RESEARCH AND TEACHING STATEMENT

SCOTT STERN

DECEMBER 2008

Introduction and Overview

My research focuses primarily on how innovation - the production, distribution and diffusion of "ideas" - differs from traditional economic goods, and the implications of these differences for economic behavior, business strategy, and public policy. The main research challenge in the economics of innovation and entrepreneurship is to isolate and identify the structural economic and strategic drivers of quite subtle phenomena. The field places a great deal of weight on empirical relevance – subjecting specific theoretical insights to rigorous empirical examination. In addition to insights into the determinants and consequences of technical change and entrepreneurship, this research draws upon and raises new questions for related fields, including industrial organization, strategy, economic sociology, and growth theory.

In this statement, I first outline my research approach and some cross-cutting findings. I then discuss specific research streams, and conclude with teaching and service activities.

Advancing the economics of innovation and entrepreneurship is often achieved by combining a detailed understanding of the underlying phenomena and institutions with novel data to assess key choices facing firms, individual researchers or entrepreneurs, or managers. As a starting point, understanding the causes and consequences of innovation depends on understanding the incentives, preferences, and opportunities of the key actors in the innovation process. For example, a central line of my research examines the incentives of technology entrepreneurs to either compete with more established firms or cooperate with these incumbents and thus *avoid* competition in the product market (e.g., through acquisition or licensing). This project was spurred by observing that while managers in the biotechnology industry (an object of early study) placed substantial weight on this strategic choice, most of the literature in economics and strategy had abstracted away from the possibility of cooperation between start-up innovators and established firms. A cross-cutting insight from my theoretical and empirical research in this area is that whether technology entrepreneurs compete with established firms depends on parameters characterizing the efficiency of the *market for ideas* (such as the strength of intellectual property rights (IPR) and the relative costs of complementary assets); variation in these parameters helps us understand why patterns of competitive conduct between start-ups and more established firms varies so widely across different high-technology sectors.

Research in the economics of innovation and entrepreneurship requires a receptivity towards novel variables, theoretical drivers and measurement methods. For example, a key puzzle in the economics of innovation is the observed boost to R&D productivity associated with firms who allow researchers to choose their own research agendas or publish in the scientific literature. While most research on this topic had focused on the potential for firms to absorb external knowledge, my research distinguished this explanation from the hypothesis that researchers themselves might value participation in the Open Science community. Using a novel empirical method based on observing *multiple* job offers for individuals scientists, my research suggests that scientists are willing to accept lower wages -- pay a "compensating differential" – in order to work in research environments that allow them to also participate in the scientific community. This research not only provides direct empirical evidence about why firms have chosen a more "open" approach to research and innovation, but has spurred follow-on studies (by myself and others) on the consequences of a "taste" for Science on the optimal organization of science-based research organizations, and the impact of intellectual property restrictions (i.e., a closed environment) on basic research productivity.

Finally, systematic research in the economics of innovation and entrepreneurship requires an assessment of endogeneity and unobserved heterogeneity. Without such an assessment, empirical work will be prone to several important statistical biases. For example, if scientific research papers that are also patented are also likely to be intrinsically more "important," then a cross-sectional comparison of the impact of patented and unpatented research articles (e.g., in terms of diffusion and follow-on use) is likely to confound the impact of intellectual property per se with differences in intrinsic importance across research articles. A potential way to overcome such biases is to exploit variation over time in the institutional environment in which knowledge is embedded (thus allowing the researcher to observe how the diffusion and use of a single piece of knowledge *changes* as the result of a shift in the institutional environment). For example, I have taken advantage of the significant and systematic time gap between the date of initial discovery and the date of patent grant (i.e., the date at which IP rights are granted) to evaluate how the granting of patent rights influences, among other things, (a) the timing and nature of licensing agreements and (b) the use and diffusion of scientific knowledge. By isolating the causal impact of factors such as intellectual property protection on the diffusion and commercialization of ideas, this research attempts to illustrate the value of a "natural experiments" approach for the economics of innovation and entrepreneurship.

Overall, my research attempts to provide novel and general insights into the economics of innovation and entrepreneurship that accord well with the phenomena and have important implications for business and public policy. My research contribution has spurred significant follow-on research, and provided me with several opportunities for professional leadership, including co-organizing the NBER Innovation Policy and the Economy Working Group and editing an annual NBER volume in this area. In 2005, this research contribution was recognized with the first Kauffman Medal for Distinguished Research in Entrepreneurship.

Research Discussion[1]

I now review specific research streams. My goal is to provide a sense of specific contributions and also comment on how each area reflects the themes and approach outlined above.

Profiting from Innovation and the Market for Ideas

The ability to profit from innovation depends far less on the invention's intrinsic "quality" than on the *commercialization environment* – the microeconomic and strategic conditions facing a firm translating an "idea" into a product of value to consumers. Though theory has often abstracted away from these issues, the commercialization environment varies dramatically across high-technology product markets, including differences in the strength of intellectual property rights and the importance of specialized complementary assets. The commercialization environment affect not only the distribution of rents from innovation, but also innovation incentives and optimal commercialization strategy, particularly for technology entrepreneurs. Building on Arrow (1962) and Teece (1987), among others, I have conducted a wide range of studies exploring how the commercialization environment impacts firm strategy. This research has helped to clarify the subtle role that formal intellectual property rights play in innovation incentives and industry dynamics.

My principal line of research in this stream focuses on the nature of strategic interaction between established firms and start-up technology entrepreneurs. The research is premised on a simple but important insight about entrepreneurial innovation: for many start-up innovators, those firms that control the crucial complementary assets required for effective commercialization are precisely those that are the most likely and/or most effective potential product market imitators of the new technology. As such, an entrepreneur must trade off the commercialization benefits of accessing those assets against the increased potential for expropriation of the entrepreneur by the more established firm. In other words, a crucial strategic choice for a technology entrepreneur is whether to commercialize their innovation through product market competition against an established firm versus cooperation with that incumbent via the "market for ideas."

I started this line with a qualitative paper on the incentives and outcomes associated with the "race" to develop human insulin during the very early history of biotechnology (*Incentives and Focus in University and*

[1] Numbered references to papers refer to Scott Stern CV, December 2008.

Industrial Research: The Case of Synthetic Insulin, National Academies Press, 1995 **[37]**). Though the scientific and technological capabilities to develop human insulin was located in biotechnology firms, commercialization was achieved through a licensing agreement with Eli Lilly, which had a dominant position in the pre-existing insulin market (the prior technology involved the extraction of pig and/or cow insulin). In other words, though the innovation itself was radical (a condition traditionally linked to Schumpeterian competition), commercialization of synthetic insulin was realized through cooperation between the incumbent and the start-up innovator, reinforcing the market power of the established firm.

Along with Joshua Gans and David Hsu (a former doctoral student), I have six papers evaluating the role of the commercialization environment in the strategic choice between Schumpeterian competition and the market for ideas. In *Incumbency and R&D Incentives: Licensing the Gale of Creative Destruction* (joint with Joshua Gans, *Journal of Economics and Management Strategy*, 2000 **[15]**), we focus on how the potential for a "market for ideas" impacts equilibrium research incentives. By allowing negotiations between technology entrepreneurs and product market incumbents to take place in the *shadow* of potential product market competition, we establish several novel theoretical results, including (a) the existence of a *purely strategic* incentive for established firms to maintain internal R&D capabilities (even if they expect to acquire technologies externally) and (b) the potential for *strategic substitutability* in R&D incentives when start-up innovators are in a sufficiently poor bargaining position so that established firms consider external technology an imperfect substitute for in-house research. While the "racing literature" assumes competition between a potential entrant and incumbent, we endogenize the choice of cooperation versus competition, which has the result of changing the nature of strategic interaction between incumbents and entrepreneurs. Motivated by this theoretical study, we sought quantitative evidence of the impact of the commercialization environment on commercialization strategy. Building a novel dataset through a detailed commercialization strategy survey of more than 100 technology entrepreneurs, we examine whether the returns on innovation are earned through product market competition versus cooperation with established firms (through licensing, alliances or acquisition) (*When Does Start-Up Innovation Spur the Gale of Creative Destruction?* (joint with Joshua Gans and David Hsu, *RAND Journal of Economics*, 2002 **[9]**). Our hypotheses are that the relative returns to cooperation are increasing in (a) control over intellectual property rights, (b) low transaction costs and (c) sunk costs associated with product market entry. In particular, since intellectual property rights reduce the potential for expropriation and enhance the outside option of a technology entrepreneur, formal IPR increases the *relative* returns to cooperation over competition. Our empirical results provide support for the key hypotheses, and we conclude that the pro-competitive impact of start-up innovation – the gale of creative destruction – depends on imperfections in the market for ideas.

We extend this analysis in *The Impact of Uncertain IP Rights on the Market for Ideas: Evidence from Patent Grant Delay* (joint with Joshua Gans and David Hsu, *Management Science*, 2008 **[4]**) where we focus on the causal role that formal IPR such as patent play in the market for ideas. If the market for technology licenses is efficient, the *timing* of licensing is independent of whether IPR have already been granted. However, if the market for ideas is imperfect (e.g., as the result of disclosure risks, search costs, or asymmetric information), technology entrepreneurs may delay cooperation until uncertainty regarding the scope of IPR has been reduced as the result of patent grant. Combining data about cooperative licensing and the timing of patent allowance, we demonstrate that the hazard rate for achieving a cooperative licensing agreement significantly increases (and is clustered immediately) after patent allowance. Moreover, the sensitivity to patent grant is higher in environments in which firms lack alternative protection mechanisms such as copyright. By employing a methodology that allows us to identify the *causal* impact of the patent system on the market for ideas, our analysis suggests that the efficient operation of the patent system may help entrepreneurs and partners realize gains from technological trade.[2]

---

[2] My use of these institutional features of the patent system builds on *Are All Patent Examiners Equal? Examiners, Patent Characteristics, and Litigation Outcomes*, (joint with Iain Cockburn and Samuel Kortum, *Intellectual Property in the Knowledge-Based Economy*, 2003 **[20]),** where we study the operation of the patent system and

Gans and I have integrated these ideas into a synthetic framework identifying the central drivers of start-up commercialization strategy and the implications of these drivers for industrial dynamics (*The Product Market and the 'Ideas' Market: Commercialization Strategies for Technology Entrepreneurs*, *Research Policy*, 2003 **[8]** and an biotechnology-focused version published as *Managing Ideas: Commercialization Strategies for Biotechnology*, *ICFAI Journal of Intellectual Property Rights*, 2003 **[27]**) This framework addresses why technology entrepreneurs in some environments undermine established firms, while others cooperate with incumbents and reinforce existing market power. Our analysis suggests that industry dynamics are the result of repeated strategic interaction between start-up innovators and established firms, and that the outcome of these interactions depends on the presence or absence of a "market for ideas." As a result, this framework distinguishes environments characterized by the Schumpeterian competitive dynamics such as the disk drive industry (Henderson and Clark (1990), Christensen (1997)) from environments in which externally developed radical technological innovation coexist with stability in market leadership (such as in the pharmaceutical, microprocessor, and Internet router industries). By focusing on the operating requirements, efficiency, and institutions associated with markets for ideas, the framework holds several testable implications for strategic behavior and for the management of high-technology entrepreneurial firms.

Finally, in a recent paper (*Is There a Market for Ideas?*, under submission **[43]**), Gans and I investigate how the nature of ideas impacts the operation and feasibility of the market for ideas. While most work on markets for ideas focus on bilateral exchange, market design principles suggest that each transaction takes place in the shadow of all other potential transactions. As highlighted by Roth (2007), effective market design ensures market thickness, lack of congestion, market safety, and lack of "repugnance." These conditions ensure that participants in a market have opportunities to trade with a wide range of potential transactors (market thickness), that the market is rapid enough (relative to the speed of transactions) that market participants can feasibly turn down offers in order to seek better matches (lack of congestion), potential market participants have a high incentive to participate in the market and avoid strategic interaction which might undermine allocative efficiency and social welfare (market safety), and that market trade is not undermined by other social values which limit the ability to charge positive prices for a good (lack of repugnance). Our paper evaluates markets for ideas in light of these principles. Our analysis suggests that the nature of ideas – such as the potential for expropriation and the low cost of replication – inhibits the functioning of the market for ideas. For example, Arrow's disclosure problem suggests that the value of a given idea to any one buyer may be decreasing in the number of other potential buyers who have been able to evaluate the idea (due to information leakages in the valuation process). As a result, a key property of ideas - the potential for expropriation - limits the potential for market thickness and lack of congestion identified by Roth. At the same time, key institutional developments such as the development of formalized IP exchanges and increased attention on how to design the patent system to facilitate technology transfer suggest that effective market design may be possible for some innovation markets. Perhaps most intriguingly, our analysis suggests that markets for ideas are beset by the "repugnance" problem: from the perspective of market design, Open Science is an institution that places normative value on "free" disclosure and so undermines the ability of ideas producers to earn market-based returns for producing even very valuable "pure" knowledge.

Overall, this research stream grounds the commercialization strategy and performance of technology entrepreneurs in the commercialization environment. Most notably, this research has identified the crucial and often neglected role of formal intellectual property such as patents in facilitating technological trade, and identified the causal role of the patent system and related institutions on technology entrepreneurship.
A second strand within this research stream focuses on how the degree of competitive insulation afforded innovative products depends on the control of complementary assets by technological innovators. These papers were part of a small group of papers to establish a new set of econometric methods for evaluating the

---

present results suggesting the interaction between examiner discretion and patent litigation outcomes.

sources of market power in differentiated product markets (Berry, 1994; Berry, Levinsohn, Pakes, 1995). In *Market Segmentation and the Sources of Rents from Innovation: Personal Computers in the Late 1980s*, (co-authored with Tim Bresnahan and Manuel Trajtenberg, *Rand Journal of Economics*, 1997 **[16]**), we evaluate the origins of *transitory* market power in personal computers (PCs) during the late 1980s, when low barriers to entry coexisted with high rates of innovation. We measure the impact of different principles of differentiation (PDs); each PD reflects a distinct notion of product similarity, offering a potential source of market segmentation. One PD measures the substitutability between Frontier and Non-Frontier products (F versus NF), while a second PD measures the advantage afforded by a brand-name reputation (B versus NB). We find segmentation along both dimensions; as well, Branded status shifted out the product demand curve. The main implication of these findings is that the effects of competitive events (such as entry) were localized. For example, less than 5% of the market share achieved by a hypothetical NB-NF product would be market-stealing from other clusters. Specifically, this research provides additional empirical support for a Teecean perspective: a substantial portion of the rents from innovation arise not from technological novelty but from embedding innovation in brands and distribution systems insulated from fringe competition.[3]

Finally, two additional papers further clarify the relationship between the commercialization environment and innovation incentives. In *When Does Funding Research by Smaller Firms Bear Fruit?: Evidence from the SBIR Program*, (with Joshua Gans, *Economics of Innovation and New Technology*, 2003 **[7]**), we evaluate whether the concentration of VC financing among a small number of industrial segments is related to differences across sectors in the appropriability environment. Using a novel test based on the relationship between industry-level private VC financing and the performance of government-subsidized research projects, our principal result is that project-level performance is highest in those segments attracting high rates of VC investment. In other words, the targeted nature of venture funding reflects, in part, differences in the product market incentives for technological innovation by smaller firms. As well, in a more policy-oriented paper, *Innovation Incentives, Compatibility, and Expropriation as an Antitrust Remedy: The Legacy of the Borland/Ashton-Tate Decree*, (with Catherine Fazio, *Antitrust Law Journal*, 2000 **[14]**), we address the relationship between underlying innovation incentives and expropriation in standards-driven markets. While cautioning against the arbitrary use of expropriation as an antitrust remedy, our analysis suggests that IP expropriation may be an appropriate *remedy* (in order to address a preexisting antitrust concern) in the presence of certain markers, including the imperfect assignment of IP rights, the presence of cumulative innovation, and when a standard-setting war is likely.

Grounded in equilibrium models of technological competition and exploiting novel data sources and econometric technique, this research stream provides evidence that the incentives for innovation and the management of knowledge and technology are powerfully shaped by the microeconomic and institutional environment within which innovation is commercialized.

The Economics of Open Science and the Science of Science Policy

[3] Similar issues of segmentation and substitution arise in my research on pharmaceutical markets (*Market Definition and the Incentives for Innovation: Substitution Patterns in Pharmaceutical Markets* **[57]**), which evaluates two sources of competition for pioneer drugs: substitution among different molecules in the same therapeutic category and substitution between the pioneer and generic versions of a given molecule. The comparison of *intermolecular* versus *intramolecular* substitution provides insight into the differential impact on appropriability played by imitators (generics) and competitive innovators (alternative molecules produced by competing firms). In innovation-oriented therapeutic categories, intermolecular substitution is the key source of substitution, while in the single market experiencing no innovation, generics provide the most important check on pioneer market power. Measuring different types of market segmentation provides nuanced evidence about the market origins of innovation incentives.

At least since Nelson (1959) and Arrow (1962), economists and management scholars have attempted to understand the incentives for abstract knowledge production. Because knowledge production is costly to monitor and subject to expropriation, the level of production may be inefficiently low in the absence of alternative institutions. While much research has focused on the provision of private incentives through mechanisms such as intellectual property, prizes, or trade secrecy, economists have only recently begun to evaluate how the norms and institutions of "Open Science" impact the production and distribution of knowledge (Dasgupta and Dasgupta, 1994). Compared with commercially motivated knowledge production and diffusion, the incentives associated with Open Science depend on establishing intellectual priority (i.e., being first to make a discovery), disclosing that knowledge publicly (e.g., in academic journals), and having that knowledge serve as a foundation for future researchers (as reflected in citations, etc.). Building on Rosenberg (1974), Dasgupta and David (1994) and Mokyr (2002), I have completed a range of studies focusing on the economic and strategic origins and implications of Open Science and the role of Open Science on cumulative knowledge production.

My first paper in this area focused on the drivers of the diffusion of Open Science within the pharmaceutical industry. In *Untangling the Origins of Competitive Advantage*, (joint with Iain Cockburn and Rebecca Henderson, *Strategic Management Journal*, **[13]**) we ask: if the productivity advantages to a science-oriented research approach are so high, why did some firms delay adoption from the late 1970s until well into the mid-1990s?[4] Using both qualitative and quantitative evidence, we investigate the historical origins of science-based drug discovery, focusing on differences among firms in terms of product market incentives, technological capabilities, geographic location, the structure of power and attention within the firm, and the residual impact of initial heterogeneity. Perhaps surprisingly, our results suggest that the most powerful single explanation for organizational heterogeneity relates to the firm's initial conditions, and that the most robust additional factors relate to the structure of power and attention within the firm. By blending our understanding of the phenomena with novel data and methods, these papers suggest the empirical importance of two specific determinants of organizational design – initial conditions and managerial attention – which have often been downplayed in the economics of innovation and more generally within industrial organization

This research stream has extended to an integrated set of papers evaluating the incentives for adoption and consequences of adopting a science-oriented approach. Firms who adopt a science-oriented research approach (i.e., Science) allow their researchers to publish in the "public" scientific literature, resulting in knowledge spillovers, and pursue individual research agendas, decreasing coordination across a firm's research projects. However, the adoption of Science has been associated with a boost in R&D productivity and overall firm performance (Henderson and Cockburn, 1994), resulting in a central empirical puzzle in the economics of innovation. In *Do Scientists Pay to Be Scientists?*, *Management Science*, 2004 **[6],** I evaluate two alternative explanations for the sources of the performance advantages associated with Science: a "taste" for Science on the part of researchers (a Preference effect) and R&D productivity gains arising from earlier

[4] My PhD thesis includes a sole-authored paper, *Incentives and Knowledge in Organizational and Technological Change: The Case of Drug Discovery in the 1980s* **[58]**, which began my exploration of these themes and served as a basis for the joint research with Cockburn and Henderson. My research with Cockburn and Henderson also includes two unpublished papers, *The Diffusion of Science-Driven Drug Discovery* **[54]** and *Balancing Incentives in Pharmaceutical Research* **[53].** These papers build more closely on economic theory and utilize careful econometric techniques to consider the incentives and consequences of adopting science-based drug discovery. For example, in *Balancing Incentives*, we draw on multi-task agency theory to derive a test of whether firms "balance" the provision of incentives between basic and applied research. Specifically, using detailed data on individual pharmaceutical research programs, we hypothesize that the shift to science-oriented drug discovery raised the precision associated with tasks linked to long-term research needs, allowing the firm to raise incentives for applied short-term research outputs. Consistent with the complementarity hypothesis, we find cross-sectional and time-series evidence that firms providing promotion-based incentives for scientists to invest in long-term basic research are more likely to provide strong incentives to supply effort towards more short-term applied research.

access to discoveries by external (often university-based) scientists (a Productivity effect). These two effects differ in their impact on wages. Whereas the Preference effect contributes to a negative compensating differential, the Productivity effect may result in rent-sharing. However, since Science may be adopted by firms employing higher-quality researchers, cross-sectional evaluations of wages and Science may be biased by unobserved heterogeneity. To overcome this bias, this paper introduces a novel empirical approach. Specifically, prior to accepting a given job, many scientists receive *multiple job offers*, allowing for the calculation of the wage-Science relationship, controlling for differences in salary levels offered to individual researchers. Using a dataset composed of multiple job offers to postdoctoral biologists, the results suggest a negative relationship between wages and Science. These findings are robust to restricting the sample to non-academic job offers, but the findings depend critically on the inclusion of researcher fixed effects. Conditional on perceived ability, scientists do indeed *pay* to be scientists.

These earlier studies have motivated my recent research on the role of scientific institutions and norms in the process of cumulative knowledge production. In the Brookings monograph *Biological Resource Centers: Knowledge Hubs for the Life Sciences* (2004, **[18]**), and *Climbing Atop the Shoulders of Giants: The Impact of Institutions on Cumulative Research* (joint with Jeff Furman, revision resubmitted **[40]**), we consider the impact of research-enhancing institutions on cumulativeness.[5] As described in the monograph, scientific institutions can enhance cumulativeness by reducing the marginal cost to researchers of drawing on prior research efforts. To make this argument concrete, we evaluate cumulativeness in the context of a specific institution, Biological Resource Centers (BRCs). BRCs are "living libraries" that authenticate, preserve, and offer independent access to biological materials, such as cells, cultures, and specimens. BRCs may enhance the cumulativeness of knowledge by reducing the marginal cost to researchers of drawing on prior research efforts. Our analysis highlights two effects. First, a selection effect may result in a high correlation between "high-quality" institutions and knowledge of high intrinsic quality. Second, an institution may have a marginal impact – an incremental influence on cumulativeness, conditional on the type and quality of knowledge considered. We exploit three key aspects of the environment in which BRCs operate to evaluate how they affect the cumulativeness of knowledge: (a) the impact of scientific knowledge is reflected in future scientific citations, (b) deposit into BRCs often occurs with a substantial lag after initial research is completed and published, and (c) "lagged" deposits often result from shocks unrelated to the characteristics of the materials themselves. Employing a difference-in-differences estimator linking specific materials deposits to journal articles, we find evidence for both selection effects and the marginal impact of BRCs on the cumulativeness of knowledge associated with deposited materials (I discuss the methodological contribution of this paper in more detail below). Our results suggest that the cumulative impact of a scientific discovery is amplified in the presence of institutions that enhance the replicability and facilitate the diffusion of scientific knowledge.

These empirical findings raise an important theoretical question: what are the economic and institutional conditions that support Open Science? In *Disclosure or Secrecy: The Dynamics of Open Science* (joint with Arijit Mukherjee, *International Journal of Industrial Organization*, forthcoming **[1]**), we begin to address that question by developing an overlapping generations model that focuses on the trade-off between disclosure and secrecy. While secrecy yields private returns that are independent of the actions of future generations, the "kudos" from disclosure depend in part on the use of disclosed knowledge by subsequent researchers. We show that Open Science and Secrecy are both potential equilibria and that the feasibility of Open Science depends on factors such as the costs of accessing knowledge from prior generations and the relative benefits to private exploitation under secrecy versus disclosure. In parameter regions where both Open Science and Secrecy can be supported, Open Science is associated with a higher level of social welfare. The analysis has policy implications for a number of areas, including public support for research training, appropriate design of formal intellectual property, and the role of scientific norms and institutions (such as institutions such as BRCs

[5] *Biological Resource Centers: An Economic Perspective* **[29]** offered an early summary of this research.

and an effective peer review process) in maintaining Open Science over the long run.

Building on this work, I have written a series of papers evaluating the *interaction* between Open Science and patents. In work with Fiona Murray (and other co-authors), I have attempted to evaluate the subtle role that formal IPR plays in the diffusion and use of scientific knowledge. In *Do Formal Intellectual Property Rights Hinder the Free Flow of Scientific Knowledge?: Evidence from Patent-Paper Pairs*, (joint with Fiona Murray, *Journal of Economic Behavior and Organization*, 2007 **[5]**), we evaluate key questions in the "anti-commons" debate by evaluating how the formal IPR over a given piece of knowledge affect the propensity of future researchers to build upon that knowledge in their own scientific research activities. This article frames this issue around the concept of dual knowledge, in which a single discovery may contribute to both scientific research and useful commercial applications. A key implication of dual knowledge is that it may be simultaneously instantiated as a scientific research article and as a patent. Such patent-paper pairs are at the heart of our empirical strategy. We exploit the fact that patents are granted with a substantial lag, often many years after the knowledge is initially disclosed through paper publication. The knowledge associated with a patent-paper pair therefore diffuses within two distinct intellectual property environments – one associated with the pre-grant period and another after formal IP rights are granted. We test a key tenet of the anti-commons perspective: the citation rate to a scientific publication should fall after formal IP rights associated with that publication are granted. Employing a differences-in-differences estimator for 169 patent-paper pairs (and including a control group of other publications from the same journal for which no patent is granted), we find evidence for a modest anti-commons effect; the decline becomes more pronounced with the number of years elapsed since the date of the patent grant, and is particularly salient for articles authored by researchers with public sector affiliations.[6] We extend this analysis in a more synthetic policy-focused essay drawing together an emerging body of research in *When Ideas are Not Free: The Impact of Patents on Scientific Research* (with Fiona Murray, *NBER Innovation Policy and the Economy*, 2007 **[25]).**

These themes have come together most sharply in two recent working papers. In *Patents, Papers and Secrecy: Contracting over the Disclosure of Scientific and Commercial Knowledge* (joint with Joshua Gans and Fiona Murray, mimeo **[46]**), we evaluate the conditions supporting the disclosure of privately funded new knowledge through scientific publication, patenting, or both. We ground our analysis in the incentives facing researchers and their funders: scientists have incentives to disclose discoveries through scientific publication, while firms have incentives to protect their ideas through patenting or secrecy. When negotiating their compensation, researchers and firms bargain over whether (and how) knowledge will be disclosed. We evaluate four different disclosure regimes: secrecy, commercial science (where the only disclosures result from patenting), open science (where the only disclosures occur through scientific publication) and patent-paper pairs (where the firm discloses along both dimensions). Our model derives conditions under which each of these outcomes emerges as the result of the strategic interaction between researchers and research funders, and offers a number of novel insights into the determinants of the *disclosure strategy* of a firm. Among other findings, our analysis highlights the subtle interdependency between patenting and publication: for example, as the knowledge required for patenting and publication converge, we will observe either secrecy or patent-paper pairs, to the exclusion of uni-dimensional disclosures (i.e., Commercial Science or Open Science).

Finally, in *Of Mice and Academics: The Impact of Openess on Innovation*, (with Philippe Aghion, Mathius Dewatripont, Fiona Murray and Julian Kolev **[44]**), we specifically examine how shifts in the openness of research tools impact the level of diversity and experimentation in scientific research. We build on recent models emphasizing that, from an economic perspective, freedom is the granting of control rights to

[6] In a recent paper, *Learning to Live with Patents* (with Fiona Murray, submitted **[41]**), we extend this analysis and consider whether the decline in citations ameliorated over time as the scientific community developed contracting practices that limited the impact of formal IPR. We find significant evidence for this evolution over time, and find that the dynamics of particular *citing* populations provides additional evidence for the initial anti-commons effects and its subsequent moderation.

researchers (similar to **[6]**). Within this framework, openness of upstream research does not simply encourage higher levels of downstream exploitation. It also raises the incentives for additional upstream research by encouraging the establishment of entirely new research directions. In other words, within academia, restrictions on scientific openness (such as those created by formal intellectual property (IP)) may limit the diversity and experimentation of basic research itself. We test this hypothesis by examining a natural experiment in openness within the academic community: NIH agreements during the late 1990s that circumscribed IP restrictions for academics regarding certain genetically engineered mice. Using a sample of engineered mice that are linked to specific scientific papers (some affected by the NIH agreements and some not), we implement a differences-in-differences estimator to evaluate how the level and type of follow-on research using these mice changes after the NIH-induced increase in openness. We find a significant increase in the level of follow-on research. Moreover, this increase is driven by a substantial increase in the rate of exploration of more diverse research paths. Overall, our findings highlight a neglected cost of IP: reductions in the diversity of experimentation that follows from a single idea.

Overall, these papers contribute to an emerging body of rigorous theoretical and empirical research on the economics, institutional and strategic drivers of science-based industries. A key insight of this research is that understanding the organization of research and the consequences of policy choices (e.g., whether to allow patents in a certain research area) depends on how these choices interact with the objectives and motivations of researchers themselves. While most research either abstracts away from scientific norms or simply takes scientific institutions for granted, my research has attempted to identify the conditions under which science-driven research will emerge and draw out the consequences of adopting scientific norms for research productivity and cumulative discovery and innovation.

In addition to these substantive contributions, this work has also introduced a novel methodology into the economics of science. Specifically, our empirical approach highlights an important but often overlooked problem in the measurement of knowledge spillovers. Identifying the impact of institutions on knowledge diffusion requires overcoming a fundamental inference problem associated with isolating the effects selecting knowledge into particular institutional environments from the *impact* of those institutional environments on knowledge diffusion. Although we cannot implement an ideal, randomized experiment, we articulate an approach combining detailed citation-level bibliometric measures for a large set of publication records with a differences-in-differences approach to causal inference exploiting different types of natural experiments. Over the past several years, science funding agencies (including the NSF and NIH) have made significant investments and placed significant priority on the development of the "Science of Science Policy" (SOSP) (Marburger, 2005; Jaffe, 2008). A contribution of this work has been to introduce the combination of citation analysis with a differences-in-differences approach as a standardized SOSP methodology.

The Impact of Technology Adoption and Organizational Design on Innovation and Performance

A third stream of research focuses on the economics of technology adoption and organizational practice adoption. This research stream focuses both on the decision-making process by which organizations or individuals choose to adopt new technologies or organizational practices and the implications of such choosing behavior for equilibrium research incentives, firm boundaries, productivity measurement, and consumer welfare.

In *An Empirical Framework for Testing Theories about Complementarity in Organizational Design* ,(joint with Susan Athey **[42]**), we develop an econometric framework for assessing the impact of pairs of organizational practices on performance and provides foundations for assessing alternative empirical approaches to testing for complementarity in the context of organizational design and technology adoption. We focus on the potential biases that arise in various procedures due to *unobserved heterogeneity* in the returns to individual practices and develop a novel estimator that provides a consistent test for complementarity. For example, unobserved factors such as the firm-specific distribution of skill and experience with certain technologies, or the preferences of managers, may affect the costs and benefits of adopting particular information technology solutions. To overcome this bias, testing for complementarity requires *choice-specific* instrumental variables (i.e., observable factors impacting the adoption of individual practices but independent of other practices *and* measured performance) and an appropriate treatment for selectivity, with implications for data gathering, survey design, and the interpretation of empirical evidence.

I have also completed several empirical studies building on this framework. In *Complementarity among Vertical Integration Decisions: Evidence from Automobile Product Development*, (joint with Sharon Novak, *Management Science*, forthcoming **[2]**) examines the potential for complementarity in vertical integration decisions in automobile product development, exploiting the identification strategy proposed in the Athey-Stern framework. The theoretical issue we consider is that though most research assumes that contracting choices are independent of each other, *contracting complementarity* may arise when governance choices impact the equilibrium degree of coordination among agents. First, effective coordination may depend on the level of (non-contractible) effort on the part of each agent; contracting complementarity results if coordination efforts are interdependent and vertical integration facilitates a higher level of non-contractible effort. Second, effective coordination may require the disclosure of proprietary trade secrets, and the potential for expropriation by external suppliers may induce complementarity among vertical integration choices. We provide evidence for complementarity in product development contracting by taking advantage of a detailed dataset that includes the level of vertical integration and the contracting environment for individual automobile systems in the luxury automobile segment. Using an instrumental variables framework that distinguishes complementarity from unobserved firm-level factors, the evidence is consistent with the hypothesis that contracting complementarity is an important driver of vertical integration choices. The resulting, building on the Athey-Stern framework, suggest that contracting complementarity may be particularly important when coordination is important to achieve but difficult to monitor.

In a follow-on paper, *How Does Outsourcing Affect Performance Dynamics? Evidence from the Auto Industry* (with Sharon Novak, *Management Science*, 2008 **[3]**), we examine the dynamic performance implications of vertical integration over the automobile product development lifecycle. Building on recent work in organizational economics and strategy, we evaluate the relationship between vertical integration and different performance margins. Outsourcing facilitates access to cutting-edge technology and the use of high-powered performance contracts. Vertical integration allows firms to adapt to unforeseen contingencies and customer feedback, maintain more balanced incentives over the lifecycle, and develop firm-specific capabilities over time. Together, these effects highlight a crucial tradeoff: while outsourcing is associated with higher levels of *initial* performance, vertical integration will be associated with performance *improvement* over the product lifecycle. Using the same detailed data from the luxury automobile segment, and employing an instrumental variables procedure building on **[2]**, we establish three key results. First, initial performance is declining in the level of vertical integration. Second, the level of performance improvement is significantly increasing in the level of vertical integration. Finally, the impact of vertical integration on alternative performance margins is mediated by the level of pre-existing capabilities, by the salience of opportunities to access external technology leaders, and by the scope for learning over the product lifecycle. Together, the findings highlight a strategic governance tradeoff between short-term performance and the evolution of firm capabilities.

Finally, Athey and I have explored these concerns, and service-sector productivity measurement more generally, in a series of papers examining the adoption and productivity of technology and job design in emergency response systems, or "911 systems." During the 1990s, many 911 systems adopted "Enhanced 911" (E911), where information technology is used to link automatic caller identification to a database of address and location information and potentially increase the timeliness and precision of emergency response. As well, we evaluate the impact of a (potentially complementary) job design practice, "Emergency Medical

Dispatching" (EMD), where call-takers gather medical information, provide medical instructions over the telephone, and prioritize the allocation of ambulance and paramedic services. To the extent that the productivity of 911 systems, in terms of timeliness, precision, and emergency outcomes, depends on the adoption of this advanced information technology and job design, this setting is useful both for evaluating the productivity of technology and job design and for exploring the impact of alternative methodological approaches on service-sector productivity measurement. Building on two somewhat exploratory papers (*The Adoption and Impact of Advanced Emergency Response Systems,* in *The Changing Hospital Industry: Comparing Not-for-Profit and For-Profit Institutions*, 1999 **[36]**, and *Information Technology and Training in Emergency Call Centers, IRRA Papers and Proceedings*, 1999 **[33]**), *The Impact of Information Technology of Emergency Health Care Outcomes, RAND Journal of Economics*, 2002 **[10]**, provides a systematic evaluation of the returns to E911 and EMD in the context of a panel dataset of Pennsylvania counties during 1994-1996, during which time almost half of the 67 counties experienced a change in technology. We measure productivity using an index of health status of cardiac patients at the time of ambulance arrival, where the index should be improved by timely response. We also consider the direct effect of E911 on several patient outcomes, including mortality within the first hours following the incident and the total hospital charges incurred by the patient. Our main findings are that (a) E911 significantly increases the survival rates for patients with cardiac diagnoses, (b) EMD has no measurable impact on survival and (c) the interaction between EMD and E911 does not have a significant impact in determining outcomes (that is, they are neither substitutes nor complements). Throughout these three papers, we pay careful attention to the process and incentives for adoption by counties within our samples. For example, in our most recent paper, we base our estimates on a differences-on-differences estimator (thus relying only on time-series variation in mortality) but also check that the counties who adopt during our sample are likely to be representative of all potential adoptors (e.g., by comparing their benefits to those counties who adopted prior to the sample and those who adopt after our sample period and by evaluating several questions gathered from a survey of 911 coordinators throughout Pennsylvania).[7]

The Drivers of Regional and National Innovative Productivity and Economic Growth

While the bulk of my research in the economics of innovation focuses on microeconomic phenomena, my final research stream addresses the determinants of the economywide level of technological innovation and the impact of innovation on economic growth. My interest and approach towards these issues is reflected, first, in two papers completed in graduate school. In (*Urban Productivity and Factor Growth in the Late 19th Century*, joint with Raphael Bostic and Joshua Gans, *Journal of Urban Economics,* 1997 **[17]**), we investigate the role of geographic externalities and cross-regional spillovers in determining the rate of urban productivity and factor growth between 1880-1890 in the United States. As well, Gavin Wright and I completed a preliminary exploration of the sources and consequences of research intensity in specific industrial sectors throughout the economy (*Assessing America's Research-Intensive Sector*).

This research serves as a foundation for the approach in my joint research with Michael Porter, Jeff Furman and Joshua Gans in understanding the sources of differences in R&D productivity across advanced economies. In *The Determinants of National Innovative Capacity*, (joint with Porter and Furman, *Research Policy*, 2002 **[11]**) and *Innovation: Location Matters*, (joint with Porter, *Sloan Management Review*, 2001

---

[7] The determinants of technology adoption are further explored in my work with Manuel Trajtenberg on the diffusion of pharmaceutical products, in two papers. In *Empirical Implications of Physician Authority in Pharmaceutical Decisionmaking* **[56]**), we examine the role of physician authority over pharmaceutical prescribing, and analyze differences among physicians in terms of their sensitivity to patient heterogeneity. In a related, more methodological paper (*Patient Welfare and Patient Compliance: An Empirical Framework For Measuring the Benefits from Pharmaceutical Innovation,* in *Medical Care Output and Productivity* and joint with both Manuel Trajtenberg and Paul Ellickson **[32]**), we extend our analysis of the divergence between physician and patient incentives and suggest that the measurement of patient welfare from new drugs requires an analysis that separately disentangles physician choice behavior from patient choice, with the suggestion of examining compliance behavior.

[12]), we propose a novel framework for understanding economywide R&D productivity. National innovative capacity depends on the strength of a nation's common innovation infrastructure (cross-cutting factors which contribute broadly to innovativeness throughout the economy), the environment for innovation in its leading industrial clusters, and the strength of linkages between these two areas. We use this framework to guide our empirical exploration into the determinants of country-level R&D productivity, specifically examining the relationship between international patenting (patenting by foreign countries in the United States) and variables associated with the national innovative capacity framework. While acknowledging important measurement issues arising from the use of patent data, we find that (a) the patents production function is surprisingly well-characterized by a small number of relatively nuanced variables (including aggregate policy choices such as the extent of IP protection and openness to international trade and measures of the composition of research and the concentration of technological activity) and (b) there has been substantial *convergence* in the level of national innovative capacity across the OECD over the past 35 years.[8]

More recently, I have extended these broader regional studies to consider the geography of innovation and the role of cluster-driven agglomeration economies in economic growth. In *Clusters, Convergence and Economic Performance* (joint with Michael Porter and Mercedes Delgado, mimeo **[45]),** we evaluate the role of regional cluster composition in the economic performance of industries, clusters and regions. On the one hand, diminishing returns to specialization within a location can result in a convergence effect: the growth rate of a narrowly defined industry within a region may be declining in the level of activity of that industry. At the same time, positive spillovers across complementary economic activities provide an impetus for agglomeration: the growth rate of a narrowly defined industry within a region may be increasing in the size and strength of related economic sectors. Building on Porter (1998, 2001), we develop a systematic empirical framework to identify the role of regional clusters – closely related and complementary industries operating within a particular region. Specifically, the industry growth rate within a region will be increasing in the strength of the regional cluster within which that industry operates, the strength of closely related clusters, and the strength of clusters in adjacent regions. We exploit newly available panel data from the US Cluster Mapping Project to disentangle the impact of convergence at the region-industry level from agglomeration within and across related clusters. Specifically, our findings suggest that, after controlling for the impact of convergence at the most narrow unit of analysis, there is significant evidence for cluster-driven agglomeration: (a) industries participating in a strong cluster are associated with higher employment and patenting growth, (b) industry and cluster level growth increases with the presence of linked clusters in the region, and (c) industry and cluster level growth increase with the presence of strong similar clusters in adjacent regions. Overall, these findings suggest the presence of cluster-driven agglomeration effects and

---

[8] This research stream has also resulted in a "best paper in proceedings" publication at the Academy of Management annual meetings (*Understanding the Drivers of National Innovative Capacity*, 2000 (joint with Furman and Porter) **[19]**) as well as several non-refereed publications which summarize this framework and apply it to specific (often policy-related) contexts. These publications include a chapter co-authored with Porter in several editions of the in the Global Competitiveness Report **[28, 30, and 31]**, *The New Challenge to America's Prosperity: Findings from the Innovation Index*, with Porter **[39]**, *Assessing Australia's Innovative Capacity in the 21st Century,* with Gans **[38]**, *Understanding the Determinants of National Innovative Capacity: Implications for Central European Economies*, with Furman [35]*;* and *The Drivers of National Innovative Capacity: Implications for Spain and Latin America*, (with Furman and Porter **[34]**). We have also linked this approach more precisely to some of the central questions with ideas-driven growth theory. In *Measuring the 'Ideas' Production Function: Evidence from International Patent Output*, joint with Porter **[55]**, we exploit variation in international patenting and resource expenditures on innovation to estimate the parameters of the "ideas" production function central to recent models of innovation-driven economic growth (Romer, 1990). We find that (a) country-level R&D productivity increases proportionally with the stock of ideas already discovered, a key parametric restriction associated with the Romer model of ideas-driven growth (Romer, 1990; Jones, 1995) but (b) ideas productivity in a given country is constant or declining in the worldwide stock of ideas. In addition to the published work in this area, this framework has been presented and recognized in a wide variety of public policy settings.

highlight the role of regional clusters in economic performance.[9]

Future Research Plans

My future research agenda focuses on two overarching goals.

First, I plan to continue my research on the interaction between scientific norms and commercial research incentives in the process of cumulative research. I am currently completing a handbook chapter with Nate Rosenberg synthesizing the disparate and subtle literature on the endogeneity of science and scientific research to economic incentives and institutions. On a more methodological perspective, I have received a 3-year NSF Science of Science Policy grant (along with Jeff Furman and Fiona Murray) to extend our empirical research in this area to investigate the impact of science policy and institutions on the rate and direction of scientific discovery. Among other projects, we are currently working on projects related to the geography of stem cell discovery (exploiting numerous policy shifts in this area over time), as well as follow-on projects examining the role of openness and formal IPR on the creation and diffusion of scientific and commercially relevant knowledge.

Second, building on my research related to the role for "markets for ideas," Joshua Gans and I plan to continue research which will ultimately result in a synthesis book in this field. Specifically, while most of our prior research has focused on the specific interaction between entrepreneurs and more established firms, we believe that the role of the commercialization environment also governs the nature of strategic interaction between established firms (and even perhaps among a group of start-up innovators). As well, our most recent research suggests linkages between our focus on technology entrepreneurship and the conditions supporting openness and disclosure in different environment. Our agenda is therefore focused on the development of a theoretically robust and empirically testable framework for evaluating commercialization strategy more generally, with particular focus on the distinctive drivers of strategy and performance in science-based industries.

Finally, along with Mike Porter, I am extending my prior research on the development of more rigorous indices for evaluating innovative capacity and competitiveness to assist with an overhaul of the competitiveness rankings published in the *Global Competitiveness Report*. We have already produced a short article outlining our methodology, and plan to introduce the revised index in 2009.

<u>Teaching and Service</u>

MBA Teaching

Since arriving at Kellogg in 2001, I have taught several sections per year of MGMT 463, Management of Technology. This course provides a strategy framework -- drawing upon the economics of technical change - for high-technology businesses. The emphasis is on the development and application of conceptual models clarifying the interactions between competition, patterns of technological and market change, and the structure and development of internal firm capabilities. The aim of this course is to provide a solid foundation for students interested in managing innovation in high-technology industries. The course teaches you (a) how to ask the right questions about high-technology markets and organizations, (b) analyze the structure and develop strategies for these markets, and (c) link analysis and strategy development to technology and innovation management. Working with Shane Greenstein to develop materials and cases for the class, the class attracts a large number of students per year and has

[9] Along with Alicia Loffler, I have also written a chapter for a recent National Academies volume drawing on the economics of clusters to evaluate the geography of innovation within the biotechnology industry (*The Globalization of Biotechnology: Science-Driven Clusters in a Flat World* **[24]**).

consistently received strong student course and professor evaluation scores. It is useful to note that MGMT 463 builds on my prior MBA teaching experience at MIT Sloan School, where I taught Introduction to Technological Innovation Management and Technology Strategy.

Doctoral Course Development

Since 2005, I have taught the second course of the econometrics sequence for the first-year Kellogg doctoral students. I teach Applied Econometrics II, which focuses on providing a structured approach towards the development of a practical yet rigorous econometrics toolkit for use in doctoral business school research in fields such as applied economics and strategy, marketing, finance, and accounting. The course develops the behavioral and statistical foundations of econometric approaches to testing causal models of individual, firm, and market behavior. The course aims to provide students with a specific and systematic approach for assessing the plausibility (and limitations) of causal inference. This includes assessing the role of a behavioral model in the formulation of an econometric model, accounting for the potential impact of unobservables on estimation and inference, and evaluating behavioral and statistical sources of identification. A syllabus for this course is available on request.

Service

Along with my research and teaching activities, I am a co-director (along with Josh Lerner) of the NBER *Innovation Policy and the Economy* Working Group. In addition to arranging several research-oriented meetings, we founded and now publish an annual volume based on accessible research presentations at an annual policy-oriented conference in Washington each April. We also host a postdoctoral IPE Fellow each year at the NBER, and run a small research grant competition. In its 10th year, the IPE program has received significant funding from the Kauffman Foundation.

I have also contributed to a number of policy-oriented publications and forums. From 2001-2003, I served as a Non-Resident Senior Fellow at the Brookings Institution, and have participated in a wide variety of public policy conferences, both domestically and abroad. I have served on several policy committees, including serving as a committee member on the National Academy of Science committee on *The Future of Supercomputing*. I have also contributed several chapters to National Academies volumes, including *Intellectual Property in the Knowledge-Based Economy* and the *Globalization of Innovation*. I have made numerous presentations to policy forums, including testimony to the President's Committee on Advancement of Science and Technology and the House Science Committee. Most recently, I have been involved in a range of meetings to develop the "science of science policy," an NSF and NIH initiative to bring more rigorous research evaluation and assessment tools to policy and funding of research and innovation.

I also serve (or have served) as an Associate Editor on a number of editorial boards, including *Management Scicence*, the *Journal of Industrial Economics*, the *International Journal of Industrial Organization*, and the *Journal of Business and Economic Statistics*. I have also served as a Contributing Editor of the *Antitrust Law Journal*, and the co-Guest Editor for a Special Issue of the *Journal of Economic Behavior and Organization.* I am currently the guest editor for a special issue of the *Journal of Economics and Management Strategy*. I have also served on a number of program committees, including the International Industrial Organization Conference and FTC Microeconomics Conference, and serve on the Managing Board of the International Schumpeter Society.

Within Northwestern, I am currently serving as a Senior Fellow of the Searle Center for Law, Regulation and Economic Growth, which involves significant involvement and participation in Searle symposia and conferences. I have also served within Kellogg as the Research Director of the Kellogg Biotechnology Center (through September, 2008) and as a member of the Student Affairs and Activities Committee. Within the Management and Strategy Department, I have served on the Junior Recruiting Committee (2001-2002) and the Senior Recruting Committee (2008), as well as numerous departmental ad hoc committees.

I am also the convenor (along with Yael Hochberg) of the Interdepartmental Entrepreneurship and Innovation seminar, which we initiated in 2005.

I have also served on the board of the student-run *Kellogg Biotechnology Review*, and participate in a number of student conferences, including the Kellogg Biotechnology Conference, the Digital Frontier Conference, and others. I have also served as an advisor to numerous doctoral students, both as principal and as a committee member.

As an NBER Research Associate, I have participated in numerous NBER conferences as a discussant, speaker and co-organizer of the NBER Universities Research Conference on Competition and Organization in Technology-Intensive Industries. During my time at MIT, my main service interactions were with doctoral students, serving as the MTI Coordinator of Doctoral Admissions (1996, 1997, 1998) and as a Sloan Undergraduate Advisor. In addition, I have participated as a discussant or speaker in numerous other conferences as well, including the annual ASSA, Academy of Management, and INFORMS meetings. Finally, I act as a regular reviewer for a variety of journals in both economics as well as technology management, including *American Economic Review*, *Quarterly Journal of Economics, Journal of Political Economy, Review of Economic Studies*, *Review of Economics and Statistics*, *Rand Journal of Economics*, *Management Science, Journal of Economics and Management Strategy*, and *Research Policy*.

References
Arrow, K. (1962). "Economic Welfare and the Allocation of Resources for Invention." *The Rate and Direction of Inventive Activity*, ed. R. Nelson, Princeton Univ. Press, Princeton (NJ), pp. 609-625.

Berry, S. (1994). "Estimating Discrete-Choice Models of Product Differentiation," *RAND Journal of Economics,* 25(2): 242-262.

Berry, S., Levinsohn, J. and A. Pakes (1995), "Automobile Prices in Market Equilibrium," Econometrica, Vol. 63, No. 4, July, pp. 841-890.

Christensen, C. (1997). *The Innovator's Dilemma,* Harvard Business School Press.

Dasgupta, P. and P. David (1994). "Towards a New Economics of Science," *Research Policy*. 23(5), pp. 487-521.

Henderson, R. and K. Clark (1990). "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms," *Administrative Science Quarterly*.

Henderson, R. and I. Cockburn (1994). "Measuring Competence? Exploring Firm Effects in Drug Discovery," *Strategic Management Journal* Winter Special Issue, 15: 63-84.

Jones, C. (1995) "R&D Based Models of Economic Growth," *Journal of Political Economy*, 103, 739-784.

Nelson, R. (1959). "The Simple Economics of Basic Scientific Research," *Journal of Political Economy,* 67(2), pp. 297-306.

Romer, P. (1990). "Endogenous Technological Change," *Journal of Political Economy* 98: S71-102.

Teece, D. (1987). "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy," *The Competitive Challenge* Ballinger. pp. 195-220.