the unit of observation in our study is the individual worker, which allows us to provide direct, systematic empirical evidence on the effects of ownership change on compensation and career development. Specifically, we analyze linked employer-employee data for the entire population of Swedish workers and over 19,000 manufacturing plants for the period 1985-1998. For each worker employed in these establishments (as well as the entire population of workers), we have data on gender, age, national origin, level of education, type of education, location, industrial sector, annual earnings, as well as each employee's complete work history during the period. We also have data on numerous plant and firm-level characteristics, which allows us to control for additional factors that might result in changes in worker compensation. We also are able to determine whether workers change employers, lose their jobs, or become self-employed in the aftermath of an ownership change, and their subsequent compensation. Our preliminary findings suggest that workers were typically compensated about 1-2% above the norm immediately before ownership change, and that the compensation of male workers who did not enter unemployment fell to about the normal level following ownership change, while the compensation of female workers who did not enter unemployment remained above the norm for several years.

9. "Bodyshopping versus Offshoring: Outsourcing Strategy in India's Software and Information Technology Industry," 40pp., with Sumit K. Majumdar and Ashok K. Nag.

Abstract: Investigations of offshore outsourcing of information systems have presented little evidence on developing country software and information technology (IT) industries. This study probes determinants among Indian supplier firms of a key outsourcing practice, bodyshopping of employees. Given differing transaction costs, different types of firms and clients from different nations and industries were theorized to rely to differing degrees on bodyshopping versus pure outsourcing. A Reserve Bank of India survey of every Indian software and IT firm elicited firms' use of bodyshopping to serve clients abroad. Consistent with transaction cost rationales, firms that were larger, incorporated, public, and owned foreign subsidiaries most frequently provided bodyshopping among their international services. Bodyshopping was used least frequently for nations where labor costs were high, most for hardware-related business segments, and least for business process segments. The evidence expands knowledge of the vibrant entrepreneurial IT industry in India and how it serves client firms abroad.

10. "Should Environmental Regulators Be Allowed to Tailor Standards?" 22pp., with Anthony G. Heyes.

    Abstract: Regulators are sometimes prevented from setting standards on a firm-by-firm basis. Such restrictions are commonly assumed to be inefficient, and existing rationales for their prevalance have been politico-economic. Whilst the requirement that regulation be uniform does not allow the agency to commit to future standards, it does mean that what is required from one firm must be required from them all. Because the stringency of regulation faced by any particular firm is tied to industry average characteristics, that firm is less prone to hide its access to a low-cost compliance technology by inefficient choice of technique. As such the requirement of uniformity offers partial mitigation of an informational ratchet problem which makes regulation based on 'averages' attractive. We characterise alternative settings in which it is desirable or undesirable to require that standards be uniform.

11. "Entrepreneurs Seeking Gains: Profit Motives and Risk Aversion in Inventors' Commercialization Decisions," 39pp., with Thomas Åstebro.

    Abstract: Direct evidence has been lacking on entrepreneurs' response to individual-specific opportunities, and recent work suggests that entrepreneurship may be a non-profit-seeking activity and that entrepreneurs evaluate risk oddly. We model heterogeneous inventors and inventions, outside opportunities, sunk and non-sunk costs, and risk, to guide data analysis. We use assessment data from a center paid to assess the inventions' economic potential. Inventors' choices whether to commercialize their inventions and later whether to remain in production were consistent with profit-seeking motives and risk aversion.

Published Papers

12. "Assessing the Effects of Mergers and Acquisitions on Firm Performance, Plant Productivity, and Workers: New Evidence from Matched Employer-Employee Data," *Strategic Management Journal*, forthcoming, 27pp., with Donald S. Siegel.

    Abstract: Empirical studies of mergers and acquisitions typically focus on firm-level financial performance. In contrast, we use human capital theory to model these events as transactions that simultaneously have cross-level real effects on workers, plants, and firms. Our empirical analysis is based on longitudinal, linked employer-employee data for virtually all Swedish manufacturing firms and employees. We find that mergers and acquisitions enhance plant productivity, although they also result in the downsizing of establishments and firms. Firm performance does not decline in aftermath of these ownership changes. We conclude that such transactions constitute a mechanism for improving the sorting and matching of plants and workers to more efficient uses.

13. "The U.S. National Innovation System," in V.K. Narayanan and Gina Colarelli O'Connor, eds., *Encyclopedia of Technology and Innovation*, Wiley-Blackwell, forthcoming, 23 pp., with Judith Walls

    This updated overview of the U.S. National Innovation System is apparently the only major synthesis on the topic in recent years. It offers insights on fruitful future policies for the U.S. and all nations, as well as key data on U.S. innovation.

14. "The U.S. National Innovation System: Potential Insights for Russia" (in Russian), in I. Danilin and E. Klochikhin, eds., *Innovative Development: International Experience and Russia's Strategy*, Moscow: MGIMO-University Press, 2009, pp. 97-119.

    This study reflects on factors that have made the U.S. economy innovative and, based on discussions involving the author in Moscow, suggests policy insights to aid innovation in Russia.

15. "Ownership Change, Productivity, and Human Capital: New Evidence from Matched Employer-Employee Data in Swedish Manufacturing," in Timothy Dunne, J. Bradford Jensen, and Mark J. Roberts, eds., *Producer Dynamics: New Evidence from Micro Data*, University of Chicago Press for the National Bureau of Economic Research, 2009, pp. 397-442, with Donald S. Siegel and Tomas Lindstrom.

    Abstract: Empirical studies of the impact of changes in ownership of manufacturing plants on productivity (e.g., Lichtenberg and Siegel (1987, 1990a, 1990b), McGuckin and Nguyen (1995,

2001), and Maksimovic and Phillips (2001)) have provided limited evidence on how such transactions affect investment in human capital and have been based strictly on U.S. and U.K. data. We attempt to fill these gaps, based on an analysis of matched employer-employee data from over 19,000 Swedish manufacturing plants for the years 1985-1998. The sample covers virtually the entire population of manufacturing plants with 20 or more employees and a probability-based sample of smaller plants. We assess whether there are differential effects on productivity for different types of ownership changes, such as partial and full acquisitions and divestitures, and related and unrelated acquisitions.

Our results suggest that ownership change results in an increase in relative productivity. This pattern emerges most strongly for full acquisitions and divestitures and unrelated acquisitions. We also find that plants involved in these transactions experience increases in average employee age, experience, and the percentage of employees with a college education. Ownership change also leads to an increase in earnings and a reduction in the percentage of female workers. Highly-educated workers appear to be the most mobile employees. Women, foreign-born, and young workers employed at plants involved in an ownership change appear to experience greater job loss and reductions in earnings than comparable workers.

– Refereed (completed four rounds) and discussed NBER publication. –

16. "SSL Technology Development and Commercialization in the Global Context," in Ian Ferguson, Christoph Hoelen, Jianzhong Jiao, and Tsunemasa Taguchi, eds., *Proceedings of SPIE: Ninth International Conference on Solid State Lighting*, SPIE, 2009, pp. 74220X-1-15, with Susan Walsh Sanderson.

    – Conference volume publication (reports on an extensive study of worldwide patenting related to light emitting diodes and solid state lighting). –

17. "Lighting Industry," in Jeffrey T. Macher and David C. Mowery, eds., *Innovation in Global Industries - U.S. Firms Competing in a New World*, Washington, D.C.: National Academies Press, 2008, pp. 163-205, with Susan Walsh Sanderson, Judith Walls, and Yin-Yi Lai.

    This report commissioned by the National Academy of Sciences analyzes U.S. competitiveness in traditional and new-technology lighting with respect to rising global competition and the international location of R&D.

18. "Shakeouts, Innovation, and Industrial Strategy and Policy," *Australian Economic Review*, vol. 40 no. 1, March 2007, pp. 106-112.

    This paper introduces readers to the processes behind industry shakeouts and the role of technological innovation in shakeouts, discusses how general are these processes across different industries and nations, and draws conclusions for strategy and policy.

19. "Assessing the Effects of Ownership Change on Women and Minority Employees: Evidence from Matched Employer-Employee Data," *International Journal of the Economics of Business*, vol. 14 no. 2, July 2007, pp. 161-178, with John Marsh and Donald S. Siegel.

    Abstract: While there have been numerous papers on the employment and wage effects of mergers and acquisitions, there has been no direct analysis of the impact of such ownership changes on minority and female workers. This is an unexplored "equity" dimension of these transactions. We fill this gap by analyzing linked employer-employee data for the entire population of Swedish workers and approximately 16,000 manufacturing plants for the period 1985-1998. For each worker employed in these establishments (as well as the entire population of workers), we have data on gender, age, national origin, level of education, type of education, location, industrial sector, annual earnings, as well as each employee's complete work history during the period. We also have data on numerous plant and firm-level characteristics, which allows us to control for additional factors that might result in changes in labor composition and relative compensation. Our findings suggest that ownership change does not significantly alter the relative earnings and employment status of minority and female workers.

20. "Industry Shakeouts and Technological Change," *International Journal of Industrial Organization*, vol. 23 no. 1-2, February 2005, pp. 23-43, with Steven Klepper.

    Abstract: We analyze the evolution of four new products that experienced an initial rise and then extreme shakeout in their number of manufacturers: automobiles, tires, televisions, and penicillin. Data on entry, exit, and innovation are collected for each product to test theories of industry shakeouts. Hazard analyses indicate that earlier entrants had persistently lower hazards during the shakeouts, which was related to their greater rates of innovation. Our findings suggest shakeouts are not triggered by particular technological or other events but are part of a competitive process in which the most able early entrants achieve dominant market positions through innovation.

21. "Predictable Cross-Industry Heterogeneity in Industry Dynamics," in Albert N. Link and F. M. Scherer, eds., *Essays in Honor of Edwin Mansfield: The Economics of R&D, Innovation and Technological Change*, Springer, 2005, pp. 275-279.

    This contribution to a book in honor of Edwin Mansfield describes my work in the line of Mansfield's work on industry dynamics and technological change.

22. "Political Instability and Growth in Dictatorships," *Public Choice*, vol, 125 no. 3-4, December 2005, pp. 445-470, with Jody Overland and Michael Spagat.

    Abstract: We model growth in dictatorships facing each period an endogenous probability of 'political catastrophe' that would extinguish the regime's wealth extraction ability. Domestic capital exhibits a bifurcation point determining economic growth or shrinkage. With low initial domestic capital the dictator plunders the country's resources and the economy shrinks. With high initial domestic capital the economy eventually grows faster than is socially optimal.

23. "Dominance by Birthright: Entry of Prior Radio Producers and Competitive Ramifications in the U.S. Television Receiver Industry," in Constance E. Helfat, ed., *The SMS Blackwell Handbook of Capability Management: Emergence, Development and Change*, Blackwell, 2003, pp. 15-42, with Steven Klepper.

    – Republication in an edited volume. –

    Abstract: The U.S. television receiver industry evolved to be an oligopoly dominated by firms that produced radios prior to tvs. Data on the experience of all U.S. radio manufacturers and on the length of survival and rate of innovation of all U.S. tv entrants are collected to analyze how radio experience influenced entry, firm performance, and the evolution of market structure in the tv industry. Consistent with a model of the evolution of an oligopolistic industry, more experienced radio firms were more likely to enter tv manufacturing, had higher innovation rates, and in turn had greater market shares and longer survival, suggesting that firm capabilities and the evolution of the tv industry's market structure were critically shaped by firms' experience prior to entry.

24. "Industry Life Cycles and Their Causes (Synopsis)," *Academy of Management Proceedings*, 2003, pp. BPS I1-I6.

    – Conference volume publication, in refereed volume (among papers chosen for the program 10% are referee-judged to contribute to this volume, always with a 6-page limit). –

25. "IT and Competition (Synopsis)," *Academy of Management Proceedings*, 2003, pp. TIM E1-E6.

    – Conference volume publication, in refereed volume (among papers chosen for the program 10% are referee-judged to contribute to this volume, always with a 6-page limit). –

26. "Salaries and Career Opportunities in the Banking Industry: Evidence from the Personnel Records of the Union Bank of Australia," *Explorations in Economic History*, vol. 38 no. 2, April 2001, pp. 195-224, with Andrew Seltzer (lead article).

    Abstract: This paper uses personnel records to examine the importance of seniority-based personnel practices in the Australian banking industry during the late 19th and early 20th centuries. It is shown that internal labor markets were well established by the 1880s as limited ports of entry, internal promotion, shielding from the external economy, and seniority-based wages were commonplace throughout the industry. Finally, it is argued that these practices were motivated by efficiency and attracted quality workers, reduced turnover, screened workers, and promoted honesty and effort.

27. "The Making of an Oligopoly: Firm Survival and Technological Change in the Evolution of the U.S. Tire Industry," *Journal of Political Economy*, vol. 108 no. 4, August 2000, pp. 728-760, with Steven Klepper.

    Abstract: The number of producers in the U.S. tire industry grew for 25 years and then declined sharply, and the industry evolved to be an oligopoly. The role of technological change in shaping the industry's market structure is explored. A model of industry evolution featuring technological change is used to derive predictions that are tested using a novel data set on firm entry, exit, size, location, distribution networks, and technological choices prior to the shakeout of producers. Consistent with the model, earlier-entering and larger firms survived longer, principally because of the influence of age and size on technological change.

28. "Dominance by Birthright: Entry of Prior Radio Producers and Competitive Ramifications in the U.S. Television Receiver Industry," *Strategic Management Journal*, vol. 21 no. 10-11, October-November 2000, pp. 997-1016, with Steven Klepper.

    Abstract: The U.S. television receiver industry evolved to be an oligopoly dominated by firms that produced radios prior to TVs. Data on the experience of all U.S. radio manufacturers and on the length of survival and rate of innovation of all U.S. TV entrants are collected to analyze how radio experience influenced entry, firm performance, and the evolution of market structure in the TV industry. Consistent with a model of the evolution of an oligopolistic industry, more experienced radio firms were more likely to enter TV manufacturing, had higher innovation rates, and in turn had greater market shares and longer survival, suggesting that firm capabilities and the evolution of the TV industry's market structure were critically shaped by firms' experience prior to entry.

29. "Technological Extinctions of Industrial Firms: An Inquiry into their Nature and Causes" (reprint of journal article), in David B. Audretsch and Steven Klepper, eds., *Innovation, Evolution of Industry and Economic Growth*, Edward Elgar, 2000, pp. 61-142, with Steven Klepper.

    – Republication in an edited volume. –

    Abstract: After a buildup in the number of firms, new industries commonly experience a 'shakeout' in which the number of firms declines sharply. Three theoretical perspectives on how technological change contributes to industry shakeouts are analyzed. The theories are used to synthesize predictions concerning technological change and industry evolution. The predictions inform an analysis of four US industries that experienced sharp shakeouts: automobiles, tires, televisions and penicillin. Using data on firm participation and innovation from the commercial inception of the four products through their formative eras, we uncover regularities in how the products evolved. The regularities suggest that shakeouts are not triggered by particular technological innovations nor by dominant designs, but by an evolutionary process in which technological innovation contributes to a mounting dominance by some early-entering firms.

30. "International Dynamics of Product Market Competition," in Tarek Khalil, Hussein El-Gammal, Louis A. Lefebvre, Yasser Hosni, and Hassan El-Laithy, eds., *Civilization, Modern Technology and Sustainable Development*, International Association for Management of Technology, 1999, pp. 787-796.

    – Conference volume publication. –

31. "Technology Requirements for Population and Economic Growth," in Tarek Khalil, Hussein El-Gammal, Louis A. Lefebvre, Yasser Hosni, and Hassan El-Laithy, eds., *Civilization, Modern Technology and Sustainable Development*, International Association for Management of Technology, 1999, pp. 797-803.

    – Conference volume publication. –

32. "Technological Extinctions of Industrial Firms: An Inquiry into their Nature and Causes," *Industrial and Corporate Change*, vol. 6 no. 2, March 1997, pp. 379-460, with Steven Klepper.

    Abstract: After a buildup in the number of firms, new industries commonly experience a 'shakeout' in which the number of firms declines sharply. Three theoretical perspectives on how technological change contributes to industry shakeouts are analyzed. The theories are used to synthesize predictions concerning technological change and industry evolution. The predictions inform an analysis of four US industries that experienced sharp shakeouts: automobiles, tires, televisions and penicillin. Using data on firm participation and innovation from the commercial inception of the four products through their formative eras, we uncover regularities in how the products evolved. The regularities suggest that shakeouts are not triggered by particular technological innovations nor by dominant designs, but by an evolutionary process in which technological innovation contributes to a mounting dominance by some early-entering firms.

33. "Innovation and Industry Shakeouts," *Business and Economic History*, vol. 25 no. 1, Fall 1996, pp. 81-89, with Steven Klepper.

    – Refereed conference special issue. –

34. "New Technologies in Simulation Games," *System Dynamics Review*, vol. 9 no. 2, Summer 1993, pp. 135-152.

    Abstract: New computer software allows modelers to create sophisticated educational tools based on models. Such computerized simulation games have generally failed as stand-alone educational tools. Effective learning requires that computerized simulation games not only simulate models but also give an understanding of structure and dynamics. Feedback during the game may be able to teach this systems understanding without textbook readings. Computerized feedback requires new methods of "expert" computer analysis; some methods are suggested in this article. Simulation games also offer the opportunity to integrate learning of structure and dynamics with learning of facts. Other tools need to be developed to help create simulation games and to give the games abilities that they do not yet have, such as access to data bases of models, pictures, and text, and connections between simulation games.

35. "New Technologies in Simulation Games," in David F. Anderson, George P. Richardson, and John D. Sterman, eds., *System Dynamics '90*, System Dynamics Society, 1990, pp. 1047-1059.

    – Conference volume publication. –

36. "Software to Communicate Global Models," in David Crookall and Kiyoshi Arai, eds., *Global Interdependence*, Springer-Verlag, 1992, pp. 57-65, with Peter J. Poole.

    – Conference volume publication. –