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# Two essays on insider trading and option grants around the filing of influential patents

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# TWO ESSAYS ON INSIDER TRADING AND OPTION GRANTS AROUND THE FILING OF INFLUENTIAL PATENTS

by

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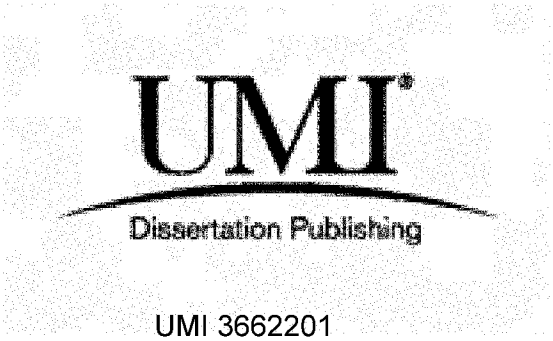





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We hereby recommend that the dissertation prepared under our supervision by Liu Pan

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be accepted in partial fulfillment of the requirements for the Degree of Doctor of Business Administration

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## ABSTRACT

Research documents that insiders, who have access to private information, appear to trade with profits before major corporate events like mergers, bankruptcy, dividend announcements, and future cash flow news (see, e.g., Seyhun, 1990; Seyhun and Bradley, 1997; John and Lang, 1991; Jiang and Zaman, 2010). Another recent stream of studies find that the size and quality of a firm's patent portfolio are positively related to the firm's future stock returns (Hirshleifer, Hsu, and Li, 2012; Pandit, Wasley, and Zach, 2011). However, there is little systematic evidence on whether insiders act opportunistically when they possess private information about the firm's patent portfolio.

In this dissertation, I empirically investigate insiders' trading and option grants throughout the different phases of an influential patent's application. An influential patent is defined as a patent with high citation impact. Chapter One focuses on insiders' open market transactions before the filing year of an influential patent, while Chapter Two centers on informed executive stock option (ESO) exercises and unscheduled option awards before two milestone dates of an influential patent: the application date and the grant date.

In Chapter One, I examine the pattern of insider trading before the filing year of an influential patent, for a sample of 2,470 firm-years from 1987 to 2006. In regressions of three insider trading measures controlling for factors related to insider trading, I find that the level of insiders' net purchases is consistently and significantly higher in the year

before filing an influential patent than in the application year. The abnormal higher level in net purchases is not from active insider trading – insiders increasing their purchases above normal levels, but from passive insider trading – insiders reducing their sales below normal levels in the year before filing an influential patent. In contrast, there is no such insider trading pattern for the industry-size matched firms. There is also no abnormal insider trading before the filing of an inconsequential patent.

Chapter Two studies whether executives' ESO exercises and options grants are related to superior information about the quality of a firm's patents, for a sample of 654 firm-events with an influential patent filed from 1996 to 2006. Using difference-in-differences (DID) regressions of two measures of option exercises, I find that executives significantly delay exercising their stock options by reducing option exercises in the year prior to the filing date of an influential patent and increasing option exercises in the year after that. In contrast, no such pattern of informed option exercises is found in the industry-size-performance matched control firms.

From the DID regression of the measure of option grants, I find no evidence of abnormal option grants around the application date of an influential patent. However, I find that executives receive more unscheduled stock options in the one-year period before the grant date of an influential patent than after that. In contrast, the matched control firms award fewer unscheduled stock options before a non-influential patent is granted than after that. My findings show that in addition to exercising options opportunistically, influencing the timing of unscheduled option grants is another channel through which insiders can pursue personal interests by exploiting the information advantages related to the quality of a patent. Moreover, I provide evidence that insiders possess private

information throughout the lengthy application process, from the filing to the grant of an influential patent.

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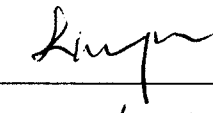
Author 

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# CHAPTER ONE

# INSIDER TRADING AROUND THE FILING OF INFLUENTIAL PATENTS

## Introduction

This study attempts to answer whether insiders can profit from their knowledge on firms' innovation outputs by empirically examining the insider trading before the filing of an influential patent measured by a high future citation count. A patent is one of the most important measures of a firm's innovation outputs (Griliches, 1990). In fact, several recent studies find that the size and quality of a firm's patent portfolio are positively related to the firm's future stock returns (Hirshleifer, Hsu, and Li, 2012; Pandit, Wasley, and Zach, 2011). Therefore, one might wonder whether insiders trade opportunistically when they possess private information about the firm's patents.

To answer the question, I investigate the insider trading before the filing of an influential patent for two reasons. First, I focus on the insiders' open market transactions in the year before an influential patent being filed, as the insiders' information advantages over the public may have been greater in the year before a patent being filed. A firm's innovation activities are highly uncertain. The year before a patent being filed is the time in which the future of an innovation is fully revealed to the insiders, as the firm is preparing the documents of the imminent patent application after an early stage of R&D (Ahuja, Coff, and Lee, 2005).

On average, it takes two years for a patent application to be granted (Hall, Jaffe, and Trajtenberg, 2001). Most firms prefer to keep the knowledge of innovation confidential until the patent is granted since the public disclosure of the patent application is not required (Ahuja, Coff, and Lee, 2005). Therefore, for several years starting from the year before the filing of a patent, only insiders have intimate knowledge of the pending patent application and of the potential economic impact of the patent. This private information provides a tempting opportunity to corporate insiders for personal gains by engaging in insider trading.

Secondly, I focus on influential patents since it is well known that the significance or value of each individual patent varies widely. A few patents with good quality are extremely valuable, while many others are worth comparatively little (Pakes and Schankerman, 1984) among a very large number of patents granted in U.S. – according to the US Patent and Trademark Office (USPTO), over 150,000 patents are granted every year (Hall, Jaffe, and Trajtenberg, 2001). Information about a firm's innovation is hard to be evaluated by outsiders since doing so requires knowledge of the expertise and of future changes in the development of a firm and/or its industry. Most outside investors would have difficulty in estimating the economic implications of an innovation, even when the patent is granted with detailed technical information available to the public. Before the filing of a patent, it would be almost impossible for outsiders to distinguish an influential patent from a less significant or incremental technological discovery and then correctly value the economic implications of a patent. Corporate insiders, who observe the developing process of an innovation from the very beginning and possess large amounts of private information, may have a stronger notion of a patent's ultimate

importance at the very beginning. Therefore, corporate insiders with private information may engage in profitable trading opportunistically since they are better at identifying an influential patent with higher future impact than outsiders before the patent is filed.

An influential patent is defined as a patent with high citation impact in this study. Trajtenberg (1990) argues that the number of citations received by a patent is a better measure of innovation quality than the number of patents a firm owns. When granted, a patent is required to cite all previous patents upon which this new technology builds. Accordingly, an influential patent can represent a platform on which future innovations will be based and is expected to receive more citations in the future. Several studies have shown that a patent's citations contain valuation-relevant information and may be used as an accurate measure of the value of a patent (see, e.g. Hall, Jaffe, and Trajtenberg, 2005; Gu, 2005; Matolcsy and Wyatt, 2008; McGahee, 2011; Pandit, Wasley, and Zach, 2011). Following these studies, I measure the impact of a patent using the total adjusted citations received by the patent. Specifically, I define an influential patent as one that is ranked in the top ten-percent most cited patents of the application year in its technology sub-category based on three-digit patent classes from the USPTO classification.

Using patent data compiled from patents filings to the USPTO by the National Bureau of Economic Research (NBER), I analyze insiders' open market transactions during the calendar year before ('informed' period) and the calendar year (control period) that a patent is filed for a sample of "influential patent" firms and two control samples. There are 2,470 firm-years, in which 3,538 influential patents were filed during the period 1987-2006. The two control samples are an industry-size matched sample in

which no influential patent was filed and a sample of "inconsequential patent" firms in which patents were ranked in the bottom ten-percent cited patents of the application year.

Before analyzing insider trading, I present two pieces of evidence that an influential patent is positively associated with the filing firm's future stock performances. First, I find that the market reacts more favorably when an influential patent is granted by USPTO than when an inconsequential patent is granted. The cumulative abnormal returns (CARs) of the filing firm when an influential patent is granted are largely positive and significantly higher than those of the filing firm when an inconsequential patent is granted. For example, the average CARs over days (-5, 5) around a patent grant date is 0.95% (significant) for an influential patent, and significantly higher than that for an inconsequential patent at -0.05% (insignificant). Secondly, I find that the sample firms with influential patents have better stock performances in three years after filing patents applications than firms in two control samples, as the post-application long-run abnormal returns (adjusted by the Fama-French three-factor model) for the sample firms of influential patents are significantly higher.

I next examine the open-market stock transactions of three groups of corporate insiders: all insiders, top management, and all insiders except for large blockholders. Following Agrawal and Nasser (2012), I investigate purchases, sales, and net purchases of insiders, using three measures of the level of insider trading.

In regressions of three insider trading measures controlling for factors related to insider trading, I find that the level of insiders' net purchases is consistently and significantly higher in the year before filing an influential patent than the application year. The abnormal higher level in net purchases is not from active insider trading,

insiders increasing their purchases above normal levels, but from passive insider trading, insiders reducing their sales below normal levels in the year before filing an influential patent. In contrast, there is no such insider trading pattern in the industry-size matched sample and no abnormal insider trading before the filing of an inconsequential patent. This pattern holds for each insider group. This pattern of passive trading by insiders the year before the filing of an influential patent is similar to the passive trading by target firms' insiders before takeover announcements as documented by Agrawal and Nasser (2012).

By examining the insider trading before the filing of an influential patent measured by high future citation impact, I add to the extensive research that has focused on insider trading activities prior to major corporate events like mergers, stock repurchases, seasoned equity offerings, earnings announcements, dividend announcements, and bankruptcy filings (see, e.g., Agrawal and Nasser, 2012; Raad and Wu, 1995; Karpoff and Lee, 1991; Sivakumar and Waymire, 1994; John and Lang, 1991; Seyhun and Bradley, 1997, respectively). Those studies provide evidences that insiders appear to trade profitably because of their access to private information that is not available to outside shareholders until the major events are publicly announced.

Despite the importance of patents that measure firms' innovation outputs to firms' future performance, there is little systematic evidence on whether insiders trade opportunistically when they possess private information on the firms' patent portfolio. Few studies find evidences that insiders gain by trading on their private information related to research and development (R&D), a measure of innovation input (Aboody and Lev, 2000; Coff and Lee, 2003 ). In a closely related paper, Ahuja, Coff, and Lee (2005)

examine insider trading related to patents and find that managers purchase stock well before breakthrough patents are filed. My study differs from Ahuja, Coff, and Lee (2005) and adds to the literature in three aspects. In the first place, this paper provides evidence based on larger and more comprehensive sample, twenty years of patent data from 1987-2006, as opposed to three years of patents from 1988-1990 in Ahuja, Coff, and Lee (2005). In the second place, I define an influential patent by the citation rank in its own technology sub-category, based on the USPTO classification to account for the varying citation patterns of patents from different technology classes. Lastly, Ahuja, Coff, and Lee (2005) only examine values of stock purchases by insiders and find evidence of active insider trading; we, however, use three measures of insider trading and investigate purchases, sales, and net purchases to provide systematic evidences of a pattern of passive trading by insiders during the year before the filing of an influential patent.

## Prior Studies on Insider Trading, Innovation, Patents, and Information Asymmetry

### *Do Insiders Gain Through Insider Trading?*

Corporate insiders are defined by the Security and Exchange Commission (SEC) as "officers, directors, or owners of more than ten percent of total common stock outstanding". Though most insiders' trading is routine, legal, and conducted for liquidity reasons, previous studies show that insiders have predictive ability to earn abnormal returns from trading in the securities of their firms (Jaffe, 1974; Seyhun, 1986; Rozeff and Zaman, 1988). Managers seem to have an informational advantage on major corporate events several months ahead of a public announcement. Extensive studies indicate that insiders appear to trade with profits before bankruptcy (Seyhun and Bradley,

1997), dividend announcements (John and Lang, 1991), stock repurchases (Lee, Mikkelson and Partch, 1992; Raad and Wu, 1995), seasoned equity offerings (Karpoff and Lee, 1991; Clarke, Dunbar, and Kahle, 2001), merger and takeover (Seyhun, 1990; Agrawal and Nasser, 2012), future cash flow news (Jiang and Zaman, 2010), accounting restatements (Agrawal and Cooper, 2008), and delayed goodwill impairments (Muller, Neamtiu, and Riedl, 2012).

The gains of insider trading stem from information asymmetries between investors and managers (Jensen and Meckling, 1976), in which managers have access to nonpublic information of important strategic events. Generally, investors may view insider purchases as a signal of good news and insider sales as a signal of bad news. Previous studies find that private information can be implied from stock purchases, but not from stock sales (see, e.g., Seyhun, 1986; Lakonishok and Lee, 2001; Jeng, Metrick, and Zeckhauser, 2003). Agrawal and Nasser (2012) find that target firms' insiders not only decrease their purchases before takeover announcements but that the insiders also reduce their sales even more, thus increasing their net purchases. Agrawal and Nasser (2012) define this pattern as "passive trading". Their findings suggest that insider sales further imply important corporate information, and they argue regulations for insider trading are not effective in regulating the insider gains from sales, not as easily recognized as insider gains from purchases.

### *Innovation as a Source of Information Asymmetry*

It is commonly recognized that technological innovation brings long-run economic benefits for firms (Griliches, 1984, 2000). However, information asymmetries are more severe in innovation-intensive firms. For example, Ciftci, Lev, and

Radhakrishnan (2011) find evidence that R&D-intensive firms which engage in basic research activities are likely to suffer from higher information asymmetry than firms that mimic and extend existing technologies. Generally, such innovation-intensive firms have a relatively large amount of intangible assets, utilize more resources for technology and innovation, and are more likely to have a fast changing technical environment. All these features make it hard for market participants to accurately value and estimate the firm's future prospects. Barth, Kasznik, and McNichols (2001) suggest that investor dependence on analysts' information is greater in R&D-intensive firms, while Gu (2005) and Ciftici (2012) find that market participants, including investors and analysts, do not fully value the implication of enhanced innovation capabilities and underestimate future earnings of R&D-intensive firms. Moreover, in innovation-intensive companies, normally the CEOs or top managers are engineers or experts in their field, which increases the difficulty for shareholders to monitor them since doing so requires the relevant technology knowledge. The less effective and less efficient monitoring mechanism for innovation-intensive firms, accordingly, provides the managers more opportunities to pursue their own interests. Insider trading could be a moderate channel for them through which to gain abnormal returns at the cost of outside investors.

Innovation, as an important source of information asymmetries and incentive of inside trading, has not been comprehensively investigated. Aboody and Lev (2000) point out that one potential source of insider gains through insider trading is research and development (R&D). They find that insider gains from insider trading in R&D-intensive firms are substantially larger than those in firms without R&D. Thus, R&D can be viewed as a major contributor to information asymmetry. Coff and Lee (2003) further

suggest that insider purchases have greater signaling value to investors in R&D firms and find evidence that insider purchases generate larger positive stock price reactions for R&D-intensive firms.

Patents, one of the most important indicators of innovative output, have been commonly used in the literature as a measure of firms' technological progress. Gu (2005), Pandit, Wasley, and Zach (2011), and Hirshleifer, Hsu, and Li (2013) show that firms with high-quality patents have better future operating/stock performances. Pandit, Wasley, and Zach (2011) measure a patent's quality by the patent's citations. Eisdorfer and Hsu (2011) report that technologically innovative firms are less likely to go bankrupt. Additionally, Hsu, Lee, Liu, and Zhang (2011) find that non-insider bondholders use the output of innovation, granted patents and associated citations, to evaluate the economic value of these innovations and to price the bonds of patent-owning firms accordingly. Therefore, patents seem to contain useful information in assessing the productivity of firms' innovation and understanding the relation between innovation and financial performances.

However, patents have received much less attention in existing research as a source of information asymmetry and an incentive of insider trading. Using three years of patent data (1988-1990), Ahuja, Coff, and Lee (2005) posit that managers may use foresight on firms' strategic assets to pursue private interests by engaging in insider trading and find that managers purchase stocks well before breakthrough patents are filed. Rong (2012) finds that effects of a firm's insider trading patterns are significant in explaining the unexpected fluctuations in patent output with control for the effect of

R&D expenditures. That finding supports the argument that management has private information about a firm's R&D productivity beyond what is known to outside investors.

## Sample Selection and Data Description

### *Sample of "Influential Patent" Firms*

Several databases are used to construct the sample, including the National Bureau of Economic Research (NBER) patent data, Thomson Financial Insiders Filings database (TFI), Compustat, and the Center for Research in Security Prices (CRSP). Patent-related data are from the updated NBER patent database originally developed by Hall, Jaffe, and Trajtenberg (2001) and revised as of August, 2010. The database includes detailed information on all patents granted by the US Patent and Trademark Office (USPTO) during the period 1976 – 2006. Patent citations, the key indicator of patent value, suffer from a truncation bias since citations are generally received for years after the patent is granted. The patents that were granted in early years would have more time to receive citations than those granted in more recent years. Thus, each patent's citation is adjusted by multiplying with the truncation weight index, which is from Hall, Jaffe, and Trajtenberg (2001) and also found in the NBER patent dataset. I use the application year as the relevant event time for the study of insider trading since a patent generally is applied for as soon as a firm has completed the innovation, while the grant date depends upon the review process at the Patent Office.

An initial patent data is constructed using all patents filed by firms during the period 1987-2006, [1] except those missing a unique assignee number, or missing a citation truncation weight as of 2006, or with the status 'M' (missing) or 'W' (withdrawn).

[1] My sample begins with patents applied for in 1987 because insider trading data in TFI Insider database starts from 1986 and I need one year of insider trading data before the application of a patent.

Specifically, I define influential patents as patents that are ranked in the top ten-percent most cited of the application year in its three-digit technology sub-category in the NBER database. The influential firm-year is the year when a firm applies for an influential patent. To avoid overlap, if a firm filed influential patents for multiple years, I only examine those years separated by at least a two-year gap in the tests. A firm may apply for multiple influential patents in a single year.

Panel A of Table 1 summarizes the sample selection procedures starting from the NBER patent data. During the period 1987-2006, there are total 11,955 firm-years, in which at least one patent filed is ranked in the top ten-percent most cited of the year in its technology sub-category in the NBER database, corresponding to 2,721 distinct firms. I drop 7,674 firm-years (168 firms) in which at least one influential patent was filed in each of any two consecutive years, and I drop 21 firm-years (four firms) in which all influential patents received zero adjusted citation before the end of year 2006.

This method results in 4,260 firm-years (2,549 firms) in which influential patents were filed. I then eliminate 1,478 firm-years (854 firms) which are not listed on CRSP and 23 firm-years (ten firms) with unavailable size data (shares outstanding times the share price) in the applying-year on CRSP. All the remaining firm-years (854 firms) are matched with Compustat database. Finally, I omit 289 firm-years are not listed in the TFI insider filing dataset. The final sample ("influential patent" firms) consists of 2,470 firm-years with influential patents filed from 1,498 distinct firms.

Table 1

*Sample Selection*

| Panel A: Sample selection | | | | |
|---|---|---|---|---|
| Criterion | Dropped firm-years | # of Firm-years | Dropped firms | # of Distinct Firms |
| Total number of observations with at least one influential patent filed | | 11955 | | 2721 |
| Less the observations for which influential patents were filed in any of two consecutive years | 7674 | | 168 | |
| Less the observation for which influential patents received zero total adjusted citations | 21 | | 4 | |
| Number of observations in which influential patent was filed | | 4260 | | 2549 |
| Less observations for which their firms are not listed on CRSP | 1478 | | 854 | |
| | | 2782 | | 1695 |
| Less observations with unavailable shares outstanding or the share price data for the applying-year on CRSP | 23 | | 10 | |
| | | 2759 | | 1685 |
| Less observations for which their firms are not covered in TFI | 289 | | 187 | |
| Final Sample | | 2470 | | 1498 |

| Panel B: Summary statistics of influential patents | | | | | |
|---|---|---|---|---|---|
| Cat. Code | Category Name | # of influential patents | Percentage Count | Average Cites | Average Cites Adjusted for Truncations |
| 1 | Chemical | 484 | 13.7% | 23.26 | 40.88 |
| 2 | Computers & Communications | 811 | 22.9% | 42.21 | 85.27 |
| 3 | Drugs & Medical | 523 | 14.8% | 34.88 | 59.45 |
| 4 | Electrical & Electronic | 630 | 17.8% | 29.17 | 55.10 |
| 5 | Mechanical | 493 | 13.9% | 24.81 | 43.47 |
| 6 | Others | 597 | 16.9% | 25.14 | 43.34 |
| | **Total** | 3538 | 100.0% | 30.91 | 57.11 |

Panel A shows the sample selection out of the 11,955 firm-years (2,721 distinct firms) in which at least one patent filed is ranked in the top ten-percent most cited of the application year in its three-digit technology class (influential patents) in the NBER database during 1987-2006. Panel B provides the technology class distribution, average cites, and average adjusted cites for the sample of 3,538 influential patents (corresponding to 2,470 filing firm-years). The influential firm-year is the year when a firm applies for an influential patent. To avoid overlap, if a firm files influential patents for multiple years, I only include those years separated by at least two years. The adjusted citation is computed as the citation times the truncation weight index from the NBER patent dataset.

Panel B of Table 1 provides the distribution of technology classes for the sample of influential patents. My main sample includes 2,470 filing firm-years, in which total 3,538 influential patents were filed. These influential patents cover 333 patent classes among the more than 400 main (three-digit) patent classes defined by the USPTO. According to the higher-level classification developed in Hall, Jaffe, and Trajtenberg (2001), I aggregate all the classes into six main categories: Chemical (excluding Drugs); Computers and Communications; Drugs and Medical; Electrical and Electronics; Mechanical; and Others. Average citations and adjusted citations (the citation times the truncation weight index) are also provided in Panel B. Influential patents within the Computers and Communications category account for the most in the sample (22.9%). They additionally have the highest average citation count at 42.21 and adjusted citation count at 85.27. The next categories are Electrical and Electronics and Others, accounting for 17.8% and 16.9% respectively. The remaining influential patents distribute evenly among the other three categories from 13.7% to 14.8%.

*Two Cross-Sectional Control Samples*

Two control samples are constructed: an industry-size matched sample of "no-influential patent" firms and an unmatched sample of "inconsequential patent" firms. All control firms are required to have data from Compustat, CRSP, and TFI. For the sample of "no-influential patent" firms, I first exclude any firm with an influential patent filed from 1987 to 2006. Each firm-year in the sample of "influential patent" firms is then matched to a control firm-year with the closest market capitalization in the application year from the same two-digit primary Standard Industrial Classification (SIC) code. I perform the match without replacement. A "no-influential patent" matched firm might or

might not apply for a patent in the matched year. The industry-size matched "no-influential patent" firms consist of 2,470 firm-years, corresponding to 1,386 distinct firms.

The sample of "inconsequential patent" firms consists of all firm-years in which at least one patent filed is ranked in the bottom ten-percent most cited of the application year in its three-digit technology sub-category based on the USPTO classification, and the firm did not have any influential patent during the period 1987-2006. The sample of "inconsequential patent" firms consists of 1,699 firm-years, corresponding to 346 distinct firms. Because of the relatively small number of "inconsequential patent" firms (346) compared to the number of "influential patent" firms (1,498), the sample of "inconsequential patent" firms is not matched to "influential patent" firms by industry and year.

Table 2 reports mean and median values of financial and operating characteristics for the main sample and two control samples. Using p-values of two-tailed t-tests and two-tailed Wilcoxon tests, Table 2 also reports differences in means and in medians between "influential patent" firms and each of the two control samples. Firm value, sales, total assets, and financial leverage ratios are for the fiscal year prior to the application year. Firms' sizes are similar in the two samples, with a mean market capitalization (total assets) of $1,454 million ($1,852 million) for "influential patent" firms and $1,258 million ($1,956 million) for "no-influential patent" firms.

Table 2

*Descriptive Statistics*

| | Mean | | | | | Median | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) "Influential patent" firms | (2) "No-influential patent" firms | (3) "Inconsequential patent" firms | p-value (1)-(2) | p-value (1)-(3) | (1) "Influential patent" firms | (2) "No-influential patent" firms | (3) "Inconsequential patent" firms | p-value (1)-(2) | p-value (1)-(3) |
| Firm size | | | | | | | | | | |
| Market value of equity ($ mill.) | 1454 | 1258 | 17129 | 0.260 | 0.000 | 229 | 200 | 4439 | 0.022 | 0.000 |
| Sales ($ mill.) | 1127 | 1082 | 11719 | 0.711 | 0.000 | 149 | 146 | 4836 | 0.742 | 0.000 |
| Total assets ($ mill.) | 1852 | 1956 | 16239 | 0.816 | 0.000 | 147 | 142 | 5053 | 0.519 | 0.000 |
| Firm value ($ mill.) | 2921 | 2860 | 29061 | 0.913 | 0.000 | 323 | 286 | 8489 | 0.092 | 0.000 |
| Stock volatility and prior returns | | | | | | | | | | |
| σ (%) | 3.75 | 3.69 | 2.36 | 0.385 | 0.000 | 3.39 | 3.26 | 1.97 | 0.080 | 0.000 |
| PRET(-1) (%) | 22.52 | 26.31 | 19.15 | 0.176 | 0.164 | 6.74 | 9.52 | 14.07 | 0.047 | 0.000 |
| Growth | | | | | | | | | | |
| B/M | 0.62 | 0.58 | 2.09 | 0.330 | 0.000 | 0.43 | 0.45 | 0.39 | 0.216 | 0.000 |
| Firm value/Total assets | 2.97 | 2.51 | 2.01 | 0.014 | 0.000 | 1.69 | 1.58 | 1.57 | 0.001 | 0.000 |
| Sales growth rate (%) | 19.33 | 16.79 | 7.93 | 0.064 | 0.000 | 10.19 | 10.29 | 6.04 | 0.837 | 0.000 |
| Operating performance (%) | | | | | | | | | | |
| OPA(-1) | -1.22 | 3.48 | 9.49 | 0.000 | 0.000 | 8.12 | 8.90 | 10.30 | 0.013 | 0.000 |
| OPA(-2) | -1.07 | 2.36 | 9.68 | 0.016 | 0.000 | 8.20 | 8.92 | 10.30 | 0.031 | 0.002 |
| OPA(-3) | -0.86 | 3.58 | 9.60 | 0.001 | 0.000 | 8.50 | 9.03 | 10.41 | 0.033 | 0.000 |
| OPA | 0.85 | 4.20 | 9.95 | 0.000 | 0.000 | 8.05 | 8.54 | 10.15 | 0.089 | 0.000 |
| Financial leverage | | | | | | | | | | |
| Long-term debt/total assets | 0.14 | 0.18 | 0.17 | 0.000 | 0.000 | 0.08 | 0.12 | 0.16 | 0.000 | 0.000 |
| Long-term debt/firm value | 0.10 | 0.12 | 0.12 | 0.000 | 0.000 | 0.04 | 0.07 | 0.09 | 0.000 | 0.000 |

This table provides summary statistics of firm characteristics for the sample of "influential patent" firms and two control samples. The sample of "influential patent" firms consists of firms with influential patents filed during 1987-2006. The two control samples are "no-influential patent" firms and the "inconsequential patent" firms. We define influential patents as those top ten-percent most cited patents of the application year in its 3-digit technology sub-category based on the USPTO classification. The influential firm-year is the year when a firm applies for an influential patent. Both control samples are required to have corresponding data from Compustat, CRSP, and TFI, and did not apply for any influential patent during the sample period.

Table 2 (Continued)

To construct the matched sample of "no-influential patent" firms, each firm-year in the sample of "influential patent" firms is matched to a control firm-year with the closest market capitalization in the same two-digit primary SIC code industry on Compustat in the same year. The sample of "inconsequential patent" firms consists of firm-years in which at least one patent filed is ranked in the bottom ten percent most cited of the application year in its technology sub-category in the NBER database. All firms of the three samples are listed on the NYEX, AMEX, or NASDAQ. Each of the samples of "influential patent" firms and "no-influential patent" firms consists of 2,470 firm-years, while the sample of "inconsequential patent" firms consists of 1,699 firm-years. Market value of equity is measured at the end of calendar year prior to the application year. Firm value equals (book value of total assets – book value of equity + market value of equity). Firm value, sales, total assets, and financial leverage ratios are for fiscal year prior to the application year. Stock return volatility ($\sigma$) is the standard deviation of stock returns for the year prior to application year. PRET(-1) (prior stock returns) is computed as the buy-and-hold returns over one year prior to the application year. B/M is calculated as book value of equity divided by market value of equity as of the end of fiscal year before the year applying influential patent. Sales growth is defined as $[\text{sales}(-1)/\text{sales}(-5)]^{1/4}-1$. OPA(t) is the operating performance to total assets for year t relative to the application year (t=0). Operation performance is operating income before depreciation. OPA is the mean of OPA(t), equal to (OPA(-1)+OPA(-2)+OPA(-3))/3. Other than been stated, all other financial data are from Compustat. The differences in means between two samples are tested by two independent samples t-test, and the differences in medians are tested by Wilcoxon-Mann Whitney test. P-values are reported.

The mean daily stock volatility for "influential patent" firms is 3.75%, similar to the one for "no-influential patent" firms, 3.69%. The prior stock returns are close at 22.52% and 26.31%. One of three growth measures, the B/M ratio, indicates that two groups have similar growth opportunities. None of these differences between firms with influential or non-influential patents is statistically significant. Other measures between the two samples are significantly different, including the operating performance (measured by operating income before depreciation to total assets), financial leverages, and the other two growth measures (firm value/total assets and sales growth rate).

Firms with inconsequential patents are significantly different from firms with influential patents. On average, firms with inconsequential patents are larger in size, have a lower stock volatility, a lower growth opportunity, and a better prior operating performance.

### *Time-Series Control*

For each observation in the sample of "influential patent" firms and two control samples, I analyze insiders' open market trading during the informed and control periods. The informed period is the calendar year before a patent is filed (the pre-application year). The control period is the calendar year when a firm applies for a patent (the application year). I examine insider trading before the application year of a patent because, as discussed above, insiders clearly have information and foresight on innovation at the first stage of the preparation for the patent application, and their trading at that period is less likely to be noticed by regulators and investors. I do not examine insider trading after the application year of the patent because the news of applying for a' patent might leak out in some way, and outsiders might pay more attention to insiders

patent might leak out in some way, and outsiders might pay more attention to insiders actions, which reduces insiders' incentive to trade on the basis of knowledge of innovation.

### *Stock-Price Reaction when an Influential/ Inconsequential Patent Is Granted*

To verify the positive association between influential patents and the filing firm's future stock performances, I first investigate the stock-price reaction when an influential patent is granted. For comparison, I also present corresponding reactions when an inconsequential patent is granted. I do not examine such stock-price reaction for the matched "no-influential patent" firms, because these firms are not required to have patents filed in the year they are matched with "influential patent" firms.

The abnormal return of stock *i* on day *t* is computed as:

$$e_{it} = r_{it} - r_{mt}, \tag{1}$$

where $r_i$ and $r_m$ are the stock returns for firm i and the market, respectively. The market return is the return on the CRSP value-weighted stock index. I then calculate the cumulative abnormal return (CAR) for firm i over days ($t_1$, $t_2$) as:

$$CAR^{i}_{t_1,t_2} = \sum_{t=t_1}^{t_2} e_{it}\,. \tag{2}$$

Table 3 reports the mean and median values of CARs for the samples of "influential patent" and "inconsequential patent" firms over three windows covering the trading days (-1, +1), (-5, +5) and (-20, +5) around the announcement date of a patent being granted (day 0).

Table 3

*Stock-Price Reaction when an Influential/Inconsequential Patent Is Granted*

| Category | N | Days around announcement | | | | | |
|---|---|---|---|---|---|---|---|
| | | Mean | | | Median | | |
| | | (-1,+1) | (-5, +5) | (-20, +5) | (-1,+1) | (-5, +5) | (-20, +5) |
| (1) Influential patents granted | 3,478 | 0.27** | 0.95*** | 1.50*** | -0.11 | 0.05* | 0.27** |
| (p-value) | | (0.0213) | (0.0000) | (0.0000) | (0.9347) | (0.0745) | (0.0117) |
| (2) Inconsequential patents granted | 36,005 | 0.04** | -0.05 | -0.05 | -0.05 | -0.20*** | -0.14** |
| (p-value) | | (0.0159) | (0.1634) | (0.3029) | (0.6940) | (0.0003) | (0.0392) |
| (1) vs. (2) difference | | 0.23*** | 1.00*** | 1.55*** | -0.06 | 0.25 | 0.41** |
| (p-value) | | (0.0007) | (0.0000) | (0.0000) | (0.3844) | (0.1263) | (0.0464) |

This table reports the mean/median cumulative abnormal returns (CARs) and average CARs differences for three windows around a patent's granting date (day 0) for the samples of "influential patent" firms and "inconsequential patent" firms. The sample of "influential patent" firms consists of firms with influential patents filed during 1987-2006. Influential patents are identified as those top ten-percent most cited patents of the application year in its technology sub-category based on the USPTO classification. The sample of "inconsequential patent" firms consists of firm-years in which at least one patent applied for is ranked in the bottom ten-percent most cited of the application year in its technology sub-category in the NBER database. "Inconsequential patent" firms are required to have corresponding data on Compustat, CRSP, and TFI, and did not apply for any influential patent in the sample period. For each patent granted, the abnormal return for trading day t is calculated as the daily return on the stock minus the value-weighted CRSP index on day t. Both returns include dividends. There are 3,478 (36,005) influential patents (inconsequential patents) with available return data on CRSP around the grant date, corresponding to 1,475 (342) applying firms in 2,432 (1,692) firm-years. Mean/median and differences values are reported as percentages. The differences in means are tested by two independent samples t-test, and the differences in medians are tested by Wilcoxon-Mann Whitney test. The p-values are reported in parentheses. ***, **, and * denote significance at the one percent, five percent, and ten percent levels, respectively

The observation size for Table 3 is 3,468 for the sample of "influential patent" firms, indicating 3,468 patents were granted with available firms' return data on CRSP for the 2,470 firm-years in which at least one influential patent was filed. For "inconsequential patent" firms, the sample size is more than ten times larger, with 36,004 patents granted for 1,699 firm-years. The difference in the sample sizes is consistent with the notion that a few patents with good quality are extremely valuable, while many others are worth comparatively little. Therefore, it is justified to separate influential patents from other patents in my study.

Over the trading window of three days (-1, +1), both groups experience significantly positive mean CARs of about 0.27% and 0.04%, respectively. However, over the longer trading windows of days (-5, +5) and (-20, +5), firms with influential patents granted experience positively larger mean CARs of about 0.95% and 1.5%, which are statistically significant at the one percent level, while firms with inconsequential patents granted experience a negative mean CARs at 0.05%, though not statistically significant. The median values of CARs have similar patterns, except that CARs in the three trading days are negative and non-significant for both groups, and the negative median CARs of "inconsequential patent" firms over the two longer trading windows are significant at five percent and one percent level. All three mean values of CARs are significantly higher for firms with influential patents than for firms with inconsequential patents at one percent level. The results show that stock price reacts positively to the news that an influential patent is granted and negatively when an inconsequential patent is granted, indicating that the market has the ability to distinguish influential patents from inconsequential patents when a patent is granted. The fact that the market reacts to the news of an influential patent being granted also suggests that non-public information does exist for a long period in firms with influential innovation.

*Long-Run Stock Performance*

I next compare the long-run stock performances between the sample of "influential patent" firms and two control samples. I use the standard Fama and French (1993) three-factor model to estimate the long-run abnormal returns for firms in each sample:

$$R_t - RF_t = \alpha + \beta_1 MKTRF_t + \beta_2 HML_t + \beta_3 SMB_t + \varepsilon_t, \qquad (3)$$

where $R_t$ is the monthly stock return for a firm, $RF_t$ is the monthly risk-free rate, $R_t$- $RF_t$ is the excess return, $MKTRF_t$ is the excess return on the market, measured as the value-weighted market return minus the risk-free rate, $HML_t$ (High Minus Low) is the average return on the two highest value (high book-to-market) portfolios minus the average return on the two highest growth (low book-to-market) portfolios, and $SMB_t$ (Small Minus Big) is the average return on the three smallest capitalization portfolios minus the average return on the three biggest capitalization portfolios. The alpha ($\alpha$) coefficient represents the difference between the monthly return predicted by the three factors and the actual monthly return, so alpha is viewed as the long-run abnormal return.

Table 4 reports the average long-run abnormal returns and the average return difference between the sample of "influential patent" firms and two control samples in two years following the application year. For the application year (year 0), the abnormal returns of "influential patent" and "no-influential patent" firms are not significantly different at 0.83% and 0.87%, respectively. However, when investors hold the stock for a longer time, "influential patent" firms outperform both control samples.

Table 4

*Long-Run Stock Performance*

| Year | N | | Mean long-run abnormal returns (%) | | | Returns Difference (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1)&(2) "Influential patent" firms & "No-influential patent" firms | (3) "Inconsequential patent" firms | (1) "Influential patent" firms | (2) "No-influential patent" firms | (3) "Inconsequential patent" firms | (1) – (2) | t-stat | (1) vs. (3) | t-stat |
| 0 | 2470 | 1699 | 0.83** | 0.87** | 0.28*** | -0.05 | -0.1 | 0.55 | 1.34 |
| (0, +1) | 2470 | 1699 | 1.04*** | 0.53*** | 0.20*** | 0.51 | 4.31*** | 0.84 | 6.96*** |
| (0, +2) | 2470 | 1699 | 0.94*** | 0.50*** | 0.22*** | 0.43 | 4.51*** | 0.72 | 7.21*** |

This table reports the mean long-run abnormal returns and the average return difference between the sample of "influential patent" firms and two control samples in two years after the application year (year 0). The sample of "influential patent" firms consists of firms with influential patents filed during 1987-2006. The two control samples are "no-influential patent" firms and "inconsequential patent" firms. The standard Fama and French (1993) three-factor model is used to estimate the long-run abnormal returns for firms in each sample based on their monthly returns data on CRSP. Influential patents are identified as those top ten-percent most cited patents of the application year in its technology sub-category based on USPTO classification. To construct the matched sample of "no-influential patent" firms, each firm-year in the sample of "influential patent" firms is matched to a control firm-year with the closest market capitalization in the same two-digit primary SIC code industry on Compustat in the same year. The sample of "inconsequential patent" firms consists of firm-years in which at least one patent filed is ranked in the bottom ten-percent most cited of the application year in its technology sub-category in the NBER database. Both control samples are required to have corresponding data from Compustat, CRSP, and TFI, and did not apply for any influential patent during the sample period. All firms in the three samples are listed on the NYEX, AMEX, or NASDAQ. Each of the samples of "influential patent" and "no-influential patent" firms consists of 2,470 firm-years, while the sample of "inconsequential patent" firms consists of 1,699 firm-years. Mean values and returns differences are reported as percentages. The returns differences in Column ((1)-(2)) are tested by two-tailed matched-pair t-tests, and those in Column ((1) vs. (3)) are by two independent samples t-tests. ***, **, and * denote significance at the one percent, five percent, and ten percent levels, respectively.

In years (0, +1) and (0, +2), the mean abnormal returns for "influential patent" firms are, respectively, 1.04% and 0.94%, while for "no-influential patent" firms, they are only 0.53% and 0.50%. The differences of abnormal returns between "influential patent" and "no-influential patent" firms are significantly positive at 0.51% and 0.43%. The differences of abnormal returns between "influential patent" and "inconsequential patent" firms have a similar pattern, except that the mean abnormal return of "inconsequential patent" firms is much smaller and return differences are accordingly larger. I also calculate buy-and-hold abnormal returns as another measure of long-run performance and

find similar results. For brevity, results of buy-and-hold abnormal returns are not reported.

It is not surprising that firms with influential patents have better long-run performances than others due to the long-term effect of technological innovation on firms' future development. This evidence together with the stock-price reaction evidence supports my definition of influential patents in that those technologies are influential and may signal future economic performance of firms.

### *Insider Trading Data*

Insider trading data is obtained from Thomson Financial Insiders Filings Data Files (TFI, September 2007). This data contains all insider activities as reported on Form Three, Four, and Five filed with the SEC.[2] Focusing on the Table One in TFI database, I only consider two types of insider transactions, 'open market or private purchase of non-derivative or derivative security' and 'open market or private sale of non-derivative security', for each "influential patent" and control firm during the pre-application and application years. I drop filings marked as inaccurate or incomplete by TFI (Cleanse Indicators as 'S' or 'A'), filings labeled as an amendment to an earlier filing (Amendment Indicator as 'A'), or transactions that involve shares indirectly owned by insiders via a partnership, corporation, trust or other entity (Ownership Type as 'I'). The open-market stock transactions of three groups of corporate insiders are examined: all insiders, top management, and all insiders except for large blockholders. The top management group consists of Chairman, Chief Executive Officer (CEO), Chief Operating Officer (COO),

[2] Most insider transactions are reported on Form Four. Form Three is the initial statement of beneficial ownership that insiders must file. Form Five is an annual statement of change in beneficial ownership and contains activity from small or exempt transactions that are not reported on Form Four.

and President in a firm. Blockholders are beneficial owners of more than ten percent of any class of equity securities of a firm.

Following prior studies, I use three measures to examine the level of insider trading: number of shares traded by insiders (#shares), dollar value of shares traded by insiders ($shares), and percentage of outstanding equity traded by insiders (%equity). The dollar value of shares traded is the number of shares traded multiplied by the transaction price reported on the TFI insider filing data. The percentage of outstanding equity traded equals the number of shares traded divided by the number of shares outstanding at the end of calendar year. In the following tests, for observations without any insider purchase or sales over the informed or control periods, I assign zero to the measures of insider purchases or sales.

## Results

### *Univariate Results*

Univariate results are presented for insider purchases, sales, and net purchases (purchases - sales) in Table 5, Table 6, and Table 7, respectively.

**Insider Purchases**

Table 5 provides mean values of three measures of insider purchases for the sample of "influential patent" firms and two control samples during the informed and control periods. The informed period is the calendar year before a patent was filed. The control period is the calendar year when a firm applied for a patent. Panels A to C present the results for each of three groups of insiders: 1) all insiders, 2) top management, 3) all insiders except for large blockholders.

Table 5

*Univariate Test: Insider Purchases*

Panel A: All insiders

| Statistic | "Influential patent" firms | | "No-influential patent" firms | | "Inconsequential patent" firms | | p-values | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insider buy measures | (1) Pre-apply year | (2) Apply year | (3) Pre-apply year | (4) Apply year | (5) Pre-apply year | (6) Apply year | (1)-(2) | (1)-(3) | (1)-(5) | (3)-(4) | (5)-(6) | (1-2)-(3-4) | (1-2)-(5-6) |
| **mean** | | | | | | | | | | | | | |
| #shares | 0.060 | 0.046 | 0.061 | 0.078 | 0.023 | 0.023 | 0.366 | 0.952 | 0.033 | 0.416 | 0.956 | 0.235 | 0.458 |
| $shares | 1.174 | 0.601 | 0.714 | 0.889 | 0.661 | 0.661 | 0.133 | 0.258 | 0.267 | 0.459 | 1.000 | 0.097 | 0.237 |
| %equity | 0.004 | 0.003 | 0.003 | 0.004 | 0.001 | 0.001 | 0.677 | 0.555 | 0.013 | 0.224 | 0.669 | 0.278 | 0.677 |

Panel B: Top management

| Statistic | "Influential patent" firms | | "No-influential patent" firms | | "Inconsequential patent" firms | | p-values | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insider buy measures | (1) Pre-apply year | (2) Apply year | (3) Pre-apply year | (4) Apply year | (5) Pre-apply year | (6) Apply year | (1)-(2) | (1)-(3) | (1)-(5) | (3)-(4) | (5)-(6) | (1-2)-(3-4) | (1-2)-(5-6) |
| **mean** | | | | | | | | | | | | | |
| #shares | 0.006 | 0.008 | 0.006 | 0.010 | 0.002 | 0.002 | 0.090 | 0.849 | 0.008 | 0.131 | 0.966 | 0.622 | 0.174 |
| $shares | 0.053 | 0.083 | 0.061 | 0.134 | 0.069 | 0.044 | 0.077 | 0.575 | 0.527 | 0.231 | 0.357 | 0.504 | 0.070 |
| %equity | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.101 | 0.834 | 0.000 | 0.086 | 0.098 | 0.902 | 0.402 |

Panel C: All insiders but blockholders

| Statistic | "Influential patent" firms | | "No-influential patent" firms | | "Inconsequential patent" firms | | p-values | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insider buy measures | (1) Pre-apply year | (2) Apply year | (3) Pre-apply year | (4) Apply year | (5) Pre-apply year | (6) Apply year | (1)-(2) | (1)-(3) | (1)-(5) | (3)-(4) | (5)-(6) | (1-2)-(3-4) | (1-2)-(5-6) |

Table 5 (Continued)

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **mean** | | | | | | | | | | | | | |
| #shares | 0.060 | 0.046 | 0.061 | 0.078 | 0.023 | 0.023 | 0.365 | 0.953 | 0.033 | 0.415 | 0.956 | 0.234 | 0.457 |
| $shares | 1.173 | 0.600 | 0.714 | 0.889 | 0.661 | 0.661 | 0.134 | 0.259 | 0.268 | 0.457 | 0.999 | 0.097 | 0.237 |
| %equity | 0.004 | 0.003 | 0.003 | 0.004 | 0.001 | 0.001 | 0.676 | 0.554 | 0.013 | 0.223 | 0.670 | 0.277 | 0.676 |

This table reports the mean values of three measures of insider purchases for "influential patent" firms and two control samples during the informed and control periods. "Influential patent" firms consist of firms with influential patents filed during 1987-2006. The two control samples are "no-influential patent" firms and "inconsequential patent" firms. The informed period is the calendar year before a patent is filed. The control period is the calendar year a firm applies for a patent. Separated by at least a two-year gap, influential patents are identified as those top ten percent most cited patents of the application year in its technology sub-category based on the USPTO classification. To construct the matched sample of "no-influential patent" firms, each firm-year in the sample of "influential patent" firms is matched to a control firm-year with the closest market capitalization in the same two-digit primary SIC code industry on Compustat in the same year. The sample of "inconsequential patent" firms consists of firm-years in which at least one patent filed is ranked in the bottom ten percent least cited of the application year in its technology sub-category in the NBER database. Both control samples are required to have corresponding data from Compustat, CRSP, and TFI, and did not apply for any influential patent during the sample period. All firms in the three samples are listed on the NYEX, AMEX, or NASDAQ. Panels A to C show the results for each of three groups of corporate insiders: all insiders, top management, and all insiders but blockholders. The top management group consists of Chairman, Chief Executive Officer (CEO), Chief Operating Officer (COO), and President in a firm. Blockholders are beneficial owners of more than ten percent of any class of equity securities of a firm. For each firm-year, I report insider purchase activity during the pre-application and application years. The three measures of insider purchases are #shares (number of shares bought by insiders in millions during a year), $shares (dollar value of shares bought by insiders in millions during a year), and %equity (number of shares bought by insiders during a year divided by number of outstanding shares). All insiders trading data is from Thomson Insiders Filings database. The differences in means are tested by two-tailed matched-pair t-tests except that we use independent samples t-test to compare means for the sample of "influential patent" firms and the sample of "inconsequential patent" firms. The p-values of differences are reported in the table.

Table 6

*Univariate Test: Insider Sales*

Panel A: All insiders

| Statistic | "Influential patent" firms | | "No-influential patent" firms | | "Inconsequential patent" firms | | p-values | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insider sales measures | (1) Pre-apply year | (2) Apply year | (3) Pre-apply year | (4) Apply year | (5) Pre-apply year | (6) Apply year | (1)-(2) | (1)-(3) | (1)-(5) | (3)-(4) | (5)-(6) | (1-2)-(3-4) | (1-2)-(5-6) |
| **mean** | | | | | | | | | | | | | |
| #shares | 0.188 | 0.292 | 0.288 | 0.433 | 0.239 | 0.278 | 0.001 | 0.024 | 0.063 | 0.087 | 0.198 | 0.648 | 0.153 |
| $shares | 6.093 | 8.935 | 7.494 | 11.342 | 13.746 | 15.436 | 0.003 | 0.242 | 0.000 | 0.123 | 0.450 | 0.702 | 0.597 |
| %equity | 0.008 | 0.011 | 0.010 | 0.015 | 0.002 | 0.004 | 0.001 | 0.036 | 0.000 | 0.009 | 0.006 | 0.422 | 0.196 |

Panel B: Top management

| Statistic | "Influential patent" firms | | "No-influential patent" firms | | "Inconsequential patent" firms | | p-values | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insider sales measures | (1) Pre-apply year | (2) Apply year | (3) Pre-apply year | (4) Apply year | (5) Pre-apply year | (6) Apply year | (1)-(2) | (1)-(3) | (1)-(5) | (3)-(4) | (5)-(6) | (1-2)-(3-4) | (1-2)-(5-6) |
| **mean** | | | | | | | | | | | | | |
| #shares | 0.043 | 0.058 | 0.041 | 0.059 | 0.050 | 0.056 | 0.073 | 0.708 | 0.357 | 0.007 | 0.287 | 0.749 | 0.411 |
| $shares | 1.709 | 2.076 | 1.286 | 1.549 | 2.585 | 2.885 | 0.294 | 0.153 | 0.025 | 0.214 | 0.315 | 0.789 | 0.892 |
| %equity | 0.002 | 0.002 | 0.002 | 0.003 | 0.001 | 0.001 | 0.014 | 0.828 | 0.000 | 0.000 | 0.541 | 0.035 | 0.094 |

Panel C: All insiders but blockholders

| Statistic | "Influential patent" firms | | "No-influential patent" firms | | "Inconsequential patent" firms | | p-values | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insider sales measures | (1) Pre-apply year | (2) Apply year | (3) Pre-apply year | (4) Apply year | (5) Pre-apply year | (6) Apply year | (1)-(2) | (1)-(3) | (1)-(5) | (3)-(4) | (5)-(6) | (1-2)-(3-4) | (1-2)-(5-6) |

Table 6 (Continued)

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **mean** | | | | | | | | | | | | | |
| #shares | 0.187 | 0.292 | 0.288 | 0.433 | 0.239 | 0.278 | 0.001 | 0.023 | 0.060 | 0.089 | 0.197 | 0.658 | 0.149 |
| $shares | 6.055 | 8.931 | 7.489 | 11.324 | 13.740 | 15.430 | 0.002 | 0.230 | 0.000 | 0.124 | 0.450 | 0.716 | 0.585 |
| %equity | 0.008 | 0.011 | 0.010 | 0.015 | 0.002 | 0.004 | 0.001 | 0.035 | 0.000 | 0.010 | 0.005 | 0.439 | 0.201 |

This table reports the mean values of three measures of insider sales for "influential patent" firms and two control samples during the informed and control periods. "Influential patent" firms consist of firms with influential patents filed during 1987-2006. The two control samples are "no-influential patent" firms and "inconsequential patent" firms. The informed period is the calendar year before a patent is filed. The control period is the calendar year a firm applies for a patent. Influential patents are identified as those top ten percent most cited patents of the application year in its technology sub-category based on the USPTO classification. To construct the matched sample of "no-influential patent" firms, each firm-year in the sample of "influential patent" firms is matched to a control firm-year with the closest market capitalization in the same two-digit primary SIC code industry on Compustat in the same year. The sample of "inconsequential patent" firms consists of firm-years in which at least one patent filed is ranked in the bottom ten percent most cited of the application year in its technology sub-category in the NBER database. Both control samples are required to have corresponding data from Compustat, CRSP, and TFI, and did not apply for any influential patent during the sample period. All firms in the three samples are listed on the NYEX, AMEX, or NASDAQ. Panels A to C show the results for each of three groups of corporate insiders: all insiders, top management, and all insiders but blockholders. The top management group consists of Chairman, Chief Executive Officer (CEO), Chief Operating Officer (COO), and President in a firm. Blockholders are beneficial owners of more than ten percent of any class of equity securities of a firm. For each firm-year, I report insider sale activity during the pre-application and application years. The three measures of insider sales are #shares (number of shares sold by insiders in millions during a year), $shares (dollar value of shares sold by insiders in millions during a year), and %equity (number of shares sold by insiders during a year divided by number of outstanding shares). All insiders trading data is from Thomson Insiders Filings database. The differences in means are tested by two-tailed matched-pair t-tests except that we use independent samples t-test to compare means for the sample of "influential patent" firms and the sample of "inconsequential patent" firms. The p-values of differences are reported in the table.

Table 7

*Univariate Test: Insiders' Net Purchases*

Panel A: All insiders

| Statistic | "Influential patent" firms | | "No-influential patent" firms | | "Inconsequential patent" firms | | p-values | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insider net buy measures | (1) Pre-apply year | (2) Apply year | (3) Pre-apply year | (4) Apply year | (5) Pre-apply year | (6) Apply year | (1)-(2) | (1)-(3) | (1)-(5) | (3)-(4) | (5)-(6) | (1-2)-(3-4) | (1-2)-(5-6) |
| **mean** | | | | | | | | | | | | | |
| #shares | -0.129 | -0.247 | -0.227 | -0.355 | -0.214 | -0.253 | 0.001 | 0.043 | 0.008 | 0.144 | 0.222 | 0.917 | 0.114 |
| $shares | -4.931 | -8.337 | -6.784 | -10.454 | -13.041 | -14.731 | 0.001 | 0.141 | 0.000 | 0.142 | 0.454 | 0.922 | 0.444 |
| %equity | -0.005 | -0.008 | -0.008 | -0.011 | -0.002 | -0.003 | 0.010 | 0.045 | 0.019 | 0.071 | 0.021 | 0.999 | 0.206 |

Panel B: Top management

| Statistic | "Influential patent" firms | | "No-influential patent" firms | | "Inconsequential patent" firms | | p-values | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insider net buy measures | (1) Pre-apply year | (2) Apply year | (3) Pre-apply year | (4) Apply year | (5) Pre-apply year | (6) Apply year | (1)-(2) | (1)-(3) | (1)-(5) | (3)-(4) | (5)-(6) | (1-2)-(3-4) | (1-2)-(5-6) |
| **mean** | | | | | | | | | | | | | |
| #shares | -0.038 | -0.050 | -0.035 | -0.049 | -0.047 | -0.053 | 0.153 | 0.683 | 0.173 | 0.051 | 0.290 | 0.872 | 0.580 |
| $shares | -1.657 | -1.992 | -1.225 | -1.416 | -2.517 | -2.841 | 0.337 | 0.146 | 0.029 | 0.384 | 0.280 | 0.711 | 0.982 |
| %equity | -0.001 | -0.001 | -0.001 | -0.002 | 0.000 | 0.000 | 0.242 | 0.919 | 0.000 | 0.001 | 0.881 | 0.058 | 0.327 |

Panel C: All insiders but blockholders

| Statistic | "Influential patent" firms | | "No-influential patent" firms | | "Inconsequential patent" firms | | p-values | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insider net buy measures | (1) Pre-apply year | (2) Apply year | (3) Pre-apply year | (4) Apply year | (5) Pre-apply year | (6) Apply year | (1)-(2) | (1)-(3) | (1)-(5) | (3)-(4) | (5)-(6) | (1-2)-(3-4) | (1-2)-(5-6) |

Table 7 (Continued)

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **mean** | | | | | | | | | | | | | |
| #shares | -0.128 | -0.247 | -0.227 | -0.354 | -0.214 | -0.253 | 0.001 | 0.042 | 0.007 | 0.146 | 0.221 | 0.928 | 0.112 |
| $shares | -4.894 | -8.334 | -6.780 | -10.436 | -13.035 | -14.726 | 0.001 | 0.133 | 0.000 | 0.144 | 0.453 | 0.936 | 0.435 |
| %equity | -0.005 | -0.008 | -0.008 | -0.011 | -0.001 | -0.003 | 0.010 | 0.045 | 0.018 | 0.075 | 0.019 | 0.979 | 0.209 |

This table reports the mean values of three measures of insider' net purchases for "influential patent" firms and two control samples during the informed and control periods. "Influential patent" firms consist of firms with influential patents filed during 1987-2006. The two control samples are "no-influential patent" firms and "inconsequential patent" firms. The informed period is the calendar year before a patent is filed. The control period is the calendar year a firm applies for a patent. Influential patents are identified as those top ten percent most cited patents of the application year in its technology sub-category based on the USPTO classification.. To construct the matched sample of "no-influential patent" firms, each firm-year in the sample of "influential patent" firms is matched to a control firm-year with the closest market capitalization in the same two-digit primary SIC code industry on Compustat in the same year. The sample of "inconsequential patent" firms consists of firm-years in which at least one patent filed is ranked in the bottom ten percent most cited of the application year in its technology sub-category in the NBER database. Both control samples are required to have corresponding data from Compustat, CRSP, and TFI, and did not apply for any influential patent during the sample period. All firms in the three samples are listed on the NYEX, AMEX, or NASDAQ. Panel A to C show the results for each of three groups of corporate insiders: all insiders, top management, and all insiders but blockholders. The top management group consists of Chairman, Chief Executive Officer (CEO), Chief Operating Officer (COO), and President in a firm. Blockholders are beneficial owners of more than ten percent of any class of equity securities of a firm. For each firm-year, I report insiders' net purchase activity during the pre-application and application years. The three measures of insiders' net purchases are #shares (net number of shares bought by insiders in millions during a year), $shares (net dollar value of shares bought by insiders in millions during a year), and %equity (number of shares bought on the net during a year divided by number of outstanding shares). All insiders trading data is from Thomson Insiders Filings database.The differences in means are tested by two-tailed matched-pair t-tests except that we use independent samples t-test to compare means for the sample of "influential patent" firms and the sample of "inconsequential patent" firms. The p-values of differences are reported in the table.

The three measures of insider purchases are number of shares bought in millions by insiders during a year (#shares), dollar value of shares bought in millions by insiders during a year ($shares), and percentage of outstanding equity bought by insiders during a year (%equity). The dollar value of shares bought is the number of shares bought multiplied by the transaction price reported on the TFI insider filing data.

Table 5 also reports p-values from t-tests. Between "influential patent" and "no-influential patent" firms (p-values (1)-(2), (1)-(3), (3)-(4), (5)-(6), and (1-2)-(3-4)), two-tailed paired t-tests is used for the difference in means. Between "influential patent" and "inconsequential patent" firms (p-values (1)-(5) and (1-2)-(5-6)), two independent samples t-tests are used for the differences in means. Column (1)-(2) (Column (3)-(4)) shows p-values of test statistics for the change in the level of purchases of insiders in "influential patent" firms ("no-influential patent" firms) between the pre-application and control periods (i.e., the time-series control); Column (1)-(3) shows p-values for the difference in the level of purchases of insiders in the pre-application period between "influential patent" and "no-influential patent" firms (i.e., the cross-sectional control); and Column (1-2)-(3-4) is for the difference between (a) the change in the level of purchases of insiders in "influential patent" firms between the pre-application and control periods and (b) the change in the level of purchases of insiders in "no-influential patent" firms between the pre-application and control periods (i.e., DID, difference-in-differences control). Similarly, for "inconsequential patent" firms, p–values are provided in Column (1)-(5), Column (5)-(6), and Column (1-2)-(5-6).

Based on the time-series control, for "influential patent" firms, the group of top management (Panel B) purchases significantly fewer stocks during the pre-application

year than the control period, while the groups of all insiders and the all insiders but large blockholders show similar and insignificant results. However, the level of their buying appears to be normal based on either the cross-sectional or DID control for all three groups in "influential patent" firms. Compared with top managers in "inconsequential patent" firms, those in "influential patent" firms purchase significantly more stocks during the informed period, though the mean dollar value of stocks they bought is not unusual.

**Insider Sales**

Univariate results of insider sales are reported in Table 6. The format of Table 6 is similar to that of Table 5, except that the measures of insider purchases are replaced by the measures of insider sales. Based on the time-series control, Column (1)-(2) shows that insiders in "influential patent" firms sell significantly fewer stocks during the pre-application year compared to the number they sell during the control year, which indicates they delay their sales in the pre-application year until the application year. Based on the cross-sectional control (Column (1)-(5)), insiders in "influential patent" firms sell significantly fewer stocks than those in "inconsequential patent" firms in the pre-application year. Both conclusions hold for each of three insider groups in Panel A to Panel C, and for almost each of three measures of the level of insider sales, yet the significant difference does not hold based on the DID control.

Table 6 provides evidence that insiders of firms with influential patents significantly delay their stock sales during the pre-application year relative to the application year, but the reduction relative to the delay is not significantly higher than the changes observed from the insider sales in the control firms. The results preliminarily

support the explanation of passive insider trading. Insiders may postpone their planned sales to avoid the penalties or notice from insider trading regulators.

**Insider Net Purchases**

Table 7 examines the level of stock net purchases of insiders. Based on the time-series control (Column (1)-(2)), insiders in "influential patent" firms have significantly higher level of net purchases during the pre-application year. The levels of insiders' net purchases in the two control samples do not have significant change. This pattern remains consistent for both groups of all insiders and all insiders except for large blockholders in "influential patent" firms. Based on the cross-sectional control (Column (1)-(5)), insiders in "influential patent" firms purchase significantly more stocks on the net than those in "inconsequential patent" firms in the pre-application year. Both conclusions hold for all three insider groups in Panel A to Panel C, and for almost all three measures of the level of insider net purchases. Nevertheless, based on the DID control, no evidence indicates unusual levels of net purchases by insiders in firms with influential patents during the pre-application year.

In summary, the univariate results imply that while insiders generally keep their purchases at the normal level, their net purchases are higher due to the lower level of sales in the year before the filing of influential patents. This pattern is similar to the profitable passive insider trading pattern of target firms' insiders before takeover announcements, as suggested in Agrawal and Nasser (2012).

*Cross-Sectional Regressions*

While univariate results provide some preliminary evidence under two sets of controls: the time-series and cross-sectional control, they do not control for other

determinants of the level of insider trading. I estimate cross-sectional regressions of the level of insider trading when controlling for other determinants. The regression results for purchases, sales, and net purchases of three insiders groups are presented.

**Regression Specification**

Prior studies find that several factors influence the level of insider trading, such as firm size, the level of stock volatility, prior stock performance, stock liquidity, firm valuation, and innovation. I attempt to control for these various factors in the cross-sectional regressions, for the sample of "influential patent" firms and two control samples respectively. All explanatory variables in the regression include two observations: One is for the pre-application (informed) period and the other is for the control period. A binary dummy variable 'Pre-apply' is used to represent the two observations, which equals one if the insider trading activity occurs during the pre-application year and zero otherwise. My model is constructed as Equation (4), and each measure of these control variables are described below:

$$IT_i = \alpha_0 + \beta_1 Ln(Market\_Cap)_i + \beta_2 \sigma_i + \beta_3 PRET_{-1i} + \beta_4 B/M\_decile_i + \beta_5 R\&D/Sales_i + \beta_6 Liquidity + \beta_7 \text{Pre}\_apply_i + \varepsilon_i, i = 1,2,... \quad (4)$$

*Firm size (Ln(Market_Cap)):* Seyhun (1986) finds insiders are likely to be net purchasers in small firms and net sellers in large firms. I control firm size by using the natural logarithm of the market capitalization. Market cap is computed as the number of total common shares outstanding times the share price at the last trading day during the calendar year prior to the pre-application year or the application year on CRSP monthly dataset.

*Stock volatility (σ):* Meulbroek (2000) finds that insiders' sales are more aggressive in those more risky companies. The risk of a stock can be measured by the

standard deviation of stock returns of a firm over all trading days during the year before the pre-application year or the application year on CRSP daily dataset.

*Prior stock performance ($PRET_{-1}$):* Lakonishok and Lee (2001) argue that insiders tend to be contrarian investors who buy stocks when the past returns are low and sell them when the past returns are high. Prior stock returns ($PRET_{-1}$) are computed as the buy-and-hold returns over one year prior to the pre-application year or the control year.

*Firm valuation (B/M_decile):* Book-to-market (B/M) ratio is often used to measure a firm's valuation ratio relative to other firms. Jenter (2005) finds that insiders trade like contrarian investors by purchasing (selling) a stock when the firm has a low (high) valuation. The B/M ratio is computed by dividing the book value of equity by the market capitalization of common shares outstanding at the end of calendar year before the pre-application year or the control year. Based on NYSE B/M decile breakpoints in a given year, B/M decile is assigned to one to ten depending on a firm's B/M ratio.

*Innovation (R&D/Sales):* Aboody and Lev (2000) argue that R&D activities create unique information asymmetries between corporate insiders and outside investors, and find that insider gains through insider trading in firms conducting R&D are significantly larger than insider gains in firms with no R&D activities. R&D/Sales ratio is R&D expenses to sales revenue for the last fiscal year before the pre-application or control year. R&D expenses are treated as zero if R&D expenses are missing on Compustat.

*Stock liquidity:* The market microstructure models developed by prior studies (i.e., Grossman and Stiglitz, 1980; Kyle, 1985; Holmstrom and Tirole, 1993) suggest that informed traders are more likely to trade when stock liquidity is higher. I also control for

stock liquidity, calculated as the mean daily trading volume divided by shares outstanding during the pre-application or control year.

*Pre-apply:* Pre-apply is a binary dummy variable equal to one if the insider trading activity occurs during the pre-application year and zero otherwise.

Controlling for those factors related to insider trading, I compare the regressions' results between the sample of "influential patent" firms and the two control samples, the sample of "no-influential patent" firms and the sample of "inconsequential patent" firms. The dependent variable (IT) is one of three measures of insider trading: 1) number of shares (#shares), 2) dollar value of shares ($shares), and 3) percentage of outstanding equity (%equity) traded by insiders during the period. To reduce the influence from outliers, the top and bottom one percent of the observations of the three dependent variables in each regression are winsorized. Further, I control for industry and year fixed effect in each regression model and calculate test statistics using robust variances.

**Insider Purchases**

I start by examining insider purchases in Table 8. Panel A shows coefficient estimates and p-values from the regressions of all insiders' purchases in the three samples. Panel A.1 lists the regression results in the sample of "influential patent" firms, Panel A.2 is for the sample of "no-influential patent" firms, and Panel A.3 is for the sample of "inconsequential patent" firms. My main interest is in the coefficient of 'Pre-apply', which measures the abnormal trading level of insiders in the pre-application year relative to the application year (i.e., the control period).

Table 8

*Regressions of Insider Purchases*

Panel A: All insiders' purchases

| Independent Variables | A.1 "Influential patent" firms | | | A.2 "No-influential patent" firms | | | A.3 "Inconsequential patent" firms | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dependent variables | | | Dependent variables | | | Dependent variables | | |
| | #shares | $shares | %equity | #shares | $shares | %equity | #shares | $shares | %equity |
| Ln(market cap) | 0.000 | 0.060*** | -0.001*** | 0.001 | 0.061*** | -0.001*** | 0.001 | 0.069*** | -0.000*** |
| | (0.869) | (0.003) | (0.000) | (0.468) | (0.001) | (0.000) | (0.351) | (0.000) | (0.000) |
| σ | 0.474*** | 0.191 | 0.023** | 0.609** | 2.252 | 0.026 | 0.707*** | 6.176*** | 0.022*** |
| | (0.000) | (0.859) | (0.046) | (0.010) | (0.224) | (0.134) | (0.000) | (0.003) | (0.001) |
| PRET(-1) | -0.002 | 0.034 | 0.000 | -0.006*** | -0.035* | -0.000*** | -0.011*** | -0.127*** | -0.000*** |
| | (0.404) | (0.249) | (0.375) | (0.000) | (0.064) | (0.007) | (0.000) | (0.010) | (0.000) |
| B/M decile | -0.001 | -0.016** | 0.000 | -0.001 | -0.011 | -0.000 | 0.000 | 0.015 | -0.000 |
| | (0.130) | (0.048) | (0.711) | (0.148) | (0.270) | (0.558) | (0.464) | (0.195) | (0.449) |
| R&D/Sales | -0.000*** | -0.000* | -0.000*** | 0.000 | -0.000 | -0.000 | -0.000 | -0.001 | -0.000 |
| | (0.005) | (0.067) | (0.008) | (0.907) | (0.990) | (0.656) | (0.644) | (0.342) | (0.778) |
| Liquidity | -0.693*** | -3.969 | -0.031** | -0.990*** | -7.350** | -0.064** | 0.025 | -0.289 | -0.010*** |
| | (0.004) | (0.150) | (0.030) | (0.008) | (0.050) | (0.012) | (0.757) | (0.836) | (0.003) |
| Pre-apply | -0.001 | -0.014 | 0.000 | -0.003 | -0.034 | -0.000 | -0.001 | -0.021 | -0.000 |
| | (0.776) | (0.763) | (0.177) | (0.449) | (0.453) | (0.327) | (0.573) | (0.690) | (0.311) |
| Industry FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 4220 | 4220 | 4220 | 4107 | 4107 | 4107 | 3183 | 3183 | 3183 |
| Adjusted $R^2$ | 0.025 | 0.029 | 0.05 | 0.024 | 0.034 | 0.027 | 0.03 | 0.021 | 0.129 |

Panel B: other insiders' purchases

| Insider Group | B.1 "Influential patent" firms | | | B.2 "No-influential patent" firms | | | B.3 "Inconsequential patent" firms | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dependent variables | | | Dependent variables | | | Dependent variables | | |
| | #shares | $shares | %equity | #shares | $shares | %equity | #shares | $shares | %equity |
| Top managers | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | -0.002 | 0.000 |
| | (0.783) | (0.949) | (0.478) | (0.694) | (0.386) | (0.883) | (0.349) | (0.706) | (0.128) |
| All insiders but blockholders | -0.001 | -0.013 | 0.000 | -0.003 | -0.034 | 0.000 | -0.001 | -0.02 | 0.000 |
| | (0.783) | (0.766) | (0.179) | (0.441) | (0.442) | (0.324) | (0.575) | (0.693) | (0.312) |

Table 8 (Continued)

This table reports the coefficient estimates from OLS regressions of three measures of insider purchases. "Influential patent" firms consist of firms with influential patents filed during 1987-2006. "No-influential patent" firms and "inconsequential patent" firms are two control samples.Influential patents are identified as those top ten percent most cited patents of the application year in its technology sub-category based on the USPTO classification. To construct the matched sample of "no-influential patent" firms, each firm-year in the sample of "influential patent" firms is matched to a control firm-year with the closest market capitalization in the same two-digit primary SIC code industry on Compustat in the same year. The sample of "inconsequential patent" firms consists of firm-years in which at least one patent filed is ranked in the bottom ten percent most cited of the application year in its technology sub-category in the NBER database. Both control samples are required to have corresponding data from Compustat, CRSP, and TFI, and did not apply for any influential patent during the sample period. All firms in the three samples are listed on the NYEX, AMEX, or NASDAQ. Insider trading activities are measured during two periods for each firm-year: One is the informed period, the year before the application year; the other is the control period, the year a firm applies for a patent. The dependable variables include: #shares (number of shares bought by insiders in millions during the year), $shares (dollar value of shares bought by insiders in millions during the year), and %equity (number of shares bought during a year divided by number of outstanding shares). The top and bottom one percent of the observations of the dependent variables in each regression are winsorized. Market cap is computed as the number of common shares outstanding times the share price at the end of calendar year before pre-application year or application year. The standard deviation of stock returns ($\sigma$) is calculated over the year prior to pre-application year or control year. PRET (-1) is the buy-and-hold return for a firm over one year prior to pre-application year or control year. B/M decile is assigned as one to ten depending on the firm's B/M ratio. I use NYSE B/M decile breakpoints to assign a firm's B/M decile. B/M is calculated as book value of equity divided by market value of equity ratio as of the last year ending prior to the pre-application or application year. R&D/Sales ratio is R&D expense to sales revenue for the last year before the pre-applying or applying year. Liquidity equals to the mean daily trading volume divided by share outstanding during the pre-applying or control year. Pre-apply is a dummy variable equal to one if the insider trading activity occurs during the pre-applying year and zero otherwise. Test statistics are calculated using robust variance. Industry and year fixed effect are included in all regressions. Panel A shows coefficient estimates of regressions of measures of purchases by all corporate insiders. Panel B only reports the coefficient estimates of 'Pre-apply' variable for regressions of measures of purchases by top management and by all insiders but blockholders. The p-values are reported in parentheses. ***, **, and * denote significance at the one percent, five percent, and ten percent levels, respectively.

Panel B shows regression estimates and p-values of Equation (4) for the level of purchases of the other two insider groups: top management and all insiders except for large blockholders. For brevity, I only report coefficient estimates of the dummy variable 'Pre-apply'. The sample of "influential patent" firms consists of 4,220 observations for which all variables in the regressions have available data in CRSP and Compustat, corresponding to 2,110 unique firm-years in which at least one influential patent was filed. Similarly, the samples of "no-influential patent" firms and "inconsequential patent" firms correspond to 2,054 and 1,592 firm-years, respectively.

Consistent with prior studies, Panel A in Table 8 provides evidence that, all insiders purchase significantly more stocks when the firm is larger, has a higher stock volatility, or has a lower prior stock return. I also find evidence that the level of insider purchases is negatively related to R&D expense and liquidity. In all three samples, estimated coefficients of the 'Pre-apply' variable are negative but not significantly different from zero. It indicates, during the year before filing an influential patent, the level of insiders' purchases is not significantly abnormal, relative to their trading level during the application year. This pattern remains constant for the other two insider groups in Panel B.

**Insider Sales**

Table 9 reports the regression results of insider sales. The format of Table 9 is similar to that of Table 8, except that three measures of insider purchases are replaced by the measures of insider sales. In Panel A, the significant determinants of insiders' sales are almost the same as those of their purchases discussed in Panel A of Table 8, except that insiders sell significantly less when the firm has a higher valuation.

Table 9

*Regressions of Insider Sales*

Panel A: All insiders' sales

| Independent Variables | A1. "Influential patent" firms | | | A2. "No-influential patent" firms | | | A3. "Inconsequential patent" firms | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dependent variables | | | Dependent variables | | | Dependent variables | | |
| | #shares | $shares | %equity | #shares | $shares | %equity | #shares | $shares | %equity |
| | 0.067*** | 3.113*** | -0.002*** | 0.065*** | 2.265*** | -0.001*** | 0.070*** | 4.841*** | -0.001*** |
| Ln(market cap) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| σ | 2.593*** | 55.583*** | -0.014 | 3.551*** | 27.167* | 0.035 | 9.673*** | 411.401*** | 0.090*** |
| | (0.000) | (0.001) | (0.550) | (0.000) | (0.060) | (0.279) | (0.000) | (0.000) | (0.000) |
| PRET(-1) | 0.031** | 1.876*** | 0.002*** | 0.006 | 1.140*** | 0.001** | 0.162*** | 12.024*** | 0.003*** |
| | (0.016) | (0.000) | (0.001) | (0.542) | (0.005) | (0.042) | (0.000) | (0.000) | (0.000) |
| B/M decile | -0.011*** | -0.205** | -0.001*** | -0.017*** | -0.380*** | -0.001*** | -0.010*** | -0.731*** | -0.000*** |
| | (0.000) | (0.024) | (0.000) | (0.000) | (0.000) | (0.000) | (0.007) | (0.000) | (0.000) |
| R&D/Sales | 0.000 | -0.001* | 0.000 | -0.001** | -0.016 | -0.000** | -0.001** | -0.078* | 0.000 |
| | (0.957) | (0.099) | (0.231) | (0.037) | (0.113) | (0.024) | (0.035) | (0.050) | (0.172) |
| Liquidity | 4.660*** | 188.299*** | 0.223*** | 3.982 | 326.366*** | 0.203* | 1.527* | 47.726 | -0.017 |
| | (0.007) | (0.002) | (0.000) | (0.173) | (0.000) | (0.095) | (0.075) | (0.329) | (0.109) |
| Pre-apply | -0.027* | -1.059** | -0.002*** | -0.022 | -0.393 | -0.002** | -0.004 | 0.128 | -0.000** |
| | (0.050) | (0.024) | (0.004) | (0.281) | (0.457) | (0.010) | (0.842) | (0.909) | (0.031) |
| Industry FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 4220 | 4220 | 4220 | 4107 | 4107 | 4107 | 3183 | 3183 | 3183 |
| Adjusted $R^2$ | 0.137 | 0.203 | 0.056 | 0.073 | 0.141 | 0.042 | 0.171 | 0.191 | 0.166 |

Panel B: other insiders' sales

| Insider Group | B.1. "Influential patent" firms | | | B.2. "No-influential patent" firms | | | B.3. "Inconsequential patent" firms | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dependent variables | | | Dependent variables | | | Dependent variables | | |
| | #shares | $shares | %equity | #shares | $shares | %equity | #shares | $shares | %equity |
| Top managers | -0.007** | -0.211* | -0.000*** | -0.005 | -0.064 | -0.000** | 0.003 | 0.137 | 0.000 |
| | (0.027) | (0.080) | (0.007) | (0.220) | (0.551) | (0.011) | (0.503) | (0.607) | (0.499) |
| All insiders but blockholders | -0.027** | -1.064** | -0.002*** | -0.022 | -0.381 | -0.002** | -0.004 | 0.127 | -0.000** |
| | (0.049) | (0.023) | (0.004) | (0.290) | (0.470) | (0.011) | (0.836) | (0.910) | (0.021) |

Table 9 (Continued)

This table reports the coefficient estimates from OLS regressions of three measures of insider sales. "Influential patent" firms consist of firms with influential patents filed during 1987-2006. "No-influential patent" firms and "inconsequential patent" firms are two control samples. Influential patents are identified as those top ten percent most cited patents of the application year in its technology sub-category based on the USPTO classification. To construct the matched sample of "no-influential patent" firms, each firm-year in the sample of "influential patent" firms is matched to a control firm-year with the closest market capitalization in the same two-digit primary SIC code industry on Compustat in the same year. The sample of "inconsequential patent" firms consists of firm-years in which at least one patent filed is ranked in the bottom ten percent most cited of the application year in its technology sub-category in the NBER database. Both control samples are required to have corresponding data from Compustat, CRSP, and TFI, and did not apply for any influential patent during the sample period. All firms in the three samples are listed on the NYEX, AMEX, or NASDAQ. Insider trading activities are measured during two periods for each firm-year: One is the informed period, the year before the application year; the other is the control period, the year a firm applies for a patent. The dependable variables include: #shares (number of shares sold by insiders in millions during the year), $shares (dollar value of shares sold by insiders in millions during the year), and %equity (number of shares sold during a year divided by number of outstanding shares). The top and bottom one percent of the observations of the dependent variables in each regression are winsorized. Market cap is computed as the number of common shares outstanding times the share price at the end of calendar year before pre-application year or application year. The standard deviation of stock returns ($\sigma$) is calculated over the year prior to pre-application year or control year. PRET(-1) is the buy-and-hold return for a firm over one year prior to pre-application year or control year. B/M decile is assigned as one to ten depending on the firm's B/M ratio. I use NYSE B/M decile breakpoints to assign a firm's B/M decile. B/M is calculated as book value of equity divided by market value of equity ratio as of the last year ending prior to the pre-application or application year. R&D/Sales ratio is R&D expense to sales revenue for the last year before the pre-applying or applying year. Liquidity equals to the mean daily trading volume divided by share outstanding during the pre-applying or control year. Pre-apply is a dummy variable equal to one if the insider trading activity occurs during the pre-applying year and zero otherwise. Test statistics are calculated using robust variance. Industry and year fixed effect are included in all regressions. Panel A shows coefficient estimates of regressions of measures of sales by all corporate insiders. Panel B only reports the coefficient estimates of 'Pre-apply' variable for regressions of measures of sales by top management and by all insiders but blockholders. The p-values are reported in parentheses. ***, **, and * denote significance at the one percent, five percent, and ten percent levels, respectively.

As expected, the signs of 'PRET' and 'Liquidity' variables of their sales are opposite to the signs of purchases. For the sample of "influential patent" firms, estimated coefficients of the 'Pre-apply' variable are significantly negative for all three measures of insider sales. On the other hand, estimated coefficients of 'Pre-apply' are not significantly different from zero for the other two control samples, except for the %equity measure of insider sales.

Panel B reports the similar pattern of insider sales for top management and all insiders but blockholders. For top managers in "inconsequential patent" firms, even the estimated coefficient of %equity measure of insider sales is not significant.

The distinct difference between the sample of "influential patent" firms and control samples indicates that, during the pre-application year, the level of insiders' sales is significantly lower, relative to their trading level during the application year for "influential patent" firms but not for control firms. This finding supports the notion that insiders postpone their planned sales to increase their gains until the filing of influential patents, when the market corporates the favorable information into the stock price.

**Insider Net Purchases**

The net effect of the delay in insiders' purchases and sales is reported in Table 10. After controlling for other determinants of insider trading, the level of net purchases of insiders in "influential patent" firms is significantly higher during the pre-application year than that during the control year. This conclusion holds for each of three insider groups and for each of three measures of the level of insiders' net purchases.

Table 10

*Regressions of Insider Net Purchases*

| Panel A: All insiders' net purchases | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Independent Variables | A.1 "Influential patent" firms | | | A.2 "No-influential patent" firms | | | A.3 "Inconsequential patent" firms | | |
| | Dependent variables | | | Dependent variables | | | Dependent variables | | |
| | #shares | $shares | %equity | #shares | $shares | %equity | #shares | $shares | %equity |
| Ln(market cap) | -0.065*** | -2.949*** | 0.001*** | -0.061*** | -2.170*** | 0.000 | -0.069*** | -4.760*** | 0.000*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.110) | (0.000) | (0.000) | (0.003) |
| σ | -2.036*** | -51.862*** | 0.038 | -2.731*** | -25.869* | -0.008 | -8.954*** | -404.614*** | -0.058*** |
| | (0.000) | (0.002) | (0.131) | (0.002) | (0.069) | (0.817) | (0.000) | (0.000) | (0.006) |
| PRET(-1) | -0.032** | -1.798*** | -0.002*** | -0.014 | -1.166*** | -0.001*** | -0.173*** | -12.165*** | -0.003*** |
| | (0.013) | (0.001) | (0.001) | (0.166) | (0.004) | (0.009) | (0.000) | (0.000) | (0.000) |
| B/M decile | 0.010*** | 0.189** | 0.001*** | 0.015*** | 0.369*** | 0.001*** | 0.010*** | 0.746*** | 0.000*** |
| | (0.000) | (0.034) | (0.000) | (0.001) | (0.000) | (0.000) | (0.006) | (0.000) | (0.001) |
| R&D/Sales | 0.000 | 0.001 | 0.000 | 0.001** | 0.016 | 0.000* | 0.001** | 0.077* | 0.000 |
| | (0.684) | (0.145) | (0.762) | (0.030) | (0.136) | (0.072) | (0.037) | (0.056) | (0.225) |
| Liquidity | -5.259*** | -191.233*** | -0.246*** | -5.665** | -332.803*** | -0.269** | -1.469* | -47.616 | 0.006 |
| | (0.002) | (0.001) | (0.000) | (0.043) | (0.000) | (0.027) | (0.086) | (0.330) | (0.610) |
| Pre-apply | 0.024* | 0.997** | 0.001** | 0.015 | 0.356 | 0.002* | 0.002 | -0.144 | 0.000 |
| | (0.087) | (0.030) | (0.026) | (0.455) | (0.490) | (0.051) | (0.894) | (0.898) | (0.106) |
| Industry FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 4220 | 4220 | 4220 | 4107 | 4107 | 4107 | 3183 | 3183 | 3183 |
| Adjusted $R^2$ | 0.135 | 0.200 | 0.051 | 0.078 | 0.144 | 0.037 | 0.167 | 0.188 | 0.121 |

Table 10 (Continued)

| Panel B: Other insiders' net purchases | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Insider Group | B.1. "Influential patent" firms | | | B.2. "No-influential patent" firms | | | B.3. "Inconsequential patent" firms | | |
| | Dependent variables | | | Dependent variables | | | Dependent variables | | |
| | #shares | $shares | %equity | #shares | $shares | %equity | #shares | $shares | %equity |
| Top managers | 0.006** | 0.204* | 0.000** | 0.005 | 0.069 | 0.000*** | -0.003 | -0.139 | 0.000 |
| | (0.048) | (0.091) | (0.024) | (0.209) | (0.510) | (0.009) | (0.471) | (0.603) | (0.720) |
| All insiders but blockholders | 0.024* | 1.002** | 0.001** | 0.014 | 0.343 | 0.002* | 0.003 | -0.143 | 0.000* |
| | (0.084) | (0.029) | (0.025) | (0.471) | (0.505) | (0.053) | (0.887) | (0.898) | (0.080) |

This table reports the coefficient estimates from OLS regressions of three measures of insiders' net purchases (purchases minus sales). "Influential patent" firms consist of firms with influential patents filed during 1987-2006. "No-influential patent" firms and "inconsequential patent" firms are two control samples. Influential patents are identified as those top ten percent most cited patents of the application year in its technology sub-category based on the USPTO classification. To construct the matched sample of "no-influential patent" firms, each firm-year in the sample of "influential patent" firms is matched to a control firm-year with the closest market capitalization in the same two-digit primary SIC code industry on Compustat in the same year. The sample of "inconsequential patent" firms consists of firm-years in which at least one patent filed is ranked in the bottom ten percent most cited of the application year in its technology sub-category in the NBER database. Both control samples are required to have corresponding data from Compustat, CRSP, and TFI, and did not apply for any influential patent during the sample period. All firms in the three samples are listed on the NYEX, AMEX, or NASDAQ. Insider trading activities are measured during two periods for each firm-year: One is the informed period, the year before the application year; the other is the control period, the year a firm applies for a patent. The dependable variables include: #shares (net number of shares bought by insiders in millions during the year), $shares (net dollar value of shares bought by insiders in millions during the year), and %equity (number of shares bought on the net during a year divided by number of outstanding shares). The top and bottom one percent of the observations of the dependent variables in each regression are winsorized. Market cap is computed as the number of common shares outstanding times the share price at the end of calendar year before pre-application year or application year. The standard deviation of stock returns ($\sigma$) is calculated over the year prior to pre-application year or control year. PRET (-1) is the buy-and-hold return for a firm over one year prior to pre-application year or control year. B/M decile is assigned as one to ten depending on the firm's B/M ratio. I use NYSE B/M decile breakpoints to assign a firm's B/M decile. B/M is calculated as book value of equity divided by market value of equity ratio as of the last year ending prior to the pre-application or application year. R&D/Sales ratio is R&D expense to sales revenue for the last year before the pre-applying or applying year. Liquidity equals to the mean daily trading volume divided by share outstanding during the pre-applying or control year. Pre-apply is a dummy variable equal to one if the insider trading activity occurs during the pre-applying year and zero otherwise. Test statistics are calculated using robust variance. Industry and year fixed effect are included in all regressions. Panel A shows coefficient estimates of regressions of measures of net purchases by all corporate insiders. Panel B only reports the coefficient estimates of 'Pre-apply' variable for regressions of measures of net purchases by top management and by all insiders but blockholders. The p-values are reported in parentheses. ***, **, and * denote significance at the one percent, five percent, and ten percent levels, respectively.

On the other hand, for the two control samples, the level of insiders' net purchases in the pre-application year is not significantly different from those in the control period. The finding indicates that the level of stock net purchases of insiders is significantly higher due to the lower level of their sales in the pre-application year before filing an influential patent, even though the level of their actual purchases does not change. This trading pattern is similar to the passive trading pattern of target firms' insiders before takeover announcements in Agrawal and Nasser (2012). There is no evidence of such passive trading in two control samples.

## Summary and Conclusions

In this study, I empirically examine whether insiders trade shares based on a firm's innovation output, measured by the filing of an influential patent. Using patents as a proxy for innovation output, I analyze insiders' open market trading in a sample of 2,470 firm-years in which influential patents were filed during the period 1987-2006. We define influential patents as those top ten-percent most cited patents of the application year in its three-digit technology sub-category based on the USPTO classification. I compare the level of insider trading in the sample of "influential patent" firms to the level in each of two control samples, an industry-year-size matched sample of "no-influential patent" firms and an unmatched sample of "inconsequential patent" firms. I separately examine insiders' purchases, sales and net purchases during the pre-application year (an informed period) and the application year (a control period) for each of three samples. For each sample, I focus on the open market stock transactions of three groups of corporate insiders: all insiders, top management, and all insiders except for large blockholders.

In regressions controlling for other factors related to insider trading, I find an interesting pattern of insider trading activities for the "influential patent" firms during the calendar year before an influential patent is applied for. Insiders in "influential patent" firms reduce their purchases in the pre-application year, though not significantly, relative to their trading level during the application year. Nevertheless, their net purchases are significantly higher for the same period due to the significantly larger reductions in their sales. This pattern of passive trading holds true for each insider group and for each of three measures of insider trading. I find no such significantly consistent pattern in the "no-influential patent" and "inconsequential patent" firms. The passive trading pattern of insiders in "influential patent" firms is similar to the findings of Agrawal and Nasser (2012) on the trading behavior of target firms' insiders before takeover announcements.

My findings suggest that managers have strong information advantages in discriminating the quality of patents even before the application of patents, and they tend to engage in passive insider trading activities only before an influential patent is filed.

# CHAPTER TWO

# EXECUTIVE STOCK OPTION EXERCISES AND OPTION GRANTS DURING THE APPLICATION PROCESS OF INFLUENTIAL PATENTS

## Introduction

Corporate insiders are well known to possess superior information about a firm's future performance, and they may utilize that information advantage to earn private benefits. This study empirically investigates whether exercising and awarding executive stock options (ESO) are correlated with firms' innovation output, represented by the application of an influential patent. Aboody and Lev (2000) study research and development (R&D) expenses, a major innovation input, as a potential source of personal gains from insider trading given the relative scarcity of public information on firms' R&D activities and the importance of R&D activities to firms' profit potential. They argue that R&D activities create unique information asymmetries between corporate insiders and outside investors, and they find that personal gains from insider trading in firms conducting R&D are significantly larger than those in firms with no R&D activities. Given the uncertainty and inefficiency of the innovation process, the outcomes of innovation, rather than R&D expenditures, provide better information on the innovation's potential economic impact on firms' future performance. Using patents to proxy for innovation output, I hypothesize that patents, especially influential patents

(patents that are ranked in the top ten percent most cited for the technology sub-category in the application year), contribute most to information asymmetry, and that some insiders may exploit this asymmetry to earn profits from ESO exercises or option grants.

I explore ESO exercises and option grants during the application process of an influential patent for three reasons. First, I focus on ESO exercises and option grants in the year prior to the filing date of an influential patent, as insiders have more private information during this period when the firm is preparing the patent application after an early stage of R&D. Information about influential patents is revealed at different stages to different stakeholders (Ahuja, Coff, and Lee, 2005). Even in the stage of filing for a patent, information about the innovation may be kept confidential until the patent is granted since the public disclosure of the patent application is not required (Ahuja, Coff, and Lee, 2005). Generally, it takes about two years for a patent application to be granted (Hall, Jaffe, and Trajtenberg, 2001). Therefore, information asymmetries between managers and investors exist during the lengthy process of patent application. The information advantage provides managers a long time lag to pursue personal interests through conducting insider trading or influencing the timing of option grants. Accordingly, I investigate ESO exercises and grants around the filing and granting dates of influential patents.

Secondly, I center on influential patents since the significance or value of each individual patent varies enormously. Among the large amounts of patents granted in the U.S every year, [3] only a few are extremely valuable, while many others have comparatively little value (Pakes and Schankerman, 1984). To evaluate the significance

[3] According to Hall, Jaffe, and Trajtenberg (2001), over 150,000 patents are granted by the US Patent and Trademark Office (USPTO) every year.

of a firm's innovation requires expertise in the relevant field and the knowledge of the future development of an industry. It is hard for most outsiders who possess little knowledge to determine the importance of a firm's patent. Even when a patent (the innovation outcome) is granted with detailed technical information, most outside investors would not be able to estimate its economic potential. However, executives who are aware of the innovation since its inception (several years) possess large amounts of private information. They may have a strong notion of a patent's ultimate importance as early as the stage of preparing for the patent application. Therefore, during a patent's application process, executives may engage in profitable trading activities opportunistically since they are better informed than outsiders about the high future value of an influential patent.

Thirdly, I concentrate on informed ESO exercises and unscheduled option awards. Executives may be more likely to engage in opportunistic option-related activities for personal gains than engage in common stock trading when they possess private information about the quality of a patent. Exercising ESOs and granting options may be motivated by a number of other factors unrelated to private information. It is not easy for outsiders to distinguish option exercises and grants likely to be associated with private information from those that are not. Therefore, the opportunistic option exercises and option awards may receive less attention from the Securities and Exchange Commission (SEC) than insiders' open market transactions.

Unlike open market trading, executives lose the time value of money associated with the ESO exercise price by exercising options prior to the expiration. However, executives may offset this loss with the profits gained from their private information.

Early exercise occurs when the benefits from the private information outweigh the costs related with early exercise. Specifically, I exclude the exercises motivated by other factors unrelated to private information, such as liquidity, diversification, and dividend capture, and exclusively focus on potentially informed exercises which are more likely to contain private information. Therefore, compared to insiders' common stock trading, the informed option exercises may be associated more with material information regarding future stock price performance. Using the method in Brooks, Chance, and Cline (2012) and Bradley, Cline, and Lian (2012), I identify informed option exercises as those exercised early, not around a vesting or ex-dividend date, and where the underlying shares were immediately sold.

Since most options have an exercise price equal to the stock's market price at the grant date, the timing of stock options awards is crucial enhancing the executives' option value. Executives prefer to receive options on dates when the company stock price is relatively low. Previous studies find that managers are aware of the change of their firm's stock price due to innovation (i.e. Ciftci, Lev, and Radhakrishnan, 2011; Barth, Kasznik, and McNichols, 2001; Gu, 2005; Ciftici, 2012); therefore, top executives may exploit this foresight by influencing the timing of option awards. Most companies have schedules to grant options to top executives on roughly the same dates of every year; therefore, it is unlikely that executives can influence the timing of these scheduled option grants. The unscheduled option grants, however, are more flexible and more likely to contain related private information. Following Lie (2005) and Heron and Lie (2007), I identify an option award as unscheduled if it does not occur within one day of the one-year anniversary of the prior year's award date. I hypothesize that corporate executives may be awarded more

unscheduled stock options before the filing of an influential patent when the stock price has not appreciated, and may receive less unscheduled stock options after the filing date.

Based on the patents literature, I define an influential patent as one with high future citation impact. Trajtenberg (1990) argues that simple patent counts are not informative about innovative output. He then claims that citations are a better indicator of the value of innovations and thus overcome the limitations of simple counts. An influential patent, which may explore a new area of technology, or is the first to find solutions to long-standing problems, is the most valuable. When granted, a patent is required to cite all previous patents upon which this new technology builds. Influential patents are expected to receive more citations in the future since subsequent innovations may be built upon the initial technology. Recent studies have shown that citations of a patent contain valuation-relevant information and may be used as an accurate measure of the patent's value (see, e.g. Hall, Jaffe, and Trajtenberg, 2005; Gu, 2005; Matolcsy and Wyatt, 2008; McGahee, 2011; Pandit, Wasley, and Zach, 2011). Since citations are generally received for years after the initial patent is granted and suffer from a truncation bias,[4] I measure the impact of a patent by using the total adjusted citations received by the patent. Specifically, I define an influential patent as one that is ranked in the top ten percent most cited of the application year for the three-digit technology sub-category based on the USPTO classification.

[4] The older patents have less truncation issue. For example, a patent that was granted in 1999 would have much more time to receive citations than a patent created in 2004 because the patent data used in the paper ends in 2006. Following Hall, Jaffe, and Trajtenberg (2001, 2005), I multiply the number of citations by a weighting index to correct for the truncation bias. The index is higher for later years.

Applying patent data compiled from patent filings with the US Patent and Trademark Office (USPTO) by the National Bureau of Economic Research (NBER), I examine ESO exercises for 654 firm-events, each with an influential patent filed during the period 1996-2006, and 654 industry-year-size-performance matched control firm-events with non-influential patents filed, both during an informed and a control period. The one-year period prior to the filing date of a patent is defined as the informed period, and the one-year period following the patent's filing date is defined as the control period. I study the change of the aggregated option exercises by all insiders in a firm during the informed period and the control period. The difference-in-differences (DID) methodology is used in the analysis.

In regressions of measures of ESO exercises controlling for related factors, I find a significant pattern of delayed option exercises from one year before filing the influential patent until the year after that. Compared to exercises over the year following the filing date of an influential patent, executives significantly reduce their option exercises in the informed period. No such pattern of significantly delayed option exercises is present in the matched control sample. It is reasonable to assume that executives are cognizant that their private information on the potential value of influential innovation will gradually be incorporated into the stock price after the filing of a patent. Therefore, executives may delay exercising their options until the stock price runs up to maximize their stock option compensation. The pattern of reducing ESO exercises before an influential patent's filing date is similar to the evidence from Agrawal and Nasser (2012) which indicates insiders of target firms significantly reduce stock sales before takeover announcements.

Next, I examine whether executives influence unscheduled option grants with the expectation of appreciation in the stock value after an influential patent is filed by the firm. I discover no evidence of abnormal option grants around the application date of an influential patent. However, when the informed period is redefined as the one-year period before granting a patent and the control period as the year after that, I do find that executives receive more options in the year before the grant date of an influential patent than the year after the grant date. There is no such pattern of option grants in the matched control sample. Although the grant date of an influential patent depends upon the review process at the USPTO, top executives may be able to forecast the approximate date and have more confidence in the potential appreciation of stock price after the announcement of the patent being granted. The results are supported by the point I discussed earlier that information about a firm's innovation may be kept confidential until the patent is granted (Ahuja, Coff, and Lee, 2005). Consistent with prior studies, I find that executives' option grants coincide with the stock's price change, which is more significant around the grant date than around the filing date of an influential patent. This finding further demonstrates that managers have an informational advantage over patent production and they may benefit from it through timing unscheduled option awards.

## Background on Executive Stock Option Exercises, Option Grants, Innovation, and Patents

### *Executive Stock Option Exercises*

Executive stock options have been broadly used as a form of performance based incentive compensation to align the long-term interests of shareholders and managers. The large amounts of option grants also provide executives with incentives to act

opportunistically to maximize the expected value of their stock and option portfolios. Generally, ESOs are non-transferable, non-hedgeable, and have vesting restrictions (forfeitable). It is reasonable for risk-averse, wealth-undiversified executives to exercise their options early for diversification or liquidity needs. Existing literature mainly examines the motives and policies of exercise behavior and provides substantial evidence that a considerable number of stock options are exercised early (see, e.g., Ofek and Yermack, 2000; Hall and Murphy, 2002; Bettis, Bizjak, and Lemmon, 2005). Fu and Ligon (2010) summarize a number of reasons to optimally exercise an ESO early, such as capturing the current intrinsic value by risk-averse executives, diversifying away the unsystematic risk associated with an underdiversified portfolio, liquidity needs of executives, or insider information. By segregating the private information factor from several other motivating factors in early exercises, Brooks, Chance and Cline (2012) find that early exercises account for about 94% of all exercises and there is strong evidence indicating that executives use private information when exercising their stock options.

One objective of my study is to identify the specific source of insiders' information leading to early exercises of stock options. The majority of previous studies investigate the information content of ESO exercises for future returns, but evidence is mixed. Considering the regulatory change on the periods of holding exercised options in May 1991,[5] Carpenter and Remmers (2001) find during 1992–1995, insider exercises are preceded by positive stock returns in the weeks prior to exercises, and are not followed by negative abnormal stock returns after exercises except for top managers at small firms.

[5] Before May 1991, insiders had to hold the stock acquired through option exercise for six months. This holding restriction was removed in May 1991, thus insiders have been able to sell acquired shares immediately if the options have been hold for at least six months.

They conclude that insiders do not use insider information to time exercises since insiders have been able to sell acquired shares immediately. In contrast, Huddart and Lang (2003) examine the option exercises by employees at seven firms, and find that when option exercises are high, stock returns in the next six months are ten percent lower than when option exercises are low. They then argue that the exercise decisions of both executives and junior employees contain price-relevant information. Using data between 1996 and 2005, Brooks, Chance and Cline (2012) also document significantly lower abnormal returns following exercises for samples that should be motivated by private information than samples that should not. It is broadly accepted that if executives have negative information, they would sell shares immediately after exercises, and the stock would more likely perform poorly for a period after exercises. In another context, influential patents play a significant role in maintaining the firms' competitive edge and deciding the firms' future value. The filing of an influential patent would signal positive information for executives in enhancing the firm's market performance. One may wonder about the pattern of option exercises when executives have positive information on the quality of a patent. Therefore, I examine whether corporate executives use private information to time the exercises of stock options when the firm has an influential innovation on the way. Specifically, I focus on exercises that are identified as potentially informed exercises, based on the method used in previous option literature (Brooks, Chance, and Cline, 2012; Bradley, Cline, and Lian, 2012).

### *Option Grants*

One key feature of options is that the exercise price of an option is equal to the stock's market price on the grant date. This feature makes the timing of stock options

awards crucial in enhancing the executives' option value. Executives prefer to receive options on dates when the company stock price is relatively low. According to Lie (2005), if executives can influence the timing of a grant, they might time it to occur either after an expected stock price decrease or before an anticipated stock price increase. Yermack (1997) and Aboody and Kaszznik (2000) provide evidence that CEOs receive stock option awards shortly before the favorable corporate news. Yermack (1997) argues that CEOs time option grants before good news or after bad news. Aboody and Kaszznik (2000) concentrate on a sample of firms with fixed award schedules and document that CEOs manipulate the timing of the news disclosure around scheduled option awards by delaying positive information or rushing negative information. Compared with scheduled option awards, which occur on nearly identical award dates every year, unscheduled option awards provide executives with more flexibility to manipulate and enhance the value of their awards. Focusing on a sample of unscheduled awards, Lie (2005) first proposes the "backdating hypothesis" to explain the systematically favorable stock price patterns surrounding option grant dates documented in earlier studies. Lie reports that the predicted returns from the three-factor model are abnormally low before unscheduled ESO awards and abnormally high afterward. Other than the "backdating hypothesis", another possible explanation suggested by Lie is that executives might have an informational advantage that allows them to develop superior forecasts regarding future market movements. When executives have positive information, they may expect future price increases and thus influence the unscheduled options to be awarded when a firm's stock price hits a low point.

More recently, Fich, Cai, and Tran (2011) find that unscheduled options are awarded to many target firms' CEOs during private merger negotiations as a substitute for golden parachutes and compensation for the benefits they forfeit because of the merger. Their results show that when target CEOs expect large pay losses after the merger goes through, their firms are more likely to extend them unscheduled options during merger negotiations. Ali, Wei, and Zhou (2011) examine option grant timing in response to fire sales and purchases of stocks by mutual funds. Their study illustrates that insiders enhance personal benefits by influencing the timing of option grants in response to the underpricing of their stock caused by fund-flow-induced price pressure.

### *Innovation and Patents*

Technological innovation in general brings long-term economic benefits to firms (Griliches, 1984, 2000). At the same time, innovation-intensive firms present more severe information asymmetries. Ciftci, Lev, and Radhakrishnan (2011) find that, compared with low R&D intensity firms which mimic and extend existing technologies, high R&D intensity firms which engage in basic research activities are likely to suffer from higher information asymmetry. In general, innovation-intensive firms share several common features, such as owning a relatively large amount of intangible assets, utilizing more resources for technology and innovation, and being more likely to have a fast changing technical environment, which increase the difficulty for market participants to accurately assess the firm's future prospects. Because intangible assets typically are unrecognized and estimates of their fair values are not disclosed, investors depend more on analyst information in R&D-intensive firms (Barth, Kasznik, and McNichols, 2001). However, even investors and analysts cannot fully value the implication of enhanced innovation

capabilities and underestimate future earnings of R&D-intensive firms (Gu, 2005; Ciftici, 2012). Furthermore, CEOs or top executives in R&D-intensive companies are mostly engineers or experts in their field, which increases the difficulty of monitoring by shareholders who are without the relevant technology knowledge. Therefore, compared to other firms, R&D-intensive firms generally have a less effective and less efficient monitoring mechanism, which, accordingly, provides top managers in R&D-intensive firms more flexibility to pursue their own interests.

Existing studies have paid little attention to the role of innovation as an important source of information asymmetries leading to executives' personal gains from insider trading. Focusing on R&D expenditures, Aboody and Lev (2000) point out that R&D is a major contributor to information asymmetry and that some insiders will exploit this asymmetry to gain from insider trading. Their findings indicate that insider gains in R&D-intensive firms are substantially larger than those in firms without R&D. According to Coff and Lee (2003), investors may assume that insider trading reflects managers' attempts to profit from their private information and view managerial trading as a signal about the firm's prospects. They test the relationship between R&D intensity and investor responses to announcements of insider-trading events. They find that insider purchases generate larger positive stock price reactions for R&D-intensive firms, which indicates that insider purchases have greater signaling value to investors in R&D firms.

Patents, an important indicator of innovative output, have been broadly used in the literature as a measure of an individual firm's technological progress. Using patent citations to proxy for the economic value of innovation, Pandit, Wasley, and Zach (2011) find that a firm's future operating performance is positively associated with the quality of

patents. Gu (2005) and Hirshleifer, Hsu, and Li (2013) find similar evidence. After analyzing the association between technology competition and bankruptcy, Eisdorfer and Hsu (2011) show that technologically innovative firms are less likely to go bankrupt. Hsu, Lee, Liu, and Zhang (2011) use a firm's patent records to measure its innovation competitiveness, and find that patenting activities provide valuable incremental information to bondholders beyond R&D investments. They report that non-insider bondholders use the number of granted patents and associated citations to assess the economic value of innovations and to price bonds of patent-owning firms accordingly. The conclusion from these studies is that patents provide useful information in evaluating a firm's innovative capability and understanding the relationship between innovation and financial performance.

When granted, a patent is required to cite all previous patents upon which this new technology builds. Accordingly, an influential patent can represent a platform upon which future innovations will be based and is expected to receive more citations in the future. These studies have shown that citations contain valuation-relevant information and may be used as an accurate measure of the patent's value. After multiplying the number of citations by a weighting index to correct for the truncation bias (Hall, Jaffe, and Trajtenberg, 2001 and 2005), I use total adjusted citations received to measure the success and the value of a patent. I identify influential patents as those ranked in the top ten percent most cited patents of the application year in its three-digit technology sub-category based on the USPTO classification.

However, as a source of information asymmetry and an incentive for insider trading, patents have received much less attention in existing research. Ahuja, Coff, and

Lee (2005) study insider trading on knowledge of imminent breakthroughs, and find that managers purchase stock well before breakthrough patents are filed. They define breakthrough patents as patents which were filed and ranked in the top ten percent most heavily cited in their technology subfield. However, their conclusions are based on only three years' patent data from 1988 to 1990. By examining 88 U.S. listed firms with the heaviest patenting for the period 1987 to 1998, Rong (2012) finds strong evidence that a firm's insider trading patterns are significant in explaining the unexpected fluctuations in patent output when controlling for R&D input effect. Rong's finding supports the argument that management has privileged knowledge about its R&D productivity.

Most related literature focuses on insiders' common stock transactions. Stock transactions, however, are not the only means by which executives can exploit private information on innovation. The extensive use of stock options as compensation provides executives with another means of exploiting private information on the quality of patterns. To the best of my knowledge, this study is the first to examine ESO exercises and option grants around the filing of influential patents.

## Sample Selection and Data Description

### *Sample of "Influential Patent" Firms*

The sample is constructed from several databases. Patent data come from the updated National Bureau of Economic Research (NBER) patent database, originally developed by Hall, Jaffe, and Trajtenberg (2001) and revised as of August, 2010. ESO exercises and option grants data is taken from Thomson Financial Insiders Filings database (TFI), which covers the period 1996 to 2007. Stock return and price data is gathered from the Center for Research in Security Prices (CRSP) and financial data is

from Compustat. The NBER database includes detailed information on all patents granted by the US Patent and Trademark Office (USPTO) during the period 1976 – 2006. Patent citations, the key indicator of patent value, suffer from a truncation bias since citations are generally received for years after the patent was granted. The patents that were granted in early years would have more time to receive citations than those granted in more recent years. Thus, each patent's citation is adjusted by multiplying with a truncation weight index, from Hall, Jaffe, and Trajtenberg (2001), and also found in the NBER patent dataset. The NBER data contains the grant dates and the grant years of all patents in the file; however, it only contains the application years for patents granted. Since I investigate executives' option exercises and option grants around the filing date of an influential patent, I collect the application date for each influential patent from the USPTO's website. The application date is then used as the relevant event time for the study of executives' option behavior.

The initial patent data is constructed using all patents applied for during the period 1996-2006, [6] except those missing a unique assignee number, or missing a citation truncation weight as of 2006, or with the status 'M' (missing) or 'W' (withdrawn). Specifically, I define influential patents as patents that are ranked in the top ten percent most cited of the application year in its three-digit technology sub-category in the NBER database, and whose total adjusted citations are not equal to zero. I then eliminate observations (influential patents) with firm-years not listed, or which have incomplete coverage in CRSP, Compustat, or the TFI insider filings database. To avoid overlap, if a firm has multiple influential patents during the sample period, I only examine the

[6] My option data ends in 2007 since the patent data ends in 2006 and I need one year of option exercise data after the application of a patent.

influential patents whose filing dates are separated by at least two years (730 days). This method leads to the final sample of 654 influential patents filed by 564 distinct firms. For the sample of "influential patent" firms, only one influential patent is included for each firm in a single year.

The USPTO continuously updates its classification system (about 400 three-digit patent classes) for the patented inventions. The 654 influential patents belong to 216 patent classes. Hall, Jaffe, and Trajtenberg (2001) develop a higher-level classification and aggregate all the classes into six main categories: Chemical (excluding Drugs); Computers and Communications; Drugs and Medical; Electrical and Electronics; Mechanical; and Others. Based on their classification, I present the distribution of technology classes for the sample of influential patents in Table 11. Average cites and adjusted cites (the citation times the truncation weight index) are also provided. More than one quarter (28%) of these influential patents belong to the Computers and Communications category. They also have the highest average citation count at 22.1 and adjusted citation count at 68.95. The remaining influential patents distribute almost evenly among the other five categories from 11.3% to 17.4%.

Table 11

*Summary Statistics of Influential Patents*

| Cat. Code | Category Name | # of influential patents | Percentage Count | Average Cites | Average Cites Adjusted for Truncations |
|---|---|---|---|---|---|
| 1 | Chemical | 78 | 11.9% | 10.44 | 31.33 |
| 2 | Computers & Communications | 183 | 28.0% | 22.10 | 68.95 |
| 3 | Drugs & Medical | 99 | 15.1% | 12.17 | 36.17 |
| 4 | Electrical & Electronic | 114 | 17.4% | 13.37 | 42.43 |
| 5 | Mechanical | 74 | 11.3% | 13.16 | 35.64 |
| 6 | Others | 106 | 16.2% | 12.43 | 34.96 |
| | **Total** | 654 | 100.0% | 15.11 | 45.6 |

This table provides the distribution of technology classes, average cites, and average adjusted cites for the sample of 654 influential patents. Influential patents are identified as those top ten percent most cited patents of the application year in its three-digit technology sub-category based on the USPTO classification. I exclude those top ten percent most cited patents with total adjusted citations equal to zero. To avoid overlap, if a firm has multiple influential patents during the sample period, I only examine those influential patents whose filing dates are separated by at least two years. The adjusted cite is computed as the citation times the truncation weight index from the NBER patent dataset.

### *The Cross-Sectional Matched Sample*

A matched control sample is constructed to compare abnormal informed option exercise behavior and assess abnormal performance. Since option exercises often follow periods of positive performance, for each firm-event in the sample of "influential patent" firms, a matched firm is identified according to industry, year, size, and prior firm performance. The matched sample of "no-influential patent" firms is required to have corresponding data on Compustat and CRSP datasets, with at least one prior-year return on CRSP and have stock options available on the TFI filing dataset. The same control sample is also used for the comparison of abnormal unscheduled option grants.

To construct the potential matching pool, I first keep firms with patents whose citations are ranked below the median value of citations of its three-digit technology class in the application year. I then exclude any firm with influential patents filed during the

period 1996 to 2006. For each firm-year in the sample of "influential patent" firms, I identify all "no-influential patent" firms in the pool of possible matching firms within the same two-digit primary Standard Industrial Classification (SIC) code in the same year. Following the matching procedure in Bradley, Cline, and Lian (2012), I then choose a matching firm which has an absolute percentage difference of market capitalization less than ten percent, and has the minimum absolute percentage difference of prior-year returns between the sample and matching firms. If a potential matching firm-year cannot be found from the same two-digit SIC industry, I repeat the same procedure on the same one-digit SIC industry, then I run the matching process again without the industry requirement. If it is still not able to match all firm-years, I relax the restriction on the percentage differences of market capitalization to be 100%. For the remaining matching, I relax the restriction on the percentage differences of prior-year returns and add the requirement for the minimum difference of market capitalization. The matching procedures are without replacement. A matching firm may apply for more than one patent in the matched year. To construct the sample of "no-influential patent", one patent with the lowest value of citations is randomly chosen for each firm-event, and then I collect the application date for each patent from the USPTO's website. Finally, the matched sample of "no-influential patent" firms consists of 654 firm-events, corresponding to 393 distinct firms. Only one patent is included for each firm in a single year.

Table 12 reports mean and median values of financial and operating characteristics for the sample of "influential patent" firms and control sample. Using p-values of t-tests and median tests, Table 12 also reports differences in means and in medians between "influential patent" and "no-influential patent" firms.

Table 12

*Descriptive Statistics of Sample Firms*

| | Mean | | | Median | | |
|---|---|---|---|---|---|---|
| | (1) "Influential patent" firms | (2) "No-influential patent" firms | p-value (1)-(2) | (1) "Influential patent" firms | (2) "No-influential patent" firms | p-value (1)-(2) |
| Firm size | | | | | | |
| Market value of equity ($ mill.) | 2045 | 2475 | 0.392 | 411 | 401 | 0.843 |
| Sales ($ mill.) | 1362 | 1789 | 0.246 | 216 | 226 | 0.710 |
| Total assets ($ mill.) | 3255 | 2489 | 0.555 | 267 | 254 | 0.755 |
| Firm value ($ mill.) | 4678 | 4184 | 0.737 | 568 | 536 | 0.843 |
| Stock volatility and prior returns | | | | | | |
| σ (%) | 4.04 | 4.15 | 0.356 | 3.81 | 3.80 | 1.000 |
| PRET(-1) (%) | 36.82 | 25.53 | 0.073 | 10.00 | 6.88 | 0.378 |
| Growth | | | | | | |
| B/M | 0.47 | 0.50 | 0.118 | 0.38 | 0.41 | 0.049 |
| Firm value/Total assets | 2.88 | 2.57 | 0.056 | 1.90 | 1.75 | 0.073 |
| Sales growth rate (%) | 15.24 | 13.17 | 0.418 | 8.83 | 7.74 | 0.462 |
| Operating performance (%) | | | | | | |
| OPA(-1) | 2.26 | -1.10 | 0.024 | 8.49 | 6.28 | 0.002 |
| OPA(-2) | 1.98 | -0.92 | 0.133 | 8.57 | 7.81 | 0.381 |
| OPA(-3) | 2.29 | 1.00 | 0.556 | 9.29 | 8.45 | 0.281 |
| OPA | 1.91 | 0.04 | 0.299 | 8.24 | 7.42 | 0.223 |
| Financial leverage | | | | | | |
| Long-term debt/total assets | 0.14 | 0.15 | 0.185 | 0.07 | 0.09 | 0.231 |
| Long-term debt/firm value | 0.09 | 0.10 | 0.094 | 0.03 | 0.04 | 0.189 |

This table provides summary statistics of firm characteristics for the sample of "influential patent" firms and control sample. The sample of "influential patent" firms consists of firms with influential patents filed during 1996-2006. Influential patents are identified as those top ten percent most cited patents of the application year in its three-digit technology sub-category based on the USPTO classification. I exclude those top ten percent most cited patents with total adjusted citations equal to zero. To avoid overlap, if a firm has multiple influential patents during the sample period, I only examine those influential patents whose filing dates are separated by at least two years. The sample of "no-influential patent" firms is the industry-year-size-performance matched control sample. The pool for the control sample consists of firms with patents whose citations are ranked below the median value of citation of its technology class in the application years. Firms in the pool are required to have corresponding data on Compustat, CRSP, and TFI, and did not apply for any influential patent in the sample period. For each "influential patent" firm, I identify a "no-influential patent" firm in the pool with the same two-digit primary SIC code, an absolute percentage difference of market capitalization less than ten percent, and the minimum difference of prior-year returns in the same year. A firm in the matched sample may apply for multiple patents in the matched year. To construct the sample of "no-influential patent", one patent with the lowest value of citations is randomly chosen for each firm-event.

Table 12 (Continued)

All firms in the two samples are listed on the NYEX, AMEX, or NASDAQ. Each of the "influential patent" and the "no-influential patent" firms consists of 654 firm-events. Market value of equity is measured at the end of calendar year prior to the filing date. Firm value equals (book value of total assets – book value of equity + market value of equity). Firm value, sales, total assets, and financial leverage ratios are for the fiscal year prior to the application year. Stock return volatility ($\sigma$) is the standard deviation of stock returns over trading days (-1, -365) relative to the application date of a patent. PRET(-1) (prior stock returns) is computed as the buy-and-hold returns over trading days (-1, -365) relative to the application date. B/M is calculated as book value of equity divided by market value of equity as of the end of the last calendar year before the year applying a patent. Sales growth is defined as $[\text{sales}(-1)/\text{sales}(-5)]^{1/4}-1$. OPA(t) is the operating performance to total assets for year t relative to the application year (t=0). Operation performance is operating income before depreciation. OPA is the mean of OPA(t), equal to (OPA(-1)+OPA(-2)+OPA(-3))/3. Other than what is stated, all other financial data are from Compustat. The differences in means between two samples are tested by two independent samples t-test, and the differences in medians are tested by Wilcoxon-Mann Whitney test. P-values are reported.

The two samples are comparable in most measures of financial and operating characteristics. Measures of firm size, financial leverage and the first two growth measures are for the end of the last fiscal year before a patent is filed. All measures of firm size indicate that two samples are similar in size, with a mean market capitalization (total assets) of $2,045 million ($3,255 million) in "influential patent" firms and $2,475 million ($2,489 million) in "no-influential patent" firms. The mean daily stock volatility in "influential patent" firms is 4.04%, similar to the one in "no-influential patent" firms, 4.15%. Two growth measures, the B/M ratio and sales growth ratio, show that the growth opportunities are similar in the two groups. Measured by operating income before depreciation to total assets, the average operating performance over the prior three years has no significant difference between the two samples. The measures of financial leverage for the two samples are very close as well. The prior stock returns are significantly different at ten percent level.

*Time-Series Control*

For each observation in the sample of "influential patent" firms and the matched control sample, I compare the levels of informed option exercises and unscheduled option grants during the informed and control periods. The informed period is the one-year period before a patent's filing date (the pre-application period), and the control period is the one-year period after that (the post-application period). I examine informed option exercises between the pre-application and post-application periods of a patent because, as I discussed, generally, insiders exercise their stock options more frequently when the stock price is high and less frequently when the stock price is low. With the foresight and confidence that the market will gradually realize the economic value of an influential patent and incorporate this information into the stock price, executives would like to postpone their informed option exercises until the price runs up in the year after an influential patent has been filed.

**Stock-Price Reaction when an Influential/ Inconsequential Patent Is Granted**

I verify the positive association between influential patents and the filing firm's future stock performance by examining the stock-price reaction when an influential patent is granted. For comparison, I further present corresponding reaction when a non-influential patent is granted.

The abnormal return of stock $i$ on day $t$ is computed as:

$$e_{it} = r_{it} - r_{mt}, \tag{5}$$

where $r_i$ and $r_m$ are the stock returns for firm i and the market, respectively. The market return is the return on the CRSP value-weighted stock index. I then calculate the cumulative abnormal return (CAR) for firm i over days ($t_1$, $t_2$) as:

$$CAR^{i}_{t_1,t_2} = \sum_{t=t_1}^{t_2} e_{it} . \quad (6)$$

Table 13 reports the mean and median values of CARs and the average CARs differences for the samples of "influential patent" and "no-influential patent" firms over three windows covering the trading days (-1, +1), (-5, +5) and (-20, +5) around the announcement date of a patent being granted (day 0). Since some firms have no available return data on CRSP around the patent's grant date, the observation size for influential patents granted (non-influential patents granted) is 649 (641), corresponding to 564 (393) applying firms in 654 (654) application firm-events.

Table 13

*Stock-Price Reaction when an Influential/Non-influential Patent Is Granted*

| Category | N | Days around announcement | | | | | |
|---|---|---|---|---|---|---|---|
| | | Mean | | | Median | | |
| | | (-1,+1) | (-5, +5) | (-20, +5) | (-1,+1) | (-5, +5) | (-20, +5) |
| (1) Influential patents granted | 649 | 0.53** | 1.33** | 1.94** | -0.07 | 0.03 | 1.05 |
| (p-value) | | (0.0351) | (0.0136) | (0.0139) | (0.3980) | (0.2916) | (0.1229) |
| (2) Non-influential patents granted | 641 | 0.30 | 0.91* | 2.50*** | -0.11 | 0.08 | 0.25* |
| (p-value) | | (0.4012) | (0.0918) | (0.0023) | (0.7222) | (0.5311) | (0.0641) |
| (1) vs. (2) difference | | 0.23 | 0.42 | -0.56 | 0.04 | -0.05 | 0.80 |
| (p-value) | | (0.5937) | (0.5810) | (0.6204) | (0.8675 | (0.8674) | (0.3440) |

This table reports the mean/median cumulative abnormal returns (CARs) and average CARs differences for three windows around a patent's granting date (day 0) for the samples of "influential patent" firms and "no-influential patent" firms. The sample of "influential patent" firms consists of firms with influential patents filed during 1996-2006. Influential patents are identified as those top ten percent most cited patents of the application year in its three-digit technology sub-category based on the USPTO classification. I exclude those top ten percent most cited patents with total adjusted citations equal to zero.

Table 13 (Continued)

To avoid overlap, if a firm has multiple influential patents during the sample period, I only examine those influential patents whose filing dates are separated by at least two years. The sample of "no-influential patent" firms is the industry-year-size-performance matched control sample. The pool for the control sample consists of firms with patents whose citations are ranked below the median value of citation of its technology class in the application years. Firms in the pool are required to have corresponding data on Compustat, CRSP, and TFI, and did not apply for any influential patent in the sample period. For each "influential patent" firm, I identify a "no-influential patent" firm in the pool with the same two-digit primary SIC code, an absolute percentage difference of market capitalization less than ten percent, and the minimum difference of prior-year returns in the same year. A firm in the matched sample may apply for multiple patents in the matched year. To construct the sample of "no-influential patent", one patent with the lowest value of citations is randomly chosen for each firm-event. All firms in the two samples are listed on the NYEX, AMEX, or NASDAQ. There are 649 (641) influential patents (non-influential patents) with available firms' return data on CRSP around the grant date, corresponding to 564 (393) applying firms in 654 (654) application firm-events. For each patent granted, the abnormal return for trading day t is calculated as the daily return on the stock minus the value-weighted CRSP index on day t. Both returns include dividends. Mean/median and differences values are reported as percentages. The differences in means are tested by two independent samples t-test, and the differences in medians are tested by Wilcoxon-Mann Whitney test. P-values are reported in parentheses. ***, **, and * denote significance at the one percent, five percent, and ten percent levels, respectively.

Over the three trading days (-1, +1), firms with influential patents granted experience a positively mean CARs of about 0.53%, which is statistically significant at the five percent level, while the mean CARs in firms with non-influential patents granted is not significant. Over the longer trading windows of days (-5, +5) and (-20, +5), firms with influential patents granted experience positively larger mean CARs of about 1.33% and 1.94%, both are statistically significant at the two percent level; firms with non-influential patents granted also experience positive mean CARs of about 0.91% and 2.50%, both are statistically significant. The results show that the stock price reacts positively to the news that an influential patent has been granted. The favorite market reaction to an influential patent when it is granted additionally suggests that non-public information does exist in firms with influential patents for a long period until the granting of the patent.

The CARs of firms with influential patents are not significantly higher than those of firms with non-influential patents at any reasonable statistical level. As stated, the

matched control sample of "no-influential patent" firms is selected from the pool of firms with patents whose citations are ranked below the median value of citation of its three-digit technology class in the application year, and a non-influential patent is randomly chosen from patents with the lowest value of citations for each "no-influential" firm-event. This randomicity may have led to the insignificant differences between the CARs of firms announcing the news of patents being granted.

*Long-Run Stock Performance*

Next, I compare the long-run stock performance of the sample of "influential patent" firms and the matched control sample without any influential patent filed in the sample period. The standard Fama and French (1993) three-factor model is used to estimate the long-run abnormal returns for firms in each sample:

$$R_t - RF_t = \alpha + \beta_1 MKTRF_t + \beta_2 HML_t + \beta_3 SMB_t + \varepsilon_t, \quad (7)$$

where $R_t$ is the monthly stock return for a firm, $RF_t$ is the monthly risk-free rate, $R_t$- $RF_t$ is the excess return, $MKTRF_t$ is the excess return on the market, measured as the value-weighted market return minus the risk-free rate, $HML_t$ (High Minus Low) is the average return on the two highest value (high book-to-market) portfolios minus the average return on the two highest growth (low book-to-market) portfolios, and $SMB_t$ (Small Minus Big) is the average return on the three smallest capitalization portfolios minus the average return on the three biggest capitalization portfolios. The alpha (α) coefficient represents the difference between the predicted monthly returns by the three factors and the actual monthly returns, so alpha is viewed as the long-run abnormal return.

Table 14 reports the average long-run abnormal returns and the average return differences between the sample of "influential patent" firms and the control sample in 36

months after the filing month (month 0). For the first year following the application month (month one to 12), the abnormal returns of "influential patent" firms and "no-influential patent" firms are not significantly different at 1.07% and 1.18%, respectively. The control firms even have a significant and higher average abnormal return than "influential patent" firms. However, when investors hold the stock for a longer time, "influential patent" firms outperform the control firms. For two or three years following the application month (month one to 24 or month one to 36), the mean abnormal returns for "influential patent" firms are1.79% and 1.64%. Both are significant at one percent level and higher than those for the control firms, though the returns difference in the months (1, 24) is not significant.

Table 14

*Long-Run Stock Performance*

| Month | N | Mean long-run abnormal returns (%) | | Returns Difference (%) | |
|---|---|---|---|---|---|
| | | (1) "Influential patent" firms | (2) "No-influential patent" firms | (1) – (2) | t-stat |
| (1,12) | 654 | 1.07 | 1.18*** | -0.11 | -0.14 |
| (1, 24) | 654 | 1.79*** | 1.49*** | 0.3 | 1.25 |
| (1, 36) | 654 | 1.64*** | 1.31*** | 0.33 | 1.78* |

This table reports the mean long-run abnormal returns and the average return difference between the sample of "influential patent" firms and the control sample of "no-influential patent" firms in 36 months after the filing month (month 0). The sample of "influential patent" firms consists of firms with influential patents filed during 1996-2006. Influential patents are identified as those top ten percent most cited patents of the application year in its three-digit technology sub-category based on the USPTO classification. I exclude the top ten percent most cited patents with total adjusted citations equal to zero. To avoid overlap, if a firm has multiple influential patents during the sample period, I only examine those influential patents whose filing dates are separated by at least two years. The sample of "no-influential patent" firms is the industry-year-size-performance matched control sample. The pool for the control sample consists of firms with patents whose citations are ranked below the median value of citation of its technology class in the application years. Firms in the pool are required to have corresponding data on Compustat, CRSP, and TFI, and did not apply for any influential patent in the sample period. For each "influential patent" firm, I identify a "no-influential patent" firm in the pool with the same two-digit primary SIC code, an absolute percentage difference of market capitalization less than ten percent, and the minimum difference of prior-year returns in the same year. A firm in the matched sample may apply for multiple patents in the matched year. To construct the sample of "no-influential patent" with filing dates, one patent with the lowest value of citations is randomly chosen for each firm-event.

Table 14 (Continued)

All firms in the two samples are listed on the NYEX, AMEX, or NASDAQ. Each sample consists of 654 firm-events. The standard Fama and French (1993) three-factor model is used to estimate the long-run abnormal returns for firms based on their monthly returns data on CRSP. Mean values and returns differences are reported as percentages. The differences in means are tested by two independent samples t-test. ***, **, and * denote significance at the one percent, five percent, and ten percent levels, respectively.

The evidence that "influential patent" firms have better long-run performance than "no-influential patent" firms supports the long-term effect of influential technological innovation on firms' future development. This evidence, together with the stock-price reaction evidence, supports my definition of influential patents in that those technologies are influential and may signal future economic performance of firms.

*ESO Exercise Data*

ESO exercises data is obtained from the Thomson Financial Insiders Filings Data Files (TFI, September, 2007). The data files capture all insider activities as reported on Form Three, Four, Five and 144 filed with the SEC.[7] Focusing on Form Four in the Table Two of the TFI database, I consider two codes of option exercise transactions, M ('exercise of in-the money or at-the-money derivative security acquired pursuant to Rule 16b-3 plan') and X ('exercise of in-the-money or at-the-money derivative security'), for each "influential patent" and control firm during the pre-application and post-application periods. I drop filings marked as inaccurate or incomplete by TFI (Cleanse Indicators as 'S' or 'A'), filings labeled as an amendment to an earlier filing (Amendment Indicator as 'A'), or transactions that involve shares indirectly owned by insiders via a partnership,

[7] Most insider transactions are reported on Form Four. Form Three is the initial statement of beneficial ownership that insiders must file. Form Five reports annual changes in beneficial ownership and contains activity from small or exempt transactions that are not reported on Form Four. Form 144 declares their intention to sell restricted shares.

corporation, trust or other entity (Ownership Type as 'I'). Moreover, I require that the security titles must include "option" except for "put option", and that the underlying security is common shares. The exercised stock options are reported both on the Table One and Table Two files on TFI, but some numbers of underlying shares exercised are not consistent. To reduce noise, I exclude those records with inconsistent numbers of underlying shares exercised in two tables.

Next, I aggregate the transactions recorded on the same document with the same exercise price, transaction date, vesting date, and expiration date by the same person, since TFI reports multiple option exercises with the same exercise price on the same day by a single manager as distinct transactions. These transactions are then analyzed as a single exercise. I drop such exercise transactions involving less than ten shares, more than 100% of firm's shares outstanding, or where the exercise price is less than one cent or more than 1,000 dollars. This action leaves 411,041 ESO exercises.

The option exercise transactions of all corporate insiders are examined. Following prior studies, I utilize two measures to examine the level of option exercises: 1) the number of underlying shares exercised and sold immediately by executives during a year (#underlying-shares) and, 2) the in-the-money value of exercises during a year ($option). The in-the-money value of exercise is the difference between the stock and exercise prices multiplied by the number of shares exercised. The later measure (in-the-money value of exercise) is related more to the executives' gains through early exercising and has been commonly used in the literature related to option exercises.

As discussed above, options may be exercised for liquidity, diversification, maturity, or other rational reasons. For the purpose of this study, it is crucial to divide

option exercises as uninformed or informed and to focus only on those potentially informed option exercises. Following Bradley, Cline, and Lian (2012), I identify uninformed ESO exercises as those exercised within 30 days after the vesting date, within 30 days before the maturity date, within 30 days before the ex-dividend date, or those underlying shares held in the executives' portfolio following the exercise. Informed exercises are defined as the complement of the above uninformed exercises. To increase the sample size, I further treat those exercises with missing relative dates as informed. I match option exercises in Table Two with open market sales in Table One to make sure that all underlying shares were immediately sold upon exercise. In this way, 160,810 informed ESO exercises are identified over the period 1996 to 2007, where the underlying shares were immediately sold. If a firm has no stock option exercised over the informed or control periods, zero is assigned to the measures of option exercises. The informed ESO exercises data is then merged with Compustat, CRSP, and patent data.

*ESO Grants Data*

ESO grants data is extracted from the TFI Filings Data Files as well. Focusing on Form Four in the Table Two of TFI database, I consider transactions with code "A" (grant or award) for each "influential patent" and control firm during the informed and control periods. Similar with the process of data clean for option exercises, I drop filings marked as inaccurate or incomplete by TFI, filings labeled as an amendment to an earlier filing, or transactions that involve shares indirectly owned by insiders. I also require that the security titles must include "option" except for "put option", and that the underlying security is common shares. I then aggregate the filings of grants that are awarded in a given company on a given date. These transactions are analyzed as a grant event. This

aggregation leaves 113,099 grant events by 11,321 distinct firms during the period 1996 to 2007. I use the total number of underlying shares granted in a given grant event (#underlying-shares) to measure the level of option grants.

Most companies have schedules to grant options to top executives on roughly the same dates of every year. Since the scheduled grants are unlikely to be timed opportunistically, the extant literature generally separates scheduled grants from other grants. Following Lie (2005) and Heron and Lie (2007), I use a tightened definition to categorize the scheduled grants that are excluded from further analysis. I identify an option award as unscheduled if it does not occur within one day of the one-year anniversary of the prior year's award date. An unscheduled option grant is excluded if it has unavailable or incomplete Compustat, CRSP, or patent data. This method yields a final sample of 3,348 unscheduled grants from 4,434 option grant events over the period 1996 – 2007. If a firm did not award any option over the informed or control periods, I assign zero to the measure of option grants.

**Results of Informed Option Exercises**

Following the method used in Agrawal and Nasser (2012), I compare the level of informed option exercises in "influential patent" firms during the one-year pre-application period under two sets of controls: the time-series control and the cross-sectional control. The time-series control examines informed option exercises in "influential patent" firms over the informed and control periods. It perfectly controls for firm characteristics, but does not control for possible changes in the exercise behavior of executives over time. The cross-sectional control investigates informed option exercises by executives of both "influential patent" and control firms over the same period. It

emphasizes the opposite trade-off by controlling for the effect of the time period and omitting firm attributes which may affect the level of option exercises. While each control has its benefits and limitations, I focus on the dual-control, which equals the abnormal exercises by executives in "influential patent" firms between the pre-application and control periods minus the abnormal exercises by executives in control firms between the pre-application and control periods. Using this difference-in-differences (DID) approach, both the effects of firm characteristics and the time period are controlled.

### *Univariate Results*

Table 15 provides mean and median values of two measures of executives' option exercises for the sample of "influential patents' firms and control sample during the informed and control periods. The informed period is the one-year period prior to a patent's filing date and control period is the one-year period after that. The two measures of option exercises are: number of underlying shares exercised and sold immediately by executives during a year (#underlying-shares) and in-the-money value of exercises during a year ($option). The in-the-money value of exercises is the difference between the stock and exercise prices multiplied by the number of shares exercised.

Table 15

*Univariate Test: Informed Option Exercises*

| All insiders | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Statistic | Influential patents | | Non-influential patents | | p-values | | | |
| ESO exercise measures | (1) Informed period | (2) Control period | (3) Informed period | (4) Control period | (1)-(2) | (1)-(3) | (3)-(4) | (1-2)-(3-4) |
| **mean** | | | | | | | | |
| #underlying-shares | 30.14 | 51.14 | 32.02 | 43.05 | 0.000 | 0.737 | 0.055 | 0.200 |
| $option | 825.44 | 1997.58 | 865.21 | 1000.35 | 0.004 | 0.816 | 0.468 | 0.019 |
| **median** | | | | | | | | |
| #underlying-shares | 0 | 0 | 0 | 0 | 0.000 | 0.527 | 0.005 | 0.165 |
| $option | 0 | 0 | 0 | 0 | 0.000 | 0.374 | 0.017 | 0.078 |

This table reports the mean and median values of two measures of executives' informed option exercises for the sample of "influential patent" firms and the control sample of "no-influential patents' firms during the informed and control periods. The informed period is the one-year period before a patent's filing date and control period is the one-year period after that The sample of "influential patent" firms consist of firms with influential patents filed during 1996-2006. Influential patents are identified as those top ten percent most cited patents of the application year in its three-digit technology sub-category based on the USPTO classification. I exclude those top ten percent most cited patents with total adjusted citations equal to zero. To avoid overlap, if a firm has multiple influential patents during the sample period, I only examine those influential patents whose filing dates are separated by at least two years. The sample of "no-influential patent" firms is the industry-year-size-performance matched control sample.. The pool for the control sample consists of firms with patents whose citations are ranked below the median value of citation of its technology class in the application years. Firms in the pool are required to have corresponding data on Compustat, CRSP, and TFI, and did not apply for any influential patent in the sample period. For each "influential patent" firm, I identify a "no-influential patent" firm in the pool with the same two-digit primary SIC code, an absolute percentage difference of market capitalization less than ten percent, and the minimum difference of prior-year returns in the same year. A firm in the matched sample may apply for multiple patents in the matched year. To construct the sample of "no-influential patent", one patent with the lowest value of citations is randomly chosen for each firm-event. All firms in the two samples are listed on the NYEX, AMEX, or NASDAQ. Informed ESO exercises are identified as those exercised not within 30 days after the vesting date, not within 30 days before the maturity date, not within 30 days before the ex-dividend date, and those underlying shares not held in the executives' portfolio following the exercise. The two measures of executives' option exercises are: #underlying-shares (number of underlying shares exercised by executives in thousands during a year) and $option (in-the-money value of exercise in thousands during a year). All insiders' informed option exercise is from TFI Filings database. The differences in means are tested by two-tailed matched-pair t-tests, and the differences in medians are tested by Wilcoxon signed ranks tests. The p-values of differences are also reported.

Table 15 also reports p-values of the paired t-tests and Wilcoxon signed ranks tests for the mean and median differences in the measures of informed option exercises between "influential patent" and "no-influential patent" firms. Column (1)-(2) (Column

(3)-(4)) shows p-values of test statistics for the change in the level of informed option exercises for executives in "influential patent" firms ("no-influential patent" firms) between the informed and control periods (i.e., the time-series control); Column (1)-(3) shows p-values for the differences in the level of informed option exercises for executives in the informed period between "influential patent" and "no-influential patent" firms (i.e., the cross-sectional control); and Column (1-2)-(3-4) is for the differences between (a) the changes in the level of informed ESO exercises in "influential patent" firms between the informed and control periods and (b) the changes in the level of informed ESO exercises in "no-influential patent" firms between the informed and control periods (i.e., DID).

Based on the time-series control, Column (1)-(2) shows that executives in "influential patent" firms exercise significantly fewer options and gain less in-the-money value of exercises during the informed period than they do during the control period at statistical one percent level; Column (3)-(4) indicates that the in-the-money value of options exercised by executives in the control firms have no significant change during the informed period and control period. The comparisons from cross-sectional control (Column (1)-(3)) suggest no significant difference in the level of informed option exercises between the two samples over the informed period. According to the DID control, Column (1-2)-(3-4) implies that, the in-the-money value of exercises increases from the pre-application period to the control period for both samples, but the increase in "influential patent" firms is significantly larger than the change in control firms.

*Cross-Sectional Regressions*

The results from univariate tests provide some preliminary evidence under the time-series or DID controls; however, univariate tests do not control for other determinants of the level of informed option exercises. Next, I estimate cross-sectional regressions when controlling for other determinants of the normal level of informed option exercises.

**Regression Specification**

To some extent, the insider behavior of exercising ESOs and selling the acquired shares is similar with insiders' open market sales; therefore, ESO exercises may be influenced by the similar factors related to insider sales, including firm size, the level of stock volatility, prior stock performance, stock liquidity, firm valuation, and innovation. I attempt to control for these various factors in the cross-sectional regressions, for "influential patent" and control firms. Two models are constructed to examine my predictions. Equation (8) is for the time-series control for "influential patent" firms or control firms only. For Equation (8), all explanatory variables for both the "influential patent" firm and the matched control firm include two observations: One is for the one-year pre-application (informed) period, and the other is for the control period. A binary dummy variable labeled Pre-apply equals one if the exercise activity occurs during the pre-application period and zero otherwise. Equation (9) is for the DID control for "influential patent" firms and control firms together. For Equation (9), all explanatory variables for each firm-event include four observations: Two observations for "influential patents' firm (for the pre-application and control periods) and two for the control firm (for the pre-application and control periods). Influential-patent is a dummy variable equal

to one if the firm has an influential patent filed and equal to zero otherwise. The main explanatory variables are Pre-apply, Influential-patent, and Pre-apply*Influential-patent. Coefficients of the first two variables estimate the abnormal level of informed exercises related to the time-series and cross-sectional controls, respectively. The coefficient of interaction term estimates abnormal informed exercises under the DID control. The two models and each measure of the control variables are described below:

$$ESO_i = \alpha_0 + \beta_1 Ln(Market\_Cap)_i + \beta_2 \sigma_i + \beta_3 PRET_{-1i} + \beta_4 B/M\_decile_i + \beta_5 R\&D/Sales_i + \beta_6 Liquidity_i + \beta_7 Pre\_apply_i + \varepsilon_i, i = 1,2,... \quad (8)$$

$$ESO_i = \alpha_0 + \beta_1 Ln(Market\_Cap)_i + \beta_2 \sigma_i + \beta_3 PRET_{-1i} + \beta_4 B/M\_decile_i + \beta_5 R\&D/Sales_i + \beta_6 Liquidity_i + \beta_7 Pre\_apply_i + \beta_8 Influential\_patent_i + \beta_9 Pre\_apply * Influential\_patent_i + \varepsilon_i, \quad (9)$$
$$i = 1,2,...$$

*Firm size (Ln(Market_Cap)):* Seyhun (1986) finds that insiders are likely to be net sellers in large firms. Fu and Ligon (2010) provide evidence that executives in large firms are more likely to exercise in-the-money ESOs within two days of the vesting date. I use the natural logarithm of the market capitalization to control firm size. Market cap is computed as the number of common shares outstanding times the share price as of the ending last calendar year prior to the beginning of the informed or control period on CRSP monthly dataset.

*Stock volatility (σ):* Meulbroek (2000) finds that insiders in those more risky companies tend to sell equity more actively. I measure the risk of a stock by the standard deviation of stock returns of a firm over trading days (-1, -365) relative to the beginning of the informed or control period on CRSP daily data.

*Prior stock performance ($PRET_{-1}$):* Lakonishok and Lee (2001) argue that insiders tend to sell stocks when the past returns are high. Prior stock returns ($PRET_{-1}$) are

computed as the buy-and-hold return for a firm over trading days (-1, -365) relative to the beginning of the informed or control period.

*Firm valuation (B/M_decile):* Jenter (2005) finds that insiders are more likely to sell a stock when the firm has a high valuation. Book-to-market (B/M) ratio is often used to measure a firm's valuation ratio relative to other firms. The B/M ratio is computed from dividing the book value of equity divided by the market capitalization of common shares outstanding as of the last calendar year ending prior to the informed or control period. Based on NYSE B/M decile breakpoints in a given year, B/M decile is assigned to one to ten depending on a firm's B/M ratio.

*Innovation (R&D/Sales):* Aboody and Lev (2000) argue that information asymmetries between corporate insiders and outside investors are more severe in R&D-intensive firms, and find that insider gains in firms conducting R&D are significantly larger than those in firms with no R&D activities. R&D/Sales ratio is computed as R&D expenses to sales revenue for the last fiscal year ending prior to the informed or control period. I treat R&D expenses as zero if R&D expenses are missing on Compustat.

*Stock liquidity:* Prior studies (i.e., Grossman and Stiglitz, 1980; Kyle, 1985; Holmstrom and Tirole, 1993) suggest that informed traders are more likely to trade when stock liquidity is higher. Stock liquidity is calculated as the mean daily trading volume divided by shares outstanding during one year prior to the informed or control period.

*Pre-apply:* A binary dummy variable equal to one if the executives' exercise activity occurs during the pre-application period and zero otherwise.

*Influential-patent:* A binary dummy variable equal to one if a firm has an influential patent and zero otherwise.

By controlling for those factors related to option exercises, I compare the regressions' results between "influential patent" and control firms. The dependent variable (ESO) is one of the two measures of option exercises: number of underlying shares exercised and sold immediately by executives during a year (#underlying-shares) and in-the-money value of exercises during a year ($option). Test statistics is calculated using robust variances in each regression model.

**Informed ESO Exercises**

Informed ESO exercises are illustrated in Table 16. Using Equation (8), Panel 16.1 and 16.2 show the coefficient estimates and p-values of the regressions of two measures of executives' option exercises in "influential patent" and control firms. Panel 16.3 presents the coefficient estimates and p-values from the regressions using Equation (9). My main interest is in the coefficients of Pre-apply, Influential-patent, and Pre-apply*Influential-patent. The sample of "influential patent" firms consists of 1,196 observations for which all the variables in the regressions have available data in CRSP and Compustat, corresponding to 598 unique firm-events in which an influential patent was filed. Similarly, the sample of "no-influential patent" firms consists of 1,293 observations, corresponding to 647 firm-events with a non-influential patent filed.

Consistent with prior studies in insider sales, Table 16 provides evidence that executives exercise significantly more stock options when the firm is large, has a high stock volatility, has a high prior stock return, has a high liquidity, or has a low B/M ratio. In the sample of "influential patent" firms (Panel 16.1), all estimated coefficients of the 'Pre-apply' variable are significantly negative. In contrast, none of the estimated coefficients of 'Pre-apply' is significantly different from zero for the control firms (Panel

16.2). Panel 16.3 provides consistent results using the DID control. The positive and significant coefficients of variable "Influential-patent" imply that executives in "influential patent" firms generally exercise more options and have higher in-the-money value of exercises than those in control firms. However, the significantly negative coefficients of the interaction term, Pre-apply*Influential-patent, suggest that, the in-the-money value of exercises in "influential patent" firms is significantly lower during the one-year pre-application period, relative to either the level during its control period or the level in control firms.

Table 16

*Regressions of Informed Option Exercises*

**Table 16 Continued**

| Independent Variables | 6.1 "Influential patent" firms | | | | 6.2 "No-influential patent" firms | | | | 6.3 Difference in differences | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dependent variables | | | | Dependent variables | | | | Dependent variables | | | |
| | #underlying-shares | $options | #underlying-shares | $options | #underlying-shares | $options | #underlying-shares | $options | #underlying-shares | $options | #underlying-shares | $options |
| Pre-apply | -19.25** | -1123.05** | -15.79** | -1020.05** | -10.98 | -134.01 | -10.48 | -138.52 | -10.98 | -134.01 | -10.13 | -116.81 |
| | (0.014) | (0.018) | (0.033) | (0.022) | (0.116) | (0.517) | (0.119) | (0.470) | (0.116) | (0.516) | (0.133) | (0.550) |
| Influential-patent | | | | | | | | | 7.94 | 991.75** | 6.38 | 955.71** |
| | | | | | | | | | (0.340) | (0.035) | (0.428) | (0.047) |
| Pre-apply *Influential-patent | | | | | | | | | -8.27 | -989.04* | -5.69 | -937.87* |
| | | | | | | | | | (0.427) | (0.052) | (0.575) | (0.064) |
| Ln(market cap) | | | 27.33*** | 1371.75*** | | | 16.49*** | 533.42*** | | | 22.04*** | 947.13*** |
| | | | (0.000) | (0.000) | | | (0.000) | (0.000) | | | (0.000) | (0.000) |
| σ | | | 865.60*** | 54367.12** | | | 555.42*** | 14654.84** | | | 746.43*** | 35483.21*** |
| | | | (0.001) | (0.034) | | | (0.002) | (0.013) | | | (0.000) | (0.008) |
| PRET(-1) | | | 8.20* | 626.43** | | | 8.98* | 744.18*** | | | 8.65** | 696.39*** |
| | | | (0.064) | (0.034) | | | (0.100) | (0.001) | | | (0.013) | (0.000) |
| B/M decile | | | -2.36** | -66.33 | | | -2.69*** | -64.65*** | | | -2.52*** | -66.18*** |
| | | | (0.015) | (0.129) | | | (0.009) | (0.006) | | | (0.000) | (0.006) |
| R&D/Sales | | | 0.00 | -0.18 | | | -0.06 | -1.72 | | | -0.00 | -0.20 |
| | | | (0.170) | (0.235) | | | (0.125) | (0.373) | | | (0.949) | (0.158) |
| Liquidity | | | 632.02 | 4318.22 | | | 1767.37*** | 54008.63*** | | | 970.24** | 20902.69 |
| | | | (0.143) | (0.819) | | | (0.003) | (0.002) | | | (0.011) | (0.146) |
| Constant | 50.94*** | 1990.96*** | -149.12*** | -8507.09*** | 43.00*** | 999.21*** | -84.99*** | -3166.61*** | | | -121.15*** | -6271.18*** |
| | (0.000) | (0.000) | (0.000) | (0.002) | (0.000) | (0.000) | (0.000) | (0.000) | | | (0.000) | (0.000) |
| N | 1276 | 1276 | 1196 | 1196 | 1308 | 1308 | 1293 | 1293 | 2584 | 2584 | 2489 | 2489 |
| Adjusted $R^2$ | 0.004 | 0.004 | 0.129 | 0.082 | 0.001 | -0.000 | 0.095 | 0.145 | 0.003 | 0.004 | 0.111 | 0.087 |

Table 16 (Continued)

This table reports the coefficient estimates from OLS regressions of two measures of executives' informed option exercises on several explanatory variables. The sample of "influential patent" firms consists of firms with influential patents filed during 1996-2006. Influential patents are identified as those top ten percent most cited patents of the application year in its three-digit technology sub-category based on the USPTO classification. I exclude those top ten percent most cited patents with total adjusted citations equal to zero. To avoid overlap, if a firm has multiple influential patents during the sample period, I only examine those influential patents whose filing dates are separated by at least two years. The sample of "no-influential patent" firms is the industry-year-size-performance matched control sample. The pool for the control sample consists of firms with patents whose citations are ranked below the median value of citation of its technology class in the application years. Firms in the pool are required to have corresponding data on Compustat, CRSP, and TFI, and did not apply for any influential patent in the sample period. For each "influential patent" firm, I identify a "no-influential patent" firm in the pool with the same two-digit primary SIC code, an absolute percentage difference of market capitalization less than ten percent, and the minimum difference of prior-year returns in the same year. A firm in the matched sample may apply for multiple patents in the matched year. To construct the sample of "no-influential patent", one patent with the lowest value of citations is randomly chosen for each firm-event. All firms in the two samples are listed on the NYEX, AMEX, or NASDAQ. Informed ESO exercises are identified as those exercised not within 30 days after the vesting date, not within 30 days before the maturity date, not within 30 days before the ex-dividend date, and those underlying shares not held in the executives' portfolio following the exercise. Executives' informed option exercises activities are measured during two periods for each firm-event: One is the informed period, one-year before a patent's filing date; the other is the control period, one-year period after a firm applies for a patent. The dependable variables include #underlying-shares (number of underlying shares exercised and sold by executives in thousands during a year) and $option (in-the-money value of exercise in thousands during a year). All insiders' option exercise data is from Thomson Insiders Filings database. Market cap is computed as the number of common shares outstanding times the share price as of the last calendar year ending prior to the beginning of the informed or control period. The standard deviation of stock returns ($\sigma$) is calculated over trading days (-1, -365) relative to the beginning of the informed or control period. PRET (-1) is the buy-and-hold return for a firm over trading days (-1, -365) relative to the beginning of the informed or control period. B/M decile is assigned as one to ten depending on the firm's B/M ratio. I use NYSE B/M decile breakpoints to assign a firm's B/M decile. B/M is calculated as book value of equity divided by market value of equity ratio as of the last calendar year ending prior to the informed or control period. R&D/Sales ratio is R&D expense to sales revenue for the last fiscal year ending prior to the informed or control period. Liquidity equals to the mean daily trading volume divided by share outstanding during one year prior to the informed or control period. "Pre-apply" is a dummy variable equal to one if the executives' informed option exercises activity occurs during the informed period and equal to zero otherwise. "Influential-patent" is a dummy variable equal to one if the firm has an influential patent filed and equal to zero otherwise. Test statistics are calculated using robust variance. The p-values are reported in parentheses. ***, **, and * denote significance at the one percent, five percent, and ten percent levels, respectively.

The distinct difference between the sample of "influential patent" and control firms indicates that executives in the "influential patent" firms exercise significantly fewer stock options over the pre-application period than over the post-application period. This finding supports the view that executives delay their planned exercises to increase their stock option compensation until after the filing of the influential patent, when the firm's stock price runs up.

## Results of Unscheduled Option Grants

Using the similar method of analyzing the level of executives' informed option exercises, I compare the level of unscheduled option grants in "influential patent" firms during the informed period under two sets of controls: the time-series control and the cross-sectional control. I focus on the dual-control to control for both effects of firm characteristics and time period. Following previous analysis, I first use the same way to define the informed and control periods, but I do not find any abnormal pattern of unscheduled option grants during the informed period (the results are not reported). I examine unscheduled option grants over the one-year period before the grant date of an influential patent (name the pre-grant period as the informed period). I do discover strong evidence of abnormal option grants around the date when an influential patent is granted by the patent office.

### *Univariate Results*

Table 17 provides mean and median values of the measure of executives' option grants for the sample of "influential patents' firms and the control sample during the informed and control periods. The format of Table 17 is similar to that of Table 15,

except that 1) the measures of informed option exercises are replaced by the measure of unscheduled option grants and, 2) the informed period indicates the one-year period before a patent's grant date. I use the total number of underlying shares granted in a given grant event (#underlying-shares) to measure the level of option grants.

Table 17

*Univariate Test: Unscheduled Option Grants*

| Statistic | Influential patents | | Non-influential patents | | p-values | | | |
|---|---|---|---|---|---|---|---|---|
| ESO grants measures | (1) Informed period | (2) Control period | (3) Informed period | (4) Control period | (1)-(2) | (1)-(3) | (3)-(4) | (1-2)-(3-4) |
| **mean** | | | | | | | | |
| #underlying-shares | 374.45 | 307.89 | 284.17 | 334.84 | 0.093 | 0.036 | 0.225 | 0.036 |
| **median** | | | | | | | | |
| #underlying-shares | 75.04 | 114.33 | 78.17 | 75.37 | 0.553 | 0.927 | 0.465 | 0.728 |

This table reports the mean values of the measure of executives' unscheduled option grants for "influential patent" firms and "no-influential patents' control firms during the informed and control periods. The sample of "influential patent" firms consist of firms with influential patents filed during 1996-2006. Influential patents are identified as those top ten percent most cited patents of the application year in its three-digit technology sub-category based on the USPTO classification. I exclude those top ten percent most cited patents with total adjusted citations equal to zero. To avoid overlap, if a firm has multiple influential patents during the sample period, I only examine those influential patents whose filing dates are separated by at least two years. The sample of "no-influential patent" firms is the industry-year-size-performance matched control sample. The pool for the control sample consists of firms with patents whose citations are ranked below the median value of citation of its technology class in the application years. Firms in the pool are required to have corresponding data on Compustat, CRSP, and TFI, and did not apply for any influential patent in the sample period. For each "influential patent" firm, I identify a "no-influential patent" firm in the pool with the same two-digit primary SIC code, an absolute percentage difference of market capitalization less than ten percent, and the minimum difference of prior-year returns in the same year. A firm in the matched sample may apply for multiple patents in the matched year. To construct the sample of "no-influential patent", one patent with the lowest value of citations is randomly chosen for each firm-event. All firms in the two samples are listed on the NYEX, AMEX, or NASDAQ. The informed period is the one-year period before a patent's grant date and control period is the one-year period after that. An option award is categorized as unscheduled if it does not occur within one day of the one-year anniversary of the prior year's award date. The measure of executives' unscheduled option grants is: #underlying-shares (number of underlying shares granted to executives in thousands during a year). All insiders' option grants data is from TFI Filings database. The differences in means are tested by two-tailed matched-pair t-test. The p-values of differences are reported in the table.

Based on the time-series control (Column (1)-(2)), firms with influential patents award significantly more options over the pre-grant period than over the post-grant period. Oppositely, firms with non-influential patents award fewer options over the pre-grant period than over the post-grant period, though the difference is not significant. Based on the cross-sectional control (Column (1)-(3)), firms with influential patents award significantly more stock options than control firms during the same informed period. According to the DID control, p-value 0.036 in Column (1-2)-(3-4) indicates that, from the pre-grant period to the post-grant period, a) firms with influential patents decrease the total number of stock options they award; b) the control firms increase the amount of stock options awarded; and 3) the difference between the changes in (a) and (b) significantly differ from zero at five percent level.

Table 17 provides evidence that firms award more options to their executives before the grant of influential patents and fewer after that. This finding is consistent with the point that executives may time an option grant to occur before an anticipated stock price appreciation. The significant difference in the dual control may be explained as top executives are able to forecast the approximate date of granting an influential patent, and executives then time option grants to occur with the expectation that the stock price will increase after the news of granting is announced.

*Cross-Sectional Regressions*

The probability of option grants is also significantly influenced by some of the firm characteristics. Smith and Watts (1992) find that large firms and growth firms are significantly more likely to use option grants as part of their incentive contracts. Therefore, I control for the lagged value of the firm's market capitalization

(*Ln(Market_Cap)*) and book to market ration (*B/M_decile*). According to prior studies (Yermack, 1997; Aboody and Kaszznik, 2000; Lie, 2005), previous stock return *(PRET_1)* is included to control for managerial manipulation of grants' issue-dates around local minimum returns. Since Yermack (1995) finds that liquidity-constrained firms appear to provide a great fraction of CEO compensation from stock options, I further control for stock liquidity in the regressions. Following Fich, Cai, and Tran (2011), who find positive relation between the prior year return volatility and probability of granting unscheduled options, I use the standard deviation of prior stock returns to control for the risk of a stock (*volatility σ*). Finally, innovation is controlled for using the measure of R&D/Sales ratio since Aboody and Lev (2000) argue that R&D activities create unique information asymmetries between corporate insiders and outside investors. All variables are computed in the same way as examining ESO exercises. The two models used in this section are:

$$Award_i = \alpha_0 + \beta_1 Ln(Market\_Cap)_i + \beta_2 \sigma_i + \beta_3 PRET_{-1i} + \beta_4 B/M\_decile_i + \beta_5 R\&D/Sales_i + \beta_6 Liquidity_i + \beta_7 Pre\_grant_i + \varepsilon_i, i = 1,2,... \quad (10)$$

$$Award_i = \alpha_0 + \beta_1 Ln(Market\_Cap)_i + \beta_2 \sigma_i + \beta_3 PRET_{-1i} + \beta_4 B/M\_decile_i + \beta_5 R\&D/Sales_i + \beta_6 Liquidity_i + \beta_7 Pre\_grant_i + \beta_8 Influential\_patent + \beta_9 Pre\_grant * Influential\_patent + \varepsilon_i, \quad (11)$$
$$i = 1,2,...$$

Equation (10) is used for the time-series control for "influential patent" firms or control firms only. The binary dummy variable Pre-grant equals one if an award occurs during the pre-grant period and zero otherwise. Equation (11) is used for the DID control for "influential patent" firms and control firms together. Influential-patent is a dummy variable equal to one if the firm has an influential patent filed and equal to zero otherwise. The main explanatory variables are Pre-grant, Influential-patent, and Pre-

grant*Influential-patent. The dependent variable (Award) is the number of underlying shares granted to executives in a firm during a year (#underlying-shares). I control for industry and year fixed effects and calculate test statistics using robust variances in each regression model.

Table 18 examines unscheduled option grants in firms around the grant date of a patent. The format of Table 18 is similar to that of Table 16, except that the measures of informed option exercises are replaced by the measure of unscheduled option grants. Using Equation (10), Panel 18.1 and 18.2 show the coefficient estimates and p-values of the regressions of the measure of option grants in "influential patent" firms and control firms. Panel 18.3 displays the coefficient estimates and p-values from the regressions using Equation (11).

The results in Table 18 show a firm is more likely to grant stock options when it is larger, has a higher stock volatility, or has a lower liquidity. In the sample of "influential patent" firms (Panel 18.1), the estimated coefficient of the 'Pre-grant' variable is significantly positive. In contrast, the estimated coefficient of 'Pre-grant' is insignificantly negative for the matched control firms (Panel 18.2).

Panel 18.3 provides consistent results using the DID control. The negative coefficient of variable "Pre-grant" indicates that firms generally award fewer options during the pre-grant period than the post-grant period. However, the significantly positive coefficient of the interaction term, Pre-grant*Influential-patent, implies that, firms with influential patents award significantly more stock options during the pre-grant period, relative to the level during the post-grant period.

The distinct difference between the sample of "influential patent" and control firms indicates that firms grant significantly more stock options over the one-year pre-grant period than over the post-grant period when they expect an influential patent being granted. This finding discovers that firms award more unscheduled stock options before the grant news of an influential patent to maximize executives' stock option compensation, given the expectation of the appreciation of stock price afterward.

Table 18

*Regressions of Unscheduled Option Grants*

| Independent Variables | 8.1 "Influential patent" firms | | 8.2 "No-influential patent" firms | | 8.3 Difference in differences | |
|---|---|---|---|---|---|---|
| | Dependent variables | | Dependent variables | | Dependent variables | |
| | #underlying-shares | #underlying-shares | #underlying-shares | #underlying-shares | #underlying-shares | #underlying-shares |
| Pre-grant | 67.48 | 88.61* | -51.66 | -17.19 | -51.66 | -17.69 |
| | (0.159) | (0.065) | (0.305) | (0.700) | (0.305) | (0.706) |
| Influential-patent | | | | | -28.85 | -74.13 |
| | | | | | (0.589) | (0.126) |
| Pre-grant *Influential-patent | | | | | 119.13* | 111.86* |
| | | | | | (0.087) | (0.096) |
| Ln(market cap) | | 119.04*** | | 138.17*** | | 123.64*** |
| | | (0.000) | | (0.000) | | (0.000) |
| σ | | 9451.21*** | | 8140.10*** | | 8809.41*** |
| | | (0.000) | | (0.000) | | (0.000) |
| PRET(-1) | | 7.71 | | -30.83 | | -7.35 |
| | | (0.796) | | (0.100) | | (0.723) |
| B/M decile | | 11.47 | | 29.03 | | 16.47 |
| | | (0.250) | | (0.191) | | (0.122) |
| R&D/Sales | | -0.07** | | 1.24*** | | -0.00 |
| | | (0.050) | | (0.000) | | (0.981) |
| Liquidity | | -2673.82* | | -1922.04 | | -2116.34* |
| | | (0.057) | | (0.592) | | (0.078) |
| Industry FE | | Yes | | Yes | | Yes |
| Year FE | | Yes | | Yes | | Yes |
| N | 1306 | 1288 | 1306 | 1289 | 2612 | 2577 |
| Adjusted $R^2$ | 0.001 | 0.105 | 0.000 | 0.044 | 0.000 | 0.075 |

Table 18 (Continued)

This table reports the coefficient estimates from OLS regressions of the measure of executives' unscheduled option grants on several explanatory variables. The sample of "influential patent" firms consists of firms with influential patents filed during 1996-2006. Influential patents are identified as those top ten percent most cited patents of the application year in its 3-digit technology sub-category based on the USPTO classification. I exclude those top ten percent most cited patents with total adjusted citations equal to zero. To avoid overlap, if a firm has multiple influential patents during the sample period, I only examine those influential patents whose filing dates are separated by at least two years. The sample of "no-influential patent" firms is the industry-year-size-performance matched control sample. The pool for the control sample consists of firms with patents whose citations are ranked below the median value of citation of its technology class in the application years. Firms in the pool are required to have corresponding data on Compustat, CRSP, and TFI, and did not apply for any influential patent in the sample period. For each "influential patent" firm, I identify a "no-influential patent" firm in the pool with the same two-digit primary SIC code, an absolute percentage difference of market capitalization less than ten percent, and the minimum difference of prior-year returns in the same year. A firm in the matched sample may apply for multiple patents in the matched year. To construct the sample of "no-influential patent", one patent with the lowest value of citations is randomly chosen for each firm-event. All firms in the two samples are listed on the NYEX, AMEX, or NASDAQ. An option award is categorized as unscheduled if it does not occur within one day of the one-year anniversary of the prior year's award date. Firms' unscheduled option awards are measured during two periods for each firm-event: One is the informed period, one-year before a patent's grant date; the other is the control period, one-year period after a patent is granted. The dependable variable is #underlying-shares (number of underlying shares granted to executives in thousands during a year). All insiders' option grants data is from Thomson Insiders Filings database. Market cap is computed as the number of common shares outstanding times the share price as of the last calendar year ending prior to the beginning of the informed or control period. The standard deviation of stock returns ($\sigma$) is calculated over trading days (-1, -365) relative to the beginning of the informed or control period. PRET (-1) is the buy-and-hold return for a firm over trading days (-1, -365) relative to the beginning of the informed or control period. B/M decile is assigned as one to ten depending on the firm's B/M ratio. I use NYSE B/M decile breakpoints to assign a firm's B/M decile. B/M is calculated as book value of equity divided by market value of equity ratio as of the last calendar year ending prior to the informed or control period. R&D/Sales ratio is R&D expense to sales revenue for the last fiscal year ending prior to the informed or control period. Liquidity equals to the mean daily trading volume divided by share outstanding during one year prior to the informed or control period. "Pre-grant" is a dummy variable equal to one if the executives' unscheduled option grants occurs during the informed period and equal to zero otherwise. "Influential-patent" is a dummy variable equal to one if the firm has an influential patent filed and equal to zero otherwise. Test statistics are calculated using robust variance. The p-values are reported in parentheses. ***, **, and * denote significance at the one percent, five percent, and ten percent levels, respectively.

## Summary and Conclusions

This study empirically examines whether the exercising and awarding of executive stock options are relevant to superior information about the quality of a firm's patents, especially for informed option exercises and unscheduled option grants. Focusing on 654 firm-events with an influential patent filed, I analyze executives' option-related behavior around the filing or granting date of an influential patent during the period 1996-2006. Influential patents are identified as those top ten percent most cited of the application year for the three-digit technology sub-category based on the USPTO classification. To compare executives' abnormal option transaction behavior and assess abnormal performance, I construct a matched sample according to industry, year, size, and prior firm performance.

In difference-in-differences regressions of two measures of option exercises, I find that executives significantly delay exercising their stock options by reducing option exercises in the year before application of an influential patent and increasing option exercises after that. I find no such pattern of informed option exercises in the matched control sample.

I further document that firms award significantly more unscheduled stock options to their executives over the year before an influential patent is granted than over the year after that, but the control firms award fewer unscheduled stock options before a non-influential patent is granted than after that.

My findings support the hypothesis that managers have a strong informational advantage in discriminating the quality of patents during the whole process of patent activity, from before the application to the grant of a patent. In addition to exercising

options opportunistically, influencing the timing of unscheduled option grants is another channel through which insiders can pursue personal gains by exploiting this informational advantage.

# CHAPTER THREE

# CONCLUSIONS

It has been broadly documented that insiders exploit information advantages to earn abnormal returns from trading in the securities of their firms prior to major corporate events. This study extensively investigates whether insiders pursue personal interests by using private information about the quality of the firm's innovation output, represented by the application and grant of an influential patent. Chapter One focuses on insiders' open market trading before the filing year of an influential patent, while Chapter Two concentrates on informed executive stock option (ESO) exercises and unscheduled option awards before the filing or grant date of an influential patent. In both chapters, influential patents are identified as those top ten-percent most cited of the application year for the three-digit technology sub-category based on the USPTO classification.

In Chapter One, I first document that the market reacts more favorably when an influential patent is granted than when an inconsequential patent is granted. I then present that post-application long-run abnormal returns for the sample firms with influential patents are significantly higher than two control samples. Next, I investigate purchases, sales, and net purchases of three groups of insiders, using three measures of the level of insider trading and controlling for factors related to insider trading.

I find that insiders in "influential patent" firms reduce their purchases in the pre-application year, though not significantly, relative to their trading level during the application year. Nevertheless, their net purchases are significantly higher for the same period due to the significantly larger reductions in their sales. This pattern of passive trading holds true for each insider group and for each of three measures of insider trading. I find no such significantly consistent pattern in two control samples.

In Chapter Two, I examine executives' informed stock option exercises and unscheduled option grants before the filing or grant date of an influential patent. To compare executives' abnormal option transaction behavior and assess abnormal performance, I construct a matched sample according to industry, year, size, and prior firm performance. Informed ESO exercises are identified as those exercised not within 30 days after the vesting date, not within 30 days before the maturity date, not within 30 days before the ex-dividend date, and those underlying shares not held in the executives' portfolio following the exercise. I categorize an option award as unscheduled if it does not occur within one day of the one-year anniversary of the prior year's award date.

In difference-in-differences regressions of two measures of option exercises, I find that executives significantly delay exercising their stock options by reducing option exercises in the year prior to the application of an influential patent and increasing option exercises after that. I find no such pattern of informed option exercises in the matched control sample.

I further document that firms award significantly more unscheduled stock options to their executives in the year before the grant of an influential patent than in the year

after that. However, the control firms award fewer unscheduled stock options before a non-influential patent is granted than after that.

My findings support the hypothesis that managers have a strong informational advantage in discriminating the quality of a patent during the lengthy process of patent activity, from preparing application to granting of a patent. In addition to insiders' open market trading, exercising ESOs opportunistically and influencing the timing of unscheduled option grants are other important channels through which insiders can pursue personal interests by exploiting this informational advantage.

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