Innovation, Future Earnings, and Market Efficiency

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This study examines whether patent citation impact, a leading indicator of technology firms' innovation capabilities, is associated with future earnings and whether this association is appropriately reflected in stock prices and analysts' earnings forecasts of patent-rich companies. The results indicate that change of patent citation impact is positively associated with future earnings, particularly in industries with relatively short time lags between technological advances and profit realization (e.g., computers, electronics, and medical equipment). The strength of this relation also significantly increases with time for up to five years in the future. Market participants, including investors and analysts, however, do not fully incorporate the implication of enhanced innovation capabilities for future earnings into stock prices and earnings forecasts. This bias is significantly associated with future abnormal stock returns.

1. Introduction

A number of recent studies have been devoted to examining the value-relevance of nonfinancial leading indicators, motivated by the increasing importance of these indicators and the economic phenomenon they are associated with—the rise of intangible assets in size and contribution to corporate growth (e.g., AICPA [1994]; FASB [2001]; Upton [2001]; SEC [2001]; Lev [2001]).[1] Value-relevance studies generally assume that the documented association between non-

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1. Examples of nonfinancial leading indicators examined in value-relevance studies include market penetration rate (Amir and Lev [1996]), customer satisfaction measures (Ittner and Larcker [1998a]), patents (Deng et al. [1999]; Hall et al. [2000]; Gu and Lev [2002]) and Web traffic measures of Internet firms (Trueman et al. [2000]; Demers and Lev [2001]; Rajgopal, Venkatachalam and Kotha [2003]). A term that is often used interchangeably with nonfinancial leading indicators in the business press and practitioners' literature is non–GAAP leading indicators. Strictly speaking, non–GAAP leading indicators are information items that are not required by the Generally Accepted Accounting Principles (GAAP). Such information can be either financial, dollar-denominated measures (e.g., order backlog [Rajgopal, Shevlin, and Venkatachalam (2003)]) or nonfinancial measures that are not denominated in monetary terms (e.g., customer satisfaction).

financial leading indicators and contemporaneous stock prices or returns is due to a relation between the examined nonfinancial indicators and future earnings, and to market efficiency in assessing this relation. This study directly examines whether patent citation impact, a nonfinancial leading indicator of firms' innovation capabilities, is in fact related to future realized earnings and whether market participants (i.e., investors and analysts) fully incorporate the implications of patent citation impact for future earnings in determining stock prices and projecting future earnings. Evidence from the earnings prediction test enhances our understanding of what gives rise to the documented value-relevance results, and insights into the extent of market efficiency could be useful for delineating the reporting standards of nonfinancial indicators.

Because nonfinancial indicators are not dollar-denominated and are not subject to well-defined standards of measurement and disclosure, documenting the relation between nonfinancial leading indicators and future earnings is not straightforward. Recent research by Rajgopal, Shevlin, and Venkatachalam (2003) examines this relation using order backlog as a proxy for nonfinancial indicators despite that order backlog is typically denominated in dollars. This study examines patent citation impact, which, in contrast, is based on nonfinancial information. The citation impact of a patent reflects the extent to which the patent is cited by subsequent patents, and hence indicates its influence on later innovations. At the firm level, patent citation impact contains useful information about the firm's technological superiority—a highly valuable intangible asset that contributes to future earnings via such value-enhancing effects as first-mover and network advantages. Accordingly, increases in patent citation impact indicate strengthened innovation capabilities that are likely to yield incremental contributions to future earnings. Hence, a positive relation between change of patent citation impact and future earnings is expected.

The relation between patent citation impact and future earnings, however, may vary across industries and over time. For example, the strength of this relation is likely greater in industries with a short lag between innovation breakthroughs and profit realization than in industries where this lag is relatively long (e.g., biotech and pharmaceuticals). Moreover, if this relation reflects the role of innovation capabilities as a driver of long-term success, the relation should remain significant beyond short-term earnings (e.g., one-year-ahead earnings) or become even greater for earnings of longer term. This study examines whether variations in the relation between change of patent citation impact and future earnings are consistent with these conjectures.

While a positive relation between change of patent citation impact and firms' future earnings is consistent with the value-enhancing effect of innovation, it is not straightforward whether market participants appropriately understand the contribution of strengthened innovation capabilities to future earnings. Patent citation impact, like other nonfinancial leading indicators, is not denominated in dollars, making it difficult to translate increased patent citation impact to profit figures. The highly technical nature of patent information also impedes a clear interpretation of the implications of patent citation impact for future earnings. This increased difficulty and associated costs of processing patent citation information suggest that investors may not fully incorporate the contribution of increased patent citation impact to future earnings into stock prices.

On the other hand, some commentators argue that investors may overestimate the value-enhancing effect conveyed by nonfinancial leading indicators, particularly in technology sectors such as computers, Internet-based businesses, and biotech (e.g., Perkins and Perkins [1999]; Damodaran [2001]). There is extensive media coverage of patent awards, patent infringement litigation, and patent licensing deals, reflecting investors' belief in the value-relevance of these events and firms' disclosure efforts to promote the development. The heightened market interest in patent information suggests that investors may be overly optimistic about the contribution of patent information to future earnings. This possibility is consistent with prior evidence that investors overprice the contribution of non–GAAP leading indicators to future earnings. For example, Rajgopal, Shevlin, and Venkatachalam (2003) find that investors place a higher weight on order backlog relative to the weight reflected in the association between order backlog and future earnings. Thus, the extent to which the information value of patent citation impact is rationally reflected in stock prices is an empirical issue. This study explicitly examines whether market participants appropriately account for the implication of patent citation impact for future earnings.

The results of this study demonstrate that, on average, change of patent citation impact is positively related to the firm's future earnings. This is consistent with patent citation impact capturing firms' innovation capabilities, a key driver of future profitability. The strength of this relation, however, varies considerably across industries: while the association is significant in industries with a short time lag between innovation breakthroughs and profit realization (e.g., computers, semiconductors, and medical equipment), it is not significant in industries where this lag is relatively long (e.g., biotech and pharmaceuticals). Thus, the length of a firm's innovation cycle appears to be a determinant of the relation between enhanced innovation capabilities and future earnings. The results of this study also show that the relation between change of patent citation impact and future earnings increases with time: change of patent citation impact appears to have a stronger relation to earnings of longer term (e.g., five-year-ahead earnings vis-à-vis one-year-ahead earnings). This is consistent with the role of innovation capabilities as a driver of a firm's long-term success. Taken together, the results of this study suggest that patent citation impact reflects the mapping from a firm's innovation activities to profit realization in the future.

This study also uses the Mishkin (1983) framework to examine whether investors appropriately incorporate the implications of patent citation impact for future earnings into stock prices. The results demonstrate that investors value firms as if change of patent citation impact has no association with future earnings. This evidence, in contrast to the documented usefulness of the patent citation measure in predicting future earnings, is consistent with investors underestimating the contribution of patent citation impact to future earnings. Further tests show that sophisticated information intermediaries, such as analysts, also fail to fully understand the contribution of patent citation impact to future earnings when making earnings forecasts. To corroborate findings from the Mishkin test and analyst forecast test, this study also examines the prediction that the mispricing will subsequently be corrected, resulting in significant abnormal stock returns. Results of this test indicate that firms with increases in patent citation impact subsequently earn positive abnormal returns for up to three years after the portfolio formation date. Thus, the valuation bias of patent citation impact appears to persist for at least three years into the future.

This study extends prior research on the relation between nonfinancial leading indicators and firms' future earnings—an attribute that is important for understanding the usefulness of nonfinancial information. Much of the existing evidence in this literature derives from relatively small samples consisting of a single industry, such as banking (Ittner and Larcker [1998a]; Banker et al. [2000]) and airlines (Behn and Riley [1999]). As a result, little is known about the cross-sectional comparability in the usefulness of nonfinancial measures, which, according to Statement of Financial Accounting Concepts No. 2, *Qualitative Characteristics of Accounting Information,* is an important criterion in evaluating the decision-usefulness of information. This study examines patent citation impact, employing a large sample of firms from a wide spectrum of industries. The results indicate that the strength of the relation between patent citation impact and future earnings varies inversely with the length of innovation cycle in the firm's industry. This evidence parallels prior findings that the informativeness of accounting information (e.g., earnings) varies directly with the length of a firm's operating cycle (Warfield and Wild [1992]) and has implications for the disclosure of nonfinancial information (discussed in section 6).

The results of this study also show that the strength of the relation between patent citation impact and future earnings increases significantly with time. This characteristic of nonfinancial leading indicators has not been previously documented, and is useful for assessing whether the economic forces captured by nonfinancial performance measures are transitory or permanent. Value-relevance studies, while suggesting a positive relation between nonfinancial performance measures and future earnings, do not inform the timing pattern of this relation (e.g., Is the strength of the relation stable over time, increasing or decreasing with time?).

This study also provides evidence on whether market participants fully incorporate the implication of patent citation impact for future earnings of patent-rich companies into stock prices and earnings forecasts. This issue of market inefficiency, though important for understanding users' processing of nonfinancial information, has not been extensively examined by prior studies. An exception is Deng et al. (1999), which examines patent count and citation impact. They find a positive association between the level of patent citation impact and future abnormal returns. The present study utilizes a larger sample and focuses on the change of patent citation impact. The results indicate that, despite the ready availability and high reliability of patent citation impact measures, investors and sophisticated analysts seem to underreact to the implication of this indicator for firms' future profitability, suggesting that the technical nature of patent information may hinder users' processing of this information. The documented market underreaction to patent citation impact is an interesting contrast to the result of Rajgopal, Shevlin, and Venkatachalam (2003) that the stock market overweights the contribution of order backlog in predicting future earnings. Investigation of why investors exhibit different biases in processing dollar-denominated versus nondollar-denominated information is beyond the scope of this study and can be an interesting topic for future research.

The remainder of this paper proceeds as follows. Section 2 provides background information about patent citation impact and the hypotheses of the study. Section 3 illustrates the measurement of patent citation impact. Section 4 describes the sample data and reports summary statistics. Section 5 presents empirical results, and Section 6 summarizes the main findings and discusses the implications of the study.

2. Background and Hypothesis

The patent citation impact measure examined in this study is derived from publicly available patent application information. The patent application prepared by a prospective patent owner is an extensive document that includes, among other things, references (citations) to prior inventions relevant for establishing the novelty of the applied patent and its intellectual property rights (claims). Analysis of citation patterns in patent applications yields a trail of evolution in technology over time, such as the impact of an earlier invention on later advances in the technology field and spillover of innovation across firms and nations. The stringent rules governing the citation criterion and the unbiased process of patent examination ensure that inferences based on citation information are relatively reliable and objective (i.e., free of manipulation by the patentee).

Economic research shows that the extent to which a patent is referenced by later patents (also termed "forward citation") indicates the economic value and technological significance of the patent. For example, Trajtenberg (1989, 1990) finds that citation intensity is positively associated with the social benefits generated by a cited patent. Lanjouw and Schankerman (2001) show that litigated patents are cited more frequently than their nonlitigated counterparts, consistent with an association between citation level and economic value. These results suggest that patent citation impact at the firm level is a useful indicator of a firm's innovation capabilities, a progenitor of successful products and sustainable future profitability.

In the specific context of fundamental analysis, patent citation impact has the following implications for the firm's future profitability. A significant number of citations to a prior patent indicates that the cited patent has led to a large number of technologically successful innovations over subsequent years. This influence is economically significant because patenting activities are highly correlated with firms' investment in technological innovation.[2] Assuming that firms undertake technology investments only after thoroughly assessing the prospects of growth and uncertainty, a heavy following by other firms in patenting in the same field of innovation suggests substantial growth opportunities in the field and resolved uncertainty concerning the economic value of the innovation. These are obviously favorable conditions for future increases in profitability, particularly for the firm that pioneers the field.[3]

Highly influential patents also attest to the technological leadership and superiority of the patent-holding company. A large body of research in economics and management demonstrates the value of technological leadership: it generates first-mover and network advantages that directly contribute to future earnings. Lieberman and Montgomery (1988) show that technological leadership constitutes a primary source of first-mover advantages—the ability of pioneering firms to earn economic profits in excess of the cost of capital.[4] They specifically identify success in patents and innovation as a key mechanism that creates sustainable leadership in technology. Hence, technological dominance conferred by highly cited patents establishes the leadership of the firm in innovation, which in turn leads to significant first-mover advantages and enhanced future profitability.

Research on network advantages recognizes that investment in technology creates standards, and that adoption of those standards by other firms facilitates the formation of networks (Shapiro and Varian [1999]). Successful networks, as a result of wide adoption of the firm's standards, generate large and sustainable economic benefits for the firm.[5] The firm with pioneering and influential patents is in a dominant position to persuade other firms to adopt its standards. This is so because other firms opting to adopt the firm's standards can avoid the technological uncer-

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2. The high correlation between the number of patents issued to the firm and the firm's investment in innovation (e.g., R&D expenditures) has been extensively documented by early research (e.g., Griliches [1984]).

3. This link between patent citation impact and future profitability assumes that subsequent citations are mostly made by other firms from the same industry. However, significant self-citations—the patent holding firm repeatedly citing one of its prior patents—also have meaningful implications for the firm's future profitability. Early research found that firms retaining dominant technologies and patents tend to obtain a large number of patents to cover alternative and derivative uses of the basic technology they control (e.g., Bright [1949]). By their nature, these subsequent patents are related to the earlier patent via citation; hence the large citation impact of the earlier patent. In competition, a thicket of patents built around the same core patent may likely deter entry by other firms and aid the patent-holding company in maintaining its monopoly and obtaining favorable licensing rates (Bresnahan [1985]).

4. See Kerin et al. (1992) for a review of theoretical and empirical studies on the first-mover advantage.

5. A case in point is the success of Qualcomm in building a large network based on its wireless technology. Qualcomm, the holder of key patents of the CDMA wireless technology, adopted the strategy of authorizing infrastructure and mobile phone suppliers, such as Motorola and Nokia, to design, manufacture and sell products based on its technology. This is widely seen as a move that has promoted the worldwide adoption of Qualcomm's standard. For an example of research empirically documenting the network value in the Internet industry, see Rajgopal, Venkatachalam and Kotha (2003).

tainty and costs of developing their own standards.[6] Hence, technological leadership gives the firm substantial strategic advantages in capturing the network value. According to Shapiro and Varian, the value of a network increases with its size, which is primarily driven by the number of firms adopting the standards of the network.[7] The higher the citation impact a patent has, the more the firm's innovation is recognized by other firms, and the larger the number of firms that may adopt the firm's standards. This suggests a positive relation between patent citation impact and the potential size of the network effect. This relation is consistent with the dominant role of intangible assets (e.g., patents) in networks (Lev [2001]).[8]

A direct benefit of the network effect is royalty income derived from licensing the firm's patents to other firms. Patent licensing is a potent strategy in promoting standards and building networks, and can generate large economic benefits for the licensor (Shapiro [1985]). Consistent with this, Gu and Lev (2004) find that patent licensing is pervasive and growing across technology industries.[9] They also find that royalty income is highly valuable to the licensor: it is more persistent over time and commands a larger valuation coefficient compared with other income. The evidence of Gu and Lev (2002) indicates a positive relation between patent citation impact and the amount of royalty income. This relation suggests that firms with influential patents retain significant technological leadership, and hence enjoy considerable advantages in licensing.

In sum, patent citation impact contains useful information about the earnings-enhancing effect of innovation, such as the first-mover and network advantages it generates. Under this view, increases in patent citation impact indicate strengthened innovation capabilities that can make incremental contributions to future earnings. Hence, a positive relation between change of patent citation impact and future earnings is expected. This is the first hypothesis of this study (in alternative form).

Hypothesis 1: Change of patent citation impact is positively associated with future earnings.

While hypothesis 1 predicts an overall positive relation between change of patent citation impact and future earnings, the strength of this relation may vary with cross-industry differences in the time lag between innovation breakthroughs

6. Relative to firms yet to invest in developing their own standards, the pioneering firm (incumbent) has a cost advantage (e.g., due to learning). This cost advantage may dissuade other firms from entering the technology field and developing their own standards (Spence [1984]). It also increases the appeal for the entrant to license the incumbent's technology and hence promotes the adoption of the incumbent's standards.

7. Shapiro and Varian (1999) also note that increases in the size of the network often create positive feedback effects, which in turn fuel further growth of the network.

8. Summarizing the greater importance of intangibles relative to other assets (e.g., physical assets) in the network markets, Lev (2001, p. 29) concludes, "But increasingly, at the core of an important network lies an innovation that was subsequently developed into a product or service, and for which property (ownership) rights are secured by patents, trademarks, or a strong brand."

9. For further evidence on the increase of royalty income from patent licensing and the large market for patent licensing in the United States, see Rivette and Kline (2000).

and profit realization. From an accounting measurement perspective, this lag is a function of two factors: the length of the firm's innovation cycle—the process starting with early research breakthroughs, as evidenced by increased patent citation impact, and ending with commercialization of products and services backed by successful innovation—and the accounting recognition rule concerning the economic benefits generated by innovation. Under current U.S. accounting standards, most firms apply the same recognition rule: a transaction-based approach that delays recognition of benefits until they are realized. Thus, cross-sectional variation in the relation between change of patent citation impact and future earnings is expected to vary directly with the length of the innovation cycle in the firm's industry.

It is well documented that the innovation cycle in the biotech and pharmaceutical industries is much longer than that in other innovation-intensive industries. On average, the development of a new drug takes twelve to fifteen years, during which time the uncertainty relating to the scientific feasibility of the drug and its regulatory status gradually resolves as the drug moves through research and development phases (Siegfried [1998]; Holmer [1999]). This prolonged process, in conjunction with the tendency of biotech and pharmaceutical firms to apply for patents at the early stage of innovation, implies that the relation between innovation breakthroughs reflected by increased patent citation impact and earnings in the foreseeable future is at best tenuous. In contrast, in industries with relatively short innovation cycles (e.g., computers, electronics, and medical equipment), it takes considerably less time to turn promising technology advances into realized profits; hence there is a stronger relation between change of patent citation impact and future earnings. These factors suggest the following hypothesis concerning the cross-sectional difference in the relation between patent citation impact and future earnings (in alternative form):

Hypothesis 2: The relation between change of patent citation impact and future earnings for firms in industries other than biotech and pharmaceuticals is stronger than that for firms in the biotech and pharmaceutical industries.

The strength of the relation between the patent citation impact and future earnings may also vary with the time horizon of earnings. Research suggests an effect of technological innovation on long-term growth at the macroeconomic level (e.g., Romer [1990]). At the firm level, Lev and Sougiannis (1996) find that R&D expenditures, the input measure of innovation activities, contribute to future earnings for up to five years. Consistent with this, a persistent relation between patent citation impact—a quality-based output measure of innovation activities—and future earnings is expected over the long term. If increases in citation impact capture enhanced innovation capabilities likely to yield increasing future earnings via marketing of profitable products in growing markets, the strength of the relation between change of patent citation impact and future earnings will increase over time.

This is the hypothesis concerning how the relation between citation impact and future earnings varies over time (in alternative form):

Hypothesis 3: Change of patent citation impact has a stronger relation to future earnings of longer term (e.g., five-year-ahead earnings) than future earnings of shorter term (e.g., one-year-ahead earnings).

Prior research found evidence of market inefficiency with respect to widely disseminated financial measures, such as earnings and accruals (Bernard and Thomas [1990]; Sloan [1996]). Investors may have even greater difficulty in assessing nonfinancial information such as patent citation impact, which tends to have a more subtle relation to future earnings. Indeed, recent studies have found that managers, let alone investors, have difficulty articulating the valuation implication of nonfinancial leading indicators (Ittner and Larcker [1998b]; Banker et al. [2000]). On account of the difficulty and uncertainty in translating patent citation impact to earnings and firm value, investors may significantly discount the value-enhancing effect of this indicator and underprice the contribution of increased patent citation impact to future earnings. On the other hand, extensive media attention to patent information may prompt investors to be overly optimistic about the implications of patent citation impact for future earnings. This is consistent with the evidence of Rajgopal, Shevlin and Venkatachalam (2003) that investors overprice the earnings-enhancing effect of order backlog, a leading indicator widely reported in the business press. These considerations lead to the following hypothesis concerning market efficiency with respect to patent citation impact (in two-sided form):

Hypothesis 4: Market participants, including investors and analysts, underweight (overweight) the contribution of change in patent citation impact to future earnings when setting stock prices and forecasting earnings.

3. Measurement of Patent Citation Impact

Using patent citation information to measure firms' innovation capabilities requires careful attention to the difference in citation propensity across technological fields and over time. Hall et al. (2001) find that computer, communication, drug, and medical patents are cited more frequently than patents from other fields (e.g., mechanical). They also show, as expected, that older patents receive more citations than newer patents. To account for these differences that are likely attributable to the mechanics of the citation process, this study measures the citation impact of a patent relative to its peers in the same technological area and of identical age that are cited in the same year.[10] The measurement procedure thus adjusts fully for

10. For the purpose of computing patent citation impact, the categorization of technological areas is based on the system of the USPTO that classifies patents into 36 subcategories, which are then aggregated into 6 main categories: chemicals (containing 6 subcategories), computers and communications (containing 4 subcategories), drugs and medical (containing 4 subcategories), electrical and

citation propensity attributed to differences in technology fields, citing year (the year in which the citation takes place) and cited year (the year in which the cited patent was issued). This adjustment, similar to the procedure used by economists to remove the effect of industry-specific and time-variant inflation rate, ensures the cross-sectional and over-time comparability of patent citation impact.

Firm-specific measure of patent citation impact in a given year is defined as the sum of the adjusted number of citations across patents issued to the firm over the prior five years that are cited by other patents in the year of measurement.[11] Formally, the patent citation impact of firm i in year t (PCI_{it}) is given by

$$PCI_{it} = \sum_{j=1}^{5} \sum_{n_{t-j}=1}^{N_{t-j}} C_{in_{t-j}},$$

where $C_{in_{t-j}}$ is the adjusted number of citations received in year t by patent n_{t-j} ($n_{t-j} = 1 \ldots N_{t-j}$), issued to firm i in year $t - j$ ($j = 1,2,3,4,5$), and N_{t-j} is the total number of patents issued to firm i in year $t - j$ that are cited in year t.[12] The five-year period used in computing the firm-level citation impact is roughly consistent with prior findings that technology cycles measured by the duration of the benefits of R&D spending are approximately five years in most industries (Lev and Sougiannis 1996). Year-to-year change of patent citation impact is computed by subtracting the citation impact measure of the prior year from that of the current year. Table 1 illustrates the computation procedure for patent citation impact pertaining to the patent portfolio of Diasonics Ultrasound, a medical equipment maker, in 1994 and 1995. While the firm's patent portfolio contains 18 (20) patents granted over the five-year period up to 1994 (1995), the adjusted patent citation impact associated with those patents is a total of 10.482 (14.937) in 1994 (1995). Therefore, the year-to-year change of patent citation impact (ΔPCI) for Diasonics Ultrasound in 1995 is an increase of 4.455 ($14.937 - 10.482 = 4.455$).[13]

An alternative measure of the firm's innovation and patenting activities is the number of new patents generated by the firm, the patent count. The patent count, however, does not capture the vast difference in the quality and value of innovation

electronic (containing 7 subcategories), mechanical (containing 6 subcategories), and others (containing 9 subcategories).

11. For example, the firm-specific measure of patent citation impact in 1996 is the sum of the adjusted number of citations received in 1996 by patents issued to the firm from 1991 to 1995.

12. This definition of patent citation impact does not incorporate possible difference among citations made by other companies, self-citation, and citations made by not-for-profit entities (e.g., universities). Prior research indicates that self-citation is indicative of the citing firm's efforts to further secure and enhance economic benefits (e.g., monopolistic profitability) generated by earlier patents (Bright [1949]; Bresnahan [1985]). This tendency suggests that the technological and economic implications of self-citation and citation by other firms are likely similar. Future research may examine whether citations made by not-for-profit entities are different from citations made by profit-seeking corporations, in terms of the attributes of the cited patent (e.g., originality and closeness to science) and the relation between citation intensity and the value of the cited invention.

13. Because the patent issued to the company in 1989 was not cited in 1994, the citation impact attributed to that patent in 1994 is zero.

TABLE 1

Computation of Patent Citation Impact for Diasonics Ultrasound: 1994 and 1995

Cited Patent ID	Grant Year	Patent Subcategory[1]	Number of Citations	Mean Number of Citations[2]	Citation Impact[3]
Panel A: Portfolio of patents cited in 1994					
NA	1989	NA	0	NA	0
4911173	1990	32	4	2.769	1.445
4930515	1990	32	2	2.769	0.722
4899109	1990	43	3	1.758	1.706
5033456	1991	32	1	2.498	0.400
5058593	1991	32	3	2.498	1.201
5065761	1991	32	2	2.498	0.800
5078705	1992	32	1	2.334	0.429
5123417	1992	32	1	2.334	0.429
5131105	1992	65	1	1.444	0.692
5228009	1993	21	4	1.505	2.658
Total citation impact					10.482
Total number of patents granted 1989–1993[4]				18 (= 1 + 4 + 5 + 5 + 3)	
Panel B: Portfolio of patents cited in 1995					
4911173	1990	32	9	2.925	3.077
4930515	1990	32	5	2.925	1.709
4899109	1990	43	3	1.720	1.744
5033456	1991	32	1	2.788	0.359
5058593	1991	32	2	2.788	0.717
5065761	1991	32	1	2.788	0.359
5003238	1991	45	1	1.890	0.529
5131105	1992	65	3	1.482	2.024
5228009	1993	21	2	2.020	0.990
5230112	1993	65	1	1.391	0.719
5299174	1994	21	2	1.584	1.262
5283808	1994	44	2	1.382	1.447
Total citation impact					14.937
Total number of patents granted 1990–1994[4]				20 (= 4 + 5 + 5 + 3 + 3)	

1. Patent subcategory is based on the patent classification system of the U.S. Patent and Trademark Office. A brief description of the subcategory of cited patents is as follows: 32 (surgery and medical instruments), 43 (measuring and testing), 65 (furniture and house fixtures), 21 (communications), 45 (power systems) and 44 (nuclear and X-rays).

2. Mean number of citations is the mean number of citations received by patents of the same subcategory/grant year group cited in the same year.

3. Citation impact of a patent is the ratio of number of citations to mean number of citations.

4. The number of patents granted to the company over 1989–1994 is as follows: 1989, 1; 1990, 4; 1991, 5; 1992, 5; 1993, 3; 1994, 3.

across patents because it implicitly assumes that the technological and economic significance of each patent is the same. Prior research found that the economic value of patents is highly uneven: a relatively small number of inventions tend to account for the lion's share of innovation value, while the others are worth much less (e.g., Pakes [1986]; Patel and Pavitt [1995]; Scherer et al. [1998]). The high skewness in the distribution of innovation's economic value suggests that patent count is likely a very noisy measure of firms' value-enhancing innovation capabilities. Consistent with this, early research indicates that patent count is closely associated with the input of firms' innovation activities, primarily with contemporaneous R&D expenditures, but has little meaningful relation to value indicators of the innovating firm (Griliches [1984]; Griliches et al. [1988]).[14]

The patent citation impact examined in this study focuses on the potential value of innovation covered by patents. This measure weights patents on the basis of their impact on subsequent innovations, as indicated by the number of citations in later patents. By construction, noncited patents receive a zero weight and are not included in the measure of the firm's patent citation impact, while cited patents enter this measure with a weight commensurate with the number of citations they receive. Therefore, the citation impact can be viewed as a quality-adjusted measure for the quantity of the firm's valuable patents. For example, the patent citation impact of Diasonics Ultrasound in 1994 (1995), 10.482 (14.937), reflects the total number of citations received by its 10 (12) cited patents out of all available 18 (20) patents in that year.

4. Sample Data

Sample firms examined in this study were obtained from the comprehensive patent database compiled by the National Bureau of Economic Research (NBER). This database covers all utility patents granted by the U.S. Patent and Trademark Office during the period 1975–1999. It includes, among other things, information on references to prior relevant inventions made by patent owners in patent applications. For details on variable definitions and measurements concerning the NBER patent database, see Hall et al. (2001). A total of 1330 companies (10,400 firm-years) in the NBER patent database have the required financial statement data available from Compustat for the period 1983–1999.

Table 2 reports the distribution of the 10,400 firm-year observations across industries (panel A) and years (panel B). It shows that patenting is prevalent in many industries: a total of 57 two-digit SIC industries are included in the sample, representing approximately 68.7% of the 83 two-digit SIC industries in Compustat.

14. The low correlation between patent count and firm value may stem from the fact that the value of patents can hardly be discerned ex ante because the examination and approval of patent applications are based entirely on the scientific and technological validity of the applied patent rather than the commercial value of the considered patent. In contrast, patent citations provide an ex post indication of the impact of a patent on later innovation, and hence its potential economic value (e.g., contribution to future profitability).

TABLE 2

Sample Breakdown by Industry and Year

Panel A: Sample breakdown by industry

SIC	Industry	Number of Firm-Years	Percentage (%)
01	Agricultural production	19	0.18%
10	Metal mining	26	0.25%
13	Oil and gas extraction	163	1.57%
14	Mining and quarry nonmetal minerals	19	0.18%
15	Building construction	1	0.01%
16	Heavy construction	23	0.22%
17	Construction	2	0.02%
20	Food and kindred products	338	3.25%
21	Tobacco products	23	0.22%
22	Textile mill products	104	1.00%
23	Apparel	47	0.45%
24	Lumber and wood products	87	0.84%
25	Furniture and fixtures	140	1.35%
26	Paper and allied products	329	3.16%
27	Printing, publishing and allied	86	0.83%
28	Chemical, biotech and drug	1301	12.51%
29	Petroleum refining	189	1.82%
30	Rubber and miscellaneous plastics	291	2.80%
31	Leather products	38	0.37%
32	Stone, clay, glass, concrete products	162	1.56%
33	Primary metal industries	403	3.88%
34	Fabricated metal	443	4.26%
35	Machinery and computer equipment	1697	16.32%
36	Electrical and electronic components	1460	14.04%
37	Transportation equipment	697	6.70%
38	Medical and scientific instruments	1266	12.17%
39	Miscellaneous manufacturing industries	122	1.17%
40	Railroad transportation	23	0.22%
42	Motor freight transportation	1	0.01%
45	Air transportation	2	0.02%
47	Transportation services	10	0.10%
48	Communications	79	0.76%
49	Electrical, gas and sanitary services	80	0.77%
50	Wholesale of durable goods	121	1.16%
51	Wholesale of nondurable goods	57	0.55%
52	Building material, hardware, gardening	19	0.18%
53	General merchandise stores	22	0.21%
54	Food stores	1	0.01%
56	Apparel and accessory stores	6	0.06%
57	Home furniture and equipment stores	15	0.14%
58	Eating and drinking places	4	0.04%
59	Miscellaneous retail	16	0.15%
60	Depository institutions	10	0.10%

TABLE 2 (*continued*)

61	Nondepository credit institutions	24	0.23%
62	Security and commodity brokers	11	0.11%
63	Insurance carriers	25	0.24%
67	Holding and other investment offices	21	0.20%
70	Hotels and other lodging places	1	0.01%
72	Personal services	16	0.15%
73	Computer software and data services	179	1.72%
75	Auto repair	18	0.17%
78	Motion pictures	3	0.03%
79	Amusements and recreation	6	0.06%
80	Health services	11	0.11%
82	Educational services	14	0.13%
87	Engineering, accounting, other	44	0.42%
99	Nonclassifiable establishments	85	0.82%
Total		10,400	100.00%

Panel B: Sample breakdown by year

1983	618	5.94%
1984	588	5.65%
1985	604	5.81%
1986	608	5.85%
1987	586	5.63%
1988	588	5.65%
1989	614	5.90%
1990	650	6.25%
1991	670	6.44%
1992	672	6.46%
1993	682	6.56%
1994	658	6.33%
1995	638	6.13%
1996	622	5.98%
1997	586	5.63%
1998	525	5.05%
1999	491	4.72%
Total	10,400	100.00%

The data source is the patent database compiled by the National Bureau of Economic Research (NBER), covering all utility patents granted by the U.S. Patent and Trademark Office. Sample firms have the required data from the NBER patent database and Compustat during the period 1983–1999 (10,400 firm-years representing 1330 firms).

Five industries—chemical, biotech and pharmaceutical (SIC 28), machinery and computer hardware (SIC 35), electrical and electronics components (SIC 36), transportation equipment (SIC 37) and medical and scientific instruments (SIC 38)—however, account for 61.74% of the observations, indicating the prominence of patents in industries relying on technology-related intangibles (e.g., innovation capabilities).[15] Except for the transportation equipment industry, the number of firm-year observations from the dominant innovation-intensive industries is similar, ranging from 1266 firm-years (12.17%) in the medical and scientific industry to 1697 firm-years (16.32%) in the machinery and computer hardware industry. Panel B shows that the sample is fairly evenly distributed across years, with 1993 containing the highest percentage of observations (6.56%) and 1999 the lowest (4.72%). The declining number of firm-years toward the end of the sample period is due to the lengthy time lag between patent application and granting decision.

Table 3 reports descriptive statistics of patent citation impact—its level (*PCI*) and change (ΔPCI)—and other firm characteristics, including net income deflated by average total assets (*NI*), market value (*MV*), market-to-book ratio (*M/B*) and R&D expenditures deflated by average total assets (*RD*).[16] The level and year-to-year change of patent citation impact are also deflated by average total assets. Panel A shows that change of patent citation impact (ΔPCI), the principal measure of enhancement or decline of firms' innovation capabilities, has mean and median values of 0.003 and 0.0003, respectively. The standard deviation is 0.194, indicating considerable cross-sectional variation in the value of ΔPCI.

Table 3, panel B, reports the correlation coefficients between change of patent citation impact and other firm characteristics. There is a consistently positive association between ΔPCI and current earnings (*NI*). The level and change of patent citation impact are also positively correlated, although the magnitude of the correlation is far less than perfect (0.165 for the Pearson correlation and 0.271 for the Spearman correlation, respectively). The association between ΔPCI and the other firm characteristics, however, is inconsistent between the Pearson and Spearman correlation coefficients. As expected, the level of patent citation impact (*PCI*) has a strong positive correlation with firms' R&D expenditures (0.364 for the Pearson correlation and 0.539 for the Spearman correlation, respectively), which measure firms' input into innovation activities.

5. Empirical Results

The empirical tests proceed in three stages. In section 5.1, the relation between current change of patent citation impact and future realized earnings is examined, using the well-established time-series model of earnings. The tests of section 5.2

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15. The paucity of software firms in the sample is likely due to the difficulty of relying on patenting to secure the legal rights of software. As a result, software firms have traditionally used other means (e.g., copyrights) to protect against illegal use of software. However, recent technological developments in the software industry and an increase in the patenting rate of software have suggested that patent protection may emerge as a more effective intellectual property protection for software (Smith and Mann [2004]).

16. Consistent with the view that patent count and patent citation impact capture fundamentally different aspects of innovation activities, unreported analysis shows that the correlation between these two measures for the sample firms is far less than perfect (0.51).

TABLE 3

Descriptive Statistics of Patent Citation Impact and Other Firm Characteristics

Panel A: Distribution statistics

Variable	*# Obs*	Mean	Standard Deviation	25%	Median	75%
ΔPCI	10,400	0.003	0.194	−0.003	0.0003	0.006
PCI	10,400	0.081	0.412	0.006	0.018	0.046
NI	10,400	0.039	0.094	0.014	0.051	0.087
MV (in $millions)	10,400	3954	14,389	113.2	527.1	2308
M/B	10,400	2.281	9.861	1.182	1.782	2.765
RD	10,400	0.045	0.056	0.007	0.026	0.064

Panel B: Pearson (above-diagonal) and Spearman (below-diagonal) correlation coefficients

	ΔPCI	*PCI*	*NI*	*LN(MV)*	*M/B*	*RD*
ΔPCI		0.165	0.091	0.061	0.003[ns]	0.007[ns]
PCI	0.271		−0.134	−0.336	0.071	0.364
NI	0.033	0.032		0.309	0.166	−0.196
LN(MV)	0.018[ns]	−0.391	0.261		0.371	−0.086
M/B	0.026	0.056	0.458	0.433		0.216
RD	0.118	0.539	0.097	−0.079	0.194	

Variable definitions are as follows. *PCI* is the firm's patent citation impact in a given year. *ΔPCI* is the change of the firm's patent citation impact in the year relative to the prior year. *NI* is net income before extraordinary items. *MV* is the firm's market value at the fiscal year-end. *M/B* is the market-to-book ratio at the fiscal year-end. *RD* is the firm's R&D expenditures. *LN(MV)* is the logarithm of the firm's market value (*MV*). All variables are deflated by the firm's average total assets, except for *MV*, *M/B,* and *LN(MV)*.

[ns] Indicates Pearson and Spearman correlation coefficients that are not significantly different from zero at the 0.01 level (two-tailed test).

focus on whether market participants (i.e., investors and analysts) fully incorporate the implications of change of patent citation impact for future earnings when setting stock prices and generating earnings forecasts. In section 5.3, the association between change of patent citation impact and future abnormal returns is examined to assess whether the market subsequently corrects the bias in investors' and analysts' assessment about the contribution of firms' innovation capabilities to future earnings.

5.1 Patent Citation Impact and Future Earnings

Hypothesis 1 predicts that change of patent citation impact is positively associated with firms' future realized earnings. To examine this, the time-series model of earnings incorporating change of patent citation impact is estimated as follows:

$$NI_{it+1} = \alpha_0 + \alpha_1 NI_{it} + \alpha_2 \Delta PCI_{it} + \nu_{it+1}, \quad (1)$$

where NI_{it} (NI_{it+1}) is firm i's net income before extraordinary items in year t ($t + 1$) and ΔPCI_{it} is the change of patent citation impact for firm i in year t. Eq. (1) is based on prior research on the time-series properties of accounting earnings (e.g., Beaver [1970]; Freeman et al. [1982]). The coefficient α_1 represents earnings persistence, and α_2 captures the incremental contribution of enhanced patent citation impact to future earnings. The previously documented persistence and mean-reverting characteristics of earnings imply $0 < \alpha_1 < 1$, whereas hypothesis 1 predicts $\alpha_2 > 0$.

The regression estimates of eq. (1) are reported in Table 4 for the full sample and for various industries.[17] Panel A shows regression results based on pooled regression that include dummy variables for year-specific effects. The first regression includes all 10,400 firm-year observations for the full sample. It shows that the coefficient of current earnings (NI_t) is 0.630 (t-statistic = 75.58). An F-test for the null hypothesis that this coefficient equals 1 is rejected at the 0.001 level. This result is consistent with prior evidence that earnings are serially correlated and mean-reverting. As predicted by hypothesis 1, the coefficient of change of patent citation impact (ΔPCI_t) is positive (0.111) and statistically significant at the 0.01 level (t-statistic = 7.06). The size of this coefficient implies that, after controlling for earnings persistence, an increase in patent citation impact in year t of 0.01 (1%) is associated with an increase in earnings of year $t + 1$ by 0.111% ($0.111 \times 0.01 = 0.111\%$), approximately 2.85% of the mean value of current-year earnings ($0.111\% \div 0.039 = 2.85\%$). Thus, the contribution of current increases in patent citation impact to future earnings is statistically significant and economically meaningful. The association between change of patent citation impact and future realized earnings reflects the value-enhancing effect of firms' innovation capabilities, which are a key driver of future profits.

The remaining regressions in panel A are estimated for six industry groups: five dominant innovation-intensive industries (SICs 28, 35, 36, 37 and 38) and a combined group of firms from all other industries. Except for biotech and pharmaceutical firms (SIC 28), the regression results at the two-digit SIC industry level are similar to those for the full sample, with the coefficient estimate of ΔPCI ranging from 0.073 to 0.175 and statistically significant at the 0.05 level or higher. While the coefficient of ΔPCI is positive (0.052) for biotech and pharmaceutical firms, it is not statistically significant at the conventional level. This cross-industry difference in the relation between patent citation impact and future earnings is consistent with the prediction of hypothesis 2 that the longer innovation cycles in biotech and pharmaceutical firms render patent citation impact less informative about earnings performance in the near future. In contrast, in industries with shorter

17. When estimating eq. (1), all variables, including the intercept (α_0), are deflated by the firm's average total assets. Coefficient estimates on the deflated intercept are generally negative and statistically significant at the conventional level (not reported).

TABLE 4

Summary Statistics for Regression of Future Earnings for Year $t + 1$ on Current Earnings and Change of Patent Citation Impact

Panel A: Results based on pooled regression

$$NI_{it+1} = \alpha_0 + \alpha_1 NI_{it} + \alpha_2 \Delta PCI_{it} + \sum \beta_Y YR_{Yit} + v_{it+1}$$

Sample	# Obs	NI_t	ΔPCI_t	Adj. R^2
All firm-years	10,400	0.630	0.111	40.2%
		(75.58)	(7.06)	
Biotech and pharmaceuticals (28)	1301	0.732	0.052	52.2%
		(34.31)	(0.34)	
Computers and machinery (35)	1697	0.541	0.160	30.4%
		(23.73)	(4.82)	
Electrical and electronics (36)	1460	0.547	0.175	31.7%
		(22.88)	(3.18)	
Transportation equipment (37)	697	0.684	0.081	41.4%
		(18.46)	(2.89)	
Medical and scientific instruments (38)	1266	0.589	0.114	37.2%
		(23.61)	(3.59)	
Other	3979	0.676	0.073	47.0%
		(55.54)	(2.40)	

Panel B: Results based on cross-sectional regression

$$NI_{it+1} = \alpha_0 + \alpha_1 NI_{it} + \alpha_2 \Delta PCI_{it} + v_{it+1}$$

Sample	# Obs	Intercept	NI_t	ΔPCI_t	Adj. R^2
All firm-years	10,400	0.024	0.629	0.103	40.1%
		(8.32)	(30.34)	(3.07)	
Biotech and pharmaceuticals (28)	1301	0.024	0.783	−0.093	56.1%
		(3.46)	(10.32)	(−0.81)	
Computers and machinery (35)	1697	0.019	0.540	0.154	35.7%
		(4.51)	(10.62)	(1.94)	
Electrical and electronics (36)	1460	0.024	0.569	0.177	36.5%
		(4.32)	(11.37)	(2.29)	
Transportation equipment (37)	697	0.010	0.789	0.102	51.2%
		(2.41)	(10.26)	(1.52)	
Medical and scientific instruments (38)	1266	0.026	0.639	0.097	38.4%
		(4.04)	(12.87)	(2.47)	
Other	3979	0.018	0.702	0.069	47.5%
		(5.19)	(20.96)	(1.72)	

Variable definitions are as follows. NI_t (NI_{t+1}) is earnings of year t ($t + 1$) deflated by average total assets of year t, and ΔPCI_t is the change of patent citation impact in year t deflated by average total assets of year t. YR_{Yit} is a series of dummy variables measuring year-specific effects. The regressions include 10,400 firm-years for 1983–1999. The t-statistics are in parentheses.

innovation cycles (e.g., computer hardware), strengthened innovation capabilities can be turned into profits more quickly, hence a stronger relation between change of patent citation impact and earnings of the next year.[18]

Table 4, panel B, reports coefficient estimates and other statistics based on cross-sectional regressions of eq. (1). This approach follows Fama and MacBeth (1973) and allays concerns that some firms are represented in multiple sample years. Under this approach, the reported coefficient estimates are the mean values of coefficient estimates obtained from 17 cross-sectional annual regressions for the period 1983–1999, and the statistical significance of the coefficient is based on the associated intertemporal *t*-statistics. Panel B shows that the relation between change of patent citation impact and future earnings, and its cross-industry variation are identical to those obtained from the pooled regression. For example, the mean coefficient estimate of ΔPCI is 0.103 (t-statistic $= 3.07$), compared with 0.111 from the pooled regression. Thus, results from the cross-sectional regression corroborate the positive relation between change of patent citation impact and future realized earnings, and how this relation varies inversely with the length of innovation cycles in different industries.

The results thus far are consistent with a significantly positive relation between change of patent citation impact and realized earnings of the next year. To extend and complement this evidence, the model of eq. (1) is estimated, using earnings of year $t + 2$ to year $t + 5$ in place of earnings of year $t + 1$. This test provides evidence on whether the relation between strengthened innovation capabilities and realized earnings varies with time, an attribute useful for understanding the persistence of this relation.

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18. The insignificant result for the biotech and drug industry seems inconsistent with the evidence of Lev and Sougiannis (1996) (LS hereafter). LS find that investment in R&D contributes to future earnings for up to five years in most industries, including chemicals and pharmaceuticals (SIC 28). There are, however, a number of differences in the research design of the two studies. First, LS focus on R&D expenditures, an input measure of firms' investment in innovation, whereas this study examines patent citation impact, which measures the outcome of innovation. As explained in section 3, patent citation impact is fundamentally different from input measures of innovation, such as R&D expenditures. Thus, significant differences likely exist in the information content of these two measures, even though they are both intended to capture the contribution of innovation to future earnings. Consistent with this, Table 3, panel B, shows that the correlation between patent citation impact and R&D expenditures is far less than perfect (0.364 and 0.539 for the Pearson and Spearman correlations, respectively). It is also possible that both R&D expenditures and patent citation impact are noisy measures for the value-enhancing effect of innovation, and they likely contain uncorrelated measurement errors. Second, the earnings measure examined in the LS study is operating income before R&D and other expenses (e.g., advertising), whereas the earnings measure used in this study is net income before extraordinary items. Third, while LS investigate the contribution of R&D expenditures to future earnings after controlling for the effect of other assets employed by the firm (e.g., physical assets), this study examines the incremental contribution of strengthened patent citation impact to future earnings after controlling for earnings persistence. Notwithstanding these significant differences, the cross-industry pattern of the results in the two studies is similar. The evidence of LS (Table 3) indicates that the initial impact of R&D spending on future earnings is considerably smaller in the chemical and drug industries than in other industries. They find that the cumulative percentage impact from year t to year $t + 2$ is 37.3% for chemicals and pharmaceuticals, compared with 46.6% for computers, 48.6% for electronics, 58.2% for instruments and 49.1% for others.

The results of this test are reported in Table 5, including coefficient estimates from the pooled regression with dummy variables for year-specific effects (panel A) and cross-sectional regression (panel B). The data requirement for earnings of the subsequent five years reduces the sample size to 8299 firm-year observations. Panel A shows that the coefficient of current-year earnings (NI_{it}) is consistently positive and follows a roughly V-shaped pattern, ranging from 0.579 in the regression of earnings for year $t + 2$ to 0.703 for year $t + 4$. The coefficient of ΔPCI, however, continues to increase as the forecasting horizon extends out, starting from 0.107 in the regression of earnings for year $t + 1$ and reaching 0.258 for year $t + 5$, an increase of 141% over five years. To assess whether the increase in the coefficient of ΔPCI is statistically significant, a time regression is estimated in which the dependent variable is the value of ΔPCI, and the independent variable is *Year*, which takes values of 1 to 5. The results of this regression are reported at the end of panel A. The coefficient of *Year* is positive (0.033) and statistically significant at the 0.01 level (t-statistic = 5.78). As a comparison, a similar regression is estimated for the coefficient of current-year earnings (NI_t). The coefficient of *Year* in this regression, however, is not statistically significant at the conventional level.

Table 5, panel B, reports coefficient estimates and other statistics based on the cross-sectional regression. The estimation procedure is identical to that used for the regressions of Table 4, panel B. The results are very similar to those obtained from the pooled regression, showing a significant increase in the coefficient of ΔPCI over time: 0.097 for year $t + 1$ versus 0.249 for year $t + 5$. Thus, the evidence of this test indicates that the contribution of strengthened innovation capabilities to future profitability does not diminish over time. In contrast, change of patent citation impact tends to have a greater impact on earnings of longer term. This evidence supports hypothesis 3 and is consistent with the view that firms' long-term prospects are driven primarily by unique and competitive intangible assets, such as innovation capabilities with far-reaching influences.[19]

In sum, the results of this section demonstrate a strong positive relation between change of patent citation impact and firms' future realized earnings. This evidence suggests that change of patent citation impact contains new information about firms' innovation capabilities, which are a potent driver of future profitability. This relation is more significant in industries with shorter innovation cycles than in those with longer time lags between technological advances and profit realization. The relation between change of patent citation impact and future realized

19. The cross-sectional difference in the strength of the relation between patent citation impact and earnings of year $t + 5$ is similar to that reported in Table 4, in that the relation is statistically insignificant for biotech and pharmaceutical firms. Biotech and pharmaceutical firms generally face long innovation cycles (12 to 15 years), and patents in this industry are typically applied for at an early stage of product development (e.g., the first year or two). Given that the time lag between observed patent citation impact and commercialization of products backed by the cited patent is substantially greater than five years, the effect of strengthened patent citation impact will not likely be reflected in earnings of year $t + 5$.

TABLE 5

Summary Statistics of Regression of Future Earnings on Current Earnings and Change of Patent Citation Impact

Panel A: Results based on pooled regression

$$NI_{it+j} = \alpha_0 + \alpha_1 NI_{it} + \alpha_2 \Delta PCI_{it} + \sum \beta_Y YR_{Yit} + v_{it+1}, j = 1, \ldots 5$$

Variables	Year $t + 1$	Year $t + 2$	Year $t + 3$	Year $t + 4$	Year $t + 5$
NI_t	0.624	0.579	0.597	0.703	0.663
	(67.64)	(36.47)	(32.25)	(30.76)	(20.92)
ΔPCI_t	0.107	0.161	0.174	0.189	0.258
	(5.67)	(5.18)	(5.22)	(4.43)	(4.30)
# Obs	8,299	8,299	8,299	8,299	8,299
Adj. R^2	39.9%	17.1%	14.7%	13.7%	7.9%

Estimates of the time regression (*t*-statistics in parentheses):

$$\Delta PCI_t = \underset{(4.16)}{0.079} + \underset{(5.78)}{0.033} \times Year_t + e_t, Year = 1\text{–}5, \text{Adj. } R^2 = 89.0\%$$

$$NI_t = \underset{(12.20)}{0.573} + \underset{(1.43)}{0.020} \times Year_t + v_t, Year = 1\text{–}5, \text{Adj. } R^2 = 20.6\%$$

Panel B: Results based on cross-sectional regression

$$NI_{it+j} = \alpha_0 + \alpha_1 NI_{it} + \alpha_2 \Delta PCI_{it} + v_{it+1}, j = 1, \ldots 5$$

Variables	Year $t + 1$	Year $t + 2$	Year $t + 3$	Year $t + 4$	Year $t + 5$
Intercept	0.028	0.030	0.034	0.032	0.047
	(8.86)	(5.66)	(4.06)	(4.18)	(4.73)
NI_t	0.600	0.567	0.590	0.706	0.655
	(19.19)	(13.82)	(13.47)	(13.39)	(14.12)
ΔPCI_t	0.097	0.170	0.175	0.147	0.249
	(2.07)	(2.15)	(2.61)	(2.14)	(2.25)
# Obs	8,299	8,299	8,299	8,299	8,299
Adj. R^2	39.8%	21.5%	18.0%	17.1%	12.3%

Estimates of the time regression (*t*-statistics in parentheses):

$$\Delta PCI_t = \underset{(2.12)}{0.083} + \underset{(2.38)}{0.028} \times Year_t + e_t, Year = 1\text{–}5, \text{Adj. } R^2 = 53.7\%$$

$$NI_t = \underset{(11.27)}{0.549} + \underset{(1.70)}{0.025} \times Year_t + v_t, Year = 1\text{–}5, \text{Adj. } R^2 = 31.9\%$$

Variable definitions are as follows. NI_t (NI_{t+j}) is earnings of year t ($t + j, j = 1, 2, \ldots 5$) deflated by average total assets of year t. ΔPCI_t is the change of patent citation impact in year t deflated by average total assets of year t. YR_{Yit} is a series of dummy variables measuring year-specific effects. The regressions include 8299 firm-years for 1983–1999. The t-statistics are in parentheses.

earnings seems to increase with time, consistent with this measure capturing the value-driver of long-term profitability, namely, firms' innovation capabilities. The strong association between patent citation impact and future earnings naturally raises questions of whether market participants fully understand the implications of this measure for future earnings, which is examined in the next section.

5.2 Market Pricing of the Implications of Patent Citation Impact for Future Earnings

This section examines whether investors and sophisticated analysts fully incorporate the implications of patent citation impact for future earnings when setting stock prices and generating earnings forecasts. The test of investors' pricing decisions employs the framework developed by Mishkin (1983). This framework was first introduced into the accounting literature by Sloan (1996), and has since been used in a number of studies examining market pricing efficiency of earnings components (e.g., Xie [2001]) and non–GAAP information such as order backlog (Rajgopal, Shevlin, and Venkatachalam [2003]). This study extends Sloan's test to incorporate the implications of change of patent citation impact for future earnings. Following Sloan, the following system is estimated to assess whether the market rationally prices the implications of change of patent citation impact for future earnings:

$$NI_{it+1} = \alpha_0 + \alpha_1 NI_{it} + \alpha_2 \Delta PCI_{it} + v_{it+1}, \qquad (2)$$

$$ARET_{it+1} = \beta_0 + \beta_1(EARN_{it+1} - \alpha_0 - \gamma_1 EARN_{it} - \gamma_2 \Delta PCI_{it}) + \varepsilon_{it+1}, \qquad (3)$$

where i and t are firm and year subscripts, respectively; NI_t (NI_{t+1}) is earnings of year t ($t + 1$) deflated by average total assets, ΔPCI_t is the change of patent citation impact in year t deflated by average total assets, and $ARET_{t+1}$ is abnormal (market-adjusted) stock returns of year $t + 1$.

As before, eq. (2) relates current earnings performance and change of patent citation impact to future earnings performance, and is referred to in this test as the *forecasting* equation. The relation in eq. (3) is based on the assumption that the market reacts only to unexpected earnings, conditioned on earnings of the prior year. It estimates market expectations of earnings persistence and the contribution of ΔPCI to future earnings as embedded in firms' stock prices. This is referred to as the *valuation* equation. The coefficient α_2 represents the actual incremental contribution of increased patent citation impact to future earnings, and γ_2 captures investors' assessment of this incremental contribution as reflected in stock prices. Hypothesis 4 predicts $\alpha_2 > \gamma_2$ ($\alpha_2 < \gamma_2$) if investors underestimate (overestimate) the contribution of enhanced innovation capabilities to future earnings.

Following Mishkin (1983) and Sloan (1996), eqs. (2) and (3) are jointly estimated, using an iterative generalized nonlinear least-squares procedure. Market efficiency with respect to the pricing of earnings persistence and the patent citation impact measure is tested, using a likelihood ratio statistic based on the sum of squared residuals (*SSR*) from the constrained and unconstrained systems:

$$2n \log (SSR^c/SSR^u)$$

where

n = the number of observations
SSR^c = the sum of squared residuals from the constrained weighted system
SSR^u = the sum of squared residuals from the unconstrained weighted system.

Mishkin (1983) shows that this statistic is distributed asymptotically: $\chi^2(q)$, where q is the number of constraints imposed by market efficiency.

Table 6 reports the results from the joint estimation of eqs. (2) and (3) based on the Mishkin approach. A total of 8,922 firm-year observations are included in this test. Panel A presents the regression estimates from a benchmark estimation that excludes change of patent citation impact. It shows that the coefficient of earnings in the forecasting equation (α_1) is 0.641, whereas the coefficient on earnings in the valuation equation (γ_1) is 0.638. The likelihood ratio statistic for the test of $\alpha_1 = \gamma_1$ is 0.024, and does not reject the null hypothesis of market efficiency with respect to the pricing of earnings persistence. Thus, the coefficient of earnings in the valuation equation is the same as its counterpart in the forecasting equation, indicating that investors price firms' earnings in a manner fully consistent with the rational expectations model. This evidence is consistent with the findings of prior studies that, on average, there is no bias in market pricing of earnings persistence (e.g., Sloan [1996]; Xie [2001]).

Panel B presents the results of the Mishkin test that incorporates the implications of change of patent citation impact (ΔPCI) for future earnings. The coefficient estimates of earnings (α_1 and γ_1) remain relatively unchanged in both forecasting and valuation equations, showing no signs of market inefficiency in the pricing of earnings persistence. Whereas the coefficient of ΔPCI (α_2) is positive (0.113) and statistically significant (t-statistic = 4.87) in the forecasting equation, its counterpart in the valuation equation (γ_2) is negative (-0.053) and statistically insignificant at the conventional level (t-statistic = -0.52). The likelihood ratio statistics for the test of $\alpha_2 = \gamma_2$ is 7.114, rejecting the null hypothesis of market efficiency (marginal significance level = 0.008). This difference is consistent with the prediction of hypothesis 4 and indicates that investors seem to ignore the information on patent citation impact when in fact change of patent citation impact is significantly associated with firms' realized future earnings. Stated differently, this result is consistent with the stock market placing a significantly lower weight on patent citation impact relative to the weight reflected in the association between patent citation impact and firms' realized future earnings.[20]

20. This result that the weight on patent citation impact is essentially zero, however, does not imply that patent citation impact is not priced by the stock market at all. By its design, the test reported in Table 6 does not examine whether information on patent citation impact is reflected in firm value,

TABLE 6

Nonlinear Generalized Least Squares Estimation of the Market Pricing of Change of Patent Citation Impact

$$NI_{it+1} = \alpha_0 + \alpha_1 NI_{it} + \alpha_2 \Delta PCI_{it} + v_{it+1} \quad \text{(2) (forecasting equation)}$$
$$ARET_{it+1} = \beta_0 + \beta_1(NI_{it+1} - \gamma_0 - \gamma_1 NI_{it} - \gamma_2 \Delta PCI_{it}) + \varepsilon_{it+1} \quad \text{(3) (valuation equation)}$$

Panel A: Regression with earnings (NI_t) only

Parameter	Pred. Sign	Estimate	Asymptotic Standard Error	t-statistic
α_0	+/−	0.024	0.001	21.37
α_1	+	0.641	0.010	64.02
γ_1	+	0.638	0.044	14.46
β_0	+/−	−0.003	0.005	−0.61
β_1	+	1.017	0.047	21.43
Test of market efficiency		$\alpha_1 = \gamma_1$		
Likelihood ratio statistic		0.024		
Marginal significance level		0.877		

Panel B: Regression with earnings (NI_t) and change of patent citation impact (ΔPCI_t)

Parameter	Pred. Sign	Estimate	Asymptotic Standard Error	t-statistic
α_0	+/−	0.024	0.001	21.42
α_1	+	0.638	0.010	63.74
γ_1	+	0.639	0.044	14.45
α_2	+	0.113	0.023	4.87
γ_2	+	−0.053	0.102	−0.52
β_0	+/−	−0.003	0.005	−0.59
β_1	+	1.015	0.048	21.38
Test of market efficiency		$\alpha_1 = \gamma_1$	$\alpha_2 = \gamma_2$	
Likelihood ratio statistic		0.011	7.114	
Marginal significance level		0.916	0.008	

$$NI_{it+1} = \alpha_0 + \alpha_1 ACC_{it} + \alpha_2 CFO_{it} + \alpha_3 \Delta PCI_{it} + v_{it+1} \quad \text{(2a)}$$
$$ARET_{it+1} = \beta_0 + \beta_1(NI_{it+1} - \gamma_0 - \gamma_1 ACC_{it} - \gamma_2 CFO_{it} - \gamma_3 \Delta PCI_{it}) + \varepsilon_{it+1} \quad \text{(3a)}$$

Panel C: Regression with accruals (ACC_t), cash flows from operating activities (CFO_t) and change of patent citation impact (ΔPCI_t)

Parameter	Pred. Sign	Estimate	Asymptotic Standard Error	t-statistic
α_0	+/−	0.027	0.002	16.09
α_1	+	0.507	0.011	46.11
γ_1	+	0.734	0.049	14.98
α_2	+	0.723	0.009	80.34
γ_2	+	0.531	0.043	12.36
α_3	+	0.108	0.024	4.51
γ_3	+	−0.031	0.105	−0.30
β_0	+/−	0.021	0.008	2.61
β_1	+	1.031	0.048	21.71

TABLE 6 (*continued*)

Parameter	Pred. Sign	Estimate	Asymptotic Standard Error	*t*-statistic
Test of market efficiency		$\alpha_1 = \gamma_1$	$\alpha_2 = \gamma_2$	$\alpha_3 = \gamma_3$
Likelihood ratio statistic		12.349	11.778	6.879
Marginal significance level		0.001	0.001	0.009

Variable definitions are as follows. NI_t (NI_{t+1}) is earnings of year t ($t + 1$) deflated by average total assets of year t. ACC_t is total accruals in year t deflated by average total assets of year t. CFO_t is cash flows from operating activities in year t deflated by average total assets of year t. ΔPCI_t is the change of patent citation impact in year t deflated by average total assets of year t. $ARET_{t+1}$ is abnormal (market-adjusted) stock returns of year $t + 1$. The system of eqs. (2) and (3) is jointly estimated using an iterative generalized nonlinear least squares estimation procedure. The regressions include 8922 firm-years for 1983–1999.

To provide a robustness check, the Mishkin test is performed after decomposing earnings into accruals (*ACC*) and cash flows from operating activities (*CFO*). Sloan (1996) and subsequent studies (e.g., Xie [2001]) find evidence of overpricing (underpricing) of accruals (cash flows from operating activities) by investors. Therefore, it is necessary to assess whether the mispricing of patent citation information is sensitive to this anomaly. Panel C reports the results of this sensitivity test. The definitions of accruals and cash flows from operating activities follow Sloan (1996).[21] Consistent with Sloan and subsequent studies, the results indicate that investors appear to overestimate (underestimate) the contribution of accruals (cash flows from operating activities) to future earnings when determining stock prices. However, the magnitude of mispricing for change of patent citation impact (*ΔPCI*) is very similar after controlling for this anomaly.

or the value-relevance of patent citation impact; instead, it examines whether investors fully incorporate the implications of patent citation impact for future earnings when pricing the shares of patent-rich companies. The value-relevance of patent citation is the focus of several prior studies (e.g., Hall et al. [2000]; Gu and Lev [2002]). These studies find a significantly positive relation between patent citation measures and metrics of *contemporaneous* firm value, consistent with the value-relevance of patent citation impact. Market inefficiency in pricing the earnings implication of patent citation impact implies correction of stock prices in the future, when investors learn about the association between patent citation and future realized earnings. Thus, like Deng et al. (1999), this study also examines whether information on patent citation impact is useful for predicting *future* abnormal returns (section 5.3). The predicted pattern of market behavior—prior inefficiency followed by subsequent correction of stock prices, and hence future abnormal returns—is consistent with extant evidence on the inefficiency of current stock prices in reflecting the implications of reported financial measures (e.g., accruals [Sloan (1996)]) and non–GAAP leading indicators (e.g., order backlog [Rajgopal, Shevlin and Venkatachalam (2003)]) for the firm's future performance.

21. Recent studies measure accruals using information on cash flows from operating activities reported under *Statement of Financial Accounting Standards* no. 95 (SFAS 95) (e.g., Bradshaw et al. [2001]; Rajgopal, Shevlin, and Venkatachalam [2003]). Because SFAS 95 was adopted after 1987, using accruals calculated from cash flows information reported under SFAS 95 would significantly reduce the sample size of this study. Nonetheless, an additional sensitivity test using the accrual measure based on SFAS 95 yields very similar results.

Having documented evidence of market inefficiency in investors' assessment of the contribution of increased patent citation impact to future earnings, this study now turns to examine whether sophisticated analysts fully incorporate the implications of patent citation impact for future earnings into their earnings forecasts. This test is based on the following model of analysts' forecast error:

$$AFE_{it+1} = \alpha_0 + \alpha_1 \Delta PCI_{it} + \alpha_2 STDE_{it} + \alpha_3 LOSS_{it} + \alpha_4 \Delta EARN_{it} + \alpha_5 RD_{it} + \alpha_6 Ln(MV)_{it} + \alpha_7 FLLW_{it} + e_{it}, \quad (4)$$

where AFE_{t+1} is the analysts' forecast error of year $t + 1$, measured as the signed difference between actual future earnings per share of year $t + 1$ and median analysts' forecast of earnings per share for that year, issued six months after the end of fiscal year *t*. *AFE* is deflated by stock price as of one month before the release of analysts' earnings forecasts. To ensure consistency, measures of earnings per share (EPS) are based on actual earnings per share provided by I/B/E/S. The main variable of interest in eq. (4) is ΔPCI_t, change of patent citation impact in year *t* deflated by a firm's market value as of one month before the release of analysts' forecasts. Hypothesis 4 predicts a positive coefficient for this variable $(\alpha_1 > 0)$ if analysts systematically underestimate the contribution of increases in innovation capabilities to a firm's future earnings.

Control variables in eq. (4) include firm characteristics that prior literature suggests are associated with analysts' forecast error. Prior research found that analysts' forecasts are more optimistically biased for firms with more uncertain earnings (Lim [2001]). To control for this effect, eq. (4) includes the standard deviation of return on equity averaged over the prior five years (*STDE*). Hwang et al. (1996) and Brown (2001) found that analysts' forecast errors are greater for loss-reporting firms than for profitable firms. Accordingly, eq. (4) includes a dummy variable that equals 1 for firms reporting negative net income before extraordinary items and 0 otherwise (*LOSS*). Prior studies also found that analysts tend to underreact to information on recent earnings (Abarbanell and Bernard [1992]; Elgers and Lo [1994]). To control for this bias, eq. (4) includes change in earnings per share deflated by stock price ($\Delta EARN$). Amir et al. (2003) found that analysts' forecast errors are greater for firms with higher R&D expenditures, due to increased uncertainty associated with R&D activities and the lack of useful information about R&D firms. Thus, eq. (4) includes R&D expenditures deflated by market value (*RD*) as a control variable.

Also included in eq. (4) as control variables are firm size, measured by the logarithm of the firm's market value (*Ln(MV)*) one month before the release of analysts' earnings forecasts, and analyst following (*FLLW*), measured as the logarithm of the number of analysts issuing forecasts used in calculating the median forecast. It is expected that analysts' forecast errors are smaller for larger firms because larger firms tend to make more information available to analysts (Lang and Lundholm [1996]). Analyst following is also likely to be negatively related to

TABLE 7

Summary Statistics of Cross-Sectional Regression of Analysts' Forecast Error on Change of Patent Citation Impact and Control Variables

$$AFE_{it+1} = a_0 + a_1\Delta PCI_{it} + a_2STDE_{it} + a_3LOSS_{it} + a_4\Delta EARN_{it} + a_5RD_{it} + a_6LN(MV)_{it} + a_7FLLW_{it} + e_{it} \quad (4)$$

Variable	Pred. Sign	Mean Coefficient	*t*-statistic
Intercept	+/−	−0.019	−6.06
ΔPCI	+	0.095	2.24
STDE	−	−0.004	−1.36
LOSS	−	−0.039	−5.57
ΔEARN	+	0.341	7.57
RD	−	−0.074	−2.95
LN(MV)	+	0.001	2.02
FLLW	+	0.003	2.33
# Obs		6,524	
Adj. R^2		34.6%	

Variable definitions are as follows. AFE_{it+1} is analysts' forecast error of year $t + 1$ for firm *i*, equal to the signed difference between actual future earnings per share of year $t + 1$ and median analysts' forecast of earnings per share for that year, issued six months after the end of fiscal year *t*. It is deflated by stock price as of one month before the release of analysts' earnings forecasts. ΔPCI_t is the change of patent citation impact in year *t* deflated by market value as of one month before the release of analysts' earnings forecasts. *STDE* is the standard deviation of return on equity averaged over the prior eight years. *LOSS* is a dummy variable that equals 1 for firms reporting negative net income before extraordinary items and 0 otherwise. *ΔEARN* is change in earnings per share deflated by stock price. *RD* is reported R&D expenditures deflated by market value as of one month before the release of analysts' earnings forecasts. *LN(MV)* is logarithm of the firm's market value one month before the release of analysts' earnings forecasts. *FLLW* is analyst following, measured as the logarithm of the number of analysts issuing forecasts used in calculating median forecast. The regression includes 6524 firm-years for 1983–1999.

forecast error. Greater analyst following may induce competition among analysts to issue less biased forecasts because analysts' reputations are likely affected by the bias of their forecasts.

Table 7 reports the mean coefficient estimates and other statistics from the cross-sectional regression of eq. (4). The model is estimated separately for each sample year, and coefficient estimates and *t*-statistics are based on the 17 annual cross-sectional regressions for the period 1983–1999. Coefficient estimates of the control variables are generally consistent with prior research and expectations. The average adjusted R^2 of the regression is 34.6%, indicating that this model explains a relatively good portion of the variation in analysts' forecast error. Turning to the main result of this test, Table 7 shows that the coefficient of *ΔPCI* is positive (0.095) and statistically significant at the 0.05 level (*t*-statistic = 2.24). This evidence is consistent with the prediction of hypothesis 4 and suggests that sophisticated analysts significantly underestimate the contribution of increases in firms' innovation capabilities to future realized earnings. This bias parallels the result of the Mishkin (1983) test that documents market underpricing of the implications of patent citation impact for future earnings.

In summary, the results of this section demonstrate that investors' expectations of future earnings, as reflected in stock prices and analysts' earnings forecasts, do not fully incorporate the implications of patent citation impact for firms' future earnings. The evidence is consistent with the prediction of hypothesis 4 that investors and analysts underreact to information on firms' innovation capabilities.

5.3 Future Stock Returns Associated with Change of Patent Citation Impact

The results thus far indicate that, despite the usefulness of patent citation impact in predicting future earnings, market participants do not fully incorporate the implications of patent citation impact for future earnings into stock prices and earnings forecasts. To further corroborate this evidence of market inefficiency, this section investigates the ability of change of patent citation impact to predict future abnormal returns. Predictable abnormal returns may result from the correction of prior mispricing when investors subsequently learn about the actual association between strengthened patent citation impact and realized earnings. This test controls for risk factors identified by Fama and French (1992), the accrual anomaly (Sloan [1996]), and R&D expenditures (Lev and Sougiannis [1996]; Chan et al. [2000]). Specifically, the regression model employed for this test is as follows:

$$\begin{aligned} RET_{it+1} = {} & b_0 + b_1\, \Delta PCI_{it} + b_2\, BETA_{it} + b_3\, Ln(MV)_{it} + b_4\, Ln(B/M)_{it} \\ & + b_5\, Ln(LEV)_{it} + b_6\, E(+)/P_{it} + b_7\, E(-)/P_{it} + b_8\, RD_{it} \\ & + b_9\, ACC_{it} + \omega_{it}, \end{aligned} \tag{5}$$

where RET_{it+1} is the monthly stock returns of firm i, starting from the fourth month after the end of fiscal year t; ΔPCI_{it} is the quartile rank of change of patent citation impact (deflated by average total assets); $BETA_{it}$ is the Capital Asset Pricing Model (CAPM) beta, estimated using monthly stock returns over the preceding 60 months; $Ln(MV)_{it}$ is the logarithm of market value at the end of fiscal year t; $Ln(B/M)_{it}$ is the logarithm of book-to-market ratio at the end of fiscal year t; $Ln(LEV)_{it}$ is the logarithm of financial leverage, calculated as the ratio of the book value of total assets to the book value of total equity; $E(+)/P_{it}$ is earnings before extraordinary items, deflated by market value, for firms with positive earnings and 0 otherwise; $E(-)/P_{it}$ is a dummy variable equal to 1 for firms with negative earnings and 0 otherwise; RD_{it} is R&D expenditures, deflated by market value; and ACC_{it} is accruals deflated by average total assets.[22] A positive coefficient of ΔPCI_{it} is expected

22. Similar to the test reported in Table 6, panel C, the definition of accruals (*ACC*) follows Sloan (1996).

TABLE 8

Summary Statistics of Monthly Regression of Future Returns on Change of Patent Citation Impact and Control Variables

$$RET_{it+1} = b_0 + b_1\ \Delta PCI_{it} + b_2\ BETA_{it} + b_3\ Ln(MV)_{it} + b_4\ Ln(B/M)_{it} + b_5\ Ln(LEV)_{it} + b_6\ E(+)/P_{it} + b_7\ E(-)/P_{it} + b_8\ RD_{it} + b_9\ ACC_{it} + \omega_{it} \quad (5)$$

Variables	Pred. Sign	Year $t + 1$	Year $t + 2$	Year $t + 3$
Intercept	+/−	0.013	0.014	0.011
		(2.68)	(2.86)	(2.17)
ΔPCI	+	0.0007	0.001	0.001
		(2.28)	(2.72)	(2.15)
BETA	+	−0.023	−0.017	−0.013
		(−0.84)	(−0.26)	(−0.24)
Ln(MV)	−	−0.001	−0.001	−0.001
		(−2.07)	(−1.85)	(−1.84)
Ln(B/M)	+	0.002	0.003	0.004
		(1.93)	(2.04)	(2.80)
Ln(LEV)	+	−0.002	−0.001	−0.002
		(−0.32)	(−0.77)	(−0.97)
E(+)/P	+	0.010	0.006	0.021
		(0.66)	(0.39)	(1.17)
E(−)/P	−	−0.007	−0.003	−0.002
		(−3.04)	(−1.37)	(−0.66)
RD	+	0.024	0.025	0.021
		(1.89)	(1.49)	(1.14)
ACC	−	−0.024	−0.005	0.006
		(−3.64)	(−0.87)	(0.78)
Average Adj. R^2		4.99%	4.26%	4.37%

Variable definitions are as follows. RET_{it+1} is monthly stock returns of firm i, starting from the fourth month after end of fiscal year t. ΔPCI_{it} is the quartile rank of change of patent citation impact deflated by average total assets. *BETA* is the Capital Asset Pricing Model (CAPM) beta, estimated using monthly stock returns over the preceding 60 months. *Ln(MV)* is logarithm of market value at end of fiscal year t. *Ln(B/M)* is logarithm of book-to-market ratio at end of fiscal year t. *Ln(LEV)* is logarithm of financial leverage, calculated as the ratio of the book value of total assets to the book value of total equity. *E(+)/P* is earnings before extraordinary items, deflated by market value for firms with positive earnings and 0 otherwise. *E(−)/P* is a dummy variable equal to 1 for firms with negative earnings and 0 otherwise. *RD* is R&D expenditures deflated by market value. *ACC* is accruals deflated by average total assets. The t-statistics are in parentheses.

($b_1 > 0$) if the initial mispricing is corrected when investors subsequently learn about the actual association between change of patent citation impact and realized earnings.

Following Fama and MacBeth (1973), eq. (5) is estimated cross-sectionally, using monthly stock returns for the period 1983–1999. Table 8 reports the mean coefficient estimates and t-statistics of eq. (5). The results are based on a total of 204 cross-sectional regressions (17 years $\times$ 12 regressions per year). Table 8 shows that for the returns of year $t + 1$, the coefficient of ΔPCI_{it} is positive (0.0007) and statistically significant at the conventional level (t-statistic = 2.28). Results for the control variables are generally consistent with prior studies. For example, the coefficient of R&D expenditures (*RD*) is significantly positive, and the coefficient of accruals (*ACC*) is significantly negative. Thus, the evidence indicates a positive relation between change of patent citation impact and future stock returns after controlling for other firm characteristics that are predictive of future stock returns.

Results for returns of years $t + 2$ and $t + 3$ also show a significantly positive coefficient of ΔPCI_{it}. Thus, evidence based on this test of future stock returns seems to corroborate the findings from the Mishkin test and the analyst forecast test. While earlier tests showed that market participants do not fully incorporate the implications of patent citation impact for future realized earnings into stock prices and earnings forecasts, this test finds that future abnormal returns are significantly associated with the change of patent citation impact. This association, while statistically significant, does not imply that economically meaningful abnormal returns can be earned by a trading strategy that exploits the documented mispricing of patent citation impact. The relatively modest magnitude of the abnormal returns (compared with returns associated with R&D expenditures and accruals) suggests that this trading strategy may not be economically viable when taking into account transaction costs and a potentially large amount of arbitrage risk in the extreme portfolios (Mashruwala et al. [2004]).

6. Summary and Conclusion

Recent studies document the value-relevance of nonfinancial leading indicators. There is, however, relatively sparse evidence on the association between nonfinancial leading indicators and firms' future earnings and market efficiency in the valuation of this association. These issues are important for interpreting the value-relevance result of nonfinancial leading indicators. This study examines whether patent citation impact, a nonfinancial leading indicator relevant for innovation-intensive firms, is significantly associated with firms' future earnings and whether investors and analysts fully appreciate this association when determining stock prices and generating earnings forecasts of patent-rich companies.

The results demonstrate that there is a positive association between change of patent citation impact and future realized earnings, more so in industries with relatively short time lags between innovation breakthroughs and profit realization (e.g., computers, electronics, and medical equipment) than in industries with long innovation cycles (e.g., biotech and pharmaceuticals). This evidence suggests that change of patent citation impact contains useful information about firms' innovation capabilities, which are a potent driver of future profitability. The results of this study also show that the association between change of patent citation impact and future earnings significantly increases with time, consistent with the role of innovation capabilities as drivers of firms' long-term profitability. However, investors and sophisticated analysts do not fully incorporate the implication of change of patent citation impact for future earnings into stock prices and earnings forecasts. Consistent with this inefficiency, change of patent citation impact is significantly associated with future abnormal stock returns, indicating subsequent correction of the mispricing.

This study has the following implications for the disclosure of nonfinancial leading indicators. The documented link between patent citation impact and future earnings, coupled with market inefficiency in the assessment of this link, suggests the need for enhanced disclosures about firms' innovation capabilities. This is consistent with the view of academics and practitioners that greater disclosure of nonfinancial information can significantly improve the information environment of innovation-intensive firms (e.g., AICPA [1994]; Eccles et al. [2001]; FASB [2001]; SEC [2001]; Lev [2001]; Upton [2001]; AAA [2002]). Examples of such disclosures may include information on the utilization rate of newly innovated technologies and share of revenues backed by new innovation.

An important consideration in this recommendation is the comparability of nonfinancial information. It is generally agreed that comparability is a key criterion for evaluating the decision-usefulness of information and should be applied to both financial and nonfinancial performance measures. The results of this study show that the association between patent citation impact and future earnings—an attribute that gives rise to the usefulness of this indicator—varies considerably with the time lag between innovation breakthroughs and profit realization in the firm's industry. This suggests that the usefulness of nonfinancial indicators, similar to their financial counterpart, is likely affected by the economics of the firm's operation, such as the length of the innovation cycle. Thus, context-specific considerations seem warranted when contemplating enhancement for the reporting standards of nonfinancial indicators. One approach might be for regulators to adopt provisions that encourage voluntary disclosure of nonfinancial performance measures, similar to the "safe harbor" rule that exempts firms from certain liabilities for disclosing forward-looking information. Although this may result in noncomparability in the type, format, and presentation of the disclosed information, it will likely increase comparability in the usefulness of the information by allowing firms to choose nonfinancial performance measures that best reflect the economics of their operation.

Last, the results of this study indicate that investors and sophisticated analysts do not fully incorporate the implication of patent citation impact for future earnings into stock prices and earnings forecasts. Given that patent information is publicly available, highly homogeneous, and relatively objective (i.e., free of managerial manipulation), it is unlikely that the availability, reliability, and accuracy of this information play a role in explaining the market inefficiency. A possible contributor to the market inefficiency is the technical complexity of patent information, which may increase the cost of information processing. Examination of this and other explanations for why investors and analysts fail to fully appreciate the implication of patent information for future profitability may be a fruitful avenue for future research.

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