To the Graduate Council:

I am submitting herewith a dissertation written by Ya-wen Yang entitled "The Value-Relevance of Nonfinancial Information: The Biotechnology Industry." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Business Administration.

Bruce K. Behn
Bruce K. Behn, Major Professor

We have read this dissertation
and recommend its acceptance:

Kenneth E. Anderson

Donald J. Bruce

Ronald E. Shrieves

Accepted for the Council:

Anne Mayhew
Vice Provost and Dean of
Graduate Studies

(Original signatures are on file with official student records.)

The Value-Relevance of Nonfinancial Information: The Biotechnology Industry

A Dissertation Presented for the
Doctor of Philosophy Degree
The University of Tennessee, Knoxville

Ya-wen Yang
December 2003

UMI Number: 3119422

Dedicated to my parents,
David T. W. Chang and Shiu-Chin Hsu,
for always believing in me, inspiring me, and encouraging me
to reach higher in order to achieve my goals.

Acknowledgments

First and foremost, I would like to thank my major advisor and committee chair, Dr. Bruce K. Behn for his guidance, constant support, and encouragement throughout my doctoral program. I feel blessed to have had him as a mentor in each of the endeavors he made possible. I would also like to express my appreciation to the committee members: Dr. Kenneth E. Anderson, Dr. Ronald E. Shrieves, and Dr. Donald J. Bruce. They have always been willing and available to consult with me when I was in need of direction. Without their invaluable suggestions, this dissertation could never have reached its final form. I also wish to thank Paul Gao for always being there to discuss research ideas with me and to drop off the articles he ran across while conducting his own research. Last but not least, I am grateful to my fiancée and best friend, Chung Ku, for his love and support during all the phases of this dissertation.

Abstract

This study examines whether nonfinancial patent information is useful to investors in assessing and valuing biotech firm's long-term financial performance. The biotech industry requires large R&D investments with uncertain payoffs. Current accounting practice expenses (rather than capitalizes) R&D expenditures. As a result, financial variables are often negative or excessively depressed. Because accounting assets do not reflect biotech firms' valuable intangible assets, this study examines whether nonfinancial patent information supplement the information content of financial information in market valuation. Using six patent variables measuring both quantity and quality aspects of patents, I found evidence consistent with the idea that nonfinancial patent information captures the biotech firms' value not currently formally valued by traditional financial indicators. In addition, patent information is associated with and can be useful in predicting a biotech firm's long-term financial performance with a two-year lag.

TABLE OF CONTENTS

LIST OF TABLES

1. Introduction

This study examines whether nonfinancial information, particularly patent information, is useful to investors in assessing and valuing biotechnology firms' long-term financial performance. The biotech industry is characterized by short-cycle technological developments requiring large investments with very uncertain payoffs. This high uncertainty, along with the lack of financial information disclosed, makes valuing biotech companies difficult.

Current accounting practice fails to make valuing fast-changing technology-based industries, such as telecommunications, software production, and biotechnology, any easier.[1] These firms make significant value enhancing investments in intangible assets, such as research and development, that they immediately expense for financial statement purposes. As a result, financial variables, such as earnings and book values, are often negative or excessively depressed and appear to be unrelated to market values. Because accounting assets do not reflect technology-based firms' valuable intangible assets, this study investigates what nonfinancial measures investors use to supplement the information content of financial information in market valuation.

To address this question, the study focuses on the biotech industry and examines whether a biotech firm's stock market value reflects the intangible assets associated with patents. R&D productivity (i.e., the quality and quantity of inventive output) is a vital determinant of long-term success in high-tech companies, particularly for the biotech

[1] For example, Amir & Lev (1996, p. 28) state in their conclusion: "The evidence presented in this study indicates that current financial reporting of wireless communications companies—a large world-wide and technologically leading industry—is inadequate. Specifically, significant value-enhancing investments in

industry because, as a percentage of revenues, R&D spending in the biotech industry is among the highest of any U.S. industry group.[2] Economic literature usually considers patent information as an indicator of inventive output, which measures the productivity of R&D spending (i.e., an indicator of inventive input) (Hall, Jaffe, and Trajtenberg 2000; Harhoff, Narin, Scherer, and Vopel 1999; Griliches 1990). A patent protects a new process or product from competition and allows a firm to recoup R&D costs while earning a good return on its investment. Because patents are among the most important benchmarks of progress in developing new biotechnology products, this study uses publicly available patent information to determine whether market participants use this nonfinancial information in assessing future cash flows.

This study should be of interest to both investors and policymakers. From the investor's perspective, the examined nonfinancial patent information provides a useful tool to assess biotech firms' potential profits and future cash flows. From the public policymaker's perspective, it sheds light on the nonfinancial disclosure issue. Although greater disclosure is generally believed to be preferable, accounting authorities are concerned that the risk of such disclosure may outweigh the benefits. For example, inaccurate measurements or surprise writedowns of intangible assets may result in federal securities lawsuits.[3] By demonstrating the value-relevance of a set of objective and publicly available patent measures in the biotech industry, this study contributes to the

---

the cellular franchise and in expanding the customer-base are fully expensed in financial reports, leading to distorted values of earnings and assets."

[2] According to Ernst & Young, R&D expenditures by public biotech firms reached $9.9 billion in 2000, up from $6.9 billion in 1999 and $6.7 billion in 1998. Standard & Poor's estimates that R&D spending was approximately $12 billion in 2001.

[3] According to Halsey Bullen, senior project manager at FASB (Business Week, Auguest 26, 2002, p. 110).

discussion of what information biotech firms should disclose to improve current financial reporting.

A number of studies express concerns about the declining importance of financial reporting and disclosure and suggest that nonfinancial value drivers may enhance financial statement users' ability to evaluate and predict financial performance (Ittner and Larcker 1998; Behn and Riley 1999; Trueman, Wong, and Zhang 2001). Contrary to this view, Francis and Schipper's (1999) study yields no systematic evidence that indicates declining relevance of financial statements over years 1951-1993. The current study contributes to the debate by investigating the value relevance of financial information in market valuation and the usefulness of nonfinancial information in predicting biotech firms' financial performance.

Deng, Lev, and Narin (1999) and Hirschey, Richardson, and Scholz (1998) address the relation between nonfinancial patent measures and financial performance in the high-tech sectors. This study builds on their study and extends prior research by incorporating a richer set of patent measures, and it tests the incremental value relevance of nonfinancial patent information for biotech companies. In addition, using the same nonfinancial patent information, this study develops a model to determine whether these nonfinancial variables can be used to predict future financial performance. Unlike prior research, this study focuses on the biotech industry instead of the high-tech sectors in general. High-tech sectors are characterized by high R&D spending and intensive R&D activities. However, not all R&D intensive sectors patent significantly. For example, the level of patenting is relatively low despite the high level of R&D (software development costs) in the software industry. Testing whether patent information can be an appropriate indicator of inventive output in the biotech industry rather than high-tech industries in general, therefore, yields more direct and reliable evidence. Given the current debate over what information should be disclosed and audited, this study contributes to the existing literature by examining whether the disclosure of biotech companies could be improved by using all the value drivers in the business, including financial results and value-enhancing nonfinancial patent measures.

This paper proceeds as follows: Section 2 provides a review of prior research on value relevance studies and patent measures. Section 3 includes an overview of the biotechnology industry. Section 4 provides theory development. Section 5 develops the hypotheses and patent variable definitions. Section 6 discusses the research design and econometrics issues. Section 7 outlines data sources and sample selection procedures. Section 8 presents research findings. Section 9 provides sensitivity tests. Finally, section 10 sets forth summary and concluding remarks.

2. Prior Research

2.1 Nonfinancial Information and Value Relevance Studies

According to Barth, Beaver, and Landsman (2001), "an accounting amount is defined as value relevant if it has a predicted association with equity market values." The extant value relevance studies use various valuation models to structure tests, and typically use equity market value as the valuation benchmark to assess how well particular accounting amounts reflect information used by investors. The primary purpose for conducting tests of value relevance is to extend our knowledge regarding the relevance and reliability of accounting amounts as reflected in equity values.

The emphasis on nonfinancial measures is motivated by the perceived absence of information on key drivers of firm value. The Jenkins Committee report (1994) stimulated a number of recent studies that examine the value relevance of nonfinancial information. Examples include market size and market penetration in the wireless industry (Amir and Lev 1996), patents in high-tech firms (Deng, Lev, and Narin 1999), customer satisfaction (Ittner and Larcker 1998), and Web traffic measures in the Internet industry (Trueman, Wong, and Zhang 2001).[4] The current study extends this line of research by turning attention to innovative, science-based biotech companies. The aim is to examine whether commonly available nonfinancial patent information can be used to supplement the information content of financial information and improve the disclosure quality and to determine how reliable these patent measures are in predicting long-term performance.

[4] Appendix 1 briefly reviews models in previous nonfinancial value relevance studies.

Most value relevance studies make inferences based on the implicit assumption that the stock market is efficient in the semi-strong form. In recent years, this assumption has raised substantial concerns among several researchers (Lee 1999; Holthausen and Watts 2001; Rajgopal, Shevlin, and Venkatachalam 2001). For example, Rajgopal, Shevlin, and Venkatachalam (2001) examine the association between order backlog and stock prices and conclude that the stock market possibly misprices non-GAAP value drivers. They suggest that, if the market has trouble interpreting dollar denominated value driver such as order backlog, the market probably will fail to fully appreciate the implications of non-dollar denominated leading indicators such as customer satisfaction, Web traffic, and patents.

Despite the concern over the market efficiency assumption and the non-dollar denominated nature of patents, examining the association between patent data and biotech firms' stock market value is worthwhile for two reasons. First, the (possible) market inefficiency is not large enough in magnitude to alter conclusions of value relevance studies. This observation is not surprising given that arbitrage should mitigate the effects of market inefficiencies on the measurement of value relevance, especially those effects found in large data sets using publicly available information (Aboody, Hughes, and Liu 2000). Second, the success of R&D activities is a vital determinant in biotech firms' value. Chan, Lakonishok, and Sougiannis (2000), however, find little difference between average stock price performance of firms engaged in R&D and firms with no R&D. The evidence reflects investors' lack of information about the nature and outcomes of firms' R&D activity. Because dollar denominated R&D spending under current accounting practice fails to provide value-relevant information, increased disclosure in direct measures of a biotechnology firm's inventive output, such as patents, may be beneficial.

2.2 Patent Measures

As patent data become more available in machine-readable form, patent-related measures, such as the number of patents and citation-weighted patents, seem to have become the most popular indicators of technological output and information flow.[5] A patent, by definition, is a temporary legal monopoly granted to inventors for the commercial use of an invention. When included in a market value equation, patents typically do not have as much explanatory power as an R&D measure. However, they do appear to add explanatory power above and beyond R&D (Hall 1998). One reason patents may not exhibit much correlation with dollar denominated measures such as R&D or market value is that they are an extremely noisy measure of the underlying economic value of the innovations with which they are associated (Grilliches, Pakes, and Hall 1987). Patents are an extremely noisy measure because the distribution of the value of patented innovations is known to be extremely skewed toward the low end, with a long and thin tail into the high-value side. Therefore, the number of patents held by a firm may be a poor proxy for the value of knowledge assets.[6] Some studies suggest that the number of citations received by a patent may be correlated with its economic value, so that weighting patents by the number of citations received may improve the measure (Harhoff, Narin, Scherer, and Vopel 1999).

[5] The research using patent counts and citations as R&D output measures is summarized in Griliches (1990) and Hall, Jaffe, and Trajtenberg (2000).

Patent citations identify the number of times each patent has been cited in subsequent patents. Harhoff, Narin, Scherer, and Vopel (1999) survey the German patent holders of 962 U.S. invention patents that also were filed in Germany, asking them to estimate at what price they would have been willing to sell the patent right in 1980, about three years after the date at which they filed the German patent. The results show that the most highly cited patents are very valuable, "with a single U.S. citation implying on average more than $1 million of economic value." The citation indicators, therefore, are expected to have a high positive correlation with market value.

Various studies have shown that patent citations capture important aspects of R&D value. For example, Trajtenberg (1990) reports a positive association between citation counts and consumer welfare measures for CAT scanners; Shane (1993) finds that patent counts weighted by citations (i.e., the firm's number of registered patents divided by the number of times these patents cited by others) contribute to the explanation of differences in Tobin's *q* measures (market value over replacement cost of assets) across semiconductor companies; and Hall, Jaffe, and Trajtenberg (2000) report that citation-weighted patent counts are positively associated with firms' market values (after controlling for R&D capital). Darby, Liu, and Zucker (2000) use patents counts, citation-weighted patent counts, claim-weighted patent counts, and the number of the firm's ties to star scientists as knowledge capital measures. They find that firms with two standard deviations more knowledge capital are valued 10% to 50% more than firms with

[6] Knowledge assets include rights to future benefits emanating from discovery and development activities (e.g., patents, know-how); brands, franchises and other customer-related assets; and unique organizational designs of corporations (Lev 2000).

mean values of all variables. Patent counts and citations thus reflect technological elements used by investors to value companies.

Other potentially informative patent measures used in prior studies are claim-weighted patents (Darby, Liu, and Zucker 2000), science linkage, and technology cycle time (Deng, Lev, and Narin 1999; Hirschey, Richardson, and Scholz 1998). Patent claims define the scope of the patent protection and describe what the patented invention does that has never been done before. Although simple patents have only a few claims, broader patents may cover separable inventions, each spelled out in a separate claim. Science linkage is measured as the average number of references cited on the front page of the patent, including academic journal articles and papers presented at scientific meetings. Technology cycle time is defined as the median age in years of earlier U.S. patents referenced by a patent. It shows how quickly a technology is evolving. Empirical analysis indicates that these patent-related measures are statistically associated with subsequent stock returns (Deng, Lev, and Narin 1999; Hirschey, Richardson, and Scholz 1998) and market-to-book ratios (Deng, Lev, and Narin 1999), suggesting that patent-related measures provide a useful tool for the investment analysis of technology and science-based firms.

Among existing patent literature, two value relevance studies address the relation between nonfinancial patent measures and financial performance in high-tech firms. Hirschey, Richardson, and Scholz (1998) obtain data from CHI's TECH-LINE database and investigate the value relevance of four patent variables, including the number of patents, current impact index, science linkage, and technology cycle time in high-tech industries.[7] They found that the four patent variables are individually and collectively important in explaining current market values. Similarly, Deng, Lev, and Narin (1999) examine the relation between the same four patent variables and stock returns and market-to-book ratios, based on all firms with positive equity on CHI research files matched with COMPUSTAT database. Their empirical analysis indicates that most of the examined patent attributes are statistically associated with subsequent stock returns and market-to-book ratios.

This study complements and extends that of Hirschey, Richardson, and Scholz (1998) and Deng, Lev, and Narin (1999). As mentioned earlier, not all high-tech industries patent significantly. Software development and production companies, for example, rely heavily on copyright and trademarks instead of on patenting activities. Therefore, the evidence in prior research documenting the value relevance of patents in the high-tech sectors in general may not be sufficient and could just indicate that firms in industries that are more likely to seek and be granted patents tend to have higher value. By focusing on the biotech industry, this paper examines the value relevance of patents on a set of firms that are equally likely (or more equally likely than those in different high-tech industries) to participate in patenting activities. It also provides more direct and reliable evidence on the underlying issue.

[7] The high-tech sector defined includes firms from SIC product group 28 (chemicals and allied products), 29 (petroleum refining), 35 (industrial and commercial machinery and computer equipment), 36 (electronic and other electrical equipment), 37 (transportation equipment), 38 (measuring, analyzing and controlling instruments), and 48 (communications).

2.3 Patents and R&D

The annual R&D expenditures of a firm are considered to be investments that add to a firm's knowledge asset. This knowledge asset depreciates over time so that the older R&D investment becomes less valuable as time passes. To supplement the information content, this study uses patent information as an indicator of the value of the additions to a biotech firm's underlying knowledge capital and future earnings potential. A maintained assumption of this study is that patents are an indicator of the output or "success" of R&D rather than an input of R&D. Testing this assumption, however, is beyond the scope of the study.

Hall, Griliches, and Hausman (1986) analyze the relation between patenting and R&D activity at the firm level by the U.S. manufacturing sector during the 1970's. They found that R&D and patents appear to be dominated by a contemporaneous relationship rather than leads or lags. Pakes and Griliches (1984), using the standard fixed effects model, found evidence of a lag truncation effect in the distributed lag of patents on R&D. That is, the estimated coefficient on R&D expenditures of four years prior was significantly higher than the coefficients of more recent R&D. Hausman, Hall, and Griliches (1984) used a different functional form and found similar results for the random effects but not in their conditional fixed effects version. When conditioning the estimates on the total number of patents received during the entire period, the study found that no coefficient except for the contemporaneous R&D variable were statistically significant either in the Poisson or negative binomial version. These earlier empirical results indicated a contemporaneous effect of R&D on patents but were inconclusive as to whether a significant lagged effect existed. The implications of prior empirical results for model specifications are that current year's R&D should be included in the value relevance model and that the lagged relationship between patents and R&D may need to be reexamined.

3. The Biotechnology Industry

In the context of current industrial practice, biotechnology commonly refers to the application of biological and biochemical science to large-scale production for the purpose of modifying human, health, food supplies, or the environment. The biotech industry today comprises many different practices, some of which involve the alteration of genetic material. Although people recognize its potential to cure diseases, many also fear that genetic research might result in the accidental creation and release of deadly new pathogens into the environment. In the early 1980s, the Supreme Court recognized patent rights on genetically altered life forms. This ruling means that U.S. biotech firms could continue to invest in costly research projects knowing that patents would protect their discoveries and ultimately maintain financial incentives.[8]

The biotech industry consists of more than 1,300 public and private entities with over 170,000 employees (Ernst & Young 2001). Biotech companies range in size from small start-ups to multibillion-dollar firms. In 2001, the top 10 publicly-owned U.S. biotech firms had over $13 billion in revenue, much higher than the $6 billion obtained by the top 10 in 1996. In the future, the disparity in revenue between the big firms and the emerging concerns is likely to grow primarily due to small biotech firms' lack of potential blockbuster research and products in the pipelines.

---

[8] Patents fall into three categories—utility, design, and plant. Utility patents may be granted to anyone who invents or discovers any new and useful process, machine, article of manufacture, or compositions of matters, or any new useful improvement thereof. Design patents may be granted to anyone who invents a new, original, and ornamental design for an article of manufacture. Plant patents may be granted to anyone who invents or discovers and asexually reproduces any distinct and new variety of plant (http://www.uspto.gov/web/patnets/howtopat.htm). Biotech firms mostly apply for utility and plant patents.

The analysis of a biotech firm, like that of any company, includes a thorough study of both business strategy and financial health. However, in contrast to companies in more mature industries, many biotech firms do not have commercial track records. The usefulness of looking at a biotech company's financial statements depends largely on whether the firm has an earnings history. Because the majority of biotech companies are in the developmental stages and not currently making money, traditional analytical techniques are of limited value. For these companies, analysts and investors tend to focus on the future earnings potential of products in development and on whether the company has the researches to fully develop those products. Absent any explicit market information on the value of a company's research pipeline or technology, patents can serve as a proxy for the firm's knowledge base and future earning potential.

Current patents can lead to royalties if a company decides to license its technology to other firms. Patents also protect companies by preventing potential competitors from entering certain markets. A recent high-profile legal case involving Transkaryotic Therapies, Inc. and Amgen underscores the value of patents. Transkaryotic was trying to develop a version of Amgen's Epogen anemia drug by a different manufacturing process than Amgen used. Although it did not research the same areas that Epogen serves, Transkaryotic found a way to manufacture a similar product through different means. In January 2001, a judge ruled that Transkaryotic's process did in fact infringe upon a patent held by Amgen and enjoined the company from entering the lucrative market that Epogen serves (Standard & Poor's 2002). As the information content of financial statements may be limited, nonfinancial patent information may fill this gap by providing important signals of financial performance in the biotech industry.

4. Theory Development

To examine whether nonfinancial patent information supplement the information content of financial information in market valuation, I follow recent theoretical work on valuation models developed by Ohlson (1995) who modeled the market value of the firm as a function of book value, earnings, and other relevant information. Knowledge asset has a crucial role in biotech firms' value creation. Therefore, to apply the Ohlson method in the biotech setting, this paper includes knowledge asset as other relevant information along with accounting data, such as book value and earnings, in the valuation model.

For a biotech firm, the largest and most important components of knowledge asset are its R&D expenditures and the discoveries made by its R&D activities. When successfully combined, these intangibles produce the intellectual property and legal patents that can rapidly translate into annual sales, profits, and/or large equity market value (Hand 2001). Because cumulative R&D expenditures and cumulative patent information measure the inventive input and inventive output that closely tie to a biotech firm's future earning potential, they are used to proxy for the knowledge asset in the biotech industry.

A biotech firm's market value can then be modeled as a function of book value, earnings, cumulative R&D spending, and cumulative patent information.[9] That is, a biotech firm's market value at the end of year t can be written as:

$$MV_t = \alpha_0 + \alpha_1 BV_t + \alpha_2 E_t + \beta_0 R\&D_t + \beta_1 R\&D_{t-1} + \ldots + \beta_m R\&D_{t-m} + \gamma_0 PATENT_t + \gamma_1 PATENT_{t-1} + \ldots + \gamma_n PATENT_{t-n} + \varepsilon_t , \quad (1.1)$$

[9] Appendix 2 presents an alternative approach to derive the return model.

where MV is market value, BV is book value, E represents earnings, m is the number of years in the economic life of R&D spending, and n is the number of years in the economic life of patents. Three problems arise in estimating equation (1.1), however. First, the appropriate economic life of R&D and patent information (i.e., m and n in equation (1.1)) in the biotechnology industry are unknown, and prior research on the lagged effects of R&D on patents are inconclusive. Second, $R\&D_t$, $R\&D_{t-1}$,…, $R\&D_{t-m}$ and $PATENT_t$, $PATENT_{t-1}$,…, $PATENT_{t-n}$ tend to move together and may result in multicollinearity problem. Third, when using time-series data over a given period, each lag included causes the loss of one data point. To avoid these problems, this study chooses to use a return model.

To derive the return model, I first assume that βs and γs follow Koyck distributed lag structure, for which the coefficients decline geometrically:

$$\beta_m = \lambda\beta_{m-1} = \lambda^2\beta_{m-2} = \ldots = \lambda^m\beta_0 ,$$

$$\gamma_n = \lambda\gamma_{n-1} = \lambda^2\gamma_{n-2} = \ldots = \lambda^n\gamma_0 , \qquad 0 < \lambda < 1, \qquad (1.2)$$

where λ measures the rate of decay of R&D expenditures and patent information. In this case, each coefficient is a certain proportion of the previous one, and the coefficients become successively smaller as they relate to earlier time periods. It then follows that

$$MV_t = \alpha_0 + \alpha_1 BV_t + \alpha_2 E_t + \beta_0 R\&D_t + \beta_0\lambda R\&D_{t-1} + \ldots + \beta_0\lambda^m R\&D_{t-m} + \gamma_0 PATENT_t + \gamma_0\lambda PATENT_{t-1} + \ldots + \gamma_0\lambda^n PATENT_{t-n} + \varepsilon_t . \qquad (1.3)$$

Next, lagging one period and multiplying by λ yields

$$\lambda MV_{t-1} = \alpha_0\lambda + \alpha_1\lambda\ BV_{t-1} + \alpha_2\lambda\ E_{t-1} + \beta_0\lambda\ R\&D_{t-1} + \ldots + \beta_0\lambda^m\ R\&D_{t-m}$$
$$+ \beta_0\lambda^{m+1}\ R\&D_{t-m-1} + \gamma_0\lambda\ PATENT_{t-1} + \ldots + \gamma_0\lambda^n\ PATENT_{t-n}$$
$$+ \gamma_0\lambda^{n+1}\ PATENT_{t-n-1} + \lambda\varepsilon_{t-1}\ . \qquad (1.4)$$

Subtracting equation (1.4) from equation (1.3) and modifying the left-hand side of the equation by subtracting and adding MV_{t-1} at the same time yields the following specified form:

$$MV_t - MV_{t-1} + MV_{t-1} - \lambda MV_{t-1} = \alpha_0\ (1 - \lambda) + \alpha_1\ (BV_t - \lambda\ BV_{t-1}) + \alpha_2\ (E_t - \lambda\ E_{t-1})$$
$$+ \beta_0\ R\&D_t + \gamma_0\ PATENT_t + (\varepsilon_t - \lambda\varepsilon_{t-1})\ , \qquad (1.5)$$

where the prior years' R&D expenditures and patent measures (i.e., $R\&D_{t-1},\ldots, R\&D_{t-m}$, $PATENT_{t-1},\ldots$, and $PATENT_{t-n}$) are cancelled out and the lagged effects of R&D on patent information are eliminated. The terms $R\&D_{t-m-1}$ and $PATENT_{t-n-1}$ are omitted in equation (1.5) because, as time passes, the knowledge asset depreciates, and the older R&D investments and patents become less valuable (i.e., the coefficients $\beta_0\lambda^{m+1}$ and $\gamma_0\lambda^{n+1}$ approach zero). Replacing $(BV_t - \lambda\ BV_{t-1})$ by $(BV_t - BV_{t-1} + BV_{t-1} - \lambda\ BV_{t-1})$ and $(E_t - \lambda\ E_{t-1})$ by $(E_t - E_{t-1} + E_{t-1} - \lambda\ E_{t-1})$, equation (1.5) can be modified as:

$$MV_t - MV_{t-1} + MV_{t-1} - \lambda MV_{t-1} = \alpha_0\ (1 - \lambda) + \alpha_1\ (BV_t + BV_{t-1} - BV_{t-1} - \lambda\ BV_{t-1})$$
$$+ \alpha_2\ (E_t + E_{t-1} - E_{t-1} - \lambda\ E_{t-1}) + \beta_0\ R\&D_t$$
$$+ \gamma_0\ PATENT_t + (\varepsilon_t - \lambda\varepsilon_{t-1})\ , \qquad (1.6)$$

Moving the terms $MV_{t-1} - \lambda MV_{t-1}$ in equation (1.6) from the left to the right-hand side and dividing both sides by MV_{t-1} yields the return model:

$$\frac{\Delta MV_t}{MV_{t-1}} = \alpha_0 (1 - \lambda) \frac{1}{MV_{t-1}} + \alpha_1 \frac{BV_t - BV_{t-1} + BV_{t-1} - \lambda BV_{t-1}}{MV_{t-1}}$$

$$+ \alpha_2 \frac{E_t - E_{t-1} + E_{t-1} - \lambda E_{t-1}}{MV_{t-1}} + \beta_0 \frac{R\,\&\,D_t}{MV_{t-1}} + \gamma_0 \frac{PATENT_t}{MV_{t-1}} - (1 - \lambda)$$

$$+ \frac{\varepsilon_t - \lambda \varepsilon_{t-1}}{MV_{t-1}}. \tag{1.7}$$

Finally, equation (1.7) can be written as:

$$\frac{\Delta MV_t}{MV_{t-1}} = \alpha_0 (1 - \lambda) \frac{1}{MV_{t-1}} + \alpha_1 \frac{\Delta BV_t}{MV_{t-1}} + \alpha_1 (1 - \lambda) \frac{BV_{t-1}}{MV_{t-1}} + \alpha_2 \frac{\Delta E_t}{MV_{t-1}}$$

$$+ \alpha_2 (1 - \lambda) \frac{E_{t-1}}{MV_{t-1}} + \beta_0 \frac{R\,\&\,D_t}{MV_{t-1}} + \gamma_0 \frac{PATENT_t}{MV_{t-1}} - (1 - \lambda)$$

$$+ \frac{\varepsilon_t - \lambda \varepsilon_{t-1}}{MV_{t-1}}, \tag{2}$$

where ΔMV_t, ΔBV_t, and ΔE_t represent the change in market value, book value, and earnings from year t-1 to year t, respectively.

Compared with equation (1.1), the return model in equation (2) does not require use of the economic life of R&D and patent information nor the lagged effects of R&D on patents. In addition, the return model provides evidence regarding the timeliness of investors' use of financial and nonfinancial patent information (Easton 1999). Therefore, this study will use the return model in equation (2) as a baseline model.

One concern about equation (2) is that the error term is proportional to $\frac{1}{MV_{t-1}}$ and may result in heteroskedasticity. Therefore, this study uses two-way random or fixed effects models instead of OLS to estimate coefficients in the return model. Two-way random or fixed effects models are designed to handle various types of heteroskedasticity. They are more general approaches than a more structural GLS approach, which would ignore other unknown sources or forms of heteroskedasticity.

5. Hypotheses and Patent Variable Definitions

5.1. Hypotheses

The first part of this study examines the value-relevance of reported financial information and that of nonfinancial intangible knowledge capital for asset valuation in the biotech industry. Biotech firms compete with others in an R&D intensive and technologically innovative environment. Consequently, frequent breakthrough innovations based on the firms' knowledge capital result in significant increases in the firms' asset values. A patent grants the property right to the inventor to exclude others from making, using, offering for sale, or selling the invention. Thus, I predict that patent information captures the biotech firms' value not currently valued by traditional financial indicators. This reasoning leads to the first hypothesis, stated in the alternative form as follows:

H1: Nonfinancial patent information adds incremental value relevance to the market valuation in biotech companies.

Another important purpose of this study is to provide understanding of the role nonfinancial performance measures play as leading indicators of financial performance. Advocates argue that nonfinancial indicators of investments in intangible assets may be better predictors of future financial performance than are historical accounting measures. Itter and Larcker (1998), for example, examine the relation between customer satisfaction and financial performance and conclude that nonfinancial indicators should supplement financial measures in internal accounting systems and executive compensation plans. In addition, Behn and Riley (1999) provide empirical evidence that timely nonfinancial information can be useful in predicting financial performance in the U.S. airline industry, and they suggest that nonfinancial information disclosure may enhance traditional financial reporting. This previous research leads to the second hypothesis, stated in the alternative form as follows:

H2: Nonfinancial patent information is associated with and can be useful in predicting financial performance in the U.S. biotech industry.

5.2. Patent Variable Definitions

Financial statements do not report patent information under current U.S. accounting standards. Testing the hypotheses requires identifying a set of patent variables. In this study, I develop six patent variables based on data obtained from the U. S. Patent and Trademark Office. PATNUM indicates the total number of U.S. patents granted to the company during a given year. CLAIM indicates the average number of claims in a firm's granted patents in a given year. Patent claims define the scope of the patent protection and describe what the patented invention does that has never been done before. CITATION, a citation intensity indicator, provides the average number of citations to the company's patents issued in a given year, divided by the average number of citations to all patents in the sample granted in the same years.[10] The percentage, rather than citation counts, is used to construct CITATION to avoid age bias caused by patents issued in earlier years receiving more citations than newly-granted patents. The fundamental idea underlying the economic analysis of patent citations is that a large

[10] For example, if a biotech firm's 1996 patents on average received 2 citations from later patents up to the end of year 2001 and all the 1996 patents of the sample firms on average received 0.5 citations from later patents during the same time period, then the firm's CITATION in 1996 is 4, calculated as 2 divided by 0.5.

number of citations to a patent indicates that the examined patent represents an important invention.[11] However, because CITATION is an ex post measure, the results indicating the value relevance of CITATION do not imply that CITATION should be or can be disclosed. REFAGE is based on the average median age of the U.S. patents cited on the front page of a patent. A tendency to cite mature patents indicates that the firm engages in old technology. REFNUM indicates the average number of references to scientific journal papers and conference proceedings cited by a patent. This variable shows how strongly a patent is linked to scientific research (Deng, Lev, and Narin 1999). DNA% is the percentage of genetic patents in a firm's total granted patents in a given year. The percentage, rather than genetic patent counts, is used to construct the variable to avoid the possible high collinearity between patent counts and genetic patent counts. A higher DNA% indicates that the firm is more strongly linked to genetic research. Of the six patent variables, PATNUM measures a biotech firm's patent quantity and CLAIM, CITATION, REFAGE, REFNUM, and DNA% assess various aspects of quality of the firm's patents.

[11] The CITATION measure in this study includes "self citations," namely citations to a firm's patent in subsequent patents of the same firm. Such self citations may represent construction of patent thickets or other behaviors that are less value-relevant than citations from other companies. On the other hand, a self citation may indicate that the company continues to build on its earlier inventions. This interpretation implies that self citations are more valuable than citations from others. A preliminary investigation in Hall, Jaffe, and Trajtenberg (2000) indicates that "the self-citation effect is small and positive: if the 'self' share of citations is higher, the market value is higher, other things equal." Because the self-citation effect is not considered to be significant, this study does not adjust its influence on the CITATION measure.

6. Research Design

6.1. Value Relevance Model

Based on the discussion in section 4, this study uses a return model as a baseline model. To test whether patent measures capture the biotech firms' value not currently valued by traditional financial indicators (H1), I first examine the relation between financial variables and returns of biotech firms. Motivated by the Fama and French (1992), the return model in equation (3) adds book-to-market ratio, market value, and CAPM-beta as control variables.

$$RETURN_{jt} = \alpha_0 + \sum_{yr=1990}^{2001} \alpha_{yr+1} YR + \sum_{n=1}^{292} \alpha_{n+1} FIRM + \alpha_1 \frac{1}{MV_{jt-1}} + \alpha_2 \frac{\Delta BV_{jt}}{MV_{jt-1}}$$

$$+ \alpha_3 \frac{BV_{jt-1}}{MV_{jt-1}} + \alpha_4 \frac{\Delta E_{jt}}{MV_{jt-1}} + \alpha_5 \frac{E_{jt-1}}{MV_{jt-1}} + \alpha_6 \frac{R\&D_{jt}}{MV_{jt-1}} + \alpha_7 B/M_{jt}$$

$$+ \alpha_8 MV_{jt} + \alpha_9 BETA_{jt} + \varepsilon_{jt}, \qquad (3)$$

where $RETURN_{jt}$ is measured as the change in market value of firm j from year t-1 to year t divided by market value at the end of year t-1; YR and FIRM are year and firm dummy variables included to control for time and firm variation; MV_{jt-1} and MV_{jt} are total market value of firm j at the end of year t-1 and year t, respectively; ΔBV_{jt} is the change in book value of firm j in year t; BV_{jt-1} is the book value of firm j at the end of year t-1; ΔE_{jt} is the change in earnings before R&D expenditures of firm j in year t; E_{jt-1} is earnings before R&D expenditures of firm j at the end of year t-1; $R\&D_{jt}$ is the R&D expenditures of firm j at the end of year t; B/M_{jt} is the book-to-market ratio of firm j at the end of year t; and $BETA_{jt}$ is the CAPM-beta of firm j, estimated from 60 monthly stock returns (minimum of 24) to the end of year t.

To test the incremental value relevance of patent information, I then regress returns on financial information along with six patent variables using the following model:

$$RETURN_{jt} = \beta_0 + \sum_{yr=1990}^{2001} \beta_{yr+1}\, YR + \sum_{n=1}^{292} \beta_{n+1}\, FIRM + \beta_1 \frac{1}{MV_{jt-1}} + \beta_2 \frac{\Delta BV_{jt}}{MV_{jt-1}}$$

$$+ \beta_3 \frac{BV_{jt-1}}{MV_{jt-1}} + \beta_4 \frac{\Delta E_{jt}}{MV_{jt-1}} + \beta_5 \frac{E_{jt-1}}{MV_{jt-1}} + \beta_6 \frac{R\&D_{jt}}{MV_{jt-1}}$$

$$+ \beta_7 \frac{PATNUM_{jt}}{MV_{jt-1}} + \beta_8 \frac{PATNUM * CLAIM_{jt}}{MV_{jt-1}}$$

$$+ \beta_9 \frac{PATNUM * CITATION_{jt}}{MV_{jt-1}} + \beta_{10} \frac{PATNUM * REFAGE_{jt}}{MV_{jt-1}}$$

$$+ \beta_{11} \frac{PATNUM * REFNUM_{jt}}{MV_{jt-1}} + \beta_{12} \frac{PATNUM * DNA\%_{jt}}{MV_{jt-1}}$$

$$+ \beta_{13}\, B/M_{jt} + \beta_{14}\, MV_{jt} + \beta_{15}\, \beta_{jt} + \varepsilon_{jt}, \qquad (4)$$

where $\frac{PATNUM_{jt}}{MV_{jt-1}}$ is the total number of U.S. patents granted to firm j in a given year t, deflated by the firm's market value at the end of year t-1; $\frac{PATNUM * CLAIM_{jt}}{MV_{jt-1}}$, $\frac{PATNUM * CITATION_{jt}}{MV_{jt-1}}$, $\frac{PATNUM * REFAGE_{jt}}{MV_{jt-1}}$, $\frac{PATNUM * REFNUM_{jt}}{MV_{jt-1}}$, and

$\frac{PATNUM * DNA\%_{jt}}{MV_{jt-1}}$ are interaction terms of deflated PATNUM and each of the five patent quality variables (e.g., $\frac{PATNUM * CLAIM_{jt}}{MV_{jt-1}}$ is the interaction of $\frac{PATNUM_{jt}}{MV_{jt-1}}$ and $CLAIM_{jt}$). The five patent quality variables (defined in section 5.2) represent averaged patent attributes (CLAIM, REFAGE, and REFNUM) or indices (CITATION and DNA%) and can measure the potential of a biotech firm's patents in turning to marketable and quality products. Therefore, I expect that the change in a biotech firm's returns corresponding to a unit change in deflated PATNUM depends on the various aspects of patent quality measured by the five patent quality variables. In other words, each of the patent quality variables has an effect on a firm's return through the firm's total patents, and the interaction terms capture that impact.[12] If the coefficients of patent variables (β_7 through β_{12}) are jointly statistically significant and the R-squares of regression (4) exceeds that of regression (3), one can conclude that patent information adds incremental value relevance to the market value of the biotech companies.

6.2. Performance Model

Performance model follows the same logic in value relevance model and empirically tests the ability of nonfinancial measures in year t to predict future annual financial performance in year t+n (H2). Three performance variables are examined, including revenues (REV), margins (MAR), and return on sales (ROS). Margins are

[12] An implicit assumption of equation (4) for not including CLAIM, CITATION, REFAGE, REFNUM, and DNA% as independent regressors is that the direct impact of patent quality variables on returns of a biotech firm is zero. Table 6 in section 9 presents the regression results releasing this restriction. The results with or without this restriction are similar.

defined as revenues minus R&D expenditures, and return on sales as margins divided by revenues. I estimate the following basic model following work done by Itter and Larcker (1998):

$$PERFORM_{jt+n} = \gamma_0 + \gamma_1 \frac{PATNUM_{jt}}{MV_{jt-1}} + \gamma_2 \frac{PATNUM * CLAIM_{jt}}{MV_{jt-1}}$$

$$+ \gamma_3 \frac{PATNUM * CITATION_{jt}}{MV_{jt-1}} + \gamma_4 \frac{PATNUM * REFAGE_{jt}}{MV_{jt-1}}$$

$$+ \gamma_5 \frac{PATNUM * REFNUM_{jt}}{MV_{jt-1}} + \gamma_6 \frac{PATNUM * DNA\%_{jt}}{MV_{jt-1}}$$

$$+ \gamma_7\, PERFORM_{jt} + \gamma_8 \frac{R\&D_{jt}}{MV_{jt-1}} + \gamma_9\, LnASSET_{jt+n} + \varepsilon_{jt+n,}\quad n=1,2,\ldots 5.$$

(5.1), (5.2), & (5.3)

where PATNUM, PATNUM*CLAIM, PATNUM*CITATION, PATNUM*REFAGE, PATNUM*REFNUM, and PATNUM*DNA% are the same set of patent variables used in equation (4). In addition, $\frac{REV_{jt+n}}{MV_{jt-1}}$ and $\frac{REV_{jt}}{MV_{jt-1}}$, $\frac{MAR_{jt+n}}{MV_{jt-1}}$ and $\frac{MAR_{jt}}{MV_{jt-1}}$, and ROS_{jt+n} and ROS_{jt} are the performance variables that substitute for $PERFORM_{jt+n}$ and $PERFORM_{jt}$ in equations (5.1), (5.2), and (5.3), respectively. Finally, $R\&D_{jt}$ is the R&D expenditures of firm j at the end of year t and $LnASSET_{jt+n}$ is the log of a firm's total assets in year t+n. ROS_{jt+n} and ROS_{jt} are not scaled by MV_{jt-1} because they are ratios instead of dollar amounts. LnASSET is included in the model to control for size effects. If coefficients γ_1 to γ_6 in equation (5.1), (5.2), and (5.3) appear to be jointly statistically significant, one can conclude that patent information is a useful predictor of future financial performance.

6.3. Econometrics Issues

A potential problem in the above equations incorporating patent variables is the degree of multicollinearity, which results in a higher standard error of estimate. I apply tests to examine the degree of multicollinearity, including using an F-test for the full model and checking variance inflation factor (VIF). Multicollinearity is not an issue in testing the hypotheses if the patent variables in the equation are jointly statistically significant. However, if the patent variables are not jointly statistically significant and the multicollinearity among them appears to be high, a patent index will be created to alleviate this problem.

Another concern is that the above models might contain omitted variables. Factors not incorporated in this study, such as human capital, strategic alliances with major pharmaceutical firms, FDA approvals, and technology platform, also could drive a biotech firm's value. These potential value drivers are not incorporated in this study because they either are difficult to quantify or do not apply to the entire biotech sample, e.g., the number of FDA approvals is not a valid value drivers to a pure biotech firm without commercialized products or drugs in the pipeline. The omitted variable bias will be large if omitted variables are important in the model or if they are related statistically to included variables. Examples for variables that are related statistically to patent variables but are not included in this study are human capital and research resources available in the neighborhood (i.e., number of research institutes or universities). A biotech firm employing more scientists with continuous distinguishing publication records and having more national labs in the neighborhood may be more likely to succeed in creating quality patents. Due to the potential omitted variable bias, the interpretation and application of the findings should be with caution.

7. Data Sources and Sample Selection

7.1 Data Sources

Nonfinancial patent data on five patent attributes (PATNUM, CLAIM, CITATION, REFAGE, and REFNUM) for the years 1990-2001 are from the United States Patent and Trademark Office's (PTO) Web page. If a patent found on PTO matches with one on the DNA Patent Database (DPD), the patent is identified as a DNA patent. DPD is a joint project of the Georgetown University's Kennedy Institute of Ethics and the Foundation for Genetic Medicine. The DPD is being created to enable relevant empirical studies of DNA-based patents issued in the United States. Patents included in the DPD were identified by virtue of their USPTO classification numbers and the presence of keywords such as "DNA," "nucleotide," or "polynucleotide" in one or more claims. All financial data are obtained from the Compustat database.

7.2 Sample Selection

Financial analysts and investors have various definitions for the biotech industry. This study adopts Standard & Poor's Market Insight industry classification, which defines the biotechnology industry as companies primarily involved in the development, manufacturing, or marketing of products based on advanced biotechnology research. Preliminary investigation reveals an initial sample contains 292 U.S. biotechnology companies on Market Insight that generate $27,090 million in combined annual sales (based on 12-month moving data). The analysis is based on these companies' financial and nonfinancial data for the years 1990-2001. A search of Compustat results in 255 possible sample companies with 1,551 firm-year observations available. Of those 1,551 firm-year observations, 273 are lost when constructing 1-year lagged data, and 95 firm-year observations are deleted because of negative book values.[13] Firms with negative book values are eliminated from the analysis because, pratically, those firms are bankrupt and the normal assumption of the earnings-returns or patent-returns relation may not hold. The final sample consists of 231 companies with 1,183 firm-year observations.

[13] An inclusion of the 95 firm-year observations with negative book values yields similar results.

8. Results

Table 1 provides descriptive statistics for the full sample.[14] Descriptive statistics for undeflated variables are in Panel A. The mean PATNUM is 4.69, but the large standard deviation (12.85) and the relatively low median (2) indicate high variability of patent counts across firms and the presence in the sample of a few firms with a large number of patents. Similar variability and skewness can be observed in other patent variables. The mean CITATION, 0.71, indicates that averagely sample biotech firms have lower-than-average citations. The median CITATION, 0.21, indicates that half of the biotech firms received 21% or less of the average citations in the industry. On average, sample biotech companies make 13.2 claims and cite 16.3 scientific study or conference proceedings per patent application. The patents cited by the firms have a median age of 4.43 years (mean REFAGE = 4.43). The percentage of genetic patents in total granted patents in a year for the sample biotech firms on average is 26% (mean DNA% = 0.26). The size of sample firms ranges from $0.34 million to $87,878.6 million in market value. Because of low sales revenue and high R&D expenditures, MAR and ROS are negative for more than half the 1,183 firm-year observations (median MAR = -2.33; median ROS = -0.46). Panel B of Table 1 reports descriptive statistics for deflated variables used in regression models. All variables (except for $1/MV_{t-1}$) in Panel B are scaled by MV_{t-1}.

Table 2 provides a correlation table for sample variables. The patent variables with the highest correlation are CLAIM and REFAGE at 52%, REFAGE and REFNUM at 41%, and CLAIM and REFNUM at 40%. When CLAIM, REFNUM, and REFAGE are included in the same model, the high correlation among them might impair the model's ability to explain the variation in returns. Therefore, in the sensitivity tests section when regressing returns on deflated PATNUM and patent quality variables, the alternative models excluding two of the three highly correlated variables at each time are also presented for comparison purpose (Columns D to F in Table 6). The independent variables with the highest correlations are REV/MV_{t-1} and MAR/MV_{t-1} at 83%. Because the performance variables, REV/MV_{t-1} and MAR/MV_{t-1}, are each identified as an independent variable in different regressions (equations (5.1) and (5.2), respectively), the high correlations between these variables do not affect the regression results.

Panel A of Table 3 provides descriptive statistics on undeflated variables for biotech firms with and without patents used in the empirical tests. The top statistic for each variable is for firms with patents; parenthetically below is the comparable statistic for those without patents. T-tests are used to examine whether significant univariate differences exist. Except for MV_{t-1} and BETA, the mean values of the variables for firms with patents are significantly different than those for firms without patents at conventional levels. Compared with the without-patent group, the with-patent group has larger numbers in MV, LnASSET, and RND. Apparently, large biotech firms with intensive R&D investment are more likely to be successful in knowledge assets development. The statistics of performance variables reflect the importance of knowledge assets in the biotech industry, given that, on average, firms with patents have better performance than those without patents in terms of revenues, margins, and return on sales. The with-patent group also has higher mean and median values in RETURN,

[14] All tables are located in Appendix 3.

which implies that patents add to biotech firms' future earning potential and that investors value patents in market valuation. Panel B of Table 3 reports the SIC composition of the sample. Approximately 81% of the sample observations are in the drugs and pharmaceuticals segment (SIC codes beginning with 283), and, on average, 69% of those in drugs and pharmaceuticals segment have patents. Similarly, about 68% of overall sample observations are in the with-patent group, suggesting a general tendency of biotech firms to engage in patenting activities.

Table 4 presents results of regressing returns on financial, patent, and control variables, using two-way random or fixed effects models. The results of fixed effects models are omitted because the low H values (reported in the Hausman test) favors random effects models. The R^2 in the regression incorporating all financial, patent, and control variables is six percentage points higher than that in the regression with only financial and control variables (R^2 = 0.29 vs. 0.26). The F-statistic to test the incremental value relevance of patent information is 9.08, rejecting the null hypothesis that the coefficients of all six patent variables are jointly zero (in the full model containing all financial, patent, and control variables) at the 1% significance level. These results indicate that patent information adds incremental value relevance to the market valuation of the biotech companies.

The negative coefficient estimate of deflated PATNUM in column C of Table 4 indicates that a patent with zeros in all patent attributes reduces a biotech firm's return. However, a biotech firm's patent with average patent attributes contributes to 0.18

percentage point increase in its return,[15] consistent with the positive coefficient of deflated PATNUM shown in column B. The results in the full model may be questionable due to the multicollinearity among the PATNUM and PATNUM interaction variables.[16] The multicollinearity leads to the regression of returns on financial, control, and each single PATNUM interaction variables. As shown in columns D to H, each interaction variable is significant at the conventional level, indicating that the change in a biotech firm's returns corresponding to a unit change in deflated PATNUM depends on the level of patent quality.

Table 5 reports the OLS results of equations (5.1), (5.2), and (5.3). Panel A and B present the results of using patent variables to predict performance for one and two years subsequent to the year examined, respectively.[17] Panel A indicates that current year's performance, including revenues, margins, and return on sales, is useful in predicting next year's performance (significant at the 1% level). Patent variables are jointly significantly associated with one-year subsequent return of sales (F-statistic = 11.17), but not for revenues and margins. However, with a two-year lag, patent information is jointly significantly associated with and can be useful in predicting a biotech firm's revenues, margins, and return on sales. Panel B reports the results.

---

[15] It is calculated as sum of the multiplicative results of the mean and coefficient estimate of each patent variable. That is, $0.05*(-8.45) + 0.9*0.33 + 0.03*5.07 + 0.31*0.38 + 1.06*(-0.01) + 0.02*1.66 \approx 0.18$.

[16] The VIFs for PATNUM, PAT*CLAIM, PAT*CITATION, PAT*REFAGE, PAT*REFNUM, and PAT*DNA% (all deflated by MV_{t-1}) are 24.52, 5.12, 2.06, 8.30, 5.42, and 9.55. The high VIFs of PATNUM and PAT*DNA% imply the existence of collinearity. The estimated coefficients of PATNUM and DNA% may be unreliable.

[17] The results of predicting three, four, and five years subsequent performance are insignificant and thus not tabulated. Because the sample covers 12-year data and most sample firms are younger than 12 years, this study did not examine the predictive power of patent information beyond five years.

Interestingly, in panel B, the coefficient of the deflated PATNUM and DNA% interaction is positive in the revenue regression but negative in the margins and return on sales regressions at the conventional significance level. In other words, an increase in the percentage of genetic patents to the total number of patents improves the change in a biotech firm's two-year ahead sales revenues but deteriorates the change in margins and returns on sales, corresponding to a unit change in current year's deflated PATNUM. The results suggest that, due to the potential of genetic patents in developing new marketable and profitable medical products, a biotech firm with a high percentage of genetic patents in its patent composition could contribute positively to 2-year ahead revenues. However, the subsequent R&D expenditures of turning those genetic patents into quality and profitable products also may grow, even at a higher rate than revenues do, hereby resulting in the negative coefficient of the deflated PATNUM and DNA% interaction in the margins and return of sales regressions.

9. Sensitivity Tests

The first sensitivity test examines the effect of including all five patent quality variables along with deflated PATNUM and its interaction terms in testing the incremental value relevance of patent information, that is, to estimate an unrestricted version of equation (4).

$$
\begin{aligned}
\text{RETURN}_{jt} = {} & \beta_0 + \sum_{yr=1990}^{2001} \beta_{yr+1}\,\text{YR} + \sum_{n=1}^{292} \beta_{n+1}\,\text{FIRM} + \beta_1 \frac{1}{\text{MV}_{jt-1}} + \beta_2 \frac{\Delta \text{BV}_{jt}}{\text{MV}_{jt-1}} + \beta_3 \frac{\text{BV}_{jt-1}}{\text{MV}_{jt-1}} \\
& + \beta_4 \frac{\Delta \text{E}_{jt}}{\text{MV}_{jt-1}} + \beta_5 \frac{\text{E}_{jt-1}}{\text{MV}_{jt-1}} + \beta_6 \frac{\text{R\&D}_{jt}}{\text{MV}_{jt-1}} + \beta_7 \frac{\text{PATNUM}_{jt}}{\text{MV}_{jt-1}} + \beta_8 \frac{\text{CLAIM}_{jt}}{\text{MV}_{jt-1}} \\
& + \beta_9 \frac{\text{CITATION}_{jt}}{\text{MV}_{jt-1}} + \beta_{10} \frac{\text{REFAGE}_{jt}}{\text{MV}_{jt-1}} + \beta_{11} \frac{\text{REFNUM}_{jt}}{\text{MV}_{jt-1}} + \beta_{12} \frac{\text{DNA\%}_{jt}}{\text{MV}_{jt-1}} \\
& + \beta_{13} \frac{\text{PATNUM} * \text{CLAIM}_{jt}}{\text{MV}_{jt-1}} + \beta_{14} \frac{\text{PATNUM} * \text{CITATION}_{jt}}{\text{MV}_{jt-1}} \\
& + \beta_{15} \frac{\text{PATNUM} * \text{REFAGE}_{jt}}{\text{MV}_{jt-1}} + \beta_{16} \frac{\text{PATNUM} * \text{REFNUM}_{jt}}{\text{MV}_{jt-1}} \\
& + \beta_{17} \frac{\text{PATNUM} * \text{DNA\%}_{jt}}{\text{MV}_{jt-1}} + \beta_{18}\,\text{B/M}_{jt} + \beta_{19}\,\text{MV}_{jt} + \beta_{20}\,\text{BETA}_{jt} + \varepsilon_{jt}\ . \quad (4')
\end{aligned}
$$

In equation (4') each patent quality variable may influence returns directly (in coefficients β_8 to β_{12}) or indirectly through the interaction with PATNUM (in coefficients β_{13} to β_{17}). Table 6 summarizes the results of this alternative model specification. As shown in column C, the R^2 of the full model is seven percentage points higher than that of the regression with only financial and control variables (column A). The F-statistic of

6.41 rejects the null hypothesis that the coefficients of all patent variables (β_7 through β_{17}) are jointly zero in the full model at the 1% significance level. On average, a biotech firm's patents and patent attributes contribute to a 0.08 percentage point increase in its return. These results support the incremental explanatory power of patent information and agree with the return model presented in Table 4. In addition, to test whether each patent variable is individually significantly associated with returns in the full model, I use the F test to determine whether the coefficients of all regressors involving the underlying patent variable are jointly zero. (For example, CLAIM is value relevant if the null hypothesis that both β_8 and β_{13} equal to zero is rejected). Results reveal that PATNUM, CLAIM, CITATION, REFAGE, and DNA% each has influence on a biotech firm's returns in the full model, even though the t ratios for the coefficients of CITATION and REFAGE are less than 2.0.[18]

Column B of Table 6 presents the results of equation (4') without presence of interaction terms. The results again support the incremental value relevance of patent information. Particularly, the t test shows that PATNUM and DNA% are significantly positively associated with returns in this model specification. Because of the high correlations among REFNUM, REFAGE, and CLAIM as shown in Table 2, columns D to F report the regression results of excluding two of the three highly correlated variables at a time for comparison purposes.[19] The results are comparable to those in column B.

[18] The F-statistics are 14.11 for CLAIM (significant at the 1% level), 5.51 for CITATION (at the 1% level), 2.53 for REFAGE (at the 10% level) and 4.24 for DNA% (at the 5% level).
[19] The VIFs for deflated PATNUM, CLAIM, CITATION, REFAGE, REFNUM, and DNA% are 1.04, 1.49, 1.13, 1.48, 1.37, and 1.19, respectively, suggesting that no notable multicollinearity exists in this model specification.

The second sensitivity test examines whether patent information is value relevant in a subsample of biotech firms with losses before R&D expenditures. Ertimur (2003) shows that firms reporting accounting losses experience higher levels of information asymmetry among investors than do those reporting profits. In this situation, one should expect to see that patent information mitigates the information asymmetry and provides more explanatory power in firms with net losses. Table 7 reports the regression results supporting this line of reasoning. Compared with the six percentage points increase in the R^2 in the full sample (column C in Table 4), the R^2s in the regressions incorporating both financial and patent variables (columns B and C) are thirteen and seventeen percentage points higher than the R^2 in the regression with only financial variables. The results indicate that patent variables provide more explanatory power for firms with losses before R&D expenditures than for those in the full sample. Patent information help mitigates the information asymmetry in biotech firms with losses before R&D expenditures. In addition, a patent with average value of all attributes results in 0.26 and 0.05 percentage point increase in a biotech firm's return, consistent to the findings in Table 4.

10. Conclusions, Limitations, and Future Research

In this study, I examined the association between nonfinancial patent information and financial information in the biotechnology industry and investigated whether this nonfinancial information is useful to investors in assessing biotechnology firms' long-term financial performance. I found evidence consistent with the idea that patent information captures the biotech firms' value not currently formally valued by traditional financial indicators and adds incremental value relevance to the market valuation of the biotech companies. In addition, patent information is associated with and can be useful in predicting a biotech firm's long-term financial performance, with a two-year lag.

This research is important because both academics and policymakers have expressed concerns about the declining importance of financial reporting and disclosure and have suggested that nonfinancial leading indicators showing how key business processes are performing may enhance financial statement users' ability to evaluate and predict financial performance. Given the current debate over what information should be disclosed and audited, this study contributes to the existing literature by providing empirical evidence that the disclosure of biotech companies could be improved by using all the value drivers in the business, including both financial results and value-enhancing nonfinancial patent measures. However, this study has its limitations.

One of the limitations is that no theoretical functional form exists for the relation between patent information and financial performance. Although this study assumes linearity, the relation also could be nonlinear. Thus, one extension may be for researchers to build an analytical modeling foundation. Another limitation is that this research is completed at the industry level. The focus on a specific industry adversely impacts the generalizability of the findings. However, Amir and Lev (1996) argue that analyses gained from industry studies are often more insightful than those found in general cross-sectional studies.

As mentioned earlier, human capital, strategic alliances, with major pharmaceutical firms, FDA approvals, and technology platform also could drive a biotech firm's value. For example, Ely, Simko, and Thomas (2003) illustrate the usefulness to investors of drug development information disclosed by start-up biotech firms. Although further research may be warranted on potential nonfinancial value drivers, I conducted the analysis of patent measures and financial performance only and will leave the exploration of other value nonfinancial leading indicators for subsequent research.

References

References

Aboody, D., J. Hughes, and J. Liu, 2000. Measuring value relevance in a (possibly) inefficient market. Working paper. University of California at Los Angeles.

AICPA. 1994. *Improving business reporting—A customer focus: Meeting the information needs of investors and creditors*. (Jenkins Committee Report). New York, NY.

Amir, E. and B. Lev, 1996. Value-relevance of nonfinancial information: the wireless communications industry. *Journal of Accounting & Economics* 22, 3-30.

Barth, M., W. Beaver, and W. Landsman, 2001. The relevance of the value relevance literature for financial accounting standard setting: another view. *Journal of Accounting & Economics* 31, 77-104.

Behn, B. and R. Riley, 1999. Using nonfinancial information to predict financial performance: The case of the U.S. airline industry. *Journal of Accounting, Auding, and Finance* (Winter), 29-56.

Business Week, New York, August 26, 2002, p.110.

Chan, L., J. Lakonishok, and T. Sougiannis, 2000. The stock market valuation of research and development expenditures. *Journal of Finance* 56(6): 2431-2456.

Darby M. R., Q. Liu, and L. G. Zucker, 2000. High stakes in high technology: high-tech market values as real options. Working paper. UCLA.

Deng, Z., B. Lev, and F. Narin, 1999. Science and technology as predictors of stock performance. *Financial Analysts Journal* 55 (May/June), 20-32.

Easton, P., 1999. Security returns and the value relevance of accounting data. *Accounting Horizons* 13: 399-412.

Ely, K., P. J. Simko, and L. G. Thomas, 2003. The usefulness of biotechnology firms' drug development status in the evaluation of research and development costs. *Journal of Accounting, Auditing & Finance* 18 (1), 163-195.

Ernst & Young's Biotechnology Industry Report, Millennium Edition.

Ertimur, Y., 2003. Financial Information Environment of Loss Firms. Working paper. NYU.

Fama, E. and K. French, 1992. The cross section of expected stock returns. *Journal of Finance* 47: 427-465.

Francis, J. and K. Schipper, 1999. Have financial statements lost their relevance? *Journal of Accounting Research* 37: 319-352.

Griliches, Z., 1990. Patent statistics as economic indicators. *Journal of Economic Literature* 92: 630–653.

Griliches, Z., A. Pakes, and B. Hall, 1987. “The value of patents as indicators of inventive activity” in Dasgupta, Partha, and Paul Stoneman (eds.), *Economic Policy and Technological Performance*. Cambridge, England: Cambridge University Press, 97-124.

Hall, B., Z. Griliches, and J. Hausman, 1986. Patents and R and D: Is there a lag? *International Economic Review* 27, 265-283.

Hall, B., 1998. Innovation and market value, prepared for the NIESR conference on Productivity and Competitiveness, London, England.

Hall, B., A. Jaffe, and M. Trajtenberg, 2000. Market value and patent citations: a first look. NBER working paper 7741. Cambridge, MA.

Hand, J., 2001. The market valuation of biotechnology firms and biotechnology R&D. Working paper. UNC Chapel Hill.

Harhoff, D., F. Narin, F. Scherer, and K. Vopel, 1999. Citation frequency and the value of patented innovations. *The Review of Economics and Statistics* 81, 3, 511-515.

Hausman, J., B. Hall, and Z. Griliches, 1984. Econometric models for count data with an application to the patents R and D relationship. *Econometrica* 52: 909-938.

Hirschey, M., V. Richardson, and S. Scholz, 2001. Value relevance of nonfinancial information: the case of patent data. *Review of Quantitative Finance & Accounting* 17: 223-235.

Holthausen, R. and R. Watts, 2001. The relevance of vale relevance literature for financial accounting standard setting. *Journal of Accounting & Economics* 31, 3-75.

Intriligator, M., 1978. *Econometric models, techniques, & applications.* Englewood Cliffs, N.J. Prentice-Hall, Inc.

Ittner, C. and D. Larcker, 1998. Are nonfinancial measures leading indicators of financial performance? An analysis of customer satisfaction. *Journal of Accounting Research* 36 (Supplement), 1-35.

Jorion, P. and E. Talmor, 2001. Value relevance of financial and non financial information in emerging industries: the changing role of web traffic data. Working paper. London Business School accounting subject area No. 021.

Kothari, S. P. and J. Zimmerman, 1995. Price and return models. *Journal of Accounting & Economics* 20: 155-192.

Lee, C., 1999. Accounting-based valuation: impact on business practices and research. Forthcoming. *Accounting Horizon* 13: 413-425.

Lev, B., 2000. Knowledge and shareholder value. Working paper. NYU.

Ohlson, J., 1995. Earnings, book values and dividends in security valuation. *Contemporary Accounting Research* 11: 661-687.

Pakes, A. and Z. Griliches, 1984. Patents and R and D at the firm level: A first look. NBER working paper 0561.

Rajgopal S., T. Shevlin, and M. Venkatachalam, 2001. Does the stock market fully appreciate the implications of leading indicators for future earnings? Evidence from order backlog. Working paper. University of Washington and Stanford University.

Shane, H., 1993. Patent citations as an indicator of the value of intangible assets in the semiconductor industry. Working paper. University of Pennsylvania.

Standard & Poor's Biotechnology Industry Survey, May 2002.

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

Trueman, B., F. Wang, and X. Zhang, 2001. The eyeballs have it: Searching for the value in Internet stocks. *Journal of Accounting Research* 38 (supplement), 137-162.

Appendixes

Appendix 1: Valuation Models in the Value Relevance Literature

This appendix describes the valuation models frequently used in prior value relevance studies, particularly those examining the association between nonfinancial information and equity market values. For the most part, valuation models test the value relevance in terms of the level of firm value. Examining changes in share prices, or returns, is an alternative approach to assessing value relevance (Ohlson 1995). Selection of which approach to use depends jointly on the hypotheses dictated by the research question and on econometric considerations (Kothari and Zimmerman 1995). A summary of the valuation models in three value relevance studies in nonfinancial information follows.

Ely, Simko, and Thomas (2003) examine the incremental association of market value with certain summary financial variables conditioned on a nonfinancial drug development stage variable in the biotech industry. The regression includes as financial independent variables net book value (NBV) and net income decomposed into R&D expenses XRD and net income before XRD (NibRD):

$$MVE_{it} = \alpha_0 + \sum_{j=1}^{7} \alpha_j YR_{it} + \beta_1 NBV_{it} + \beta_2 NibRD_{it} + \beta_3 XRD_{it} + \delta_1 AGE_{it}$$

$$+ \sum_{k=2}^{6} \delta_k \text{ (Drug Phase)}_{it} + \varepsilon_{it} ,$$

where Drug Phase is the count of drugs in-process for each five possible development stages. To mitigate potential scale effects each variable in the regression, including the intercept, is deflated by total shares outstanding.

Deng, Lev, and Narin (1999) examine whether patent attributes are significantly associated with subsequent stock returns and market-to-book ratios. Specifically, they run the following pooled cross-sectional regressions:

$$M/B_{i,t+\tau} = \alpha_1 \; NPAT_{it} + \alpha_2 \; CIMP_{it} + \alpha_3 \; SL_{it} + \alpha_4 \; TC_{it} + \alpha_5 RNDINT_{it} + \alpha_6 \; SPIL_{it} + \alpha_7 E/B_{it} + \varepsilon_{it} \,,$$

$$R_{i,t+\tau} = \alpha_1 \; NPAT_{it} + \alpha_2 \; CIMP_{it} + \alpha_3 \; SL_{it} + \alpha_4 \; TC_{it} + \alpha_5 RDINT_{it} + \alpha_6 \; SPIL_{it} + \alpha_7 Size_{it} + \alpha_8 B/M_{it} + \varepsilon_{it} \,,$$

where M/B is a firm's ratio of market value to book value at one, two, and three years ($\tau = 1, 2, 3$) after fiscal year-end. NPAT is the firm's number of patents granted in year t, scaled by the book value (equity) of the firm. CIMP is Citation Impact. SL is the Science Linkage indicator. TC is the Technology Cycle Time indicator. NPAT, CIMP, SL, and TC are nonfinancial patent variables. RDINT is the R&D intensity. SPIL is a spillover indicator. Size is firm size measured as total market value. B/M is the firm's ratio of book value to market value. RDINT, SPIL, Size, and B/M are control variables. E/B is the earning-to-book ratio and represents financial information.

Jorion and Talmor (2001) examine the value relevance of financial and nonfinancial Web traffic information in Internet industry in the light of the theory of life-cycle stages. They find that, as the industry matures, gross profit and R&D become increasingly value relevant. Importantly, a clear negative time trend appears in the Web traffic measures. Although still of high importance, the value relevance of non-financial

Web traffic measures has materially diminished over the 24-month testing period. Assuming linear form, they investigate the value relevance using the following set-up:

$$\frac{MV_{it}}{AV_{it}} = a_0 + a_1 \frac{BV_{it}}{AV_{it}} + a_2 \frac{\overline{F}_{it}}{AV_{it}} + a_2'(T^* \frac{\overline{F}_{it}}{AV_{it}}) + a_3 \frac{\overline{WEB}_{it}}{AV_{it}} + a_3'(T^* \frac{\overline{WEB}_{it}}{AV_{it}}) + \varepsilon_{it} ,$$

where MV is market value; BV is book value; AV is book value of assets; $\overline{F}$ denotes a vector of income statement variables; and $\overline{WEB}$ represents the Internet usage (Web traffic).

Appendix 2: Alternative Approach in Deriving Return Model

In the alternative framework, a biotech firm's market value is separated into three components: market value of tangible assets, market value of intangibles related to R&D activities, and market value of intangibles related to patents. That is, a biotech firm's market value at the end of year t can be written as:

$$MV_t = MV(TA)_t + MV(R\&D)_t + MV(PATENT)_t \,, \qquad (A1.1)$$

and the change of market value in year t can be expressed as:

$$\Delta MV_t = \Delta MV(TA)_t + \Delta MV(R\&D)_t + \Delta MV(PATENT)_t \,, \qquad (A1.2)$$

where MV(TA) is the market value of tangible assets; MV(R&D) is the market value of intangibles related to R&D activities; MV(PATENT) is the market value of intangibles related to patents; and Δ represents the change of the variable in year t.

The market value of R&D activities is a function of cumulative R&D expenditures. Therefore,

$$MV(R\&D)_t = \delta_0 + \beta_0\, R\&D_t + \beta_1\, R\&D_{t-1} + \ldots + \beta_m\, R\&D_{t-m} + \varepsilon_t \,, \qquad (A1.3)$$

where m is the number of years in the economic life of R&D expenditures. Assume that βs follow a Koyck distributed lag structure, for which the coefficients decline geometrically following the rate of decay of R&D expenditures, $\lambda_{R\&D}$. That is, assume

$$\beta_m = \lambda_{R\&D}\beta_{m-1} = \lambda_{R\&D}{}^2\beta_{m-2} = \ldots = \lambda_{R\&D}{}^m\beta_0 \,, \qquad 0<\lambda_{R\&D}<1. \qquad (A1.4)$$

Then equation (A1.3) becomes:

$$MV(R\&D)_t = \delta_0 + \beta_0 R\&D_t + \beta_0\lambda_{R\&D} R\&D_{t-1} + \ldots + \beta_0\lambda_{R\&D}^{m} R\&D_{t-m} + \varepsilon_t . \quad (A1.5)$$

Lagged one period and multiplied by $\lambda_{R\&D}$, equation (A1.5) becomes:

$$\lambda_{R\&D} MV(R\&D)_{t-1} = \delta_0\lambda_{R\&D} + \beta_0\lambda_{R\&D} R\&D_{t-1} + \ldots + \beta_0\lambda_{R\&D}^{m} R\&D_{t-m} + \beta_0\lambda_{R\&D}^{m+1} R\&D_{t-m-1} + \lambda_{R\&D}\varepsilon_{t-1} . \quad (A1.6)$$

Next, subtracting equation (A1.6) from equation (A1.5) and modifying the left-hand side of the equation by subtracting and adding $MV(R\&D)_{t-1}$ at the same time yields the following specified form:

$$MV(R\&D)_t - MV(R\&D)_{t-1} + MV(R\&D)_{t-1} - \lambda_{R\&D}MV(R\&D)_{t-1} = \delta_0 (1 - \lambda_{R\&D}) + \beta_0 R\&D_t + (\varepsilon_t - \lambda_{R\&D}\varepsilon_{t-1}) , \quad (A1.7)$$

where the prior years' R&D expenditures are eliminated. The term $R\&D_{t-m-1}$ is omitted in equation (A1.7) because, as time passes, the knowledge asset depreciates, and the older R&D investments become less valuable (i.e., $\beta_0\lambda_{R\&D}^{m+1}$ approaches zero).

Moving the terms $MV(R\&D)_{t-1} - \lambda_{R\&D}MV(R\&D)_{t-1}$ in equation (A1.7) from the left-hand to the right-hand side and dividing both sides by $MV(R\&D)_{t-1}$ yields:

$$\Delta MV(R\&D)_t = -(1-\lambda_{R\&D}) MV(R\&D)_{t-1} + \delta_0 (1 - \lambda_{R\&D}) + \beta_0 R\&D_t + (\varepsilon_t - \lambda_{R\&D}\varepsilon_{t-1}). \quad (A2.1)$$

Similarly, for patent-related intangible capital:

$$\Delta MV(PATENT)_t = -(1-\lambda_{PAT})\, MV(PATENT)_{t-1} + \varphi_0 (1 - \lambda_{PAT}) + \gamma_0\, PATENT_t + (\xi_t - \lambda_{PAT}\xi_{t-1}) , \qquad (A2.2)$$

where λ_{PAT} is the rate of decay of patents, and

$$\gamma_n = \lambda_{PAT}\gamma_{n-1} = \lambda_{PAT}^{\ 2}\gamma_{n-2} = \ldots = \lambda_{PAT}^{\ n}\gamma_0 , \qquad 0 < \lambda_{PAT} < 1. \qquad (A2.3)$$

Now summing $MV(TA)_t$, (A2.1), and (A2.2) gives total change in MV_t:

$$\begin{aligned}\Delta MV_t &= \Delta MV(TA)_t + \Delta MV(R\&D)_t + \Delta MV(PATENT)_t \\ &= \Delta MV(TA)_t - (1-\lambda_{R\&D})\, MV(R\&D)_{t-1} - (1-\lambda_{PAT})\, MV(PATENT)_{t-1} \\ &\quad + \delta_0 (1 - \lambda_{R\&D}) + \varphi_0 (1 - \lambda_{PAT}) + \beta_0\, R\&D_t + \gamma_0\, PATENT_t + (\varepsilon_t - \lambda_{R\&D}\varepsilon_{t-1}) \\ &\quad + (\xi_t - \lambda_{PAT}\xi_{t-1}) . \qquad (A3.1)\end{aligned}$$

Assume that $\lambda_{R\&D} = \lambda_{PAT} = \lambda$, equation (A3.1) can be modified as:

$$\begin{aligned}\Delta MV_t &= \Delta MV(TA)_t - (1-\lambda)\, [MV(R\&D)_{t-1} + MV(PATENT)_{t-1}] + (1 - \lambda)(\delta_0 + \varphi_0) \\ &\quad + \beta_0\, R\&D_t + \gamma_0\, PATENT_t + (\varepsilon_t - \lambda\varepsilon_{t-1}) + (\xi_t - \lambda\xi_{t-1}) . \qquad (A3.2)\end{aligned}$$

Equation (A1.1) shows that

$$MV_{t-1} = MV(TA)_{t-1} + MV(R\&D)_{t-1} + MV(PATENT)_{t-1}, \qquad (A3.3)$$

and

$$MV(R\&D)_{t-1} + MV(PATENT)_{t-1} = MV_{t-1} - MV(TA)_{t-1}. \qquad (A3.4)$$

Thus, equation (A3.2) can be revised using equations (A3.3) and (A3.4) as follows:

$$\Delta MV_t = \Delta\, MV(TA)_t - (1-\lambda)\,[MV_{t-1} - MV(TA)_{t-1}] + (1-\lambda)\,(\delta_0 + \varphi_0) + \beta_0\, R\&D_t$$
$$+ \gamma_0\, PATENT_t + (\varepsilon_t - \lambda\varepsilon_{t-1}) + (\xi_t - \lambda\xi_{t-1})\,. \qquad (A3.5)$$

Now dividing both sides by MV_{t-1} gives:

$$\frac{\Delta MV_t}{MV_{t-1}} = \frac{\Delta MV(TA)_t}{MV_{t-1}} + (1-\lambda)\frac{MV(TA)_{t-1}}{MV_{t-1}} - (1-\lambda) + (1-\lambda)\,(\delta_0 + \varphi_0)\,\frac{1}{MV_{t-1}}$$
$$+ \beta_0\,\frac{R\&D_t}{MV_{t-1}} + \gamma_0\,\frac{PATENT_t}{MV_{t-1}} + \frac{(\varepsilon_t - \lambda\varepsilon_{t-1}) + (\xi_t - \lambda\xi_{t-1})}{MV_{t-1}}\,. \qquad (A3.6)$$

Assuming that the market value of tangible assets is a function of book value and earnings, the market value of tangible assets in year t and t-1 can be expressed as:

$$MV(TA)_t = \alpha_0 + \alpha_1\, BV_t + \alpha_2\, E_t + \mu_t\,, \qquad (A3.7)$$

$$MV(TA)_{t-1} = \alpha_0 + \alpha_1\, BV_{t-1} + \alpha_2\, E_{t-1} + \mu_{t-1}\,. \qquad (A3.8)$$

Subtracting equation (A3.8) from equation (A3.7) gives the change of market value in year t:

$$\Delta MV(TA)_t = \alpha_1\, \Delta BV_t + \alpha_2\, \Delta E_t + \Delta\mu_t\,. \qquad (A3.9)$$

Modifying equation (A3.6) with equations (A3.8) and (A3.9) finally yields:

$$\frac{\Delta MV_t}{MV_{t-1}} = \frac{\alpha_1 \Delta BV_t + \alpha_2 \Delta E_t + \Delta\mu_t}{MV_{t-1}} + (1-\lambda)\frac{\alpha_0 + \alpha_1 BV_{t-1} + \alpha_2 E_{t-1} + \mu_{t-1}}{MV_{t-1}} - (1-\lambda)$$

$$+ (1 - \lambda)(\delta_0 + \varphi_0)\frac{1}{MV_{t-1}} + \beta_0 \frac{R\&D_t}{MV_{t-1}} + \gamma_0 \frac{PATENT_t}{MV_{t-1}}$$

$$+ \frac{(\varepsilon_t - \lambda\varepsilon_{t-1}) + (\xi_t - \lambda\xi_{t-1})}{MV_{t-1}}$$

$$= (\alpha_0 + \delta_0 + \varphi_0)(1 - \lambda)\frac{1}{MV_{t-1}} + \alpha_1 \frac{\Delta BV_t}{MV_{t-1}} + \alpha_2 \frac{\Delta E_t}{MV_{t-1}}$$

$$+ \alpha_1 (1-\lambda)\frac{BV_{t-1}}{MV_{t-1}} + \alpha_2 (1-\lambda)\frac{E_{t-1}}{MV_{t-1}} + \beta_0 \frac{R\&D_t}{MV_{t-1}} + \gamma_0 \frac{PATENT_t}{MV_{t-1}}$$

$$- (1-\lambda) + \frac{(\varepsilon_t - \lambda\varepsilon_{t-1}) + (\xi_t - \lambda\xi_{t-1}) + (\mu_t - \lambda\mu_{t-1})}{MV_{t-1}} . \qquad (A4.1)$$

The variables included in equation (A4.1) are identical to those in the return model presented in equation (2) of section 4.

Appendix 3: Tables

TABLE 1 DESCRIPTIVE STATISTICS

Panel A: Undeflated Variables

Variable	Mean	Std Dev	Min	Median	Max
Financial					
MV_{t-1}	941.70	7007.91	0.45	115.83	152398.00
R&D	28.23	71.13	0	11.34	875.10
Patent					
PATNUM	4.69	12.85	0	2	248
CLAIM	13.20	14.60	0	11.71	176
CITATION	0.71	1.63	0	0.21	30.61
REFAGE	4.43	4.29	0	4.41	27.08
REFNUM	16.30	23.39	0	8.11	230
DNA%	0.26	0.38	0	0	1.00
Performance					
REV	57.12	262.74	0.01	7.4	4015.70
MAR	28.88	204.66	-654.64	-2.33	3150.70
ROS	-9.28	49.37	-1000.37	-0.46	1.00
Control					
BM	0.37	0.46	0.00	0.25	5.80
MV	999.48	5973.75	0.34	128.93	87878.60
BETA	1.68	0.82	0.00	1.62	6.44
LnAsset	3.73	1.53	-0.92	3.69	8.77
Obs = 1183 (872 for BETA)					

MV_{t-1} = Market value of a firm at the beginning of a given year.
R&D = R&D expenditures.
PATNUM = Number of U.S. patents granted to the company during a given year.
CLAIM = Average number of claims in a firm's granted patents in a given year.
CITATION = Total number of citations to the firm's patents issued in a given year, divided by the average number of citations to all patents in the sample granted in the corresponding years.
REFAGE = Median age of the U.S. patents cited on the front page of a patent.
REFNUM = Number of references to scientific journal papers and conference proceedings cited by a patent.
DNA% = Percentage of genetic patents in a firm's granted patents in a given year.
REV = Sales revenue.
MAR = Margins, defined as sales revenue minus R&D expenses.
ROS = Return on sales, defined as MAR divided by sales revenues.
BM = Book-to-market ratio.
MV = Total market value of a firm at the end of a given year.
BETA = CAPM-beta of each firm.
LnAsset = Log of a firm's total assets.

TABLE 1 CONTINUED

Panel B: Deflated Variables
All financial (except for 1/ MV_{t-1}), patent, and performance variables are deflated by MV_{t-1}.

Variable	Mean	Std Dev	Min	Median	Max
RETURN	0.51	2.37	-0.98	-0.09	40.25
Financial					
$1/MV_{t-1}$	0.04	0.13	0.00	0.01	2.23
ΔBV_t	0.08	0.43	-1.85	0.00	5.20
ΔE_t	0.02	0.22	-2.23	0.00	4.69
BV_{t-1}	0.37	0.44	0.00	0.25	5.80
E_{t-1}	0.00	0.20	-4.10	0.00	1.09
R&D	0.15	0.26	0	0.09	4.68
Patent					
PATNUM	0.05	0.16	0	0.01	2.23
PATNUM*CLAIM	0.89	3.37	0	0.14	69.82
PATNUM*CITATION	0.03	0.09	0	0	1.24
PATNUM*REFAGE	0.29	1.13	0	0.05	18.52
PATNUM*REFNUM	0.94	3.42	0	0.10	56.08
PATNUM*DNA%	0.02	0.10	0	0	1.89
Performance					
REV	0.22	0.49	0.00	0.07	7.18
MAR	0.07	0.46	-2.08	-0.02	6.71
Obs = 1183 (872 for BETA)					

RETURN = Change in market value of a firm in year t divided by market value of the firm at the end of year t-1.
$1/MV_{t-1}$ = Inverse of the market value of a firm at the end of year t-1.
ΔBV_t = Change in book value of a firm in year t.
ΔE_t = Change in earnings before R&D expenditures of a firm in year t.
BV_{t-1} = Book value at the end of year t-1.
E_{t-1} = Earnings before R&D expenditures at the end of year t-1.
R&D = R&D expenditures.
PATNUM = Number of U.S. patents granted to the company during a given year.
PATNUM*CLAIM = PATNUM and CLAIM interaction.
PATNUM*CITATION = PATNUM and CITATION interaction.
PATNUM*REFAGE = PATNUM and REFAGE interaction.
PATNUM*REFNUM = PATNUM and REFNUM interaction.
PATNUM*DNA% = PATNUM and DNA% interaction.
REV = Sales revenue.
MAR = Margins, defined as sales revenue minus R&D expenses.

TABLE 2 CORRELATION MATRIX

VARIABLES	$1/MV_{t-1}$	$\Delta BV_t/MV_{t-1}$	$\Delta E_t/MV_{t-1}$	BV_{t-1}/MV_{t-1}	E_{t-1}/MV_{t-1}	$R\&D/MV_{t-1}$	$PATNUM/MV_{t-1}$	CLAIM	CITATION
$\Delta BV_t/MV_{t-1}$	-0.03	1							
	(0.32)								
$\Delta E_t/MV_{t-1}$	0.12	0.09	1						
	(0.00)	(0.01)							
BV_{t-1}/MV_{t-1}	0.38	-0.10	0.15	1					
	(0.00)	(0.00)	(0.00)						
E_{t-1}/MV_{t-1}	-0.13	0.00	**-0.70**	0.00	1				
	(0.00)	(0.97)	(0.00)	(0.98)					
$R\&D/MV_{t-1}$	0.21	0.13	0.07	**0.69**	0.14	1			
	(0.00)	(0.00)	(0.04)	(0.00)	(0.00)				
$PATNUM/MV_{t-1}$	0.24	-0.02	0.11	0.16	-0.11	0.11	1		
	(0.00)	(0.54)	(0.00)	(0.00)	(0.00)	(0.00)			
CLAIM	-0.10	-0.04	-0.03	-0.08	-0.00	0.01	0.08	1	
	(0.00)	(0.30)	(0.39)	(0.02)	(0.93)	(0.74)	(0.01)		
CITATION	-0.1	0.04	-0.01	-0.04	0.00	-0.05	-0.01	0.25	1
	(0.00)	(0.30)	(0.67)	(0.28)	(0.89)	(0.11)	(0.83)	(0.00)	
REFAGE	-0.12	-0.04	-0.02	-0.10	-0.01	-0.07	0.11	**0.52**	0.25
	(0.00)	(0.24)	(0.61)	(0.00)	(0.66)	(0.05)	(0.00)	(0.00)	(0.00)
REFNUM	-0.12	0.01	-0.01	-0.09	0.02	-0.02	0.05	**0.40**	0.27
	(0.00)	(0.81)	(0.79)	(0.01)	(0.49)	(0.62)	(0.16)	(0.00)	(0.00)
DNA%	-0.11	0.1	-0.02	-0.04	0.08	0.03	0.16	0.29	0.19
	(0.00)	(0.00)	(0.54)	(0.28)	(0.02)	(0.36)	(0.00)	(0.00)	(0.00)
REV/MV_{t-1}	**0.49**	0.15	**0.46**	**0.57**	-0.20	**0.40**	0.16	-0.12	-0.08
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
MAR/MV_{t-1}	**0.40**	0.08	**0.45**	0.19	-0.30	-0.18	0.10	-0.14	-0.06
	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.09)
ROS	0.02	-0.09	0.03	0.05	0.04	-0.01	0.02	0.04	0.02
	(0.53)	(0.01)	(0.42)	(0.13)	(0.23)	(0.83)	(0.63)	(0.24)	(0.57)
BM	0.17	-0.06	0.22	**0.57**	-0.12	0.25	0.07	-0.13	-0.05
	(0.00)	(0.08)	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)	(0.00)	(0.17)
MV	-0.06	0.03	-0.01	-0.08	0.04	-0.06	-0.05	0.03	-0.02
	(0.06)	(0.43)	(0.83)	(0.01)	(0.24)	(0.07)	(0.17)	(0.38)	(0.60)
BETA	-0.12	0.08	0.05	0.05	-0.00	0.14	-0.11	-0.01	0.12
	(0.00)	(0.02)	(0.16)	(0.15)	(0.95)	(0.00)	(0.00)	(0.76)	(0.00)
LnAsset	-0.39	0.22	-0.03	-0.01	0.18	-0.01	-0.18	0.14	0.12
	(0.00)	(0.00)	(0.43)	(0.73)	(0.00)	(0.80)	(0.00)	(0.00)	(0.00)

Correlations greater than 0.40 are in bold, and probability > |r| under H_0: Rho = 0 is in parenthesis.

Table 2 Continued

VARIABLES	REFAGE	REFNUM	DNA%	REV/ MV_{t-1}	MAR/ MV_{t-1}	ROS	BM	MV	BETA
REFAGE	1								
REFNUM	**0.41**	1							
	(0.00)								
DNA%	0.17	0.32	1						
	(0.00)	(0.00)							
REV/MV_{t-1}	-0.13	-0.11	-0.05	1					
	(0.00)	(0.00)	(0.17)						
MAR/MV_{t-1}	-0.1	-0.11	-0.07	**0.83**	1				
	(0.00)	(0.00)	(0.04)	(0.00)					
ROS	0.06	0.03	0.04	0.09	0.11	1			
	(0.08)	(0.45)	(0.23)	(0.01)	(0.00)				
BM	-0.09	-0.07	-0.07	0.35	0.23	0.04	1		
	(0.01)	(0.03)	(0.05)	(0.00)	(0.00)	(0.22)			
MV	0.05	0.10	0.13	-0.04	-0.003	0.03	-0.09	1	
	(0.11)	(0.00)	(0.00)	(0.27)	(0.92)	(0.42)	(0.01)		
BETA	-0.03	0.07	0.08	-0.07	-0.17	0.04	0.01	-0.07	1
	(0.40)	(0.03)	(0.01)	(0.03)	(0.00)	(0.23)	(0.67)	(0.03)	
LnAsset	0.15	0.24	0.33	-0.06	-0.06	0.06	0.01	**0.41**	0.11
	(0.00)	(0.00)	(0.00)	(0.08)	(0.08)	(0.09)	(0.86)	(0.00)	(0.00)

Correlations greater than 0.40 are in bold, and probability > |r| under H_0: Rho = 0 is in parenthesis. Variable definitions appear in Table 1.

TABLE 3 DESCRIPTIVE STATISTICS OF UNDEFLATED VARIABLES AND SIC COMPOSITION FOR FIRMS WITH AND WITHOUT PATENTS

Panel A: Undeflated Variables

The full sample is partitioned by whether the firms have patents. The top row of each variable is for firms with patents, and the bottom (in parenthesis) is for those without patents.

Variable	Mean	Std Dev	Min	Median	Max
RETURN	0.60 *	2.64	-0.97	-0.08	40.25
	(0.39)	(1.62)	(-1.00)	(-0.15)	(9.60)
Financial					
MV_{t-1}	1045.90	6351.70	0.85	146.47	87878.60
	(724.81)	(8211.88)	(0.45)	(67.09)	(152398)
R&D	36.10 ***	83.680	0	14.58	875.10
	(11.87)	(24.98)	(0)	(5.27)	(283.07)
Patent					
PATNUM	6.94 ***	15.14	1	3	248
	(0)	(0)	(0)	(0)	(0)
CLAIM	19.55 ***	13.85	0	16.83	176
	(0)	(0)	(0)	(0)	(0)
CITATION	1.06 ***	1.89	0	0.59	30.61
	(0)	(0)	(0)	(0)	(0)
REFAGE	6.56 ***	3.65	0	6.22	27.08
	(0)	(0)	(0)	(0)	(0)
REFNUM	24.14 ***	24.92	0	17	230
	(0)	(0)	(0)	(0)	(0)
DNA%	0.39 ***	0.40	0	0.29	1
	(0)	(0)	(0)	(0)	(0)
Performance					
REV	71.71 ***	312.23	0.01	9.45	4015.70
	(26.75)	(92.49)	(0.01)	(4.46)	(981.93)
MAR	35.61 **	242.98	-654.64	-3.71	3150.70
	(14.88)	(77.22)	(-125.08)	(-0.69)	(698.86)
ROS	-6.52 **	30.62	-482.95	-0.51	1
	(-15.01)	(74.29)	(-1000.37)	(-0.25)	(1)
Obs = 799 (384)					

The notations *, **, and *** indicate that the mean of the variable for firms with patents is significantly different than that for firms without patents at the 10%, 5%, and 1% level, respectively.

TABLE 3 CONTINUED

The full sample is partitioned by whether the firms have patents. The top row of each variable is for firms with patents, and the bottom (in parenthesis) is for those without patents.

Variable	Mean	Std Dev	Min	Median	Max
Control					
BM	0.34 ***	0.40	0.00	0.23	5.69
	(0.44)	(0.56)	(0)	(0.29)	(5.80)
MV	1188.12 *	6285	1.04	179.85	87878.60
	(606.97)	(5252.40)	(0.34)	(63.30)	(87847.50)
BETA	1.69	0.74	0.03	1.65	5.06
	(1.65)	(0.99)	(0.003)	(1.49)	(6.44)
LnASSET	4.02 ***	1.50	-0.06	3.92	8.77
	(3.13)	(1.45)	(-0.92)	(3.22)	(8.08)
Obs = 799 (384)					
Obs = 612 (260) for BETA					

The notations * and *** indicate that the mean of the variable for firms with patents is significantly different than that for firms without patents at the 10% and 1% level, respectively.

Panel B: SIC Composition

SIC Composition	Firm-Year Obs				
	Without Patent	With Patent	Subtotal (no. of obs. & %)		with-patent obs as a % of subtotal
2836 Biological products, except diagnostic substances	149	326	475	40.15	68.63
2834 Pharmaceutical preparations	53	176	229	19.36	76.86
2835 In vitro and in vivo diagnostic substances	84	136	220	18.60	61.82
8731 Commercial physical and biological research	20	28	48	4.06	58.33
2833 Medicinal chemicals and botanical products	7	24	31	2.62	77.42
3841 Surgical and medical instruments and apparatus	11	14	25	2.11	56.00
3842 Orthopedic, prosthetic, and surgical appliances and supplies	7	13	20	1.69	65.00
Others (0100, 2810, 2820, 2821, 2840, 2860, 2844, 2870, 2890, 3559, 3580, 3826, 3845, 3829, 7370, 5160, 6552, 6794, 7372, 8071, 9995)	50	85	135	11.41	62.96
Total	381	802	1183	100.00	67.79

Other SICs list the SICs with less than 1% of the total sample observations (12 firm-year observations).

TABLE 4 REGRESSION OF RETURNS ON FINANCIAL, PATENT AND CONTROL VARIABLES

$$RETURN_{jt} = \beta_0 + \sum_{yr=1990}^{2001} \beta_{yr+1} \text{ YR} + \sum_{n=1}^{292} \beta_{n+1} \text{ FIRM} + \beta_1 (1/MV_{jt-1}) + \beta_2 \Delta BV_{jt}/MV_{jt-1} + \beta_3 BV_{jt-1}/MV_{jt-1}$$

$$+ \beta_4 \Delta E_{jt}/MV_{jt-1} + \beta_5 E_{jt-1}/MV_{jt-1} + \beta_6 R\&D_{jt}/MV_{jt-1} + \beta_7 PATNUM_{jt}/MV_{jt-1} + \beta_8 (PATNUM*CLAIM_{jt})/MV_{jt-1}$$

$$+ \beta_9 (PATNUM*CITATION_{jt})/MV_{jt-1} + \beta_{10}(PATNUM*REFAGE_{jt})/MV_{jt-1} + \beta_{11} (PATNUM*REFNUM_{jt})/MV_{jt-1}$$

$$+ \beta_{12} (PATNUM*DNA\%_{jt})/MV_{jt-1} + \beta_{13} B/M_{jt} + \beta_{14} MV_{jt} + \beta_{15} \beta_{jt} + \varepsilon_{jt}. \quad (4)$$

Variables	Coefficients			Mean
	A	B	C	
Constant	-0.08	-0.12	-0.22	
	(-0.25)	(-0.40)	(-0.73)	
$1/MV_{t-1}$	3.86 **	3.73 **	4.19 **	
	(2.28)	(2.18)	(2.49)	
$\Delta BV_t/MV_{t-1}$	1.57 ***	1.57 ***	1.54 ***	
	(7.63)	(7.66)	(7.48)	
$\Delta E_t/MV_{t-1}$	0.34	0.33	0.96 **	
	(0.7)	(0.67)	(1.96)	
BV_{t-1}/MV_{t-1}	2.41 ***	2.35 ***	2.05 ***	
	(7.44)	(7.21)	(6.4)	
E_{t-1}/MV_{t-1}	-0.55	-0.42	0.40	
	(-0.98)	(-0.76)	(0.71)	
$R\&D/MV_{t-1}$	-0.72 *	-0.73 *	-0.86 **	
	(-1.66)	(-1.68)	(-2.01)	
$PATNUM/MV_{t-1}$		1.27 **	-8.45 ***	0.05
		(2.44)	(-3.69)	
$(PATNUM*CLAIM)/MV_{t-1}$			0.33 ***	0.9
			(5.00)	
$(PATNUM*CITATION)/MV_{t-1}$			5.07 ***	0.03
			(3.62)	
$(PATNUM*REFAGE)/MV_{t-1}$			0.38 **	0.31
			(1.99)	
$(PATNUM*REFNUM)/MV_{t-1}$			0.00	1.06
			(-0.08)	
$(PATNUM*DNA\%)/MV_{t-1}$			1.64	0.02
			(0.77)	
BM	-1.74 ***	-1.72 ***	-1.49 ***	
	(-8.63)	(-8.54)	(-7.45)	
MV	0.00	0.00	0.00	
	(-0.28)	(-0.17)	(-0.07)	
BETA	0.13	0.14	0.14	
	(1.18)	(1.24)	(1.29)	
R^2	0.23	0.23	0.29	
Hausman test	7.86	11.73	11.7	
F stat. for overall model	28.03 ***	25.74 ***	22.59 ***	
F stat. for joint significance of patent variables			9.08 ***	
Obs	860	860	860	

t-statistics are in the parenthesis. The notations *, **, and *** refer to significance at the 10%, 5% and 1% levels.

TABLE 4 CONTINUTED

$$\text{RETURN}_{jt} = \beta_0 + \sum_{yr=1990}^{2001} \beta_{yr+1} \text{ YR} + \sum_{n=1}^{292} \beta_{n+1} \text{ FIRM} + \beta_1 (1/\text{MV}_{jt-1}) + \beta_2 \Delta\text{BV}_{jt}/\text{MV}_{jt-1} + \beta_3 \text{BV}_{jt-1}/\text{MV}_{jt-1}$$

$$+ \beta_4 \Delta\text{E}_{jt}/\text{MV}_{jt-1} + \beta_5 \text{E}_{jt-1}/\text{MV}_{jt-1} + \beta_6 \text{R\&D}_{jt}/\text{MV}_{jt-1} + \beta_7 \text{PATNUM}_{jt}/\text{MV}_{jt-1} + \beta_8 (\text{PATNUM*CLAIM}_{jt})/\text{MV}_{jt-1}$$

$$+ \beta_9 (\text{PATNUM*CITATION}_{jt})/\text{MV}_{jt-1} + \beta_{10}(\text{PATNUM*REFAGE}_{jt})/\text{MV}_{jt-1} + \beta_{11} (\text{PATNUM*REFNUM}_{jt})/\text{MV}_{jt-1}$$

$$+ \beta_{12} (\text{PATNUM*DNA\%}_{jt})/\text{MV}_{jt-1} + \beta_{13} \text{B/M}_{jt} + \beta_{14} \text{MV}_{jt} + \beta_{15} \beta_{jt} + \varepsilon_{jt}. \quad (4)$$

Variables	Coefficients				
	D	E	F	G	H
Constant	-0.19	-0.16	-0.12	-0.11	-0.11
	(-0.63)	(-0.55)	(-0.40)	(-0.37)	(-0.35)
$1/MV_{t-1}$	3.81 **	3.58 **	3.68 **	3.93 **	4.04 **
	(2.25)	(2.13)	(2.16)	(2.3)	(2.36)
$\Delta BV_t/MV_{t-1}$	1.63 ***	1.43 ***	1.57 ***	1.56 ***	1.56 ***
	(8.06)	(6.98)	(7.7)	(7.64)	(7.63)
$\Delta E_t/MV_{t-1}$	0.52	0.48	0.36	0.27	0.30
	(1.07)	(0.98)	(0.74)	(0.54)	(0.61)
BV_{t-1}/MV_{t-1}	2.23 ***	2.26 ***	2.31 ***	2.40 ***	2.38 ***
	(6.9)	(6.98)	(7.07)	(7.39)	(7.31)
E_{t-1}/MV_{t-1}	-0.06	-0.23	-0.36	-0.58	-0.54
	(-0.10)	(-0.41)	(-0.64)	(-1.04)	(-0.96)
$R\&D/MV_{t-1}$	-0.86 **	-0.66	-0.70	-0.75 *	-0.73 *
	(-2.00)	(-1.54)	(-1.62)	(-1.73)	(-1.67)
$(PATNUM*CLAIM)/MV_{t-1}$	0.15 ***				
	(5.05)				
$(PATNUM*CITATION)/MV_{t-1}$		4.28 ***			
		(4.22)			
$(PATNUM*REFAGE)/MV_{t-1}$			0.22 ***		
			(2.97)		
$(PATNUM*REFNUM)/MV_{t-1}$				0.05 **	
				(2.11)	
$(PATNUM*DNA\%)/MV_{t-1}$					1.52 **
					(2.08)
BM	-1.62 ***	-1.67 ***	-1.71 ***	-1.75 ***	-1.74 ***
	(-8.12)	(-8.34)	(-8.52)	(-8.69)	(-8.61)
MV	0.00	0.00	0.00	0.00	0.00
	(-0.08)	(-0.14)	(-0.18)	(-0.18)	(-0.17)
BETA	0.15	0.13	0.14	0.14	0.13
	(1.38)	(1.14)	(1.27)	(1.21)	(1.2)
R^2	0.25	0.25	0.23	0.23	0.23
Hausman test	14.11	10.06	11.36	11.51	12.6
F stat. for overall model	28.36 ***	27.96 ***	26.00 ***	25.65 ***	25.55 ***
Obs	860	860	860	860	860

t-statistics are in the parenthesis. The notations *, **, and *** refer to significance at the 10%, 5% and 1% levels.

TABLE 5 REGRESSION OF PERFORMANCE VARIABLES ON PATENT AND CONTROL VARIABLES

$$PERFORM_{jt+n}/MV_{jt-1} = \gamma_0 + \gamma_1\, PATNUM_{jt}/MV_{jt-1} + \gamma_2\, (PATNUM*CLAIM_{jt})/MV_{jt-1}$$
$$+ \gamma_3\, (PATNUM*CITATION_{jt})/MV_{jt-1} + \gamma_4\, (PATNUM*REFAGE_{jt})/MV_{jt-1}$$
$$+ \gamma_5\, (PATNUM*REFNUM_{jt})/MV_{jt-1} + \gamma_6\, (PATNUM*DNA\%_{jt})/MV_{jt-1}$$
$$+ \gamma_7\, PERFOM_{jt}/ MV_{jt-1} + \gamma_8\, R\&D_{jt}/ MV_{jt-1} + \gamma_9\, LnASSET_{jt+n} + \varepsilon_{jt+n}, \quad n=1,2,\ldots 5.$$

(5.1), (5.2), &(5.3)

Panel A: n = 1

Variables	Coefficients		
Dependent Variable	REV_{t+1}/MV_{t-1}	MAR_{t+1}/MV_{t-1}	ROS_{t+1}
Constant	-0.04	0.07	-6.63 **
	(-1.50)	(0.95)	(-2.00)
$PATNUM/MV_{t-1}$	-0.99	-0.09	-12.28
	(-0.93)	(-0.14)	(-0.43)
$(PATNUM*CLAIM)/MV_{t-1}$	-0.01	0.04 *	-2.29 **
	(-0.91)	(1.85)	(-2.28)
$(PATNUM*CITATION)/MV_{t-1}$	-0.07	-0.26	-7.11
	(-0.41)	(-.60)	(-0.36)
$(PATNUM*REFAGE)/MV_{t-1}$	0.02	-0.07	-1.84
	(0.69)	(-1.09)	(-0.65)
$(PATNUM*REFNUM)/MV_{t-1}$	-0.001	0.03	3.66 ***
	(-0.22)	(1.61)	(4.90)
$(PATNUM*DNA\%)/MV_{t-1}$	0.29	-0.88	-63.71 **
	(1.23)	(-1.41)	(-2.26)
REV_t/MV_{t-1}	1.06 ***		
	(46.58)		
MAR_t/MV_{t-1}		1.23 ***	
		(20.47)	
ROS_t			0.2 ***
			(7.04)
$R\&D/MV_{t-1}$	0.56 ***	-0.87 ***	-0.8
	(16.11)	(-9.59)	(-0.21)
LNASSET	0.002	-0.01	0.63
	(0.27)	(0.71)	(0.80)
Adj. R^2	0.79	0.42	0.09
F stat. for overall model	385.53 ***	77.00 ***	11.17 ***
F-stat. for joint significance of patent variables	1.56	1.32	8.04 ***
Obs	944	944	944

t-statistics are in the parenthesis. The notations *, **, and *** refer to significance at the 10%, 5%, and 1% levels.

Table 5 Continued

$$PERFORM_{jt+n}/MV_{jt-1} = \gamma_0 + \gamma_1\, PATNUM_{jt}/MV_{jt-1} + \gamma_2\, (PATNUM*CLAIM_{jt})/MV_{jt-1}$$

$$+ \gamma_3\, (PATNUM*CITATION_{jt})/MV_{jt-1} + \gamma_4\, (PATNUM*REFAGE_{jt})/MV_{jt-1}$$

$$+ \gamma_5\, (PATNUM*REFNUM_{jt})/MV_{jt-1} + \gamma_6\, (PATNUM*DNA\%_{jt})/MV_{jt-1}$$

$$+ \gamma_7\, PERFOM_{jt}/ MV_{jt-1} + \gamma_8\, R\&D_{jt}/ MV_{jt-1} + \gamma_9\, LnASSET_{jt+n} + \varepsilon_{jt+n}, \quad n=1,2,\ldots 5.$$

(5.1), (5.2), &(5.3)

Panel B: n = 2

Variables	Coefficients		
Dependent Variable	REV_{t+2}/MV_{t-1}	MAR_{t+2}/MV_{t-1}	ROS_{t+2}
Constant	-0.13 ***	0.05	-4.08
	(-2.48)	(0.80)	(-1.11)
$PATNUM/MV_{t-1}$	-0.67	0.08	26.66
	(-1.49)	(0.15)	(0.84)
$(PATNUM*CLAIM)/MV_{t-1}$	-0.02	-0.001	-1.12
	(-1.03)	(-0.05)	(-1.07)
$(PATNUM*CITATION)/MV_{t-1}$	0.18	-0.003	10.66
	(0.60)	(-0.01)	(0.51)
$(PATNUM*REFAGE)/MV_{t-1}$	0.04	-0.21 ***	-6.33 *
	(0.82)	(-3.75)	(-1.81)
$(PATNUM*REFNUM)/MV_{t-1}$	-0.01	0.07 ***	1.84 **
	(-0.70)	(5.27)	(2.30)
$(PATNUM*DNA\%)/MV_{t-1}$	0.79 *	-2.29 ***	-76.3 **
	(1.69)	(-4.30)	(-2.30)
REV_t/MV_{t-1}	1.29 ***		
	(31.83)		
MAR_t/MV_{t-1}		1.41 ***	
		(30.58)	
ROS_t			0.42 ***
			(10.87)
$R\&D/MV_{t-1}$	1.19 ***	0.35 ***	1.15
	(18.96)	(5.16)	(0.28)
LNASSET	0.01	-0.01	0.21
	(0.78)	(-1.00)	(0.24)
Adj. R^2	0.75	0.58	0.15
F stat. for overall model	247.61 ***	116.75 ***	15.5 ***
F-stat. for joint significance of patent variables	2.41 ***	19.23 ***	3.86 ***
Obs	757	757	757

t-statistics are in the parenthesis. The notations *, **, and *** refer to significance at the 10%, 5%, and 1% levels.

TABLE 6 REGRESSION OF RETURNS ON FINANCIAL, PATENT AND CONTROL VARIABLES

$$RETURN_{jt} = \beta_0 + \sum_{yr=1990}^{2001} \beta_{yr+1}\ YR + \sum_{n=1}^{292} \beta_{n+1}\ FIRM + \beta_1 (1/ MV_{jt-1}) + \beta_2\ \Delta BV_{jt}/ MV_{jt-1} + \beta_3\ BV_{jt-1}/ MV_{jt-1}$$

$$+ \beta_4\ \Delta E_{jt}/ MV_{jt-1} + \beta_5\ E_{jt-1}/ MV_{jt-1} + \beta_6\ R\&D_{jt}/ MV_{jt-1} + \beta_7\ PATNUM_{jt}/ MV_{jt-1} + \beta_8\ CLAIM_{jt}$$

$$+ \beta_9\ CITATION_{jt} + \beta_{10}\ REFAGE_{jt} + \beta_{11}\ REFNUM_{jt} + \beta_{12}\ DNA\%_{jt} + \beta_{13}\ (PATNUM{*}CLAIM_{jt})/ MV_{jt-1}$$

$$+ \beta_{14}\ (PAT{*}CITATION_{jt})/ MV_{jt-1} + \beta_{15}\ (PATNUM{*}REFAGE_{jt})/MV_{jt-1} + \beta_{16}\ (PATNUM{*}REFNUM_{jt})/ MV_{jt-1}$$

$$+ \beta_{17}\ (PATNUM{*}DNA\%_{jt})/ MV_{jt-1} + \beta_{18}\ B/M_{jt} + \beta_{19}\ MV_{jt} + \beta_{20}\ BETA_{jt} + \varepsilon_{jt}\ . \qquad (4')$$

Variables	Coefficients A	Coefficients B	Coefficients C	Mean
Constant	-0.08	-0.24	-0.09	
	(-0.25)	(-0.76)	(-0.29)	
$1/MV_{t-1}$	3.86 **	4.15 **	4.02 **	
	(2.28)	(2.39)	(2.37)	
$\Delta BV_t/MV_{t-1}$	1.57 ***	1.55 ***	1.49 ***	
	(7.63)	(7.51)	(7.27)	
$\Delta E_t/MV_{t-1}$	0.34	0.32	1.04 **	
	(0.7)	(0.65)	(2.12)	
BV_{t-1}/MV_{t-1}	2.41 ***	2.34 ***	1.98 ***	
	(7.44)	(7.15)	(6.19)	
E_{t-1}/MV_{t-1}	-0.55	-0.44	0.51	
	(-0.98)	(-0.79)	(0.89)	
$R\&D/MV_{t-1}$	-0.72 *	-0.73 *	-0.87 **	
	(-1.66)	(-1.67)	(-2.04)	
$PATNUM/MV_{t-1}$		1.08 **	-9.66 ***	0.05
		(2.03)	(-4.07)	
CLAIM		0.002	-0.02 ***	13.91
		(0.34)	(-2.95)	
CITATION		0.01	-0.09	0.68
		(0.17)	(-1.19)	
REFAGE		0.01	0.02	4.70
		(0.24)	(0.9)	
REFNUM		-0.003	-0.004	17.52
		(-0.69)	(-0.90)	
DNA%		0.48 *	0.64 **	0.28
		(1.86)	(2.41)	
$(PATNUM{*}CLAIM)/MV_{t-1}$			0.44 ***	0.90
			(5.73)	
$(PATNUM{*}CITATION)/MV_{t-1}$			5.75 ***	0.03
			(3.61)	
$(PATNUM{*}REFAGE)/MV_{t-1}$			0.35 *	0.31
			(1.73)	
$(PATNUM{*}REFNUM)/MV_{t-1}$			0.05	1.05
			(0.83)	
$(PATNUM{*}DNA\%)/MV_{t-1}$			-0.79	0.02
			(-0.34)	

t-statistics are in the parenthesis. The notations *, **, and *** refer to significance at the 10%, 5%, and 1% levels.

TABLE 6 CONTINUED

$$RETURN_{jt} = \beta_0 + \sum_{yr=1990}^{2001} \beta_{yr+1}\ YR + \sum_{n=1}^{292} \beta_{n+1}\ FIRM + \beta_1 (1/MV_{jt-1}) + \beta_2\ \Delta BV_{jt}/MV_{jt-1} + \beta_3\ BV_{jt-1}/MV_{jt-1}$$

$$+ \beta_4\ \Delta E_{jt}/MV_{jt-1} + \beta_5\ E_{jt-1}/MV_{jt-1} + \beta_6\ R\&D_{jt}/MV_{jt-1} + \beta_7\ PATNUM_{jt}/MV_{jt-1} + \beta_8\ CLAIM_{jt}$$

$$+ \beta_9\ CITATION_{jt} + \beta_{10}\ REFAGE_{jt} + \beta_{11}\ REFNUM_{jt} + \beta_{12}\ DNA\%_{jt} + \beta_{13}\ (PATNUM*CLAIM_{jt})/MV_{jt-1}$$

$$+ \beta_{14}\ (PAT*CITATION_{jt})/MV_{jt-1} + \beta_{15}\ (PATNUM*REFAGE_{jt})/MV_{jt-1} + \beta_{16}\ (PATNUM*REFNUM_{jt})/MV_{jt-1}$$

$$+ \beta_{17}\ (PATNUM*DNA\%_{jt})/MV_{jt-1} + \beta_{18}\ B/M_{jt} + \beta_{19}\ MV_{jt} + \beta_{20}\ BETA_{jt} + \varepsilon_{jt}\ . \quad (4')$$

Variables	Coefficients			Mean
	A	B	C	
BM	-1.74 ***	-1.70 ***	-1.49 ***	
	(-8.63)	(-8.40)	(-7.50)	
MV	0.00	0.00	0.00	
	(-0.28)	(-0.21)	(-0.08)	
BETA	0.13	0.12	0.14	
	(1.18)	(1.07)	(1.34)	
R^2	0.23	0.24	0.30	
Hausman test	7.86	15.52	13.81	
F stat. for overall model	28.03 ***	17.39 ***	18.24 ***	
F stat. for joint significance of patent variables		2.97 ***	6.41 ***	
Obs	860	860	860	

t-statistics are in the parenthesis. The notations *, **, and *** refer to significance at the 10%, 5%, and 1% levels.

Table 6 Continued

$$\text{RETURN}_{jt} = \beta_0 + \sum_{yr=1990}^{2001} \beta_{yr+1}\,\text{YR} + \sum_{n=1}^{292} \beta_{n+1}\,\text{FIRM} + \beta_1 (1/\text{MV}_{jt-1}) + \beta_2\,\Delta\text{BV}_{jt}/\text{MV}_{jt-1} + \beta_3\,\text{BV}_{jt-1}/\text{MV}_{jt-1}$$

$$+ \beta_4\,\Delta\text{E}_{jt}/\text{MV}_{jt-1} + \beta_5\,\text{E}_{jt-1}/\text{MV}_{jt-1} + \beta_6\,\text{R\&D}_{jt}/\text{MV}_{jt-1} + \beta_7\,\text{PATNUM}_{jt}/\text{MV}_{jt-1} + \beta_8\,\text{CLAIM}_{jt}$$

$$+ \beta_9\,\text{CITATION}_{jt} + \beta_{10}\,\text{REFAGE}_{jt} + \beta_{11}\,\text{REFNUM}_{jt} + \beta_{12}\,\text{DNA\%}_{jt} + \beta_{13}\,(\text{PATNUM*CLAIM}_{jt})/\text{MV}_{jt-1}$$

$$+ \beta_{14}\,(\text{PAT*CITATION}_{jt})/\text{MV}_{jt-1} + \beta_{15}\,(\text{PATNUM*REFAGE}_{jt})/\text{MV}_{jt-1} + \beta_{16}\,(\text{PATNUM*REFNUM}_{jt})/\text{MV}_{jt-1}$$

$$+ \beta_{17}\,(\text{PATNUM*DNA\%}_{jt})/\text{MV}_{jt-1} + \beta_{18}\,\text{B/M}_{jt} + \beta_{19}\,\text{MV}_{jt} + \beta_{20}\,\text{BETA}_{jt} + \varepsilon_{jt}\,. \tag{4'}$$

Variables	Coefficients		
	D	E	F
Constant	-0.12	-0.24	-0.20
	(-0.40)	(-0.74)	(-0.65)
$1/MV_{t-1}$	4.15 **	4.17 **	4.12 **
	(2.4)	(2.41)	(2.38)
$\Delta BV_t/MV_{t-1}$	1.55 ***	1.54 ***	1.54 ***
	(7.53)	(7.53)	(7.51)
$\Delta E_t/MV_{t-1}$	0.31	0.31	0.31
	(0.64)	(0.63)	(0.64)
BV_{t-1}/MV_{t-1}	2.35 ***	2.35 ***	2.34 ***
	(7.18)	(7.17)	(7.15)
E_{t-1}/MV_{t-1}	-0.45	-0.45	-0.46
	(-0.80)	(-0.81)	(-0.81)
$R\&D/MV_{t-1}$	-0.74 *	-0.73 *	-0.72 *
	(-1.70)	(-1.68)	(-1.65)
$PATNUM/MV_{t-1}$	1.08 **	1.08 **	1.10 **
	(2.05)	(2.04)	(2.09)
CLAIM	0.002		
	0.32		
CITATION	0.01	0.01	0.02
	(0.1)	(0.12)	(0.25)
REFAGE		0.004	
		(0.2)	
REFNUM			-0.002
			(-0.55)
DNA%	0.45 *	0.47 *	0.5 **
	(1.77)	(1.87)	(1.97)
BM	-1.70 ***	-1.70 ***	-1.70 ***
	(-8.42)	(-8.45)	(-8.46)
MV	0.00	0.00	0.00
	(-0.25)	(-0.26)	(-0.21)
BETA	0.12	0.11	0.12
	(1.02)	(1.01)	(1.04)
R^2	0.24	0.24	0.24
Hausman test	15.49	15.51	15.46
F stat. for overall model	20.03 ***	19.99 ***	20.04 ***
of patent variables	4.37 ***	4.43 ***	4.38 ***
Obs	860	860	860

t-statistics are in the parenthesis. The notations *, **, and *** refer to significance at the 10%, 5%, and 1% levels.

TABLE 7 REGRESSION OF RETURNS ON FINANCIAL, PATENT AND CONTROL VARIABLES IN A SUBSAMPLE OF FIRMS WITH LOSSES BEFORE R&D EXPENDITURES

Variables	Coefficients A	Coefficients B	Coefficients C	Mean
Constant	-1.03 *	-1.20 **	-0.79	
	(-1.71)	(-2.16)	(-1.39)	
$1/MV_{t-1}$	32.73 ***	30.19 ***	25.98 ***	
	(4.41)	(4.43)	(3.87)	
$\Delta BV_t/MV_{t-1}$	1.52 ***	1.57 ***	1.53 ***	
	(4.34)	(4.46)	(4.43)	
$\Delta E_t/MV_{t-1}$	0.59	0.90	1.31	
	(0.43)	(0.71)	(1.06)	
BV_{t-1}/MV_{t-1}	2.69 ***	1.19	1.23	
	(3.19)	(1.4)	(1.48)	
E_{t-1}/MV_{t-1}	0.43	0.62	0.84	
	0.26	(0.35)	(0.49)	
$R\&D/MV_{t-1}$	-3.65 ***	-4.82 ***	-4.26 ***	
	(-2.99)	(-4.13)	(-3.66)	
$PATNUM/MV_{t-1}$		-38.25 ***	-32.36 ***	0.05
		(-5.28)	(-5.35)	
CLAIM			-0.06 ***	13.60
			(-3.63)	
CITATION			0.05	0.67
			(0.26)	
REFAGE			0.04	4.72
			(0.87)	
REFNUM			-0.02 **	16.02
			(-2.09)	
DNA%			0.93 **	0.22
			(1.42)	
$(PATNUM*CLAIM)/MV_{t-1}$		0.36 ***	0.81 ***	0.94
		(2.98)	(4.65)	
$(PATNUM*CITATION)/MV_{t-1}$		8.36 ***	8.82 ***	0.04
		(3.21)	(3.00)	
$(PATNUM*REFAGE)/MV_{t-1}$		3.70 ***	3.07 ***	0.31
		(4.58)	(3.46)	
$(PATNUM*REFNUM)/MV_{t-1}$		0.31 ***	0.46 ***	0.91
		(2.53)	(3.35)	
$(PATNUM*DNA\%)/MV_{t-1}$		3.62	-5.24	0.02
		(0.62)	(-0.83)	

t-statistics are in the parenthesis. The notations *, **, and *** refer to significance at the 10%, 5%, and 1% levels.

TABLE 7 CONTINUED

Variables	Coefficients			Mean
	A	B	C	
BM	-1.29 ***	-0.53	-0.53	
	(-2.88)	(-1.26)	(-1.30)	
MV	0.00 *	0.00 **	0.00 **	
	(1.69)	(2.15)	(1.94)	
BETA	0.28	0.44	0.6 **	
	(0.94)	(1.6)	(2.19)	
Adj. R^2	0.30	0.43	0.47	
Hausman test	21.54 **	32.46 ***	29.82 *	
F stat. for overall model	2.22 ***	3.09 ***	3.32 ***	
F stat. for joint significance of patent variables		11.00 ***	8.31 ***	
Obs	391	391	391	

t-statistics are in the parenthesis. The notations *, **, and *** refer to significance at the 10%, 5%, and 1% levels.

Vita

Ya-wen Yang was born and raised in Taipei, Taiwan. She graduated from Tunghai University with her Bachelor degree in Accounting in 1997. She then came to the United States and attended the University of Illinois at Urbana-Champaign where she received her MBA degree with a major in Corporate Finance in 1999. She passed the Certified Public Accountant exam in the State of Illinois in the same year. In August 1999, she accepted a Graduate Teaching Assistantship from the University of Tennessee at Knoxville and began to work towards her Ph.D. degree in Accounting.