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A FIRST LOOK AT FINANCE PATENTS, 1971-2000

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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. The final section discusses the challenges that these developments pose to academic finance.

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1. Introduction

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 unambiguously established the patentability of financial and other business methods. 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 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 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 have strong academic ties. 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 self-described consulting activities and book authorship are significant. The analyses suggest that the faculties' awareness of the policy changes and orientation towards 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 research into financial innovation more generally. Many of the empirical studies (for instance, Ben-Horim and Silber [1977] and van Horne [1985]) have highlighted the importance of government policy, particularly tax and regulatory shifts, in stimulating financial innovation. In Miller's [1986] memorable phrase, public policy has been "the grain of sand in the oyster" of financial innovation. But the desirability of government protection of financial innovators' rights has attracted little scrutiny. 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 are imitated by competitors.

The plan of this paper is as follows. Section 2 provides a brief historical overview. The data are described in Section 3. Section 4 presents the analysis, and the final section concludes the paper.

2. Background

There has long been ambiguity about the patentability of financial discoveries in the U.S. 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 attempt to enforce their awards.

Attitudes towards 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 centralized appellate court for patent cases, the Court of Appeals for the Federal Circuit, 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.[1]

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

3. The Sample

In order 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 in 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 system or method for writing insurance policy, processing insurance claim, *etc*.)

Many of the patents in this subclass have little relationship to finance. I thus 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 IBM's Intellectual Property Network (http://www.patents.ibm.com), I identified 445 financial

patents awarded from January 1971 to the end of February 2000.[2] 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 analysis below, I seek to compare financial patents to patents in other academic-related areas. To undertake these comparisons, I first identified a random sample of 100 finance patents out of the 445 in the population. I then selected a sample of 100 patents in other technologies where academics had done a considerable amount of research. I selected ten patents each from the ten patent classes where patents were most frequently assigned to universities.[3] I constructed the matching sample to have the same distribution of award years as the finance patents. As discussed below, very few of the finance patents were assigned to universities, government agencies, or non-profits. In comparing the finance patents to those in other academic-related fields, I did not wish to introduce differences solely due to the nature of the applicants. Thus, in constructing the two samples, I restricted them to awards to corporations and individuals.

I collected a variety of supplemental information about the 100 random finance patents and the 100 matching patents. These included the name and background of the

[2]Patents awarded before 1971 were not available in electronic form. Because financial patents were not given a distinct subclass until much later, it was very 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.

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

patent examiner, the history of the patent application, and the details of the examination process. This information was taken from the IBM and USPTO web sites and the patent files themselves, which were reviewed in the USPTO's Patent File Room.

4. Analysis

In this analysis, I sought to answer four sets of 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 that 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 is sustained, there will be 222 patent awards in this 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.[4] 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 of business patent grants over the four-year period. Second, I assumed that the share of finance patents was increasing (as the data suggests). In particular, I set the finance-related share of

[4]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 methods patents. The totals included all patents assigned to Class 705.

applications equal to these patents' share of business method awards two years later (reflecting the approximate time that the applications took to be processed).[5]

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 three-fold between the 1997 and 1999 fiscal years. Assuming a linear trend in the finance patents' share, the increase during this period was more than four-fold. These projections suggested that the number of awards would continue to grow in future years.

The second basic pattern was the composition of the awardees. Panel A of Table 2 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.

[5]In order 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.

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 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.[6]

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 1000 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].)

[6]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 a certain technological areas or to inventions that were developed as a part of the faculty'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 that 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.[7]

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 fifteen full-

[7]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.

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 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 2 summarizes the results of the questionnaire. There appeared to be a consensus that at least three of the papers covered patentable subject matter: Bakshi and Madan [2000], Barberis [2000], and Pástor [2000]. 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.

The second methodological approach was to examine the finance patents that had 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, whether 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, discussion of the prior art, and 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% 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 thirty of the largest investment banks, and examined the count of successful patent applications filed in three six-year periods: 1980-1985, 1986-1991, and 1992-1997. 1997 was the last year used 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: e.g., 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 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 is 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. In order 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. I employed the set of predicted citations computed by Jaffe and Trajtenberg [1998].[8] Thus, the weight was as follows:

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

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.

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).

[8]The predicted citations were only calculated through 1996. In order 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.

- The investment bank's reputation among its peers on a nine-point scale (with 9.0 being the highest and zero being the lowest), as compiled by Carter and Manaster [1990] (for the 1980-1986 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.[9]
- 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 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.[10]

Table 3 presents the regression analyses. I first estimated a Poisson specification, reflecting the ordinal, non-negative nature of the count of patent awards. In order 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.

[9]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.

[10]This calculation was based on examination of these boards as reported of 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.

The goodness-of-fit in many of the regressions was not as high as would be desired. This may reflect the non-systematic manner in which many organizations approached financial patenting in the pre-*State Street* era. At the same time, the results were suggestive. 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. For instance, in the fifth regression in Table 2, a one standard deviation increase in research intensity more than doubled the predicted level of citation-weighted patenting (a 119% increase).

This effect disappeared, however, when fixed effects were used. The change was probably a consequence of banks' ties with the academic community changing slowly: the absence of variation over time makes it difficult to identify these effects. In order to examine this possibility, in unreported regressions I employed the two-step procedure recommended by Mundlak [1978]. I estimated a first-stage regression employing fixed effects and all independent variables except the very slowly changing ones (the academic ties and Carter-Manaster ranking). I then regressed the fixed effects in a second-stage regression on the means of all the independent variables for each bank. The academic connection variable was significant at the five-percent confidence level.[11]

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[11]The volume of debt security issuance was also associated with more patenting in some of regressions, but not the volume of equity issuance. This result was consistent with Tufano's [1989] tabulation of financial innovations developed between 1974 and 1986. Of the 58 innovations in his sample, there were 33 advances in debt securities, four in equity securities, and 21 in hybrid securities (equity-linked debt and preferred stock).

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 the pattern of investment bank patenting all suggested that the answer to the title question of this section was "no." Academic research appeared to have been closely related to the types of subjects being patented, and ties to academia appeared to be associated with patenting activity.

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. In order 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 regression 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 thirty 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 1980-1985 period), Borokhovich, *et al.* [1995] (for the 1986-1991 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 paragraph 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 4, the size and productivity of the finance faculty had little explanatory power. Rather, the only consistently significant explanatory variable was the number of non-financial 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 fifteen 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 on each faculty member:

- The location and year of his or her Ph.D. (Hasselback [1999]).
- The number of articles authored or co-authored 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, co-authored, 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,[12] the International Directory of Finance and Economics Professionals,[13] and various businesses school home pages.
- The area of faculty research expertise (from Hasselback [1999] and faculty web sites).

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

- 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 5, were weaker those estimated at the department level. This pattern may have reflected the greater heterogeneity in the behavior of individual faculty members. The key patterns, however, were generally consistent with those above. In the basic specification, the most frequent patentees were those specializing in asset pricing, with a greater number of books, and (at the ten-percent confidence level) with a greater number of words about consulting on their web pages. Meanwhile, the number of articles published in major journals was insignificant, and in fact negative in sign. Faculty members who publicized their consulting activities may have had a "real world" orientation, and those who authored books (many of which digested or popularized academic research) may also. These patterns suggested that the orientation of the faculty member, rather than his or her research productivity, was critical in determining patenting activity.

When fixed effects were used, however, the patterns were much weaker. Only the number of books authored and edited was significant, and then at the ten-percent confidence level. Much of the heterogeneity among faculty members appeared to be subsumed into the fixed effects for each university. 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 non-patent 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. I examined in depth two awards from 1999.

U.S. Patent no. 5884286, "Apparatus and process for executing an expirationless option transaction," was awarded to Virgil Daugherty III, 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.

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]. 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 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 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.

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.

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 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 more recent 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 6 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 (using again 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 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 literature appeared, it would strengthen the more subjective analyses above. I compared the 100 random finance patents with the sample of 100 patents awarded to corporations and individuals in classes where universities were active patentees (described in Section 3). I contrasted the two 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 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 7. 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 patent classes.

The next lines provide some clues as to why this differential came 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 (though this difference is not significant). Rather, much of the difference may stem from the lack of the experience on the part of the examiners. The examiners of finance patents had previously examined many fewer patents in the same patent class, and were far less likely to have a doctorate in a related field.

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. Once again, this suggests that the finance patent examiners' lack of familiarity with the academic research may have led to the neglect of this work.

5. Conclusions and Policy Implications

This paper examined 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 lack of experience and training in this area by the examiners.

It is important to acknowledge three 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 arrived at. Patenting, licensing, and litigation strategies are likely to evolve over time. The conclusions of this analysis must thus necessarily be tentative ones.

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.[14] In light of the ease of imitation, patent protection may provide an added spur to innovation. On the other hand, it has

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

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.

Finally, the analysis did not provide clear prescriptions for business schools and universities more generally about how to respond to finance patents. In thinking about these trends, it may be helpful to consider an industry where academics have played a much more significant role in patenting from its inception: genetic engineering. Some observers argue that patenting by universities has encouraged the widespread diffusion of basic technologies that might not have happened if the private sector had patented the discoveries instead. But critics have argued that the ability to profit from patented biotechnology discoveries hurt the academic enterprise. Because the private benefits from commercializing discoveries were so large, academics may have become unwilling to share ideas, lest they jeopardize their ability to profit from them. These incentives may have led to the decreased production and dissemination of new academic ideas.

Schools may wish to consider at least three alternatives:

- One possibility would be for universities to emulate the biotechnology model, and protect aggressively financial innovations. Financial patents might generate significant revenues for many schools, as life science patents already have. But such

activities may impose some of the same costs on academic finance that observers suggest have occurred in biotechnology.

- An alternative approach would be a defensive one: schools could seek, individually or collectively, to block applications that appropriate its faculties' ideas. This goal might be accomplished, for instance, through a mechanism similar to the joint prior art web site that Amazon CEO Jeff Bezos has recently urged the e-commerce industry to establish.[15] Other such joint efforts, however, have faced substantial governance and credibility issues.[16] It also might be possible for universities to provide input into the USPTO's efforts to improve business method patent quality.[17]
- Finally, universities could discourage their finance faculty from becoming active in patenting. While initially appealing, it is unclear how effective such a step would be. The ability of companies to obtain patents that do not reference highly relevant academic literature, and the difficulty of policing professors' interactions with industry, may make it inevitable that many of the central discoveries in academic finance will be patented.

While it is premature to suggest a definitive approach, the author hopes that this initial investigation will encourage further discussion about and research into these challenges.

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[15]This proposal, as well as several others, is discussed by Bezos at http://www.amazon.com/exec/obidos/subst/misc/patents.html/104-3929745-0506052 (accessed March 21, 2000).

[16]For instance, the limitations of the Software Patent Institute have been frequently discussed in postings to the Internet Patent News Service, which are archived at http://www.bustpatents.com/archive.htm (accessed March 21, 2000). It should be noted, however, that the operator of this on-line newsletter offers a competing service.

[17]For a discussion, see http://www.uspto.gov/web/offices/com/sol/actionplan.html (accessed March 31, 2000).

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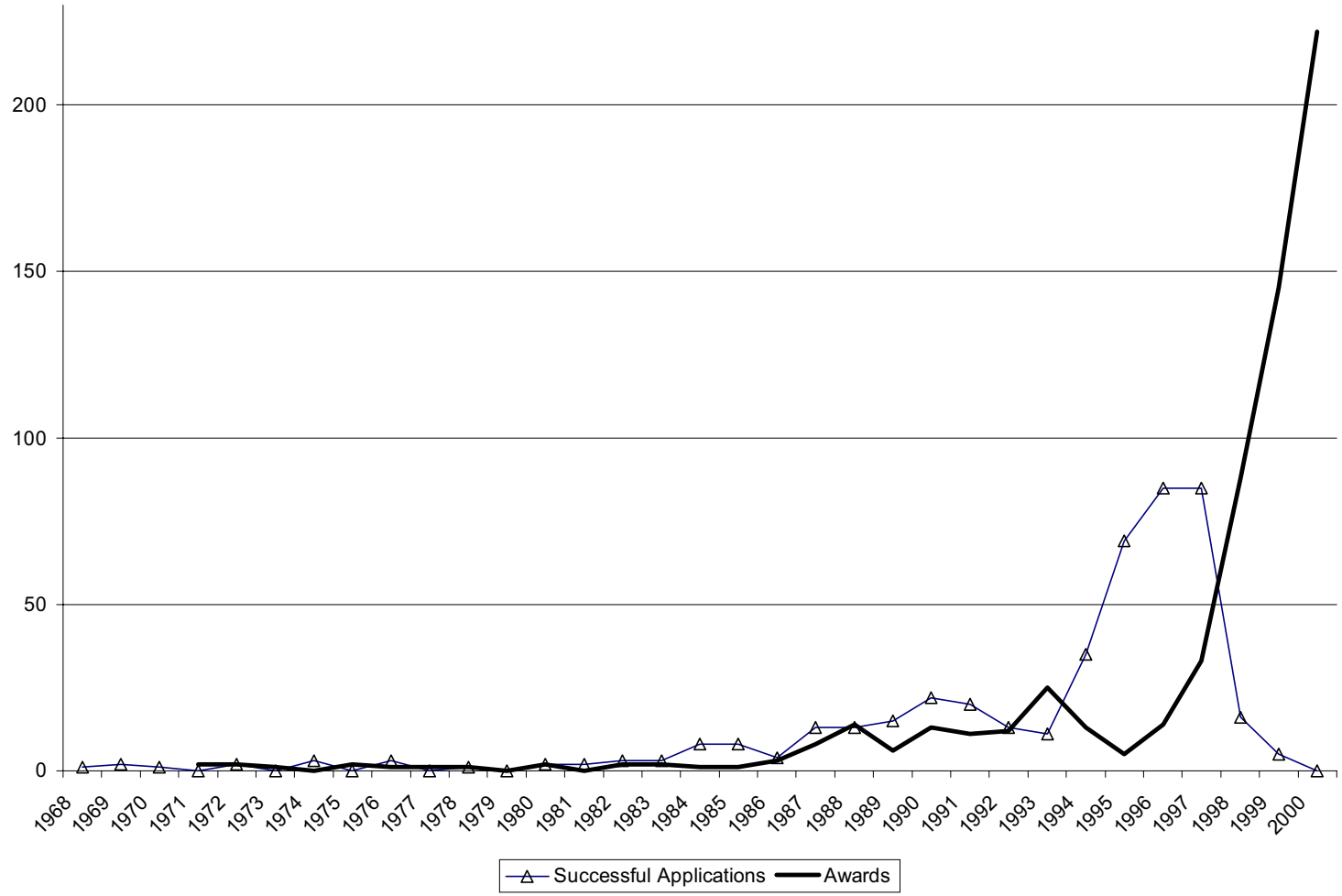

Figure 1. The number of U.S. financial patent awards and successful applications, by year. The number of awards for 2000 is imputed based on awards by the U.S. Patent and Trademark Office through the end of February 2000. The number of successful applications is based only on patents awarded through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

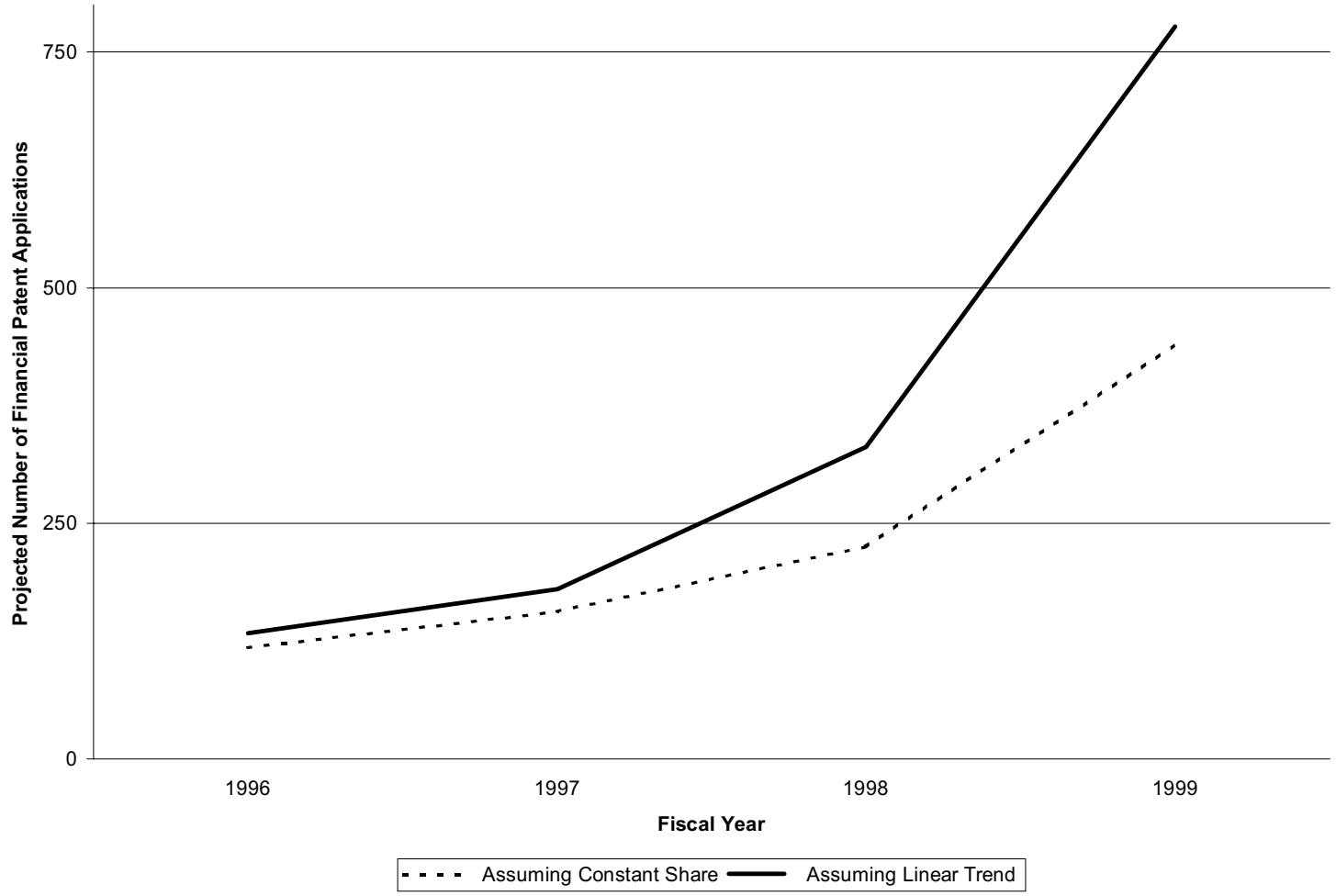

Figure 2. The estimated number of financial patent applications, by year. All estimates are based on U.S. Patent and Trademark Office statistics. The dotted line assumes that financial patents' share of business method patent applications remained constant (at their average share of business method patent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

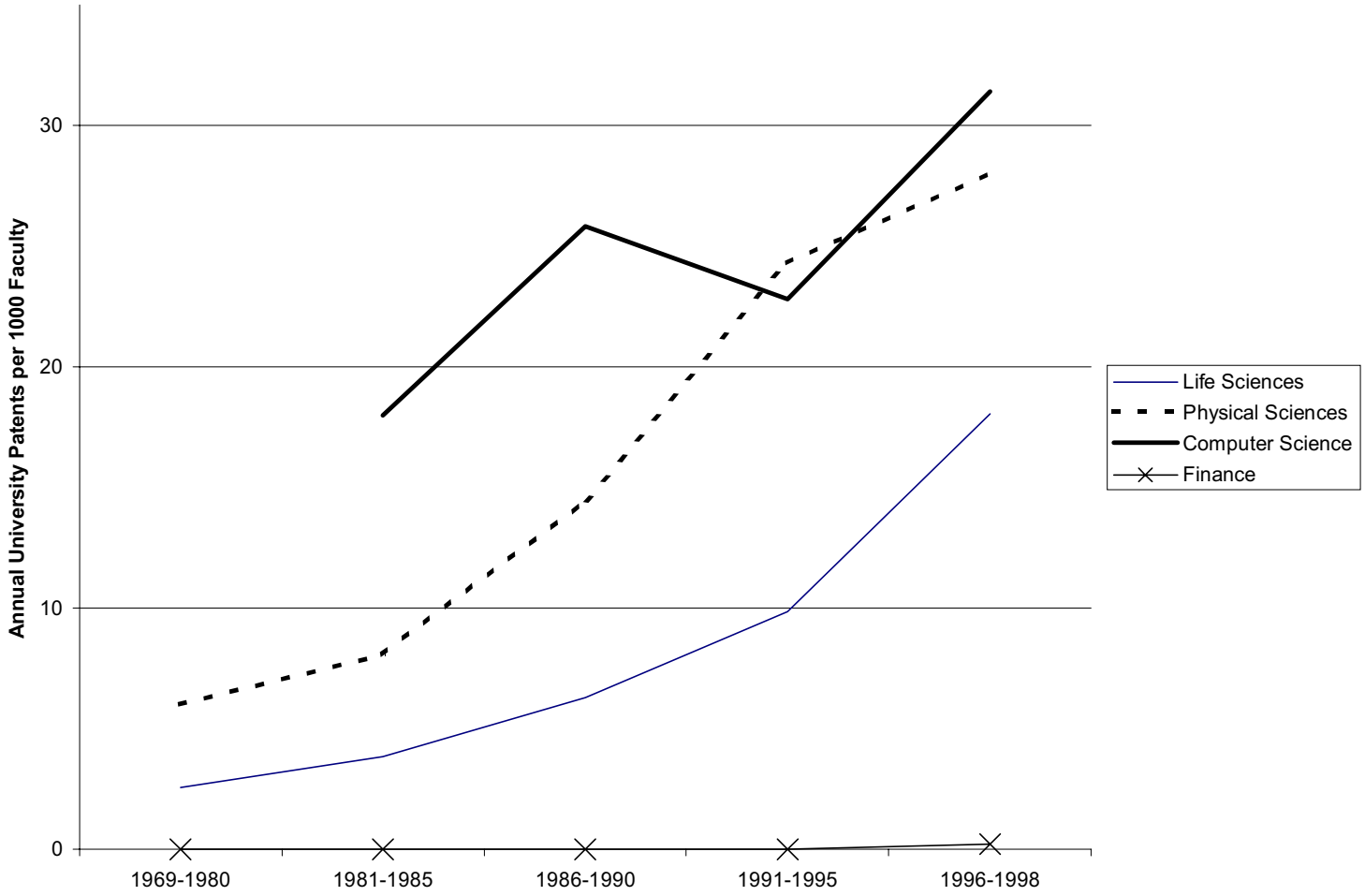

Figure 3. University-assigned patents per 1000 faculty members, by discipline and year. The table presents the ratio of the total number of patent awards by the U.S. Patent and Trademark Office assigned to U.S. universities and colleges in patent classes related to four academic disciplines to the number of faculty members (in thousands) in those disciplines at U.S. universities and colleges.

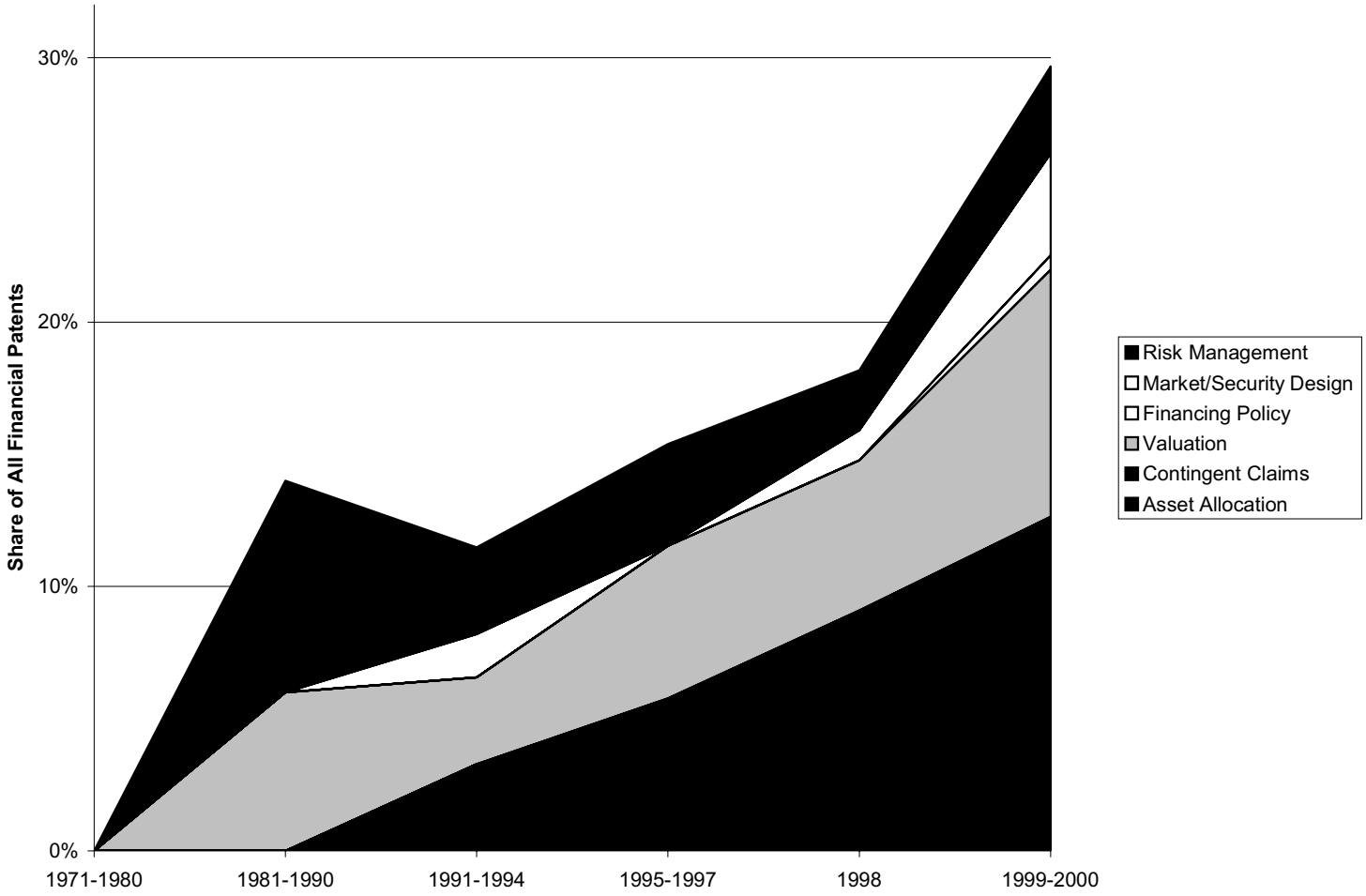

Figure 4. Share of finance patents with cited or uncited academic prior art, by year and sub-field. The table presents the share of 445 finance patents awarded by the U.S. Patent and Trademark Office between 1971 and February 2000 with significant prior art in one of 15 finance journals.

Table 1

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		All Awards[b]
Entity	Number	Percent	
Corporations	317	71%	***80%
Domestic	258	58%	***42%
Foreign	59	13%	***38%
Individuals and Family Trusts	122	27%	***17%
Universities and Affiliates[a]	4	1%	*2%
Government Bodies	2	0%	1%

[a]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.

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

* = Significantly different from financial patents in a χ^2-tests at the 10% confidence level; ** = significantly different at the 5% level; *** = significantly different at the 1% level.

Table 2

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	+	+ +	+ +
Pástor	+ +	+ +	+ +
Rajan, Servaes, and Zingales	- -	- -	0
Wilner	- -	-	0
Journal of Financial Economics			
Bakshi and Madan	+	+	+ +
Bertsimas, Kogan, and Lo	+	-	+ +
Gupta and Subrahmanyam	- -	0	+ +

Table 3

"Financial patent production functions" for investment banks. The sample consists of observations of the union of the twenty-five 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 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), and assigned to that entity. 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 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 a 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 specifications 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 specifications, where absolute t-statistics are reported).

	Dependent Variable: Patent Applications				*Dependent Variable: Weighted Applications*		
	Poisson and	OLS Specification			OLS Specification		
	Pooled	Pooled	Within	Between	Pooled	Within	Between
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]
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]
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-statstic	100.82						
F-statistic		9.27	5.87	11.51	7.56	200.57	7.37
p-Value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R^2		0.39	0.69	0.49	0.22	0.69	0.43
Number of observations	95	95	95	44	95	95	44

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

Table 4

"Financial patent production functions" for academic institutions. The sample consists of observations of thirty 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 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), 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 a one hundred 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 specifications 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 specifications, where absolute t-statistics are reported).

	Dependent Variable: Patent Applications				*Dependent Variable: Weighted Applications*		
	Poisson and	OLS Specification			OLS Specification		
	Pooled	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-statstic	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% confidence level; ** = significant at the 5% level; *** = significant at the 1% level.

Table 5

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 co-authored by the faculty member, the number of books authored, co-authored, 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 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-statstic	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% confidence level; ** = significant at the 5% level; *** = significant at the 1% level.

Table 6

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 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

Table 7

Comparison of 100 finance and 100 matching patents. The two samples consist of 100 random patents among the 445 financial patents awarded by the U.S. Patent and Trademark Office between January 1971 and February 2000 and 100 patents awarded to corporations and individuals in ten patent classes where universities have been active patentees. The matching sample is constructed to have the same distribution of award years as the random finance sample. 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 patent 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. The final column presents absolute test statistics from t- and χ^2-tests comparing the finance and matching patents.

	Finance Patents	Matching Patents	Test Statistic
Academic articles cited	0.63	5.10	***4.46
Period from application to award (years):			
Using patent application date	3.02	2.13	***4.41
Using original application date	3.80	2.63	***4.43
Number of rejections prior to issuance	1.45	1.25	0.24
Previous patents examined by examiner:			
Total	751.58	874.04	1.05
Number in patent class	74.16	351.21	***4.59
Share of patents examined by examiner:			
With Ph.D.	2%	13%	***8.72
With Ph.D. in related discipline	1%	12%	***9.95
Number of citations added by examiner:			
Domestic patents	4.55	4.17	0.60
Foreign patents	0.28	0.24	0.28
Non-patent prior art (excluding academic articles)	1.28	1.22	0.90
Academic articles	0.27	1.26	**2.07

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