THE JOURNAL OF FINANCE • VOL. LVII, NO. 2 • APRIL 2002

Where Does *State Street* Lead? A First Look at Finance Patents, 1971 to 2000

JOSH LERNER*

ABSTRACT

This paper empirically examines patents for financial formulas and methods, whose patentability was recently confirmed in the litigation between State Street Bank and Trust and Signature Financial Group. The number of such filings and awards has been accelerating. Patent filings by academics have been very infrequent, which appears to be a consequence of a lack of awareness or interest on the part of faculty members, rather than any fundamental unsuitability of their research for patenting. The failure to cite academic research in this area appears to be problematic and may reflect patent examiners' limited exposure to finance research and patents.

PATENTS FOR FINANCIAL FORMULAS and methods, which have been awarded by the U.S. Patent and Trademark Office (USPTO) since at least the early 1970s, have become increasingly frequent in recent years. Interest in these awards has surged since a 1998 decision in a lawsuit between Signature Financial Group and State Street Bank, which established the patentability of financial and other business methods.[1] This paper takes a comprehensive look at financial patenting, in an effort to understand this growing area of activity and its implications for academia.

The analysis proceeds in four parts. The first part documents two basic facts about finance patenting. First, numerous financial patents have been issued—through February 2000, 445 awards—and the number of applications and grants has been accelerating. Second, the involvement of academics and universities in patenting finance has been modest: universities and their affiliates have patented only four inventions. University patenting per faculty member is far less than in other scientific disciplines.

The next sections explore two explanations for the paucity of academic patenting in finance. The first alternative is that academic work is fundamentally different from the type of work being patented. A survey of patent

* Harvard University and National Bureau of Economic Research. Jim Hirabayashi, Adam Jaffe, Sam Kortum, and Brigid Quinn provided data or assistance in accessing data. Steve Bauer, Phelim Boyle, Richard Green, J. B. Heaton, Mark Lemley, Robert Merton, Robert Merges, Frank Morris, Sam Petuchowshi, Cecil Quillen, Jean Tirole, Peter Tufano, Rosemarie Ziedonis, an anonymous referee, and seminar participants at Harvard, MIT, and Wharton made helpful suggestions. Chris Allen, Regina Grebla, Rajiv Shukla, Matt Thompson, and especially Trang Tran provided research assistance. Harvard Business School's Division of Research provided financial support. All errors are my own.

[1] As discussed in the conclusion of this paper, important questions still surround the validity of business method patents. It is likely to take a number of years before the ambiguities around the nature and use of these patents are resolved.

attorneys, however, reveals that they believe that a number of recent academic finance articles contain patentable subject matter. An examination of issued finance patents shows that a significant minority has academic research as prior art (whether cited or not). Finally, the investment banks that have been most active in patenting appear to have academic ties, although this result is weaker than the others. All these findings suggest that academic research is indeed suitable for patenting.

A second explanation is that the absence of academic patents is due to a lack of awareness or interest on the part of faculty members. To assess this possibility, I examine academic patenting behavior, on both a department and faculty member level. The size, productivity, and academic ranking of the department have little explanatory power. Rather, the only consistently significant explanatory variable is the number of patents awarded to the university in other areas, which is likely to be associated with an established university technology transfer office. In the faculty member regressions, age and major journal publications have little explanatory power. Rather, only the faculty member's book authorship and (in one regression) self-described consulting activities are significant. The analyses suggest that the faculties' awareness of the policy changes and orientation toward outside activities are important determinants of academic patenting.

The final analysis examines the extent to which academic prior art was considered in finance patents. First, I examine in depth two finance patents. I then tabulate citations to academic research more generally in finance patents and highlight their infrequency. Finally, I show that compared to other technological areas where academics have patented, academic papers are far less likely to be cited in the finance awards. The comparisons suggest that this disparity may be due to the background of the examiners, rather than the process through which the patents are examined. Examiners of finance patents have less experience in examining related patents and are less likely to have a doctorate in a related area. While not conclusive, these analyses serve to raise concerns about the citation of academic research in these patents.

This paper is related to two strands of research about financial innovation more generally. First, a number of largely descriptive papers have sought to understand the determinants of financial innovation. Several studies of financial innovations suggest that academic research plays an important role in stimulating financial innovation, although not as critical as tax policy and regulatory changes. Van Horne (1985), for instance, concludes that academic research was an important stimulant for 25 percent of the major new financial products between 1978 and 1984. Faulhaber and Baumol (1988), however, conclude that academic discoveries frequently take an extended time to be used by finance practitioners. The case studies that they examine highlight the extent to which management inertia and the difficulty of displacing incumbent financial intermediaries delay the diffusion of innovations.

A second strand in this literature has examined the diffusion of financial innovations across firms. Theoretical models of financial innovation (e.g., Bhattacharyya and Nanda (1997), Persons and Warther (1997)) have generally

assumed that new financial products will diffuse rapidly to rivals. This assumption reflects the historical patterns: Tufano (1989) has highlighted the rapidity with which financial innovations by one firm are imitated by competitors. With the exception of Herrera and Schroth (2000),[2] however, no academic finance papers of which the author is aware have previously considered the impact of financial patents from a theoretical or empirical perspective.

The plan of this paper is as follows. Section I provides a brief historical overview. The data are described in Section II. Section III presents the analysis, and the final section concludes the paper.

I. Background

There has long been ambiguity about the patentability of financial discoveries in the United States. At least since a 1908 court decision that established the "business methods exception," many judges and lawyers have presumed that business methods were not patentable subject matter. While the USPTO has issued patents on financial and other business methods for several decades, many observers questioned their validity. Consequently, awardees were reluctant to incur the time and expense to litigate their awards.

Attitudes toward business method patents changed with the July 1998 appellate decision in *State Street Bank and Trust v. Signature Financial Group*. This case had originated with a software program used to determine the value of mutual funds, on which Signature had obtained a patent in 1993. State Street Bank sued to have the patent invalidated on the grounds that it covered a business method and was hence not patentable. While State Street's argument prevailed in the district court, the Court of Appeals for the Federal Circuit, the centralized appellate court for patent cases, reversed the finding. In its decision, the court explicitly rejected the notion of a "business method exception." The Supreme Court declined to hear State Street's appeal of the appellate decision in January 1999.

In the numerous articles in the trade press that followed the two decisions, the case was interpreted as unambiguously establishing the patentability of business methods. Even if the Supreme Court revisits the question of the patentability of business methods, many commentators believe that a November 1999 law, which explicitly recognizes these patents, will limit its ability to undo this shift.[3]

[2] These authors consider why financial institutions are willing to invest in developing innovations in the absence of patent protection. They hypothesize that rivals cannot exactly duplicate new financial innovations costlessly: the very process of developing the product produces an informational advantage for the innovator. They argue that their model can explain many of the empirical patterns identified by Tufano (1989).

[3] It should be noted that few foreign countries, with the notable exception of Japan, allow these patents. Past policy shifts by the United States, however, have often eventually been emulated by foreign patent offices.

II. The Sample

To identify financial patents, I employed the U.S. patent classification scheme. Each patent is assigned at the time of its award to one or more of approximately 100,000 patent classes. The USPTO updates these assignments as new patent subclasses are created. I used all patents assigned as of March 2000 to the following subclasses of class 705, "Data Processing: Financial, Business Practice, Management, or Cost/Price Determination":

- 705/35: Finance (e.g., banking, investment, or credit);
- 705/36: Portfolio selection, planning, or analysis;
- 705/37: Trading, matching, or bidding;
- 705/38: Credit (risk) processing or loan processing (e.g., mortgages).

I did not include subclasses 705/39 through 705/45, which focus on bank back office operations (e.g., ATM networks, remote banking, and electronic funds transfer). I also employed some, but not all, of the patents assigned to one subclass:

- 705/4: Insurance (e.g., computer implemented systems or methods for writing insurance policies, processing insurance claims, etc.).

Many of the patents in this subclass have little relationship to finance. Therefore, I reviewed the abstracts of these patents, and identified those related to the calculation of annuity rates, the investment of insurance company assets, the management of risk through financial instruments, and related topics.

Using the USPTO's web site (http://www.uspto.gov/patft/index.html) and the Delphion (formerly IBM) Intellectual Property Network (http://www.delphion.com), I identified 445 financial patents awarded from January 1971 to the end of February 2000.[4] I also collected a variety of other information from the database: the name of the inventor, the assignee (the entity to which the patent is assigned at the time of its award), the application and award dates, and the prior art cited by the patent.

In the final analysis in this paper, I explore how the processing of finance patent applications differs from those in other academic-related fields. By comparing the treatment of finance patents with those in other fields related to academia, I hope to discern to what extent the concerns about finance patents are unique or reflect more general difficulties with patents

[4] Patents awarded before 1971 were not available in electronic form. Because financial patents were not given a distinct subclass until much later, it was exceedingly difficult to identify the earlier awards. These databases did not contain information on U.S. patent applications that have not yet issued, since all filings before November 2000 were held confidential in the United States until they were awarded. A spreadsheet summarizing these patents, along with additional descriptive material about business method patents, is available at http://www.people.hbs.edu/jlerner/publications.html.

in areas close to the academic frontier. To explore this question, I employ information from the patent folders maintained by the USPTO. These folders were time consuming to retrieve and difficult to work with. (In fact, they have not been used hitherto in academic research.) As a result, I did not examine the folders of all 445 awards, but rather only a random sample of 100 of the awards.

For the same reason, I chose to examine only a subset of the patent awards in other academic-related areas. To this end, I created two random sets of 100 patents that were awarded in other such areas. I then compared the 100 finance patents to each of the sets of 100 matching patents. I followed different methodologies to create the two sets of matching patents to limit concerns that the results were an artifact of the particular matching process employed.

As discussed below, very few of the finance patents were assigned to universities, government agencies, or nonprofits. Awards to such parties were much more frequent in other academic-related fields. In comparing the finance patents to those in other academic-related arenas, I did not wish to introduce differences solely due to the nature of the applicants. Thus, in constructing the two matching samples, I restricted them to awards to corporations and individuals.

The first sample was created following the methodology of Jaffe, Henderson, and Trajtenberg (1993). (These authors had grappled with a similar problem: creating a sample of corporate patents that were in the same technology classes and of the same maturity as a set of awards to universities.) I first chose a random sample of 100 patents in areas other than finance that were awarded to U.S. universities between January 1971 and February 2000. I then chose the nearest patent (the one with the closest patent number) assigned to the same patent subclass and awarded to a corporation or an individual. This procedure led to a sample of 100 patents in academic-related topics.

My second approach also generated a sample of 100 academic-related patents not assigned to universities. I simply focused on the 10 patent classes where universities have been most active patentees. I selected 10 patents from each of the 10 patent classes where patents were most frequently awarded to universities,[5] matching the award date of each one as closely as possible to one of the 100 random finance patents. I only selected awards to individuals or corporations.

I collected a variety of supplemental information about the 100 random finance patents and the two sets of 100 nonfinance patents. These included the name and background of the patent examiner, the history of the patent application, and the details of the examination process. This information was taken from the Delphion and USPTO web sites and the patent files themselves, which were reviewed in the USPTO's Patent File Room.

[5] These were tabulated in National Science Board (2000). The technologies encompassed chemistry, energy, instrumentation, microbiology, and surgery.

III. Analysis

In this analysis, I sought to answer four questions:

- What have been the basic patterns in finance patenting?
- Is the paucity of patenting by finance academicians a consequence of the topics considered by academic finance?
- Is the paucity of patenting by finance academicians a consequence of a lack of knowledge or interest by faculty members?
- Are the contributions of academic finance being cited in the patent awards?

As discussed below, this list did not exhaust the important issues related to finance patents. These were, however, the questions for which the data allowed me to formulate at least preliminary answers.

A. What Were the Basic Patterns?

Before seeking to understand *why* the distribution of financial patents has arisen, I first considered the basic patterns in these awards. Two patterns stood out: the dramatic increase in activity and the small share of awards going to academic institutions.

The most fundamental pattern—the acceleration in the number of patent awards—is depicted in Figure 1. In no year prior to 1997 were more than 25 financial patents awarded. The number of awards then climbed to 33 in 1997, 88 in 1998, and 145 in 1999. If the pace set in the first two months of 2000 was sustained, there would have been 222 patent awards in that year.

The figure depicts only five successful patent applications in 1999 not because these were the only ones filed, but because these were the only applications to be awarded through February 2000. Exact data on still-pending financial patent applications are not available. The changing volume of applications could, however, be estimated using data about applications relating to business methods in general.[6] These tabulations were prepared for fiscal years 1996 through 1999 (the USPTO's 1999 fiscal year, for instance, runs between October 1, 1998, and September 30, 1999).

Figure 2 presents the estimated number of financial patent applications in recent years. The estimates were based on the number of business method patent applications in each year and the estimated ratio of financial patents to all business method patent grants. Because the share of business method patent grants that have been finance-related has risen over time, I estimated the ratio in two ways. First, I assumed that their share of business method applications was constant and equal to their share over the four-year period. Second, I assumed that the share of finance patents was

[6] Typically, only data on applications across all industries are released. The USPTO's Office of Public Affairs compiled these data in response to the intense public interest in business method patents. The totals included all patents assigned to Class 705.

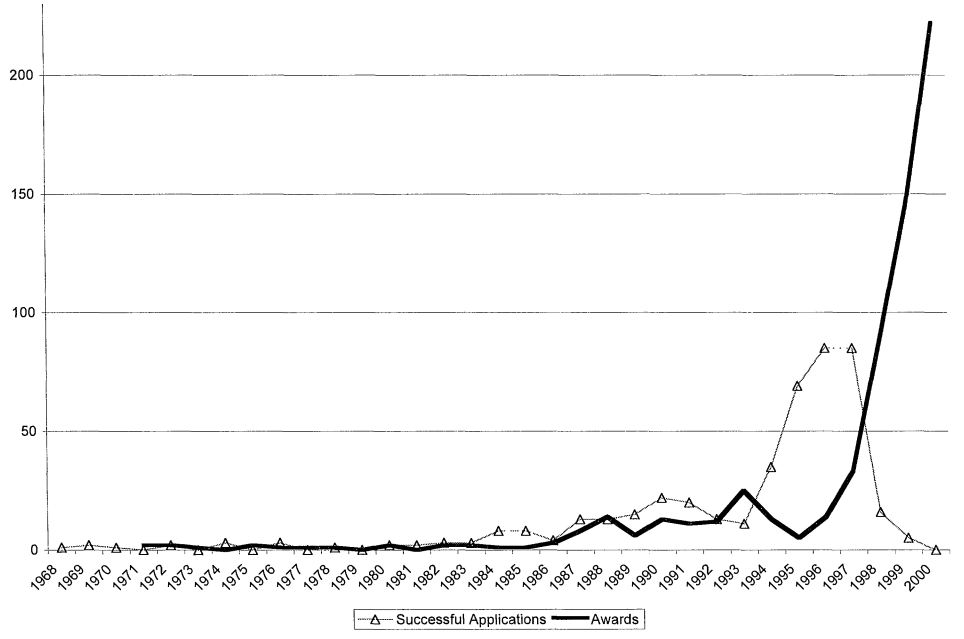

Figure 1. The number of U.S. financial patent awards and successful applications, by year. The number of awards for 2000 is imputed based on awards by the U.S. Patent and Trademark Office through the end of February 2000. The number of successful applications is based only on patents awarded through February 2000.

increasing (as the data suggests). In particular, I set the finance-related share of applications equal to these patents' share of business method awards two years later (reflecting the approximate time that the applications took to be processed).[7]

Both methods suggested that patent applications have been climbing sharply since the *State Street* decision. Assuming a constant share of business method patents, the number of finance applications increased nearly threefold between the 1997 and 1999 fiscal years. Assuming a linear trend in the finance patents' share, the increase during this period was more than fourfold. These projections suggested that the number of awards would continue to grow in future years. Implicit in these projections was the assumption that the USPTO's examination practices for business method patents would remain relatively constant, which, as will be discussed later, may or may not be the case.

[7] To project the share of applications that were finance related in the 1998 and 1999 fiscal years, I assumed that the percentage would follow a linear trend. Given the small number of observations, the projection was very noisy.

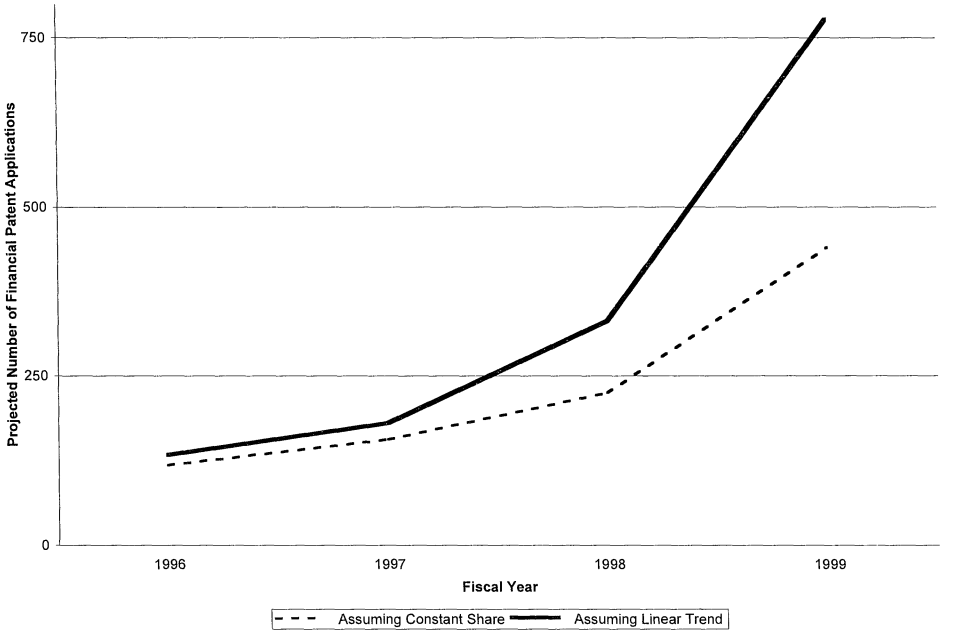

Figure 2. The estimated number of financial patent applications, by year. All estimates are based on U.S. Patent and Trademark Office statistics. The dotted line assumes that financial patents' share of business method patent applications remained constant (at their average share of business method patent awards between 1996 and 1999); the solid line assumes that the financial patents' share followed the trend seen in patent awards between 1996 and 1999.

The second basic pattern was the composition of the awardees. Panel A of Table I presents a breakdown of the entities to which the patents were assigned. The two recipients of the most patents, Merrill Lynch and Citigroup, were not surprising: Both were large, diversified financial services organizations with a long history of new product development. The rest of the list, however, was more diverse. The list included many computing equipment manufacturers such as Hitachi and International Business Machines. It also included some groups that are specializing in compiling large numbers of business method patents, such as Walker Asset Management, the majority owner of Priceline.com and other entities.

Panel B presents the overall distribution of awards and compares them to the distribution of all patents awarded in 1998 (the most recent calendar year for which data were available). A disproportionately large number of patents were awarded to individuals and to U.S. corporations. The role of non-U.S.-based corporations in financial patenting to date was modest relative to patenting across all technologies. Just four patents were awarded to universities and their affiliates. In addition, nine patents were applied for

Table I

The Distribution of Entities Assigned Financial Patents

The sample consists of 445 patents awarded by the U.S. Patent and Trademark Office between January 1971 and February 2000 classified in one of five U.S. patent subclasses (705/35, 705/36, 705/37, 705/38, and part of 705/4). Panel A presents the most frequent assignees of these patents and the number of awards each received. Companies that had merged as of March 2000 are combined in the table. Panel B presents summary information on the types of entities assigned the patent awards in the sample. The sample is compared to the distribution of all patent awards in 1998.

Panel A: Largest Patentees in the Sample

Entity	Number of Patent Awards
Merrill Lynch & Co.	16
Citigroup	14
Hitachi	10
Reuters	10
Fujitsu	9
NCR Corporation	8
Optimark Technologies	5
Casio Computer	4
General Electric	4
International Business Machines	4
Walker Asset Management	4
Cantor Fitzgerald	3
College Savings Bank	3
Financial Engines	3
Foreign Exchange Transaction Services	3
Golden 1 Credit Union	3
Huntington Bancshares	3
Sun Microsystems	3
Xerox Corporation	3

Panel B: Summary Information on Assignees of Finance and All Patents

	Finance Patent Awards		
Entity	Number	Percent	All Awards[a]
Corporations	317	71%	80%***
Domestic	258	58%	42%***
Foreign	59	13%	38%***
Individuals and family trusts	122	27%	17%***
Universities and affiliates[b]	4	1%	2%*
Government bodies	2	0%	1%

[a] Compiled from U.S. Department of Commerce (1999a) and databases posted at http://www.autm.net and http://caspar.nsf.gov/webcaspar.

[b] For the sake of comparability, the finance patent total does not include eight patents applied for by university faculty that were assigned to corporations and one that was assigned to the individual inventors.

* Significantly different from financial patents in a χ^2-test at the 10 percent confidence level; *** significantly different at the 1 percent level.

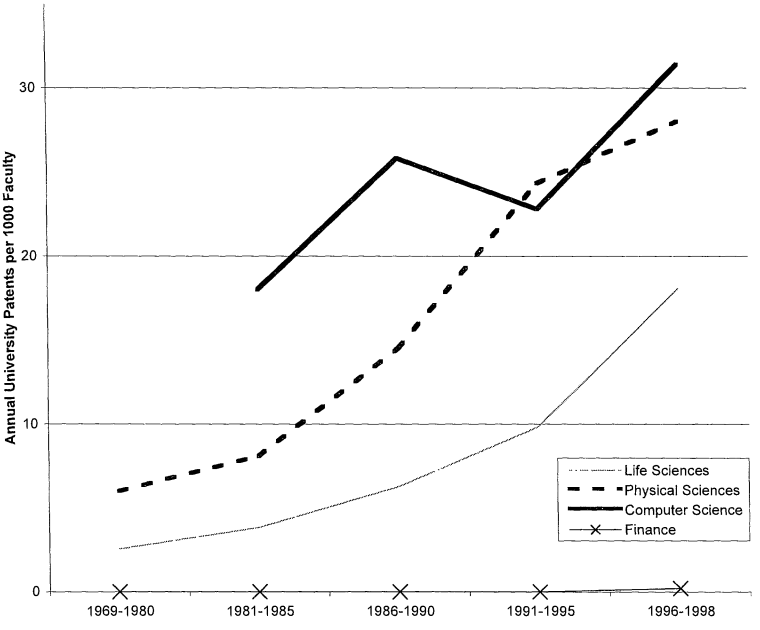

Figure 3. University-assigned patents per 1,000 faculty members, by discipline and year. The table presents the ratio of (a) the total number of patent awards by the U.S. Patent and Trademark Office assigned to U.S. universities and colleges in patent classes related to four academic disciplines to (b) the number of faculty members (in thousands) in those disciplines at U.S. universities and colleges.

by university faculty members and assigned not to their academic institutions, but rather to the companies with which they were affiliated or to the faculty as individuals.[8]

Figure 3 presents another illustration of how little involvement academic institutions have had in the patenting of financial discoveries. The figure depicts the number of patents assigned annually to academic institutions per 1,000 faculty members in four disciplines: biology, the physical sciences, computer science, and finance. (Data were compiled from National Science Board (2000) and the U.S. Department of Commerce (1999b).)

[8] Universities typically require faculty members to file a disclosure on each commercially relevant discovery that they make in the course of their teaching and research. (In some cases, this requirement is restricted to certain technological areas or to inventions that were developed as a part of the faculty member's employment.) Since the passage of the Bayh–Dole Act of 1980, universities have had the unambiguous right to then decide whether to patent these discoveries or not. If the research was federally funded and the university chooses not to file a patent, the government agency that funded the research must then be offered the right to patent it. If this offer is declined, or if the research was not federally funded, the ownership of the invention is then typically offered to the faculty member. (More complex arrangements often characterize industry-funded research.)

The figure highlights how academic patenting was much less common in finance than in the other disciplines. Even in the most recent period considered, academics in other disciplines were between 90 and 150 times more likely to patent discoveries through their university than finance academicians.[9]

B. Was Academic Research Not Patented Because of Unsuitability for Patenting?

The next two sections consider alternative explanations for the paucity of academic patenting. First, I examined the possibility that academic research was not patented because the research was unsuitable for patenting. I then considered whether these discoveries were not patented because of a lack of awareness or interest on the part of faculty members. These hypotheses were difficult to test definitively. But a variety of methodologies provided a consistent answer, in favor of the second explanation.

My first, and most direct approach, was to present academic research to legal specialists. I solicited the opinion of a practitioner who had successfully prosecuted a number of important business method and finance patents, a legal scholar who had extensively written about business method patents (and been a participant in a number of cases involving them), and a lawyer who had previously received a finance Ph.D. I asked each to review seven selected articles from the February 2000 issues of the *Journal of Finance* and *Journal of Financial Economics*. I selected the papers (from the 15 full-length articles in these issues) that developed new theoretical models or empirical methodologies, rather than those that applied existing econometric tools to new data sets.

In each case, I asked the respondents to focus on the question of whether the approach and/or methodology employed in the paper met the criteria for patentable subject matter under § 101 of the patent statute. I asked them to ignore other considerations that would be important if a patent application were to be filed, such as the novelty of the approach. This decision was motivated by two considerations. First, given the fact that a patent lawyer typically spends several weeks and thousands of dollars establishing the novelty of a potential filing, undertaking a novelty search for seven discoveries would be impractical. Second, the fact that the papers were published in major finance journals suggested that there was a substantial degree of novelty.

Table II summarizes the results of the questionnaire. There appeared to be a consensus that at least three of the papers covered patentable subject

[9] This figure only depicts patents assigned to universities. Even if finance patents applied for by academics and assigned elsewhere were included, the ratio for finance would be far lower than other disciplines. It is also likely that some patents applied for by faculty members in other disciplines were assigned to companies or to them as individuals.

Table II

Opinions of Legal Experts About the Potential Patentability of Ideas Contained in Academic Articles

The table presents assessments of the patentability of the subject matter of seven articles included in the February 2000 editions of the *Journal of Finance* and *Journal of Financial Economics*. ++ denotes cases where the respondents were highly confident that the article's subject matter was patentable, + where they were somewhat confident of its patentability, 0 where they were uncertain, − where they were somewhat confident that the subject matter was not patentable, and −− where they were highly confident that it was not patentable.

Journal and Author	Survey Responses		
	Expert A	Expert B	Expert C
Journal of Finance			
Barberis (2000)	+	++	++
Pástor (2000)	++	++	++
Rajan, Servaes, and Zingales (2000)	−−	−−	0
Wilner (2000)	−−	−	0
Journal of Financial Economics			
Bakshi and Madan (2000)	+	+	++
Bertsimas, Kogan, and Lo (2000)	+	−	++
Gupta and Subrahmanyam (2000)	−−	0	++

matter: Bakshi and Madan (2000), Barberis (2000), and Pástor (2000).[10] In other cases, the assessments were negative, or else conflicting. One of the respondents went as far as to suggest language that could be used in drafting the patent claims. For instance, in the case of Barberis (2000), the suggested first claim read:

1. A method of balancing an investment portfolio that includes a plurality of assets, the method comprising:
   a. establishing risk/reward criteria for each of the plurality of assets, wherein the risk/reward criteria are functions of the investment horizon;
   b. buying and selling specified assets in such a manner as to optimize an anticipated return based on a specified risk profile and investment horizon; and
   c. repeating steps a and b on a periodic basis as to maintain the portfolio balance in accordance with the specified risk profile and investment horizon.

[10] A natural question is the validity of these assessments. When questioned on this point, the practitioners insisted that virtually all patent applications that they filed were eventually granted (though sometimes after several refilings and with narrower breadth than anticipated). These claims are corroborated by tabulations by Quillen and Webster (2001), who show that once refilings of earlier applications are accounted for, between 80 percent and 97 percent of U.S. patent applications are ultimately granted.

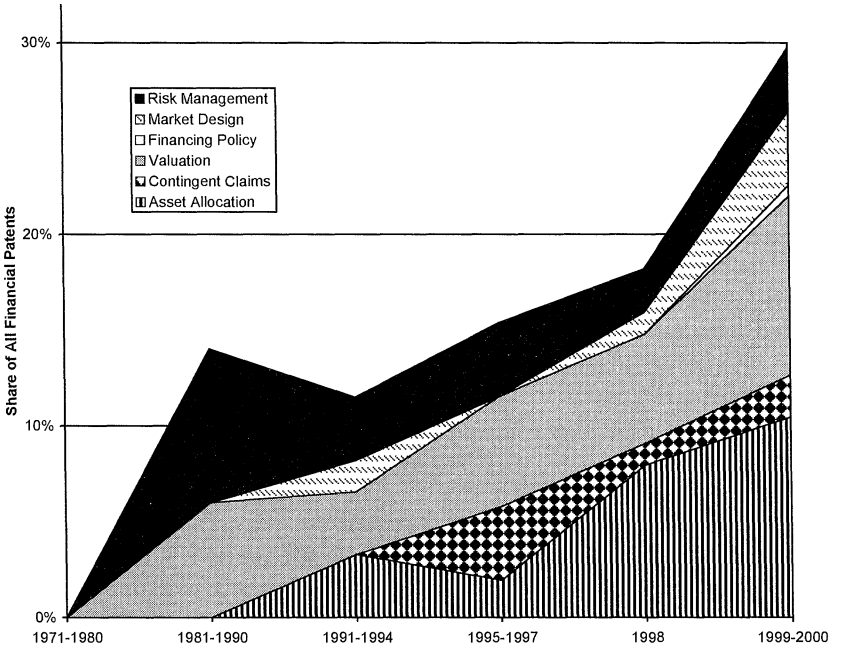

Figure 4. Share of finance patents with cited or uncited academic prior art, by year and subfield. The table presents the share of 445 finance patents awarded by the U.S. Patent and Trademark Office between 1971 and February 2000 with significant prior art in one of 15 finance journals.

The second methodological approach was to examine the finance patents that had been issued to date. In particular, I sought to ascertain in how many cases the patents drew upon academic research: more technically, whether there was relevant "prior art" in the academic literature, as well as whether it was actually cited in the patent or uncited. (As will be discussed in more detail below, patentees are required to cite all relevant patents and published material of which they are aware.)

To undertake this analysis, I examined the citations, the discussion of the prior art, and the claims in each of the 445 patents in the sample. I restricted the search of the prior art to articles in the 15 leading finance journals identified by Fishe (1998). To facilitate the searches, I used Brealey and Edwards (1991) and the EconLit database. The relevant articles fell into six classes: asset allocation, contingent claims design and valuation, financing policy, market design, risk management, and valuation (excluding contingent claims). (I had intended to employ a number of additional categories, but found no cases where they were relevant.) When a single patent had relevant articles in a number of these classifications, I gave partial credit to each category.

Figure 4 summarizes the findings. The share of all financial patents where there was relevant prior art in the academic literature increased sharply over time. In the most recent period (patents awarded between January 1999

and February 2000), this was true for nearly 30 percent of the awards. The most frequent categories were asset allocation (which had been growing particularly rapidly), risk management, and valuation.

My third approach was to examine the patenting of one well-documented class of financial institutions, investment banks, to see if linkages to the academic community were associated with a greater propensity to file finance patents. To examine this issue, I estimated a "patent production function," which sought to explain the patenting by each entity. Similar equations have been estimated for patenting by traditional manufacturing and service firms (see Griliches (1990) for an overview).

I created a panel of approximately 30 of the largest investment banks and examined the count of successful patent applications filed in three six-year periods: 1980 to 1985, 1986 to 1991, and 1992 to 1997. I used 1997 as the last year in the analysis because, as noted above, I could only observe issued U.S. patents. While many patents filed in 1998 and 1999 may ultimately issue, few have done so to date.

The investment banks were characterized by a considerable degree of exit and merger activity. Furthermore, because patents are not assigned to an institution until the time they are awarded, it was sometimes hard to determine where they originated; for example, a recently awarded patent assigned to Citigroup may have been originally applied for by an employee of Citicorp, Salomon Brothers, Smith Barney, or Travelers. I addressed this problem in two ways:

- I employed the largest firms in terms of underwriting volume in each six-year period. In particular, I took the union of the 25 largest global debt and equity issuers as compiled by Securities Data Company (SDC). Because in many cases investment banks were included on both lists, the actual sample size varied from 29 to 33.
- I undertook all calculations as if the firms were in their current configuration: for instance, I combined the patents and underwriting volume of Salomon Brothers and Smith Barney in each period.

One problem with using patent counts as the dependent variable was the implicit assumption that each patent was equal in importance. This was unlikely to be the case. In particular, extensive research (e.g., Pakes (1986)) has shown that the distribution of patent values is highly skewed. One way to address this problem was to examine the citations to the patent in subsequent patent awards. Patent citations are a powerful measure since they play an important legal role: Patent applicants must cite the relevant prior art of which they are aware in their application or risk their patents being subsequently held invalid due to "fraud on the patent office." Trajtenberg (1990) demonstrated a strong relationship between the number of patent citations received and the economic importance of a patent. As in that analysis, I assigned each patent a weight equal to one plus the number of citations received through February 2000.

One complication with using citations as a measure of importance was that the patents had different periods to be cited. While Trajtenberg (1990) analyzed a population of mature patents that had already received nearly all the citations they were likely to obtain, many of the patents in my sample were recent. To compare patents of different vintages, I constructed a "normalized" citation-based weight for each patent. To do this, I calculated the ratio between the patent's actual weight and the predicted weight. The predicted weight was the one plus expected number of citations for a patent in the same technological classification and of the same age. This normalized weight controlled for differences across time in the "propensity to cite," as well as for the impact of the truncation imposed by our lack of knowledge of citations that will occur in the future. Thus, the weight was as follows:

$$\frac{1 + \sum_{i=A}^{2000} C_i}{1 + \sum_{i=A}^{2000} P_i}, \tag{1}$$

where C_i is the actual number of citations received in year i, P_i is the predicted number of citations in year i, and A is the year of the award. I employed the set of predicted citations computed by Jaffe and Trajtenberg (1998).[11]

As independent variables, I employed:

- The volume of equity securities underwritten by the investment bank in the period, in 1999 dollars (as compiled by SDC).
- The volume of debt securities underwritten by the investment bank in the period, in 1999 dollars (as compiled by SDC).
- The investment bank's reputation among its peers on a nine-point scale (with 9.0 being the highest and 0 being the lowest), as compiled by Carter and Manaster (1990) (for the 1980 to 1986 period) and Carter, Dark, and Singh (1998) (for subsequent periods). This ranking was compiled based on the positioning of the bank in "tombstone" advertisements commemorating securities offerings.[12]
- The investment bank's research intensity. This was the most difficult measure to compile, as it was impossible to identify either the R&D expenditures or the number of researchers at the banks over an extended period of time. As a result, I employed the average share of each

[11] The predicted citations were only calculated through 1996. To estimate the expected number of citations in more recent years, I examined citations of similarly "seasoned" patents. I computed the mean number of citations that previous cohorts of similar patents received in the same year after the award.

[12] A few banks—typically foreign ones—were not included in either ranking scheme. In these cases, I used the mid-point of the rating scheme (4.5) as the ranking.

bank's employees on the editorial or advisory boards of two academic-practitioner journals—*Financial Management* and the *Journal of Portfolio Management*—over each six-year period.[13]

Table III presents the regression analyses. I first estimated a Poisson specification, reflecting the ordinal, nonnegative nature of the count of patent awards. To undertake the other estimations, I employed an ordinary least squares (OLS) specification. In particular, I estimated pooled (where each observation is treated as independent), within (with fixed effects for each organization), and between (employing the average of the dependent and independent variables for each organization) equations. In all but the final regressions, I employed heteroskedastic-consistent standard errors.

The goodness-of-fit in many of the regressions was not as high as would be desired. This may reflect the nonsystematic manner in which many organizations approached financial patenting in the pre-*State Street* era. While the measure of the bank's ties to the academic community was a crude one, it was positive and statistically significant in all regressions that did not use fixed effects. This effect disappeared, however, when fixed effects were used. The change was probably a consequence of banks' ties with the academic community changing slowly. Those investment banks that had strong connections early in the sample period, such as Goldman Sachs and Salomon Brothers, generally continued to maintain these relationships. The absence of variation over time makes it difficult to identify the effects of slowly changing regressors in the fixed-effects regression.

I can, however, ask to what extent the investment bank fixed effect is associated with the observable characteristics. I do this by first estimating the regression with dummy variables for each bank and then projecting the estimated dummy coefficients on the mean for each bank of the observable characteristics. The results of this projection tell us the "effects" of the characteristics on the dependent variables, estimated in a way that takes into account an unbiased estimate of the effect of the time-varying regressors.[14] As the final two regressions in Table III report, in each case, the estimated dummy coefficients were positively and significantly associated with the academic ties of the investment bank. An important caveat relates to the interpretation of these results: because I am unable to control

[13] This calculation was based on the composition of these boards as reported in the first issue of each year. I used as my independent variable each bank's board seats as a percentage of the total number of investment bank board seats (multiplied by 100). A bank with a board seat in two of the six years was given twice the weight as one with a seat in only one year. I counted an instance where an institution was a sponsor of a journal, but did not have a board representative, as equivalent to having one-half of a board seat.

[14] This methodology is discussed in Mundlak (1978). The coefficients for the time-varying regressors in the second-stage regression indicate the partial correlation between the bank mean for these variables and the unobserved fixed effect. Since this does not have a structural interpretation, I do not report these coefficients.

Table III

"Financial Patent Production Functions" for Investment Banks

The sample consists of observations of the union of the 25 leading investment banks in global debt and equity underwriting during three six-year time intervals (1980–1985, 1986–1991, and 1992–1997). (Observations of banks that merged through March 2000 are combined.) The dependent variable in the first four regressions consists of the number of patents applied for in the time period, awarded by the U.S. Patent and Trademark Office through February 2000, classified in one of five U.S. patent subclasses (705/35, 705/36, 705/37, 705/38, and part of 705/4), and assigned to that entity. The dependent variable is the same in the next three regressions, except that each patent is weighted by the normalized total number of citations. The independent variables are the institution's volume of debt and equity underwriting (expressed in billions of 1999 dollars), the bank's "Carter–Manaster" reputation rating (expressed on a scale of 9.0 to 0.0, with 9.0 being the most prestigious), a ranking of the institution's connection to the academic community (expressed as one hundred times its percentage share of the investment bank board seats at two academic-practitioner journals), dummies for each bank (in the within regression specification only and not reported), and (in all but the between specification) dummies for the first two time periods. The final two regressions are from the second-stage of a two-stage approach, in which either unweighted or weighted patent applications are the dependent variable in the first phase, and the fixed effects for each bank are the dependent variable in the second regression (see text). The first regression employs a Poisson specification; the others employ an ordinary least squares specification. Absolute heteroskedastistic-consistent t-statistics in brackets (except in the between specification, where absolute t-statistics are reported).

	Dependent Variable: Patent Applications				Dependent Variable: Weighted Applications			Dependent Variable: Fixed Bank Effect from First-Stage Regression	
	Poisson and Pooled	OLS Specification			OLS Specification				
		Pooled	Within	Between	Pooled	Within	Between	Applications	Weighted
Equity underwriting volume	0.005 [0.36]	−0.004 [0.17]	0.01 [0.32]	−0.02 [1.12]	0.01 [0.11]	−0.01 [0.26]	−0.02 [0.37]		
Debt underwriting volume	0.004* [1.74]	0.004 [1.25]	0.003 [0.52]	0.005** [2.12]	0.005 [0.72]	0.001 [0.05]	0.01* [1.94]		
Reputation ranking	0.33 [0.63]	−0.07* [1.76]	0.04 [0.61]	−0.07 [1.03]	−0.05 [0.35]	0.06 [0.44]	−0.27 [1.26]	−0.09 [1.19]	−0.26 [1.68]
Academic connection measure	0.07* [1.80]	0.07*** [4.49]	0.03 [0.34]	0.10*** [3.47]	0.15*** [3.90]	−0.07 [0.44]	0.14* [1.73]	0.09*** [2.89]	0.13** [2.32]
Is observation from 1980–85?	1.23 [0.83]	0.32 [1.04]	0.52 [1.40]		0.82 [0.91]	−0.32 [0.22]			
Is observation from 1986–91?	−0.17 [0.20]	−0.06 [0.34]	−0.02 [0.06]		0.07 [0.13]	−0.80 [0.59]			
Log likelihood	−47.24								
χ^2-statistic	100.82								
F-statistic		9.27	5.87	11.51	7.56	200.57	7.37	2.76	3.68
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.041	0.012
R^2		0.39	0.69	0.49	0.22	0.69	0.43	0.22	0.45
Number of observations	95	95	95	44	95	95	44	44	44

* Significant at the 10 percent confidence level; ** significant at the 5 percent level; *** significant at the 1 percent level.

in the second-stage regression for unobserved bank effects, I cannot say whether this effect is causal or due to a common correlation with the unobserved characteristics.

While each of the three analyses used a different methodology, they painted a consistent picture. The responses of the patent lawyers, the subject matter of the granted finance patents, and (more weakly) the pattern of investment bank patenting all suggested that the answer to the title question of this section was "no."

C. Was Academic Research Not Patented Because of a Lack of Awareness or Interest?

An alternative explanation is that academics did not patent finance discoveries because they were unaware of and/or indifferent to the policy change. To explore this hypothesis, I undertook two analyses. First, I examined which finance departments were generating the most patents. I then examined the propensity to patent at the faculty member level.

The first analysis addressed this question by examining which finance departments were most active in patenting. To do this, I employed a panel regression approach similar to the investment bank analysis in the previous section. The construction of the panel and the independent variables employed, however, differed somewhat. Unlike the investment banks, there was relatively little change in the set of largest and most productive finance departments over the period under study. Thus, I employed a "balanced panel," in which the 30 universities with the most active finance programs in the years before the period under study (as tabulated by Klemkosky and Tuttle (1977)) were used throughout. (I eliminated from the listing foreign universities, since a number of these were not free to undertake patent applications until very recently.)

I employed the following independent variables:

- The share of articles in major finance journals published by affiliates of the university, as reported by Niemi (1987) (for the 1980 to 1985 period), Borokhovich et al. (1995) (for the 1986 to 1991 period), and from the annual tabulations in the July issue of the *Journal of Finance* (for the most recent period).
- The number of finance faculty members in the department, as reported by Hasselback (1999) and the sources cited in the item above.
- The extent of technology transfer activities at the school as a whole, as measured by the number of successful non-finance patents applied for during each period.

Because, as noted above, in some cases, faculty members assigned patents to themselves or to a consulting firm rather than their university, I estimated these equations using the total count of successful patents applied for by the finance faculty as the dependent variable.

In the regressions in Table IV, the size and productivity of the finance faculty had little explanatory power. Rather, the only consistently significant explanatory variable was the number of nonfinancial patents being applied for by the university. An interpretation of this result was suggested in conversations with technology transfer officials at a variety of schools. At most institutions, technology transfer officers and business school faculty remained largely unaware of financial patents during this period. The exceptional technology transfer offices tended to be the largest and most sophisticated groups. In some cases, these groups sought to aggressively "market their services" (encourage patent filings) in the parts of the university that had not traditionally made patent filings (e.g., at business schools).

A complementary empirical approach was to examine the patenting by individual faculty members. I focused in on the 15 highest-ranked finance departments (identified using the average total impact factor compiled by Borokhovich et al. (1995)), because a number of small departments did not have extensive information about faculty members on their web sites. I again eliminated foreign schools.

I collected a variety of information about each faculty member:

- The location and year of his or her Ph.D. (Hasselback (1999)).
- The number of articles authored or coauthored in the four major finance journals and three most relevant economics journals identified by Fishe (1998). These publications were identified through the EconLit database.
- The number of books authored, coauthored, or edited, determined from the bibliographic information in the Harvard on-line library catalog (HOLLIS) and faculty web sites. The web sites were identified through the Worldwide Directory of Finance Faculty and Professionals,[15] the International Directory of Finance and Economics Professionals,[16] and various business school home pages.
- The area of faculty research expertise (from Hasselback (1999) and faculty web sites).
- The number of words on the faculty member's official and personal web sites discussing consulting or other outside compensated activities.

Again, I employed a Poisson specification and an OLS specification with fixed effects.

The results, presented in Table V, were weaker than those estimated at the department level. This pattern may have reflected the greater heterogeneity in the behavior of individual faculty members. The number of articles published in major journals was insignificant, and, in fact, negative in sign. Only the number of books authored and edited was consistently significant. The words about consulting on the faculty member's web page were

[15] http://www.cob.ohio-state.edu/~fin/findir/ (accessed June 15, 2000).
[16] http://welch.som.yale.edu/dir/ (accessed June 15, 2000).

Table IV

"Financial Patent Production Functions" for Academic Institutions

The sample consists of observations of 30 leading universities during three six-year time intervals (1980–1985, 1986–1991, and 1992–1997). (In the "between" specifications, the observations for each school are averaged.) The dependent variable in the first four regressions consists of the number of patents applied for in the time period, awarded by the U.S. Patent and Trademark Office through February 2000, classified in one of five U.S. patent subclasses (705/35, 705/36, 705/37, 705/38, and part of 705/4), and assigned to that entity. Patents assigned to university faculty members individually or to an entity associated with a university faculty member (who was the patentee) are included in the total. The dependent variable is the same in the final three regressions, except that each patent is weighted by the normalized total number of citations. The independent variables include the institution's share of major finance publications during the period (expressed as 100 times its percentage share), the number of finance faculty at the institution in the period, the number of non-finance patents applied for by the university in this period, dummies for each school (in the within regression specification only and not reported), and (in all but the between specification) dummies for the first two time periods. The first regression employs a Poisson specification; the others employ an ordinary least squares specification. Absolute heteroskedastistic-consistent t-statistics in brackets (except in the between specification, where absolute t-statistics are reported).

	Dependent Variable: Patent Applications				Dependent Variable: Weighted Applications		
	Poisson and Pooled	OLS Specification			OLS Specification		
		Pooled	Within	Between	Pooled	Within	Between
Finance journal share	−0.04 [0.14]	−0.02 [0.73]	−0.06 [0.89]	0.01 [0.15]	−0.06 [1.39]	−0.19 [1.54]	0.02 [0.15]
Number of finance faculty	0.06 [1.22]	0.01 [1.57]	0.05 [1.36]	0.005 [0.69]	0.01 [1.47]	0.09 [1.46]	0.003 [0.25]
Non-finance patent applications	0.004*** [3.74]	0.001*** [2.88]	0.002* [1.83]	0.001** [2.27]	0.003*** [3.10]	0.005** [2.14]	0.003*** [3.24]
Is observation from 1980–85?	−18.02*** [28.77]	−0.13 [1.40]	0.04 [0.43]		−0.18 [1.07]	0.20 [1.15]	
Is observation from 1986–91?	−16.66*** [27.73]	−0.18 [1.70]	−0.04 [0.49]		−0.31 [1.49]	−0.03 [0.15]	
Log likelihood	−17.44						
χ^2-statistic	2810.15						
F-statistic		2.19	11.30	2.28	2.53	9.21	3.93
p-value	0.000	0.083	0.000	0.103	0.051	0.000	0.019
R^2		0.21	0.47	0.21	0.24	0.49	0.31
Number of observations	90	90	90	30	90	90	30

* Significant at the 10 percent confidence level; ** significant at the 5 percent level; *** significant at the 1 percent level.

Table V

Regression Analysis of Patenting by Faculty Members

The sample consists of observations of 348 finance academics at 15 universities with leading finance departments. The dependent variable consists of the number of patents in which the faculty member was an inventor, awarded by the U.S. Patent and Trademark Office between January 1971 and February 2000, and classified in one of five U.S. patent subclasses (705/35, 705/36, 705/37, 705/38, and part of 705/4). The independent variables include dummy variables denoting whether the faculty member was a specialist in asset pricing, derivatives, international finance, or investment banking; the number of years since the faculty member received his or her terminal degree; the square of this period; the number of articles in seven leading finance and economics journals authored or coauthored by the faculty member; the number of books authored, coauthored, or edited by the faculty member; the number of words describing consulting and other outside activities on the faculty member's official and personal web sites; and (in the second specification) dummies for the school at which the faculty member is employed. The first regression employs a Poisson specification; the second employs an ordinary least squares specification. Absolute heteroskedastistic-consistent t-statistics are in brackets.

	Dependent Variable: Patent Awards	
	Poisson Specification	OLS Specification
Asset pricing specialist?	5.25*** [2.82]	0.02 [1.04]
Derivatives specialist?	1.14 [0.84]	0.01 [0.34]
International finance specialist?	1.24 [0.88]	−0.004 [0.15]
Investment banking specialist?	−13.73 [0.01]	−0.03 [0.89]
Years since terminal degree	−0.04 [0.24]	−0.002 [0.68]
(Years since terminal degree)^2	0.003 [1.03]	0.00007 [1.02]
Number of major articles	−0.08 [0.83]	−0.001 [0.53]
Number of books	0.31** [2.28]	0.01* [1.69]
Web words about consulting	0.02* [1.65]	0.0003 [0.86]
School fixed effects	No	Yes
Log likelihood	−16.61	
χ^2-statistic	22.53	
F-statistic		2.54
p-value	0.007	0.000
R^2		0.15
Number of observations	339	339

* Significant at the 10 percent confidence level; ** significant at the 5 percent level; *** significant at the 1 percent level.

associated with more patents in the Poisson specification, but the effect disappeared when fixed effects were used. Faculty members who authored books (many of which digested or popularized academic research) may have had a "real world" orientation, as may have those who publicized their consulting activities. These patterns suggested, at least tentatively, that the orientation of the faculty member, rather than his or her research productivity, determined patenting activity. The results using citation-weighted patents, while not reported, were very similar.

D. Was Academic Research Cited?

The final analysis considered the treatment of the academic literature in the patent awards. As noted above, patent applicants are not only required to cite the patented prior art that they are aware of, but also the relevant nonpatent literature. If the patent applicant does not include these references, the patent examiner is expected to add them, as they serve as the legal equivalent of property boundary markers. But in recent years, critics have argued that examiners did not adequately consider unpatented prior art when reviewing applications. I assessed this question through a variety of approaches.

The first approach was an examination of a number of academic-related finance patents identified in the course of the preparation of Figure 4. The group included a number of striking examples where highly relevant finance articles were not cited. Two awards from 1999 make illustrative "case studies."[17]

U.S. Patent no. 5884286, "Apparatus and process for executing an expirationless option transaction," was awarded to Vergil Daughtery III (1999), an individual inventor based in Americus, Georgia. The patent covered the valuation of infinitely lived call and put options. As the abstract read:

> The apparatus and process of the present invention use a computer system to receive and store data representative of a particular asset, a type of option (call or put), requested exercise price, and a multitude of other variables related to the asset. The apparatus and process then generate data representative of an expirationless option premium for use in transacting an expirationless option. (p. 1)

Only three academic articles were cited: Merton's early essay (1973) and two reprints included in *The Handbook of Financial Engineering* (Cox, Ross, and Rubinstein (1990), Smith (1990)).[18] In his discussion of the prior art, the inventor claimed that he had made an important conceptual breakthrough:

> Of importance, the common denominator among the variety of prior art systems for transacting asset-based options are that they are only capable of transacting options which expire after a certain period of "time." . . . Therefore, a need exists for an apparatus and process for transacting an option which is not dependent on "time." In other words, a need exists for a system which transacts an expirationless option. . . . More specifically, all algorithms that have been derived for generating fair

[17] A natural question is how these two case studies were selected. As in effective case studies for pedagogical purposes, these patents illustrate a general problem in a particularly stark manner.

[18] In correspondence with the author, Daughtery stated that he had disclosed additional academic works to the USPTO, but these were not cited in the final patent because the patent examiner classified them as "reviewed, but not found to be applicable."

> option premiums include a variable for "time." Such algorithms include the Black–Sholes [*sic*], Binomial Pricing, and Analytic Approximation algorithms.

This characterization of the prior art is quite problematic. The earliest explicit pricing model for a perpetual contingent claim was Samuelson (1965). The pricing of perpetual warrants was refined in Merton and Samuelson (1969), Merton (1973), and numerous subsequent papers. (Only the latter of these papers is cited in the patent, and its contribution is mischaracterized in the description of the prior art.) An explicit derivation of a trading strategy involving perpetual options was found in Black and Perold (1992).

A second example is U.S. Patent no. 5,940,810, "Estimation method and system for complex securities using low-discrepancy deterministic sequences," awarded to Joseph Traub and two colleagues (1999) and assigned to their employer, Columbia University. The patent covered the use of advanced simulation techniques to value securities. As the abstract read:

> In securities trading, in setting the initial offering price of a financial instrument, or in later revaluation as financial parameters such as interest rates may change, an estimate of the value of the instrument may be represented as a multi-dimensional integral. For evaluation of the integral, numerical integration is preferred with the integrand being sampled at deterministic points having a low-discrepancy property. The technique produces approximate values at significant computational savings and with greater reliability as compared with the Monte Carlo technique. (p. 1)

The breadth of the patent's claims, or the area to which the patentee claims ownership, was striking. The first claim was illustrative:

> A method for one of buying, holding, and selling a complex security, comprising: (i) deriving a multivariate integrand which, when integrated over a domain of integration having at least 50 dimensions, represents an estimated value of the security; (ii) calculating, by computer, integrand values at points in the domain of integration which are obtained from a low-discrepancy deterministic sequence; (iii) combining the integrand values, by computer, to approximate the estimated value; and (iv) effecting, based on the estimated value, one of buying, holding, and selling the security. (p. 16)

While the patent cited 19 articles or working papers, all but one of these was in the mathematics literature. Even here, mathematics researchers have questioned whether the patented algorithm was not a simple extension of

the previously published literature that would be obvious[19] to someone specializing in the area and hence not patentable (see the discussion in Falloon (1999)).

The only finance article cited in this patent was Nimomiya and Tezuka (1996). In actuality, the use of Monte Carlo methods in the finance literature dates back as far as Boyle (1977). Once again, the application of quasi Monte Carlo techniques might be thought of as an obvious extension of the literature. More recently, a number of working papers and articles explicitly addressed the use of quasi Monte Carlo techniques in financial applications, including Cheyette (1992), Joy, Boyle, and Tan (1994), and Tan and Boyle (1997). The Traub patent's failure to cite this work was both puzzling and problematic.

I then examined references to the major finance journals and researchers in the population of finance patents. Panel A of Table VI presents the number of citations in the 445 patents to the managing editors, founding editors, advisory editors, and editors of the three major journals devoted solely to financial economics (*Journal of Finance*, *Journal of Financial Economics*, and *Review of Financial Studies*) in March 2000. I also included the Economics Nobel Laureates who specialized in financial economics. In many cases, the cited works were textbooks, which often synthesized existing knowledge and were further from the frontier of academic research. I thus also compiled the number of citations to articles in seven major finance and economics journals (again using Fishe (1998)). Finally, two of the researchers in the sample had been awarded financial patents. I thus also computed the number of citations, net of citations in patents that the author had filed. Panel B presents a similar compilation of the total number of references to articles in the seven major finance and economics journals.

The results highlighted the relatively few references to the academic finance literature in these patents. There were only a total of 21 references to these authors in the 445 patents and only six references to their articles in major finance and economics journals. Overall, there were only 19 citations to these journals in the patents. To be sure, some of the other material cited (for instance, articles in the business press) drew upon or referenced some of the ideas originally presented in academic articles. But the table—in conjunction with the results in Figure 4—raised questions about whether applicants for and examiners of financial patents had considered the substantial body of cutting-edge academic research.

A third way to examine the quality of the examination process was to compare finance patents to those in other areas where academic research was important. If significant differences in the treatment of the academic

[19] One of the requirements for patentability in Section 103 of the Patent Act is "nonobviousness." As the Act states, "at the time the invention was made[,] a person having ordinary skill in the art to which such subject matter pertains" (which has been defined by the courts as someone who has understands the prior knowledge in the field fully, but thinks along conventional lines) should not consider "the differences between the subject matter sought to be patented and the prior art" to be obvious.

Table VI

Citations to Writings of Leading Financial Economists and to Leading Academic Journals in Finance Patents

The patent sample consists of 445 patents awarded by the U.S. Patent and Trademark Office between January 1971 and February 2000 and classified in one of five U.S. patent subclasses (705/35, 705/36, 705/37, 705/38, and part of 705/4). Panel A lists citations in finance patents to writings by the financial economists who were the managing editors, founding editors, advisory editors, and editors of the three leading finance journals (*Journal of Finance*, *Journal of Financial Economics*, and *Review of Financial Studies*) as of March 2000, as well as by the Nobel Laureates specializing in financial economics. The panel reports the total number of citations to their writings in the patent sample, the total number of citations to their articles in the seven leading finance and economics journals, and the total number of citations not in patent awards that were filed by the author. Panel B presents the number of citations and the citations per patent in finance patents to articles in seven leading finance and economics journals.

Panel A: Citations to Leading Financial Economists in Finance Patents

Individual	Total Citations	Top Journal Citations	Non-self-citations
William F. Sharpe	9	1	3
Merton H. Miller	3	3	3
Clifford W. Smith, Jr.	3	0	2
Eugene F. Fama	2	0	2
Franco Modigliani	2	2	2
Harry M. Markowitz	1	0	1
Robert C. Merton	1	0	1
Michael Barclay	0	0	0
Bernard Dumas	0	0	0
Wayne Ferson	0	0	0
Kenneth R. French	0	0	0
Lawrence Glosten	0	0	0
Gary Gorton	0	0	0
Richard C. Green	0	0	0
Michael C. Jensen	0	0	0
Wayne H. Mikkelson	0	0	0
Maureen O'Hara	0	0	0
Paul A. Samuelson	0	0	0
Myron S. Scholes	0	0	0
G. William Schwert	0	0	0
Jay Shanken	0	0	0
Andrei Shleifer	0	0	0
René M. Stulz	0	0	0
Total	21	6	15

Panel B: Citations to Leading Finance and Economics Journals in Finance Patents

Journal	Number of Citations	Citations/Patent
Journal of Finance	6	0.013
American Economic Review	5	0.011
Journal of Political Economy	5	0.011
Econometrica	1	0.002
Journal of Business	1	0.002
Journal of Financial Economics	1	0.002
Review of Financial Studies	0	0.000
Total	19	0.043

literature appeared, it would strengthen the more subjective analyses above. I compared the 100 random finance patents with the two random sets of 100 patents awarded to corporations and individuals described in Section III. I contrasted the sets of patents on several dimensions:

- The number of academic articles cited by the patent (defined as those in a journal indexed in *Science Citation Index* or *Social Science Citation Index*).
- The length of time that the patent took to be examined, whether calculated from the patent's application date or that of any predecessor patent application.
- The number of times the patent was rejected prior to issuance, determined through an examination of the Forms 326, "Office Action Summary," in the patent folder.
- The number of issued patents examined by the patent examiner before this award, both in general and with a primary assignment to the particular patent class. In undertaking the latter tabulation, I used the current assignment of the patent, not that at the time the patent was issued.
- Whether the examiner had a Ph.D. and, if so, whether it was in a discipline related to the primary class into which the patent was classified. The doctoral awards were determined through the Dissertation Abstracts database.
- The items added by the examiner to the patent application, determined through an examination of Form 892, "Notice of References Cited," in the patent folder.

These comparisons—as well as the results of t- and χ^2-tests of the differences—are displayed in Table VII. The most striking difference is displayed in the first line. The typical matching patent had eight times more citations to academic papers than the average finance patent. The paucity of citations to the academic prior art discussed above appears to be extraordinary relative to other academic-related patents.

The next lines provide some clues as to why this differential may have come about. The cause did not appear to be the process that the patent examinations followed. Finance patents actually took longer to issue than the matching patents and experienced more rejections prior to issue (although this difference is not significant). Rather, much of the difference may stem from the lack of experience on the part of the examiners. The examiners of finance patents had previously examined fewer patents (as well as fewer in the same patent class) and were far less likely to have a doctorate in a related field.[20]

[20] The especial lack of familiarity in the case of finance patents may be due to the recruitment standards at the USPTO. The Office requires an engineering or science degree as a prerequisite for consideration for employment as a patent examiner. While it has sought to staff the groups examining business method patents with individuals who have both an engineering and a business degree, these have been difficult to recruit at the prevailing salary levels. (Annual entry-level salaries at the USPTO are about $40,000.) These points are discussed in Aharonian (2000).

Table VII

Comparison of 100 Finance and Two Sets of 100 Nonfinance Patents

The finance sample consists of 100 random patents among the 445 financial patents awarded by the U.S. Patent and Trademark Office between January 1971 and February 2000. The first nonfinance sample consists of 100 patents awarded to corporations and individuals in the same subclasses as and the most proximate to 100 random nonfinance patents awarded to universities. The second nonfinance sample consists of 100 patents awarded to corporations and individuals in 10 patent classes where universities have been active patentees, chosen to have an identical distribution of award dates as the finance patents. The awards are compared on several features of the patents and their examinations. These include the number of academic articles cited in the patent, the duration of the patent application process (from the application date and that of any predecessor patent), the number of rejections of the patent application prior to issuance, the experience of the patent examiner (measured by total number of patents previously examined and those in this patent class), the education of the patent examiner (whether the patent examiner has a doctorate in any field or a field related to the patent class), and the extent to which the examiner added citations to the patent. Each column of nonfinance patents also denotes the significance levels of t- and χ^2-tests comparing that set of awards with the finance patents.

	Finance Patents	Non-Finance Sample I	Non-Finance Sample II
Academic articles cited	0.63	5.03***	5.10***
Period from application to award (years)			
Using patent application date	3.02	2.09***	2.13***
Using original application date	3.80	3.02***	2.63***
Number of rejections prior to issuance	1.45	1.28	1.25
Previous patents examined by examiner			
Total	751.58	1,015.09**	874.04
Number in patent class	74.16	154.91	351.21***
Share of patents examined by examiner			
With Ph.D.	2%	29%***	13%***
With Ph.D. in related discipline	1%	26%***	12%***
Number of citations added by examiner			
Domestic patents	4.55	4.21	4.17
Foreign patents	0.28	0.36	0.24
Nonpatent prior art (excluding academic articles)	1.28	1.18	1.22
Academic articles	0.27	1.14***	1.26**

** Significant at the five percent confidence level; *** significant at the one percent level.

Consistent evidence is presented in the last four lines, which summarize the prior art added to the patent application by the examiner. While the examiners of both samples were relatively consistent in adding patented prior art (which was readily accessible through USPTO databases), they differed significantly in their addition of academic articles. In particular, examiners of finance patents were far less likely to add citations of academic articles. To be sure, this failure to add citations may reflect the fact that there was less relevant material to cite in the case of the financial patents.

But in light of the analyses above, this result suggests that the finance patent examiners' lack of familiarity with academic research may be having detrimental effects on patent quality.

IV. Conclusions

This paper examines the recent growth of financial patents. The number of such filings and awards has been accelerating, even before the *State Street* decision unquestionably established the validity of these patents. The absence of academic patenting appeared to be due to a lack of awareness or interest on the part of faculty members, rather than the unpatentability of academic research. The failure of these patents to cite academic research seemed problematic and may have reflected the examiners' lack of experience and training in this area.

It is important to acknowledge two limitations of this analysis, which suggest topics for future research. First, if past patent policy changes are any guide, it is likely to take a number of years before the "steady state" is reached. Patenting, licensing, and litigation strategies are likely to evolve over time. The conclusions of this analysis thus, necessarily, must be tentative ones. In particular, in March 2000, the USPTO announced the "Business Method Patent Initiative Action Plan" to insure higher quality business method patents. But at least to date, the effects of the program appear modest.[21]

A second limitation is that this analysis did not consider the impact of patenting on the extent of financial innovation. Despite over a century of research, the ability of economists to assess the impact of patent policy shifts on innovation remains limited. On the one hand, financial innovations are quickly imitated: Tufano (1989) shows that the median developer of a new financial product can only undertake one securities issuance before that product is imitated by another underwriter.[22] In light of the ease of imitation, patent protection may provide an added spur to innovation. On the other hand, it has been argued (e.g., Miller (1986)) that the past decades have seen a tremendous wave of financial innovation. The rewards to financial innovation may be sufficiently large that patent protection will stimulate little additional activity, while imposing substantial costs on society (e.g., the cost of litigation and the distortions introduced by monopoly power). These trade-offs will reward research in the years to come.

[21] The initiative calls for a second review of business method patent applications before they are granted. These reviews, however, have led to questions being raised about any of the claims of only 6.1 percent of the business method patents. Questions have been raised about the overall validity of only 1.3 percent of the patents (http://www.uspto.gov/web/offices/ac/ahrpa/opa/ptotoday/ptotoday12.pdf, p. 10, accessed April 16, 2001). Nor has the number of applications for business method patents slowed: there were 2,932 such applications in the last quarter of 2000, an increase of 62 percent over the number of filings in the previous record quarter (http://www.uspto.gov/web/menu/pbmethod/inauguralmeeting.ppt, slide 5, accessed April 16, 2001).

[22] Despite the speed with which they are imitated, the product innovators in Tufano's (1989) sample retained a dominant market share in the product in the years after the offering.

REFERENCES

Aharonian, Gregory, 2000, PATNEWS: Detailed notes of PTO roundtable on business method patents (e-mail dated August 3, 2000; archived at http://www.bustpatents.com; accessed November 2, 2000).

Bakshi, Gurdip, and Dilip Madan, 2000, Spanning and derivative security valuation, *Journal of Financial Economics* 55, 205–238.

Barberis, Nicholas, 2000, Investing for the long run when returns are predictable, *Journal of Finance* 55, 225–264.

Bertsimus, Dimitris, Leonid Kogan, and Andrew W. Lo, 2000, When is time continuous? *Journal of Financial Economics* 55, 173–204.

Bhattacharyya, Sugato, and Vikram K. Nanda, 1997, Client discretion, switching costs and financial innovation. Unpublished working paper, University of Michigan.

Black, Fisher, and Andre Perold, 1992, Theory of constant proportion portfolio insurance, *Journal of Economic Dynamics and Control* 16, 403–426.

Borokhovich, Kenneth A., Robert J. Bricker, Kelly R. Brunarski, and Betty J. Simkins, 1995, Finance research productivity and influence, *Journal of Finance* 50, 1691–1717.

Boyle, Phelim P., 1977, Options: A Monte Carlo approach, *Journal of Financial Economics* 4, 323–338.

Brealey, Richard A., and Helen Edwards, 1991, *A Bibliography of Finance* (MIT Press, Cambridge).

Carter, Richard B., Frederick H. Dark, and Ajai K. Singh, 1998, Underwriter reputation, initial returns, and the long-run performance of IPO stocks, *Journal of Finance* 53, 285–311.

Carter, Richard B., and Steven Manaster, 1990, Initial public offerings and underwriter reputation, *Journal of Finance* 45, 1045–1067.

Cheyette, Oren, 1992, Term structure dynamics and mortgage valuation, *Journal of Fixed Income* 2 (March), 28–42.

Cox, John C., Stephen A. Ross, and Mark Rubinstein, 1990, Option pricing: A simplified approach, in Clifford W. Smith, Jr. and Charles W. Smithson, eds.: *The Handbook of Financial Engineering* (Harper Business, New York) [reprint of earlier *Journal of Financial Economics* article].

Daughtery, Virgil L., III, 1999, Apparatus and Process for Executing an Expirationless Option Transaction, U.S. Patent no. 5884286.

Falloon, William, 1999, Patent power: Who owns the ideas that drive derivatives?, *Risk* 12 (December), 22–26.

Faulhaber, Gerald R., and William J. Baumol, 1988, Economists as innovators: Practical products of theoretical research, *Journal of Economics Literature* 26, 577–600.

Fishe, Raymond P. H., 1998, What are the research standards for full professor of finance? *Journal of Finance* 53, 1053–1079.

Griliches, Zvi, 1990, Patent statistics as economic indicators: A survey, *Journal of Economic Literature* 28, 1661–1707.

Gupta, Anurag, and Marti G. Subrahmanyan, 2000, An empirical examination of the convexity bias in the pricing of interest rate swaps, *Journal of Financial Economics* 55, 234–274.

Hasselback, James R., 1999 and earlier years, *Prentice-Hall Guide to Finance Faculty* (Prentice Hall, New York).

Herrera, Helios, and Enrique Schroth, 2000, Welfare in unpatentable financial inventions, Unpublished working paper, New York University.

Jaffe, Adam B., Rebecca Henderson, and Manuel Trajtenberg, 1993, Geographic localization of knowledge spillovers as evidenced by patent citations, *Quarterly Journal of Economics* 108, 577–598.

Jaffe, Adam B., and Manuel Trajtenberg, 1998, International knowledge flows: Evidence from patent citations. Working paper no. 6507, National Bureau of Economic Research.

Joy, Corwin, Phelim P. Boyle, and Ken Seng Tan, 1994, Quasi-Monte Carlo methods in numerical finance. Working paper 94-23, Institute of Insurance and Pension Research, Department of Statistics and Actuarial Science, University of Waterloo.

Klemkosky, Robert C., and Donald L. Tuttle, 1977, The institutional source and concentration of financial research, *Journal of Finance* 32, 901–907.

Merton, Robert C., 1973, Theory of rational option pricing, *Bell Journal of Economics and Management Science* 4, 141–183.

Merton, Robert C., and Paul A. Samuelson, 1969, A complete theory of warrant pricing that maximizes utility, *Industrial Management Review* 10 (Winter), 17–46.

Miller, Merton H., 1986, Financial innovation: The last twenty years and the next, *Journal of Financial and Quantitative Analysis* 21, 459–471.

Mundlak, Yair, 1978, On the pooling of time series and cross section data, *Econometrica* 46, 69–86.

National Science Board, 2000, *Science and Technology Indicators–2000* (Government Printing Office, Washington).

Niemi, Albert W., Jr., 1987, Institutional contributions to the leading finance journals, 1975 through 1986: A note, *Journal of Finance* 42, 1389–1397.

Ninomiya, S., and S. Tezuka, 1996, Toward real-time pricing of complex financial derivatives, *Applied Mathematical Finance* 3, 1, 2, 20.

Pakes, Ariel, 1986, Patents as options: Some estimates of the value of holding European patent stocks, *Econometrica* 54, 755–784.

Pástor, Lubos, 2000, Portfolio selection and asset pricing models, *Journal of Finance* 55, 179–223.

Persons, John C., and Vincent A. Warther, 1997, Boom and bust patterns in the adoption of financial innovations, *Review of Financial Studies* 10, 939–967.

Quillen, Cecil D., Jr., and Ogden H. Webster, 2001, Continuing patent applications and performance of the U.S. Patent Office, *Federal Circuit Bar Journal* 11 (August), 1–21.

Rajan, Raghuram, Henri Servaes, and Luigi Zingales, 2000, The cost of diversity: The diversification discount and inefficient investment, *The Journal of Finance* 55, 35–80.

Samuelson, Paul A., 1965, Rational theory of warrant pricing, *Industrial Management Review* 6 (Spring), 13–31.

Smith, Clifford W., Jr., 1990, Option pricing: A review, in Clifford W. Smith, Jr. and Charles W. Smithson, eds.: *The Handbook of Financial Engineering* (Harper Business, New York) [reprint of earlier *Journal of Financial Economics* article].

Tan, Ken Seng, and Phelim P. Boyle, 1997, Applications of scrambled low discrepancy sequences to the valuation of complex securities. Working paper 97-12, Institute of Insurance and Pension Research, Department of Statistics and Actuarial Science, University of Waterloo.

Trajtenberg, Manuel, 1990, A penny for your quotes: Patent citations and the value of inventions, *Rand Journal of Economics* 21, 172–187.

Traub, Joseph F., Spassimir Paskov, and Irwin F. Vanderhoof, 1999, Estimation Method and System for Complex Securities Using Low-Discrepancy Deterministic Sequences, U.S. Patent no. 5940810.

Tufano, Peter, 1989, Financial innovation and first-mover advantages, *Journal of Financial Economics* 25, 213–240.

U.S. Department of Commerce, Patent and Trademark Office, Technology Assessment and Forecast Program, 1999a, TAF special report: All patents, all types, January 1977—December 1998, mimeo archived at http://www.uspto.gov/web/offices/ac/ido/oeip/taf/apat.pdf, accessed March 14, 2000.

U.S. Department of Commerce, Patent and Trademark Office, Technology Assessment and Forecast Program, 1999b, *Technology Assessment And Forecast Report: U.S. Colleges And Universities–Utility Patent Grants, 1969–1998* (Government Printing Office, Washington).

Van Horne, James C., 1985, Of financial innovations and excesses, *Journal of Finance* 40, 620–631.

Wilner, Benjamin S., 2000, The exploitation of relationships in financial distress: The case of trade credit, *The Journal of Finance* 55, 153–178.