Value Creation of Independent Directors with STEM PhD: Evidence from Target Shareholder Gains

Chaehyun Kim[*1]

Hyeongsop Shim[2]

Choong-Yuel Yoo[3]

This version: August 30, 2016

Preliminary Draft – Please do not cite or quote without permission from the authors

[*] Acknowledgements: This work was supported by NRF (National Research Foundation of Korea) Grant funded by the Korean Government (NRF - 2015 - Global Ph.D. Fellowship Program).

[1] Management Engineering, Ulsan National Institute of Science and Technology; 50 UNIST-gil 114 Dong #701-11 Ulsan 44909, Republic of Korea; chkim@unist.ac.kr

[2] Graduate School of Technology Management, Ulsan National Institute of Science and Technology; 50 UNIST-gil 114 Dong #701-9 Ulsan 44909, Republic of Korea; +82-52-217-3132; hshim@unist.ac.kr

[3] College of Business, Korea Advanced Institute of Science and Technology; 85 Hoegiro SUPEX 432 Seoul 02455, Republic of Korea; +82-2-958-3326; cyoo@kaist.ac.kr

Value Creation of Independent Directors with STEM PhD: Evidence from Target Shareholder Gains

Abstract

This paper examines whether independent outside directors who hold a PhD in science, technology, engineering, and mathematics (i.e., STEM directors) enhance shareholder wealth in mergers and acquisitions. Using 772 mergers completed in U.S. between 2005 and 2014, we find that the market responds more favorably to M&A announcements when target firms have STEM directors, but not when their independent directors hold PhDs in other disciplines (e.g., business or law). In subsample tests, we find that the short-term announcement day premium from STEM directors is particularly pronounced for firms with higher R&D intensity, firms in high-tech industries, and firms located in high-tech cities. Further, we find that the short-term premium exists only when STEM directors' academic discipline is in line with the target firm's primary operation. Last, we find that target firms are more likely to be acquired by bidders in the same industry than in other industries and by public bidders than private bidders if target firms have STEM directors. Overall, our findings suggest that independent directors with STEM expertise enhance shareholder wealth owing to their technical advisory role in corporate innovation.

JEL Classification: G30, G34, O32
Keywords: Innovation, Independent Directors, STEM PhD, Target Shareholder Gains, Mergers and Acquisitions

[Science] is more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world, and to share this accumulated knowledge. It's a mindset that says we that can use reason and logic and honest inquiry to reach new conclusions and solve big problems.

- President Barack Obama, March 23, 2015

1. Introduction

Science, technology, engineering, and mathematics (i.e., STEM) pervade every aspect of our lives. STEM enables the prosperity and competitiveness of individuals, corporations and the nation by fostering productivity and innovation. Today, STEM knowledge and skills are used in many more occupations than the stereotypical academics wearing lab coats. For example, 65 percent of engineering PhDs in U.S. work in the business sector while only 26 percent of them work in 4 year colleges (National Science Foundation 2010). Indeed, according to a survey among PhD students at the top 39 U.S. research universities (Sauermann and Roach 2012), more than 53 percent of chemists consider a corporate career working at an established firm to be the most attractive career path after graduation, followed by a working at a startup firm (31%). Thus, we are interested in a role that STEM PhDs play in corporate America, particularly their role in corporate boardrooms.

There has been an influx of STEM PhDs into corporate boards since a series of regulatory reforms in early 2000s. After the Sarbanes-Oxley Act of 2002 (SOX) was enacted, regulations adopted by New York Stock Exchange (NYSE) in 2003 and National Association of Securities Dealers (NASD) in 2004 mandate a majority of directors on boards to be independent outside directors. In response, firms have increased the proportion of independent directors by appointing outsiders and, accordingly, existing directors with internal or external executive experience have been replaced with non-executive outside directors with financial, legal, or STEM expertise (Duchin, Matsusaka, and Ozbas 2010).

A few recent studies investigate the effect of non-executive outsider directors who have STEM expertise. White, Woidtke, Black, and Schweitzer (2014) show that high growth firms with intensive R&D spending are more likely to appoint STEM professors as outside directors than other types of firms and that the market responds favorably to such STEM professor appointments, indirectly implying that STEM professors can be valued technical advisors on corporate boards. Jung, Liu, Podolski, Rhee, and Yoo (2015) examine such a technical advisory role of STEM professors more directly and show that firms with STEM professors on their boards experience corporate innovative success. While the extant literature (White et al. 2014; Jung et al. 2015) restricts its analysis to STEM professors (i.e., university-employed STEM PhDs), our study encompasses all STEM PhDs regardless of whether they work in universities or in non-academic sectors (e.g., for-profit firms, research institutes, hospitals and government agencies). In the U.S., the number of STEM PhDs working in non-academic sectors is greater than that in academic sectors (Austin 2013; Turk-Bicakci, Berger, and Haxton 2014). Thus, we are able to examine the whole effect of scientific knowledge and skills that STEM PhDs bring to firms when they are appointed as outside directors regardless of whether they work in academic or non-academic sectors.

Mergers and acquisitions (M&A) provide an exit channel for entrepreneurs who create innovation and early equity investors such as angels and venture capitalists who facilitate the innovative activities of entrepreneurs. Initial public offerings may be the best exit channel for those investors in terms of investment returns, but the frequency of this type of exit is quite low, around 5 to 10 percent. In fact, M&A is the most frequent alternative exit channel which constitutes about 70 to 80 percent of total exits (Lerner, Leamon, and Hardymon 2012, Chapter 7). If entrepreneurs of target firms (i.e., target shareholders) successfully exit from their investments with substantial increase in their wealth through M&A, they become experienced founders who can actively participate in the nation's innovation ecosystem as facilitators like angel investors.

Phillips and Zhdanov (2013) propose that the existence of active M&A markets can create an incentive for small innovative firms in an industry to engage in competitive R&D spending, since small innovative firms with competitive technology are sought by large bidders in the same industry who are willing to buy the innovations of the small firms. That is, in the model, the large bidders, rather than participating in an R&D race, choose to outsource R&D investments to small firms by acquiring successfully innovated target firms.[4] Phillips and Zhdanov also point out the additional benefits of acquisitions: 1) enhanced acquisition potential generates positive feedback to the expected gain from successful R&D for small firms; 2) higher expected gains lead small firms to aggressively pursue innovation through R&D; 3) both bidder and target firms can share the innovation for their products and processes. Therefore, the increase in wealth for target firm shareholders arising from M&A is not only important to the shareholders themselves but also to the health of the nation's entrepreneurial ecosystem.

Audretsch and Stephan (1996) suggest that STEM researchers based on universities can offer the following three benefits to biotech firms: helping accessing and absorbing external knowledge; enhancing product effectiveness; and signaling the firm's research competitiveness to capital and resource markets. While Audretsch and Stephan (1996) do not explicitly examine STEM PhDs on corporate boards and do not examine those STEM PhDs working in non-academic sectors, their findings imply that STEM PhDs on corporate boards can play an

---

[4] Refer to the examples of Google's 108 total acquisitions of smaller firms by 2010 since its IPO in 2004 and Cisco's 21 total acquisitions since 1999 in Phillips and Zhdanov (2013).

important role in corporate innovation as technical advisors. Accordingly, we investigate whether and how independent outside directors with STEM PhDs help increase target shareholder gains.

Using manually-collected biographical information on directors in 772 target firms over the period 2005 to 2014, we find strong evidence that target firms' shareholders gain wealth from takeover announcements when the target firms have independent outside directors who hold doctoral degrees in STEM (STEM directors, hereafter). That is, three-day cumulative abnormal returns (CARs) around takeover announcements are more positive when the target firms have STEM directors, suggesting that the market responds more favorably to takeover announcements when target firms have STEM directors. This finding is robust after we address potential endogeneity bias with two-stage least squares (2SLS) regression approach adopting the proportion of doctoral graduates with different academic disciplines as an instrument.

Having established that the existence of STEM directors is positively associated with market reactions to takeover announcements, we conduct subsample tests to investigate the channel of STEM directors' positive impact on target shareholder value. We observe that the positive effect of STEM directors on CARs is manifested (1) when target firms' research and development (R&D) intensity is high; (2) when target firms belong to high-tech industries related to science and technology; and (3) when target firms are headquartered in high-tech cities. These results imply that STEM directors play an important role in corporate innovation.

Moreover, we find that the positive effect of STEM directors on CARs is stronger when STEM directors' academic discipline is in line with the target firm's industry membership. Results further suggests that STEM directors play a technical advisory role in corporate innovation using their knowledge and skills gained from rigorous academic training.

Next, we examine whether the positive effect of STEM directors on CARs is universal regardless of certain situations where their technical advisory role might be limited. We find that the positive effect of STEM directors on CARs is reduced when target firms have complex management structure (based on the number of business segments, firm size, and leverage) thus requiring independent directors' solid understanding in business and financial management, and when STEM directors have social ties with CEO indicating that STEM directors are appointed owing to their social ties with CEO rather than their specific STEM knowledge and skills. The results again suggest that the positive effect of STEM directors on CARs is attributable to their technical advisory role in corporate innovation but not to their monitoring role in management (or a role of managerial advisors).

Lastly, we find that target firms are more likely to be acquired by bidders in the same industry than in a different industry and by public firms rather than private firms when the target firms have STEM directors. This deliberate choice of bidders can contribute to the higher CARs around takeover announcements since bidders in the same industry can create greater synergy than bidders in a different industry, and public bidders pay higher acquisition premiums to target firms than private bidders. Overall, our findings suggest that independent directors with STEM expertise enhance target shareholder wealth during corporate takeovers when they serve as technical advisors, but not as managerial advisors.

Our study contributes to the literature in several ways. First, we offer an important policy implication for the national effort to produce more doctorates in science. Critics often point out that the already low ratio of faculty job openings to science PhD graduates for a given year has gotten worsen for decades; to make things worse, only 15 percent of science PhDs eventually get faculty positions at so-called research universities (McKenna 2016; Benderly

2010).[5] We show that science researchers with knowledge and skills acquired from rigorous scientific training can contribute to the nation's innovative and entrepreneurial ecosystem regardless of whether they stay in academia or outside the ivory towers of academia and laboratories.

Second, we contribute to the finance literature on corporate innovation. Most of the existing finance research investigates corporate innovation in the context of the determinants of corporate innovative inputs and outputs such as R&D and patents (Galasso and Simcoe 2011; Hirshleifer et al. 2012; Aghion, Van Reenen, and Zingales 2013; Tian and Wang 2014; Chen, Podolski, Rhee, and Veeraraghavan 2014; Jung et. al. 2015). However, this study sheds light on *how* outside directors with scientific knowledge and skills help increase shareholder wealth, namely by playing a technological advisory role in corporate innovation. To our knowledge, it is the first to link M&A with the dynamics between independent directors and corporate innovation.

Third, our findings extend the literature on independent outside directors (Duchin et al. 2010; White et al. 2014; Francis, Hasan, and Wu 2015; Cho, Jung, Kwak, Lee, and Yoo 2015; Jung et al. 2015). In particular, while prior research (White et al. 2014; Jung et al. 2015) restricts its analysis to STEM professors, our study encompasses all STEM doctorates regardless of whether they work in universities or in non-academic sectors. This is important in that the number of STEM doctorates working in non-academic sectors is greater than that in academic sectors (Turk-Bicakci et al. 2014). This paper examines the whole effect of scientific knowledge and skills that STEM doctorates bring into firms when they are appointed as outside

[5] Some critics even call the situation as the Pyramid scheme launched by a large numbers of National Science Foundation (NSF) Graduate Research and National Defense Education Act Fellowships and conspired with the grant-awarded professors and their research universities (Benderly 2010).

directors.

Finally, we contribute to the literature on M&A. In particular, by manually collecting takeover information of small target firms, we first identify one source of negotiation powers of R&D intensive small targets which is a crucial element in the model prediction of Phillips and Zhdanov (2013): that is, the presence of STEM independent directors leads the target firm to choose public bidder in the same industry which tend to overpay acquisition premium and appreciate the strategic value of target firms due to technological complementarity.

2. Data and summary statistics

2.1. The data

Our initial sample includes the M&A announcements by U.S public targets between 2005 and 2014. Following Masulis, Wang, and Xie (2007) and Bates, Becher, and Lemmon (2008), we obtain all deals from Securities Data Company's (SDC Platinum) Mergers and Acquisitions database and apply the following restrictions to construct our M&A sample identified as merger, acquisition of majority interest, or tender offer: (i) the acquisition is completed with transaction value at least $1 million; (ii) the bidder must own less than 50% of the target's share before the transaction and 100% afterward; (iii) the target has accounting data available from the Compustat annual files and daily stock return data (from 245 days prior to the announcement date (day 0)) from the Center for Research in Security Prices (CRSP); and (iv) the target is not a financial institution with SIC code between 6000 and 6999. This initial screening results in 906 transactions.

We collect information about directors from the ISS database (formerly known as RiskMetrics). Although ISS offers decent coverage of firms, it covers only firms that comprise the S&P 1500 and other major US corporations. Considering that target firms tend to be small, the database does not cover the majority of target firms in the SDC M&A database.[6] To fill this gap, we supplement the missing director information by manually reviewing DEF 14A proxy statements, 10-K annual reports, and the S&P Capital IQ database. DEF 14A forms, published by firms prior to their annual proxy meeting, contain considerable details on board composition and profiles of each board member. Specifically, the 'Election of Directors' section gives information on existing board members and nominees, including the number of directors, the biographies of directors and officers, and the independence of directors. We double check the board information from 10-K filings and Capital IQ when specific information from DEF 14A is unclear or we require additional information. We exclude transactions when governance information is not available in this process. Our final sample with full information for analysis has 772 observations. A detailed description of sample selection procedure is included in Appendix A.

2.2. Main variables of interests

We manually collect each independent director's detailed educational information such as degrees and academic disciplines by searching through SEC filings (e.g., DEF 14As and 10-Ks), press websites (e.g., *Businessweek* and *Forbes*), and other search engines (e.g., *Zoominfo* and *FindTheCompany*). We include some professional doctoral degrees such as Doctor of Jurisprudence (J.D.) and Doctor of Medicine (M.D.) in our sample.[7]

We classify doctoral independent directors into two groups based on the area of study: STEM – independent directors with technology-related degrees such as science, technology, engineering, and mathematics as well as medicine; and Non-STEM – independent directors

---

[6] We find that only about 30% of 906 transactions are merged with ISS database.

[7] These two disciplines take up the largest part of our doctoral independent directors.

with doctoral degrees in other areas such as business, law, economics, psychology, and politics.

Next, we convert our director-firm information into firm level to conduct our main analysis. Our indicator variables, *STEM* and *Non-STEM*, capture the presence of doctoral independent directors and equal one if the target firm has at least one independent director with a doctoral degree in each category. To measure the relative size of doctoral independent directors on the board, we create continuous variables, *% STEM* and *% Non-STEM*, that equal the ratio of the number of doctoral independent directors with degrees in each category to the total number of independent directors in the boardroom. We exclude a target firm only if all directors' educational information in the firm is entirely missing. Including target firms with incomplete educational information, however, may lead to underestimating the existence and fraction of doctoral independent directors. Thus, all the regressions in this study include a continuous variable, *Edu_missing*, which equals the number of independent directors with missing educational information divided by the total number of independent directors on the board, to account for the underestimation.

2.3. Measures of shareholder wealth and other controls

2.3.1. Announcement returns

We examine the impact of STEM director presence (proportion) on shareholder wealth around the announcement. In particular, we examine market-adjusted cumulative abnormal returns (CARs) around the announcement as a measure of the change in target shareholder wealth. Using the daily CRSP value-weighted market index returns, we obtain market model estimates during the estimation window from 245 days to 41 days before the announcement. We then calculate CARs for three, five, and seven days centered on the announcement date by summing the excess return over the market model-adjusted CRSP index returns during each event window.

2.3.2. Target characteristics

Firm Size has been found to affect target acquisition premium. Prior literature suggests that acquirers tend to pay lower premiums for large targets since the likelihood of a target being acquired decreases as its size increases. For example, Gorton, Kahl, and Rosen (2009) suggest that large targets tend to have weaker acquirer competition. We use the natural logarithm of total assets as a proxy for firm size. Firm Profitability is negatively correlated with target shareholder gains since less profitable targets are more likely to be acquired. We include return on assets (*ROA)* to control for the profitability of target firms. Israel (1991) finds that the gains to acquiring firms decrease as the target debtholders' proportion of the gains increases, suggesting that higher financial leverage in the target can deter takeovers. We control for *Leverage* defined as the ratio of a firm's total liabilities to total assets. Servaes (1991) finds that Tobin's Q is negatively related to target returns. Consequently, we include the target's *Tobin's Q* measured as the ratio of the market value of total assets to the book value of total assets.

To account for target board characteristics related to advising and monitoring roles, we include governance factors that might significantly influence target shareholder gains. Yermack (1996) finds that board size is negatively associated with Tobin's Q, suggesting that smaller boards can monitor the firm more effectively. Thus, we include *Board Size* measured as the log of the total number of directors. Cotter, Shivdasani, and Zenner (1997) find that independent directors can enhance target shareholder wealth by inducing managers to negotiate takeover premiums more aggressively. The variable *Board Independence* represents the fraction of independent directors to total directors on the board. Finally, two CEO characteristics, CEO Duality, which represents the practice of a firm's CEO simultaneously serving the chairman of its board, and *CEO Age*, which equals the log of CEO age, are also included to account for CEO influence on the board.

2.3.3. Deal characteristics

Our sample includes private acquirers. Bargeron, Schlingemann, Stulz, and Zutter (2008) show that target firms receive higher takeover premiums from public acquirers than from private acquirers. Consequently, we include a dummy variable *Private Acquirer* indicating that the acquirer is a private firm. Huang and Walkling (1987) and Comment and Schwert (1995) demonstrate that cash payment method is more beneficial for target shareholders than the method of stock payment. To account for this variation, we include a dummy variable, *Cash Only*. We also include *Deal Size* to control for the size of deal and a dummy variable, *Tender Offer*, following prior literature.

2.4 Summary statistics

[Insert Table 1 Here]

Panel A of Table 1 reports information on the doctoral independent directors and firm and governance and deal characteristics. Our sample shows that a significant portion of target firms (67.7%) have at least one doctoral independent director on the board. As for difference in major, 31.7% of target firms have at least one STEM doctoral independent directors and 50.6% of target firms have at least one Non-STEM doctoral independent directors. Target firms, on average, have 20.8% of independent directors with doctoral degrees on the board. 8.3% and 12.5% of independent directors on the board are STEM and Non-STEM doctoral degrees, respectively.

All of the target firm characteristics are measured at the end of the fiscal year immediately prior to the announcement. The mean (median) value of Tobin's Q is 1.861 (1.525) while the mean (median) ROA is -0.039 (0.026). The mean target firm size (6.048), measured as the log of total assets, is smaller than other studies such as Bates et al. (2008), suggesting that our sample includes smaller target firms. With respect to board characteristics, we find that the average board size is 7.83, with the median board having eight members.[8] The mean (median) fraction of board independence is 75% (77.8%). The proportion of targets' CEOs serving as the chairman of the board is observed in 46.1%. 22.5% of target firms are acquired by private firms. Finally, about 59.1% of acquirers pay all cash.

[Insert Table 2 Here]

Table 2 lists the Fama and French 48 industry classifications along with the number and the fraction of targets firms with at least one STEM directors. The fraction of target firms with at least one STEM director is highest in Pharmaceutical Products industry (22%), followed by Business Services[9], Electronic Equipment, Medical Equipment, Healthcare, and Computers. The majority of demand (73.1%) for the expertise of STEM director is clustered in these industries. Specifically, Pharmaceutical Products, Medical Equipment, and Healthcare industries account for 38.3%, consistent with the fact that medical degrees represent the largest part of STEM directors.

3. Results

3.1. Univariate Analysis

In this section, we make an initial assessment of the M&A wealth effects of STEM directors. Panel B of Table 1 presents the differences in means (medians) between target firms

---

[8] These numbers are smaller than those in prior literature. For example, Huson, Parrino, and Starks (2001) and Coles, Daniel, and Naveen (2008) report the median of 12 and 10 board members, respectively. Given that our sample is composed of relatively smaller firms, these numbers are consistent with the findings of Lehn, Sukesh, and Mengxin (2009) that larger firms are likely to have larger boards.

[9] Business Services industry includes prepackaged software (7372), computer processing, and data preparation and processing services (7374), information retrieval services (7375), computer facilities management services (7376), computer rental and leasing (7377), computer maintenance and repair (7378), and security systems services (7382), news syndicates (7383), photofinishing laboratories (7384).

with and without doctoral, STEM, and Non-STEM directors, with statistical significance measured by *t*-tests (Wilcoxon Rank Sum tests). The mean (median) three-day CARs for target firms with at least one STEM director is 0.357% (0.261%), compared with 0.259% (0.213%) of those without. The difference in CARs between two groups is statistically significant at the 1% level. The results for five-day and seven-day CARs are the same as the three-day result. The significantly higher CARs suggest that STEM directors in target firms, on average, help target shareholders gain higher wealth than target shareholders without STEM directors do from M&A announcements.

In contrast, we find that differences in the mean (median) values of CARs between targets with and without Non-STEM directors are not statistically significant, implying that Non-STEM directors do not create value for target shareholder in M&A transactions. These results also suggest that the overall insignificant influence of doctoral independent directors is driven by Non-STEM doctoral directors.

3.2. Multivariate tests

While the results above hint the positive influence of STEM directors, the univariate analysis does not control for other determinants of shareholder wealth. This section uses multivariate settings to extend our analysis. In addition, we conduct subsample tests to examine channels through which STEM directors have a positive influence on shareholder wealth.

3.2.1. Baseline regressions: Do STEM directors enhance target shareholder value?

We begin our multivariate analysis with the following OLS regression model to determine target shareholder gains around the announcement as a function of the presence of STEM and Non-STEM directors, target firm characteristics, target board structure, and deal characteristics:

$$\text{CAR}\ (-1,+1) = \beta_0 + \beta_1 \text{STEM (or Non} - \text{STEM)} + \beta_2 \text{Firm Size} + \beta_3 \text{ROA} +$$

$$\beta_4 \text{Leverage} + \beta_5 \text{Tobin's Q} + \beta_6 \text{Board Size} + \beta_7 \text{Board Independence} + \beta_8 \text{CEO Duality} + \beta_9 \text{CEO Age} + \beta_{10} \text{Private Acquirer} + \beta_{11} \text{Deal Value} + \beta_{12} \text{Tender Offer} + \beta_{13} \text{Cash Only} + \beta_{14} \text{Edu}_{\text{missing}} + \text{Year Dummies} + \varepsilon.$$

We include control variables for target firm and governance characteristics measured in the fiscal year immediately prior to the M&A announcement. We include year and Fama-French 12 industry dummies to control for year and industry fixed effects. For statistical significance, we use standard errors clustered by Fama-French 12 industries to correct for correlation of residuals within industries following Petersen (2009) and report *t*-statistics based on the robust standard errors in parentheses.

[Insert Table 3 Here]

Models 1 and 2 of Table 3 examine the influence of the presence of STEM and Non-STEM directors on three-day CARs. We model the effect of STEM and Non-STEM directors with indicator variables which equal to one if targets have at least one of each type of directors and zero otherwise. Models 1 and 2 show that, on average, the presence of STEM directors is associated with significantly higher CARs, while Non-STEM directors are not significantly associated with CARs. The positive and significant coefficient on *STEM* (*t*=2.993) suggests that CARs are 6.6% higher for targets with STEM directors on the board. The results are consistent with our univariate analysis. In Model 3 and 4, we use the relative size of STEM and Non-STEM directors *(% STEM* and *% Non-STEM*) and find consistent results. The coefficient on *% STEM* in Model 3 is significantly different from zero at the 5% level, but the coefficient on *% Non-STEM* is not significantly different from zero. The economic magnitude of the coefficient on *% STEM* is about 0.235, indicating that one standard deviation increase in the proportion of STEM directors is associated with an increase of CAR by 3.4% (0.145*0.235).. ~~a unit increase in the proportion of *STEM* directors is associated with an increase of CARs by~~

~~23.5%~~.

Overall, we find evidence consistent with our univariate tests in Panel B of Table 1. The coefficients on control variables are consistent with prior literature.

3.2.2. Endogeneity Issue: Instrumental variable approach

In the preceding regression analysis, we include both control variables and fixed effects to control for omitted variable bias. However, the potential problem of endogeneity may still exist. Thus, in this subsection, we use an instrumental variable (IV) approach to address potential endogeneity. We argue that the supply ratio of doctoral students by major fields provides a unique instrument in determining the likelihood of doctoral directors serving on the board. Specifically, our conjecture is that a major field of study that produces more doctoral degree holders are likely to supply more doctoral graduates to the industry. In addition, the supply ratio is less likely associated with shareholder gains, fulfilling the requirements for an instrument variable.

We assume that the relative size of producing doctoral degree holders by academic field remains stable and use the ratio on 2014 as a proxy for historical supply ratio. We first obtain the data on the number of doctor's degrees conferred by U.S. higher education institutions in 2014 from U.S. Department of Education website. We then measure the *Supply Ratio* of each academic field by dividing the number of doctoral graduates in each field by the total number of doctoral graduates. In defining IV, we exclude a firm if it has a doctoral independent director with a degree from a non-U.S. institution because the data from U.S. Department of Education covers only U.S institutions.

[Insert Table 4 Here]

The results are reported in Table 4. In the first stage, we regress *% STEM* and *% Non-STEM*, on the supply ratio, and the same control variables as those in Table 3. Model 1 and

Model 3 reports the results of the first stage regressions where we use *% STEM* and *% Non-STEM* as dependent variables, respectively. We find that the supply ratio is positively and significantly associated with the relative size of *STEM* and *Non-STEM* directors on the board, implying that doctoral degree holders graduated from the field of high supply ratio are more likely to serve on the board. The first stage *F*-statistics are 12.112 (in Model 1) and 680.771 (in Model 3), respectively, confirming the supply ratio as a valid instrument for *% STEM* and *% Non-STEM*.[10] Model 2 and Model 4 show results from the second stage regressions. We find that the coefficients on fitted *% STEM* is positive and significant at the 5% level in both specifications. Model 4 shows that the coefficient on fitted *% Non-STEM* is negatively and significantly related to CARs. Overall, the results are consistent with those from Table 3, indicating that the relation between *STEM* directors and shareholder gains are not driven by the potential endogeneity bias.

3.2.3. STEM Directors and Corporate Innovation

Having established the positive influence of the presence and the proportion of STEM directors on target shareholder wealth, we conduct subsample tests to explore channels through which STEM directors positively influence target shareholder value. In particular, we investigate whether the expertise of STEM directors is associated with higher CARs by considering environments in which their expertise is more likely to be beneficial to shareholder wealth.

[Insert Table 5 Here]

First, we use R&D intensity, measured as R&D expenditure divided by total assets, as a proxy for needs for firm-specific knowledge (see Coles et al. 2008). We define target firms

[10] Cragg and Donald (1993) test also confirms that our instrument is relevant.

with above-median R&D intensity in a given year as high R&D intensity firms. Following the prior literature, we assume that targets with missing R&D expenditure from Compustat have zero R&D expenditure and include *R&D_missing*, a dummy variable that takes one if missing value of R&D expenditure is replaced with zero, to control for possible underestimation.

Panel A of Table 5 reports the results of high and low R&D intensity subsamples. We find that STEM directors in target firms create value for shareholders only when the R&D intensity of the target firms is high. Specifically, Model 1 shows that the coefficient on *STEM* is positive and statistically significant (0.103; *t*=3.132), implying that targets with STEM directors on the board earn 10.3% higher CARs when they have high R&D intensity. In contrast, Model 3 suggests that targets with STEM directors do not realize significantly higher CARs when they have low R&D intensity. In Model 2 and 4, the coefficients on *Non-STEM* are insignificant.

Second, we divide our sample into high- and low-tech industries. We define high-tech industries following Loughran and Ritter (2004) and also include Drugs industries based on the Fama and French 48 industry classifications. The results in Panel B of Table 5 show that the market responds positively to target firms with STEM directors when the target firms belong to high-tech industries. Model 1 suggests that the existence of STEM directors on the board are associated with 8.3% higher CARs in high-tech industries. Model 3 shows, however, that the market responds indifferently to STEM directors in low-tech industries.

Finally, we compare CARs of targets firms headquartered in high-tech cities with those headquartered in low-tech cities. We obtain information on the headquarter location of each target firm from Compustat. Using city and county information, we classify the target firm's location as a high-tech city if it is headquartered in the high-tech metropolitan area defined in

Advanced Industry Data from Brookings Institution.[11] Panel C of Table 5 shows that STEM directors have positive influence on CARs only when target firms are located in high-tech cities (0.074; t=2.929).

In sum, we observe that the positive effect of STEM directors on CARs is more pronounced (1) when target firms' R&D intensity is high; (2) when target firms belong to high-tech industries; and (3) when target firms are headquartered in high-tech cities. We argue that these results imply that STEM directors play an important role on corporate innovation, and the market responds more favorably to target firms with greater need for innovation when they have STEM directors on the board.

[Insert Table 6 Here]

We further test whether the positive effect of STEM directors on CARs is more pronounced when their STEM expertise is relevant to the target firm's industry membership. We first determine whether STEM directors' academic discipline is in line with the target firm's primary operation based on the Fama and French 48 industry classification. For example, the expertise of independent directors with M.D. degrees should be in line with target firms in Healthcare, Medical Equipment, and Pharmaceutical Products industries. We also find information on the target firm's products and service from 10-K and news articles to double check the association between STEM directors' academic discipline and the target firm's operations.[12]

In Table 6, we find that the positive effect of STEM directors on CARs is statistically

[11] Refer to http://www.brookings.edu/research/reports2/2015/02/03-advanced-industries#/M10420

[12] For example, the corporate innovation of target firm classified as computer programming and data processing industry do not appear to be related to the expertise of M.D. However, we define that M.D. directors' academic discipline is in line with the target firm's operations if the firm provides medical data processing as main service.

significant only when STEM directors' academic discipline is pertinent to the target firm's industry. Specifically, the presence of STEM directors whose academic discipline matching with the target firm's operations improves CARs by 6.1% (*t*=2.302) (Model 1), but those with non-matched academic discipline have insignificant effect on CARs (Model 3). The coefficients on the relative size of STEM directors with matched (Model 2) and non-matched (Model 4) academic discipline show consistent result. Overall, the result in Table 6 further suggests that STEM directors play a technical advisory role on corporate innovation using their knowledge and skills acquired from rigorous academic training.

3.2.4. Technical Advisors versus Managerial Advisors

We next explore whether the positive effect of STEM directors on CARs is universal regardless of certain situations in which their role might be limited, such as target firms with high complexity and close social ties between CEO and STEM directors.

[Insert Table 7 Here]

First, following Coles et al. (2008) and Linck, Netter, and Yang (2008), we use firm complexity as a proxy for an expected managerial advisory role of independent directors. We first compute a factor score (principal component analysis) based on the number of business segments, firm size, and leverage. We then define complex target firms as those with above the median factor score. Panel A of table 7 presents the results. Model 1 suggests that STEM directors do not have a significantly positive influence on CARs of complex targets (0.039; *t*=1.338) when they sit on corporate boards in which independent directors are expected to have solid understanding in business and financial management. In contrast, the simple targets with STEM directors have significantly higher CARs (0.077; *t*=2.477) in Model 3. The result suggests that STEM directors with specific STEM knowledge and skills do not provide valuable advising in situations where the need for general advising regarding business and corporate financing is high.

Next, we examine social networks between CEOs and STEM directors to further investigate the role of STEM directors. Social ties can be an important determinant of the independence of outside directors (Hwang and Kim, 2009). On the one hand, social connections can enhance mutual understanding and reduce information asymmetry between CEOs and independent directors, thereby improving the advisory roles of boards (Westphal 1999; Adams and Ferreira 2007). However, we argue that STEM directors who have social ties with CEOs are more likely to be appointed as independent directors not because of their STEM expertise but because of the friendship with the CEO or social status. Thus, while social ties may facilitate the role of managerial advisor, they limit STEM directors' role of technical advisor.

Following Fracassi and Tate (2012), we use employment ties between CEOs and doctoral independent directors as a proxy for social ties. We hand-collect the employment history of CEOs and doctoral independent directors from various sources. Our primary source is DEF 14A proxy statements and 10-K annual reports. If we are unable to find the information on employment from the primary sources, we rely on search engines such as *Zoominfo.com, Businessweek.com,* and *Forbes.com*. We classify doctoral independent directors as "socially connected to CEO" if they have worked together for other companies as managers or directors at the same time. We measure the presence of STEM and Non-STEM directors with and without social ties. We include two indicator variables, *tied STEM* and *tied Non-STEM*, and also use *non-tied STEM* and *non-tied Non-STEM*, for comparison. We include *Employ_missing* in all specifications to account for the proportion of independent directors with missing information on employment.

Panel B of Table 7 presents the results. Consistent with our conjecture, Model 1 shows that the existence of tied STEM directors is insignificantly associated with CARs (*t*=0.317), but Model 2 shows that a unit increase of the relative size of non-tied STEM directors is associated with 6.9% increase in CARs (*t*=2.842). These results suggest that social ties with CEOs limit the quality of STEM directors' technical advising. Interestingly, Non-STEM directors significantly enhance shareholder wealth only when they are socially connected to CEO (0.094; *t*=2.232), indicating that social ties between CEOs and Non-STEM directors improve the quality of a managerial advising role conducted by Non-STEM directors.

Overall, the results in Table 7 imply that the presence of STEM directors on the board is not always beneficial to target shareholders. Our findings further support our conjecture that the positive effect of STEM directors on shareholder gains is attributable to their technical advisory role in corporate innovation instead of their monitoring role in management (i.e., a role of managerial advisors).

3.2.5. Target's bidder choice

We examine whether the presence of STEM directors is associated with the choice of certain types of bidders which can create more synergistic gains and pay more acquisition premium to target firms. First, it is well accepted that bidders in the same industry as the target can create greater synergy than bidders in different industries. Bidders from the same industry can assess the value of intangible assets (such as patents) of target firms much better than bidders from different industries. Table 8 shows test results of whether firms with STEM directors are more likely to be acquired by bidders in the same industry. We consider three different levels of SIC code. In the first case, we classify a M&A deal into the same industry transaction only if bidder and target firms have the identical four digit SIC code. We also consider less restrictive classification of same industry deals where the first three and first two SIC digits match. We estimate the likelihood of target's choice on bidder industry with logistic regression.

[Insert Table 8 Here]

In Table 8, Model 1 with different requirements (SIC 4 digit, first 3 digit, and first 2 digit match) for the classification of same industry M&A deal presents positive coefficient for *STEM*, significant at the 1 percent level. This implies that the existence of STEM doctoral independent directors increases the probability of target firms choosing buyers in the same industry. In contrast, the coefficient on Non-STEM in Model 2 is insignificant, suggesting that the existence on non-STEM doctoral independent directors does not increase the probability to choose bidders in the same industry.

Further, the coefficient on *Private Acquirer* is negative and significant across all models and industry classifications, indicating that public bidders tend to acquire target firms in the same industry. Bargeron et al. (2008) report that target shareholders gain much more when a public firm makes an acquisition than when a private firm does. They examine why wealth increase in target shareholders differs so much between public and private bidders and conclude that bidders operating in public markets expect to benefit from synergies more than private equity bidders. Thus, we argue the negative coefficient on *Private Acquirer* suggests that public acquirers are more likely to be strategic buyers than private acquirers.

[Insert Table 9 Here]

Finally, Table 9 examines whether target firms with STEM directors are more likely to choose public bidders rather than private bidders. We use an indicator variable, *Public*, that equals 1 if target firms are acquired by public firms and 0 otherwise. Models 1 and 2 use a logistic regression model and Models 3 and 4 employ a probit regression model. The positively significant coefficients on *STEM* in Models 1 and 3 suggest that target firms are more likely to be acquired by public bidders, whereas Models 2 and 4 imply that Non-STEM firms are less likely to be acquired by public bidders.

4. Concluding Remarks

We examine whether and how independent directors with doctoral degrees in science and technology enhance target shareholder wealth in mergers and acquisitions. We find that those directors with doctoral degrees in science and technology help target firms generate greater shareholder gains around takeover announcements and lead target firms to choose public firms in the same industry as the acquirer. The results suggest that they play an important technical advisory role in corporate innovation. That is, our findings suggest that their knowledge and skills gained from rigorous scientific training in science and technology contribute to the nation's innovative and entrepreneurial ecosystem even when they work in non-academic sectors.

Interestingly, we find that independent outside directors with doctoral degrees in non-science and technology related disciplines do not exhibit such increases in target shareholder wealth. However, one should not prematurely interpret the absence of an effect for non-science and technology doctoral independent directors as evidence that they do not add value to target shareholder wealth or do not contribute to corporate America. Non-science doctoral independent directors may play a variety of roles such as monitoring managers and offering social and political connections and reputation.

References

Adams, R. B., Ferreira, D., 2007. A theory of friendly boards. *Journal of Finance* 62, 217-250.

Aghion, P., Van Reenen, J., Zingales, L., 2013. Innovation and institutional ownership. *American Economic Review* 103, 277-304.

Audretsch, D. B., Stephan, P. E., 1996. Company-Scientist locational links: The case of biotechnology. *American Economic Review*, 86: 641-652.

Austin, J. 2013. Want to be a professor? Choose math. *Science*. Retrieved from http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2013_07_24/caredit.a1300150

Bargeron, L. L., Schlingemann, F. P., Stulz, R. M., Zutter, C. J., 2008. Why do private acquirers pay so little compared to public acquirers? *Journal of Financial Economics* 89, 375-390.

Bates, T. W., Becher, D. A., Lemmon, M. L., 2008. Board classification and managerial entrenchment: Evidence from the market for corporate control. *Journal of Financial Economics* 87, 656-677.

Benderly, B. L., 2010. Does the US produce too many scientists? *Scientific American*.

Chen, Y., Podolski, E. J., Rhee, S. G., Veeraraghavan, M., 2014. Local gambling preferences and corporate innovative success. *Journal of Financial and Quantitative Analysis* 49, 77-106.

Cho, C. H., Jung, J. H., Kwak, B., Lee, J., Yoo, C-Y., 2014. Professors on the board: Do they contribute to society outside the classroom? *Journal of Business Ethics*, 1-17.

Coles, J. L., Daniel, N. D., Naveen, L., 2008. Boards: Does one size fit all? *Journal of Financial Economics* 87, 329-356.

Comment, R., Schwert, G. W., 1995. Poison or placebo? Evidence on the deterrence and wealth effects of modern antitakeover measures. *Journal of Financial Economics* 39, 3-43.

Cotter, J. F., Shivdasani, A., Zenner, M., 1997. Do independent directors enhance target shareholder wealth during tender offers? *Journal of Financial Economics* 43, 195-218.

Cragg, J. G., Donald, S. G., 1993. Testing identifiability and specification in instrumental variable models. *Econometric Theory* 9, 222-240.

Duchin, R., Matsusaka, J. G., Ozbas, O., 2010. When are outside directors effective? *Journal of Financial Economics* 96, 195–214.

Fracassi, C., Tate, G., 2012. External networking and internal firm governance. *Journal of Finance* 67, 153-194.

Francis, B., Hasan, I., Wu, Q., 2015. Professors in the boardroom and their impact on corporate governance and firm performance. *Financial Management* 44, 547 – 581.

Galasso, A., Simcoe, T. S., 2011. CEO overconfidence and innovation. *Management Science* 57, 1469–1484.

Gorton, G., Kahl, M., Rosen, R. J., 2009. Eat or be eaten: A theory of mergers and firm size. *Journal of Finance* 64, 1291-1344.

Hirshleifer, D., Low, A., and Teoh, S. H., 2012. Are overconfident CEOs better innovators? *Journal of Finance* 67, 1457–1498.

Huang, Y. S., Walkling, R. A., 1987. Target abnormal returns associated with acquisition announcements: Payment, acquisition form, and managerial resistance. *Journal of Financial Economics* 19, 329-349.

Huson, M. R., Parrino, R., Starks, L. T., 2001. Internal monitoring mechanisms and CEO turnover: A long-term perspective. *Journal of Finance* 56, 2265-2297.

Hwang, B. H., Kim, S., 2009. It pays to have friends. *Journal of Financial Economics* 93, 138-158.

Israel, R., 1991. Capital structure and the market for corporate control: The defensive role of debt financing. *Journal of Finance* 46, 1391-1409.

Jung, B., Liu, Y., Podolski, E. J., Rhee, S. G., and Yoo, C-Y., 2015. Do professors on the board facilitate corporate innovation? Unpublished working paper. University of Hawaii, Manoa. Presented at the 3rd AIEA-NBER Conference in Tokyo, Japan

Lehn, K. M., Patro, S., Zhao, M., 2009. Determinants of the size and composition of US corporate boards: 1935-2000. *Financial Management* 38, 747-780.

Lerner, J., Leamon, A., Hardymon, F., 2012. Venture Capital, Private Equity, and the Financing of Entrepreneurship. New York: John Wiley & Sons.

Linck, J. S., Netter, J. M., Yang, T., 2008. The determinants of board structure. *Journal of Financial Economics* 87, 308-328.

Loughran, T., Ritter, J. R., 2004. Why has IPO underpricing changed over time? *Financial Management* 33, 5 – 37.

Masulis, R. W., Wang, C., Xie, F., 2007. Corporate governance and acquirer returns. *Journal of Finance* 62, 1851-1889.

Mckenna, L., 2016. The Ever-Tightening Job Market for Ph.D.s: Why do so many people continue to pursue doctorates? *The Atlantic*.

National Science Foundation, 2010. National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov/.

Obama, B., March 23, 2015. Remarks by the President at White House Science Fair url: https://www.whitehouse.gov/the-press-office/2015/03/23/remarks-president-white-house-science-fair

Petersen, M. A., 2009. Estimating standard errors in finance panel data sets: Comparing approaches. *Review of Financial Studies* 22, 435-480.

Phillips, G. M., Zhdanov, A., 2013. R&D and the incentives from merger and acquisition activity. *Review of Financial Studies* 26, 34-78.

Sauermann H, Roach M., 2012. Science PhD career preferences: Levels, changes, and advisor encouragement. *PLoS ONE* 7(5):e36307. CrossRef

Servaes, H., 1991. Tobin's Q and the gains from takeovers. *Journal of Finance* 46, 409-419.

Turk-Bicakci, L., Berger, A., Haxton, C., 2014. The Nonacademic Careers of STEM PhD Holders (Washington, DC: American Institutes for Research, April 2014). Retrieved from: http://www.air.org/sites/default/files/downloads/report/STEM%20nonacademic%20careers%2 April14.pdf

Westphal, J. D., 1999. Collaboration in the boardroom: Behavioral and performance consequences of CEO-board social ties. *Academy of Management Journal* 42, 7-24.

White, J. T., Woidtke, T., Black, H. A., Schweitzer, R. L., 2014. Appointments of academic directors. *Journal of Corporate Finance* 28, 135–151.

Yermack, D., 1996. Higher market valuation of companies with a small board of directors. *Journal of Financial Economics* 40, 185-211.

Appendix A. Sample Selection Procedure

Procedure		Obs.
1.	Number of completed M&As announced between 2005 and 2014 (from SDC Platinum)	4,025
2.	Exclude 'Acquisition of Assets,' 'Acquisition of Certain Assets,' 'Acquisition of Remaining Interests,' 'Buyback,' 'Exchange Offer,' or 'Recapitalization.'	2,311
3.	Deal value greater than $1 million	1,919
4.	The bidder should own less than 50% of the target's share before the transaction and 100% afterward	1,760
5.	Targets with accounting and stock return information prior to the announcement date	1,214
6.	The target is not a financial institution	906
7.	Targets with Governance information immediately prior to the announcement date	772

Appendix B. Variable Descriptions

Variable Names	Descriptions	Source
Dependent Variables		
CAR (-1, +1)	Three-day market-adjusted cumulative abnormal returns (CARs) around announcements.	CRSP
Same Industry	An indicator variable that equals one if a target shares same industry membership with its acquirer based on four-digit, three-digit, and two digit SIC code and zero otherwise.	Compustat
Public	An indicator variable that equals one if a target is acquired by a public bidder and zero otherwise.	SDC Platinum
Main Variables of Interest		
STEM	An indicator variable that equals one if a target firm has at least one STEM independent directors and zero otherwise.	ISS & Manually collected
Non-STEM	An indicator variable that equals one if a target firm has at least one Non-STEM independent directors and zero otherwise.	ISS & Manually collected
% STEM	A continuous variable measured by dividing the number of STEM independent directors by the total number of independent directors on the board.	ISS & Manually collected
% Non-STEM	A continuous variable measured by the proportion of the number of Non-STEM independent directors to the total number of independent directors on the board.	ISS & Manually collected
STEM Supply	An instrument variable (IV) for % STEM that equals (1+STEM supply ratio), where STEM supply ratio is measured by dividing the number of STEM graduates in each area by the total number of graduates from doctoral programs in the U.S. in 2014.	ISS & Manually collected
Non-STEM Supply	An instrument variable for % Non-STEM that equals (1+Non-STEM supply ratio), where Non-STEM supply ratio is measured by the proportion of Non-STEM graduates in each area to the total number of doctoral graduates in the U.S. in 2014.	ISS & Manually collected
STEM matched	An indicator variable that equals one if a target firm has at least one STEM directors with academic discipline closely related to the firm’s industry membership and zero otherwise.	ISS & Manually collected
STEM non-matched	An indicator variable that equals one if a target firm has at least one STEM directors who has academic discipline irrelevant to the firm’s industry membership and zero otherwise.	ISS & Manually collected
tied STEM	An indicator variable that equals one if at least one STEM director and the target’s CEO worked at the same place other than the target firm prior to the M&A announcement (employment ties) and zero otherwise.	ISS & Manually collected
non-tied STEM	An indicator variable that equals one if a target firm has at least one STEM director and none of its STEM directors has employment ties with its CEO and zero otherwise.	ISS & Manually collected
tied Non-STEM	An indicator variable that equals one if at least one Non-STEM director and the target’s CEO worked at the same place other than the target firm prior to the M&A announcement and zero otherwise	ISS & Manually collected
non-tied Non-STEM	An indicator variable that equals one if a target firm has at least one Non-STEM director and none of its Non-STEM directors has employment ties with its CEO and zero otherwise.	ISS & Manually collected

Firms Characteristics		
Firm Size	The natural log of total assets (Compustat item AT), deflated to 2014 dollars using the consumer price index (CPI).	Compustat
ROA	Income before extraordinary items (IB) divided by total assets (AT).	Compustat
Leverage	The sum of long term debt (DLTT) and debt in current liabilities (DLC) over total assets (AT).	Compustat
Tobin's Q	The market value of assets divided by the book value of assets (AT), where the market value of assets is measured by [total assets (AT) – book value of equity (AT – LT – PSTK + TXDITC) + market value of equity (PRCC_F × CSHO)].	Compustat
Governance Characteristics		
Board Size	The natural log of the total number of directors on the board	ISS & Manually collected
Board Independence	The proportion of independent directors on the board	ISS & Manually collected
CEO Duality	An indicator variable that equals one if the CEO also serves as chairman of the board and zero otherwise	ISS & Manually collected
CEO Age	The natural log of CEO Age	ISS & Manually collected
Deal Characteristics		
Private Acquirer	An indicator variable that equals one if a target firm is acquired by a private acquirer and zero otherwise	SDC Platinum
Deal Value	The natural log of transaction value, deflated to 2014 dollars using the consumer price index (CPI).	SDC Platinum
Tender Offer	An indicator variable that equals one if the deal is identified by SDC platinum as a 'Tender Offer' and zero otherwise	SDC Platinum
Cash Only	An indicator variable that equals one if only cash is used to pay for the deal and zero otherwise	SDC Platinum
Hostile	An indicator variable that equals one if the deal is identified by SDC platinum as 'Unsolicited' and zero otherwise	SDC Platinum
Toehold	Percentage of target firm equity owned by the acquirer prior to the announcement	SDC Platinum

Table 1. Summary Statistics (N=722)

Panel A. Summary of Doctoral Independent Directors, Firm, and Deal Characteristics

Variable	Mean	Median	SD	25th Percentile	75th Percentile
Dr.	0.677	1.000	0.468	0.000	1.000
STEM	0.317	0.000	0.466	0.000	1.000
Non-STEM	0.506	1.000	0.500	0.000	1.000
% Dr.	0.208	0.200	0.192	0.000	0.333
% STEM	0.083	0.000	0.145	0.000	0.143
% Non-STEM	0.125	0.100	0.150	0.000	0.200
Firm Characteristics					
Firm Size (ln)	6.048	5.958	1.722	4.755	7.247
ROA	-0.039	0.026	0.264	-0.040	0.067
Leverage	0.203	0.121	0.249	0.000	0.323
Tobin's Q	1.861	1.525	1.171	1.145	2.199
Governance Characteristics					
Board Size	7.830	8.000	1.958	7.000	9.000
Board Independence	0.750	0.778	0.126	0.667	0.857
CEO Duality	0.461	0.000	0.499	0.000	1.000
CEO Age	54.554	54.000	8.074	49.000	60.000
Deal Characteristics					
Private Acquirer	0.225	0.000	0.418	0.000	0.000
Deal Value (ln)	6.406	6.389	1.756	5.233	7.665
Tender Offer	0.199	0.000	0.400	0.000	0.000
Cash Only	0.591	1.000	0.492	0.000	1.000

Panel B. Doctoral Independent Directors and Target Shareholder Gains

Variable	With Doctoral Directors		Without Doctoral Directors		Test of Difference	
	Mean	Median	Mean	Median	*t*-statistics	*z*-statistics
Dr.						
CAR (-1, +1)	0.2990	0.2338	0.2728	0.2093	-1.015	-0.967
CAR (-2, +2)	0.3027	0.2343	0.2725	0.2109	-1.176	-0.988
CAR (-3, +3)	0.3120	0.2376	0.2765	0.2122	-1.336	-1.265
STEM						
CAR (-1, +1)	0.3570	0.2605	0.2591	0.2126	-3.833***	-2.869***
CAR (-2, +2)	0.3599	0.2641	0.2614	0.2143	-3.879***	-2.616***
CAR (-3, +3)	0.3639	0.2721	0.2707	0.2230	-3.540***	-2.649***
Non-STEM						
CAR (-1, +1)	0.2705	0.2241	0.3113	0.2253	1.695*	1.204
CAR (-2, +2)	0.2741	0.2244	0.3127	0.2230	1.615	1.123
CAR (-3, +3)	0.2861	0.2325	0.3157	0.2345	1.193	0.787

The table summarizes the statistics for the variables used in this study. The sample consists of 772 U.S. mergers and acquisitions completed between 2005 and 2014. Panel A shows summary statistics for *STEM* and *Non-STEM* independent directors and firm, governance and deal characteristics. We report the mean, median, standard deviation, and 25th and 75th percentiles for each variable. To allow for heterogeneity in academic area, we classify doctoral independent directors into two categories: STEM – those who have degrees in science, technology, engineering, and mathematics; and Non-STEM – those who have degrees in other area. *STEM* and *Non-STEM* are dummy variables indicating the existence of each group on the board. *% STEM* and *% Non-STEM* are continuous variables measured by dividing the number of independent directors with each major

category by the total number of independent directors on the board. *Firm Size* is the natural logarithm of total assets. *ROA* represents income before extraordinary items divided by total assets. *Leverage* is the sum of long term debt and current debt over total assets. *Tobin's Q* is measured as the market value of assets divided by the book value of assets. *Board Size* represents the number of total directors on the board. *Board Independence* is the proportion of independent directors on the board. *CEO Duality* indicates CEOs serving as the chairperson of board at the same time. *CEO Age* is the natural logarithm of CEO age. *Private Acquirer* is a dummy variable indicating if a target is acquired by a private firm. All variables are measured as of the end of the fiscal year immediately prior to the announcement. A detailed description of each variable is included in Appendix B.
Panel B reports the mean and median of three-day, five-day, and seven-day cumulative abnormal returns (CARs). Two sample *t*-tests (Wilcoxon Rank Sum tests) are conducted to test whether means (medians) of targets with doctoral independent directors are significantly different from those without such directors. ***, **, and * denote significance at the 10%, 5%, and 1% levels, respectively.

Table 2. Industry Distribution of Firms with STEM

Fama & French 48 industries	Number of Observations	Proportion (%)
Pharmaceutical Products	54	22.0
Business Services	44	18.0
Electronic Equipment	31	12.7
Medical Equipment	26	10.6
Healthcare	14	5.7
Computers	10	4.1
Petroleum and Natural Gas	9	3.7
Communication	9	3.7
Measuring and Control Equipment	8	3.3
Machinery	6	2.5
Others	34	13.9
Total	245	100.0

The table reports the distribution of 245 U.S. target firms with at least one STEM independent director by the Fama-French 48 industry classifications.

Table 3. Baseline Regressions: Doctoral Directors and the Wealth of Target Shareholders

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5
STEM	0.066**				
	(2.993)				
Non-STEM		-0.017			
		(-1.029)			
% STEM			0.235**		0.229**
			(3.136)		(3.063)
% Non-STEM				-0.075	-0.057
				(-1.454)	(-1.154)
Firm Size	-0.040	-0.037	-0.036	-0.036	-0.035
	(-1.050)	(-0.979)	(-0.974)	(-0.959)	(-0.940)
ROA	-0.172**	-0.180***	-0.165**	-0.182***	-0.165**
	(-3.125)	(-3.327)	(-2.964)	(-3.356)	(-2.997)
Leverage	0.107	0.091	0.104	0.090	0.104
	(1.562)	(1.443)	(1.593)	(1.435)	(1.603)
Tobin's Q	-0.020	-0.020	-0.019	-0.020	-0.020
	(-1.215)	(-1.185)	(-1.175)	(-1.195)	(-1.185)
Board Size	-0.023	-0.004	-0.016	-0.008	-0.014
	(-0.414)	(-0.075)	(-0.283)	(-0.149)	(-0.251)
Board Independence	0.113	0.154	0.126	0.147	0.126
	(1.078)	(1.530)	(1.170)	(1.416)	(1.182)
CEO Duality	-0.036	-0.038	-0.033	-0.038	-0.033
	(-0.904)	(-0.966)	(-0.861)	(-0.965)	(-0.854)
CEO Age	-0.062	-0.034	-0.064	-0.037	-0.066
	(-0.673)	(-0.374)	(-0.708)	(-0.407)	(-0.741)
Private Acquirer	-0.071	-0.069	-0.068	-0.068	-0.065
	(-1.563)	(-1.594)	(-1.535)	(-1.574)	(-1.528)
Deal Value	0.013	0.012	0.011	0.011	0.010
	(0.414)	(0.374)	(0.342)	(0.355)	(0.321)
Tender Offer	0.044	0.048	0.041	0.048	0.040
	(1.138)	(1.185)	(1.069)	(1.186)	(1.036)
Cash Only	0.119***	0.120***	0.120***	0.120***	0.121***
	(3.663)	(3.650)	(3.647)	(3.640)	(3.614)
Edu_missing	0.012	-0.017	0.021	-0.021	0.013
	(0.375)	(-0.459)	(0.705)	(-0.548)	(0.428)
Constant	0.534	0.385	0.511	0.410	0.522
	(1.296)	(0.939)	(1.279)	(0.995)	(1.304)
F-test					$\beta_1=\beta_2$***
					(p=0.008)
Year Fixed Effects	Y	Y	Y	Y	Y
Industry Fixed Effects	Y	Y	Y	Y	Y
Observations	750	750	750	750	750
Adjusted R-squared	0.129	0.123	0.130	0.123	0.130

The table contains the results of OLS regressions of target shareholder wealth on the presence and the relative size of STEM and Non-STEM independent directors and other control variables. The sample consists of 772 U.S. mergers and acquisitions completed between 2005 and 2014. The dependent variable is the three-day CAR around the merger announcement date. *STEM* and *Non-STEM* are dummy variables which equal one if a firm has at least one independent director with a doctoral degree in each field. *% STEM* and *% Non-STEM* are continuous variables measured by dividing the number of independent directors with each major category by the total number of independent directors on the board. All specifications control for year and industry (Fama-French 12 industry classifications) fixed effects. A detailed description of each variable is included in Appendix B. *t*-statistics based on standard errors clustered by the Fama-French 12 industry classifications are in parentheses. ***, **, and * represent significance at the 1%, 5%, and 10% level, respectively.

Table 5. STEM Directors and Corporate Innovation

Panel A. Firm-Level R&D Intensity: High vs Low R&D Intensity

VARIABLES	High R&D Intensity		Low R&D Intensity	
	Model 1	Model 2	Model 3	Model 4
STEM	0.103**		0.028	
	(3.132)		(0.602)	
Non-STEM		-0.011		-0.022
		(-0.481)		(-0.754)
R&D missing	N	N	Y	Y
Intercept	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Industry Fixed Effects	Y	Y	Y	Y
Observations	376	376	374	374
Adjusted R-squared	0.143	0.128	0.128	0.128

Panel B. Industries: High-Tech vs Low-Tech Industries

VARIABLES	High Tech Industries		Low Tech Industry	
	Model 1	Model 2	Model 3	Model 4
STEM	0.083**		0.054	
	(6.894)		(0.828)	
Non-STEM		-0.005		-0.023
		(-0.165)		(-0.780)
Intercept	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Industry Fixed Effects	Y	Y	Y	Y
Observations	381	381	369	369
Adjusted R-squared	0.163	0.153	0.108	0.104

Panel C. Location: High-Tech Cities vs Low-Tech Cities

VARIABLES	High-Tech Cities		Low-Tech Cities	
	Model 1	Model 2	Model 3	Model 4
STEM	0.074**		0.065	
	(2.929)		(1.718)	
Non-STEM		0.050*		-0.069*
		(2.107)		(-2.059)
Intercept	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Industry Fixed Effects	Y	Y	Y	Y
Observations	357	357	393	393
Adjusted R-squared	0.204	0.201	0.057	0.060

The table presents results of subsample tests that examine the relation between the presence of STEM directors and corporate innovation. The sample consists of 772 U.S. mergers and acquisitions completed between 2005 and 2014. The dependent variable is three-day cumulative abnormal returns. *STEM* and *Non-STEM* are dummy variables which equal one if a firm has at least one independent directors with a doctoral degrees in each field. Panel A divides our sample into high and low R&D intensity targets. We use R&D

intensity, measured by dividing R&D expenditure by total assets, as a proxy for needs for specific knowledge following Coles et al. (2008). We classify a target into High R&D intensity firm if the firm's R&D intensity is greater than the median value in a given year. *R&D_missing* is a dummy variable that takes one if missing value of R&D expenditure is replaced with zero. Panel B separates our sample into high and low tech industries. High-tech industries include those defined in Loughran and Ritter (2004) and Drugs industries based on the Fama-French 48 industry classifications. Panel C divides our sample based on the locations in which target firms are headquartered. We define a target firm to be in a high-tech city if it is headquartered in the high-tech metropolitan areas defined in Advanced Industry Data from the Brookings Institution. Regressions also control for the set of variables used in the baseline regression in Table 3. A detailed description of each variable is included in Appendix B. All specifications control for year and industry (Fama-French 12 industry classifications) fixed effects. *t*-statistics based on standard errors clustered by the Fama-French 12 industry classifications are in parentheses. ***, **, and * represent significance at the 1%, 5%, and 10% level, respectively.

Table 6. Specialty Matching of STEM Directors

VARIABLES	Model 1	Model 2	Model 3	Model 4
STEM matched	0.061**			
	(2.302)			
% STEM matched		0.228*		
		(2.173)		
STEM non-matched			0.052	
			(1.200)	
% STEM non-matched				0.255
				(1.031)
Firm Size	-0.038	-0.035	-0.038	-0.038
	(-1.009)	(-0.939)	(-1.036)	(-1.024)
ROA	-0.174***	-0.167**	-0.179***	-0.180***
	(-3.195)	(-2.985)	(-3.247)	(-3.295)
Leverage	0.103	0.104	0.088	0.089
	(1.618)	(1.678)	(1.337)	(1.360)
Tobin's Q	-0.020	-0.019	-0.020	-0.020
	(-1.228)	(-1.145)	(-1.184)	(-1.179)
Board Size	-0.020	-0.015	-0.013	-0.011
	(-0.361)	(-0.258)	(-0.252)	(-0.216)
Board Independence	0.119	0.131	0.138	0.141
	(1.124)	(1.219)	(1.294)	(1.333)
CEO Duality	-0.036	-0.033	-0.039	-0.039
	(-0.895)	(-0.864)	(-1.003)	(-0.999)
CEO Age	-0.058	-0.060	-0.038	-0.036
	(-0.648)	(-0.686)	(-0.403)	(-0.388)
Private Acquirer	-0.071	-0.068	-0.069	-0.070
	(-1.542)	(-1.528)	(-1.564)	(-1.600)
Deal Value	0.012	0.010	0.013	0.012
	(0.391)	(0.321)	(0.403)	(0.398)
Tender Offer	0.045	0.043	0.048	0.048
	(1.228)	(1.160)	(1.125)	(1.130)
Cash Only	0.120***	0.122***	0.117***	0.117***
	(3.674)	(3.709)	(3.591)	(3.566)
Edu_missing	0.002	0.014	-0.003	-0.004
	(0.072)	(0.436)	(-0.069)	(-0.112)
Constant	0.512	0.496	0.417	0.403
	(1.302)	(1.275)	(0.981)	(0.966)
Year Fixed Effects	Y	Y	Y	Y
Industry Fixed Effects	Y	Y	Y	Y
Observations	750	750	750	750
Adjusted R-squared	0.127	0.129	0.124	0.124

This table reports results of regressing STEM directors with specialty matching on CARs. The sample consists of 772 U.S. mergers and acquisitions completed between 2005 and 2014. The dependent variable is the three-day CAR around the merger announcement date. *STEM matched* is a dummy variable which equals one if a target firm has at least one *STEM* director whose academic discipline is relevant to the firm's industry, while *STEM non-matched* takes one if the firm has at least one STEM director without specialty matching. *% STEM matched* and *% STEM non-matched* are continuous variables measured by dividing the number of STEM directors with matched and non-matched academic disciplines by the total number of independent directors. All specifications control for year and industry (Fama-French 12 industry classifications) fixed effects. A detailed description of each variable is included in Appendix B. *t*-statistics based on standard errors clustered by the Fama-French 12 industry classifications are in parentheses. ***, **, and * represent significance at the 1%, 5%, and 10% level, respectively.

Table 7. Technical Advisors versus Managerial Advisors

Panel A. Firm-Level Complexity: High vs Low Complexity

VARIABLES	High Complexity		Low Complexity	
	Model 1	Model 2	Model 3	Model 4
STEM	0.039		0.077**	
	(1.338)		(2.477)	
Non-STEM		0.013		-0.050*
		(0.472)		(-1.894)
Intercept	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Exclude Firm Size and Leverage	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Industry Fixed Effects	Y	Y	Y	Y
Observations	376	376	374	374
Adjusted R-squared	0.113	0.111	0.098	0.094

Panel B. Employment Ties with CEO

VARIABLES	Model 1	Model 2	Model 3	Model 4
tied STEM	0.045			
	(0.317)			
non-tied STEM		0.069**		
		(2.842)		
tied Non-STEM			0.094**	
			(2.232)	
non-tied Non-STEM				-0.041*
				(-1.918)
Intercept	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Industry Fixed Effects	Y	Y	Y	Y
Observations	750	750	750	750
Adjusted R-squared	0.122	0.128	0.124	0.125

The table presents results of tests that confirm the technical advisory role of STEM directors. The sample consists of 772 U.S. mergers and acquisitions completed between 2005 and 2014. The dependent variable is the three-day CAR around the merger announcement date. Panel A divides our sample into targets with high and low complexity. We use a factor score computed based on the number of business segments, firm size, and leverage as a proxy for advising needs following Coles et al. (2008) and Linck et al. (2008). *STEM* and *Non-STEM* are dummy variables which equal one if a firm has at least one independent director with a doctoral degree in each field. Regressions also control for the set of variables used in the baseline regression in Table 3 except for *Firm Size* and *Leverage*. In Panel B, *tied STEM* is an indicator variable that equals one if a target firm has at least one STEM director with employment ties with the target's CEO, while *non-tied STEM* equals one if a target firm has at least one STEM director and none of its STEM directors has such ties. *tied Non-STEM* is an indicator variable that equals one if a target firm has at least one Non-STEM director with employment ties with the target's CEO, while *non-tied Non-STEM* equals one if a target firm has at least one Non-STEM director and none of its Non-STEM directors has such ties. *Employ_missing* represents the proportion of independent directors with missing information on employment. A detailed description of each variable is included in Appendix B. All specifications control for year and industry (Fama-French 12 industry classifications) fixed effects. *t*-statistics based on standard errors clustered by the Fama-French 12 industry classifications are in parentheses. ***, **, and * represent significance at the 1%, 5%, and 10% level, respectively.

Table 8. Target's Bidder Choice: Same Industry

VARIABLES	Four-digit SIC		Three-digit SIC		Two-digit SIC	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
STEM	0.390***		0.437***		0.395***	
	(3.199)		(3.419)		(3.187)	
Non-STEM		0.122		0.076		0.023
		(1.046)		(0.603)		(0.184)
Firm Size	0.211	0.190	0.037	0.017	0.043	0.027
	(1.078)	(0.945)	(0.163)	(0.070)	(0.208)	(0.123)
ROA	-0.117	-0.229	-0.751	-0.924*	-0.536	-0.681
	(-0.277)	(-0.506)	(-1.629)	(-1.727)	(-1.044)	(-1.151)
Leverage	-0.702**	-0.784**	-0.251	-0.352	-0.055	-0.138
	(-2.304)	(-2.351)	(-0.467)	(-0.646)	(-0.097)	(-0.245)
Tobin's Q	-0.030	-0.028	0.045	0.046	-0.004	-0.002
	(-0.362)	(-0.358)	(0.631)	(0.660)	(-0.047)	(-0.026)
Board Size	0.050	0.087	0.030	0.090	-0.150	-0.078
	(0.178)	(0.284)	(0.116)	(0.321)	(-0.431)	(-0.226)
Board Independence	-2.172***	-1.963***	-1.202**	-0.966*	-0.451	-0.232
	(-3.808)	(-3.438)	(-1.986)	(-1.677)	(-1.281)	(-0.656)
CEO Duality	0.344**	0.319**	0.091	0.066	0.044	0.024
	(2.385)	(2.183)	(0.511)	(0.366)	(0.207)	(0.112)
CEO Age	-0.441	-0.265	-0.192	0.006	-0.081	0.098
	(-0.923)	(-0.526)	(-0.430)	(0.011)	(-0.117)	(0.142)
Private Acquirer	-1.036***	-1.069***	-1.251***	-1.273***	-1.470***	-1.484***
	(-3.206)	(-3.326)	(-4.270)	(-4.456)	(-5.058)	(-5.154)
Deal Value	-0.204	-0.183	-0.019	0.005	-0.071	-0.050
	(-0.940)	(-0.817)	(-0.078)	(0.021)	(-0.300)	(-0.198)
Tender Offer	0.385***	0.439***	0.235	0.289*	0.317*	0.360**
	(2.733)	(3.221)	(1.490)	(1.927)	(1.860)	(2.093)
Cash Only	-0.731***	-0.726***	-0.515***	-0.506***	-0.736***	-0.723***
	(-4.441)	(-4.506)	(-2.906)	(-2.857)	(-4.437)	(-4.184)
Edu_missing	1.157	0.956	0.645	0.426	-0.121	-0.319
	(1.209)	(1.008)	(0.563)	(0.393)	(-0.124)	(-0.349)
Constant	3.316	2.493	1.855	0.892	2.010	1.108
	(1.336)	(0.943)	(0.998)	(0.435)	(0.701)	(0.389)
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	770	770	770	770	770	770
Pseudo R-squared	0.084	0.080	0.091	0.086	0.113	0.109

The table reports results of regressing a target's bidder choice (same industry) on STEM directors using logistic regression models. The sample consists of 772 U.S. mergers and acquisitions completed between 2005 and 2014. The dependent variable, *Same Industry*, is an indicator variable that equals one if a target frim chooses a bidder in the same industry. We define the same industry based on four-digit (Model 1 and 2), three-digit (Models 3 and 4), and two-digit (Models 5 and 6) SIC code. A detailed description of each variable is included in Appendix B. All specifications control for year fixed effects. t-statistics based on standard errors clustered by the Fama-French 12 industry classifications are in parentheses. ***, **, and * represent significance at the 1%, 5%, and 10% level, respectively.

Table 9. Target's Bidder Choice: Public versus Private buyer

VARIABLES	Logit		Probit	
	Model 1	Model 2	Model 3	Model 4
	Public	*Public*	*Public*	*Public*
STEM	0.490*		0.306*	
	(1.771)		(1.870)	
Non-STEM		-0.583***		-0.347***
		(-2.656)		(-2.735)
Deal Value	0.351***	0.379***	0.196***	0.214***
	(6.276)	(6.147)	(6.647)	(6.566)
Tender Offer	0.799**	0.817**	0.469**	0.482**
	(2.020)	(2.260)	(2.107)	(2.421)
Hostile	0.066	0.060	0.020	0.021
	(0.134)	(0.135)	(0.075)	(0.087)
Toehold	-0.033**	-0.030*	-0.019**	-0.017*
	(-2.104)	(-1.933)	(-2.098)	(-1.883)
Cash Only	-1.927***	-1.914***	-1.058***	-1.046***
	(-6.946)	(-6.525)	(-8.034)	(-7.300)
Edu_missing	0.296	-0.077	0.135	-0.092
	(0.494)	(-0.117)	(0.403)	(-0.253)
Constant	0.309	0.592	0.176	0.341
	(0.349)	(0.802)	(0.391)	(0.914)
Year Fixed Effects	Y	Y	Y	Y
Observations	772	772	772	772
Pseudo R-squared	0.183	0.187	0.181	0.186

The table reports results of regressing a target's bidder choice (public versus private buyer) on STEM directors using logistic (Models 1 and 2) and probit (Models 3 and 4) regression models. The sample consists of 772 U.S. mergers and acquisitions completed between 2005 and 2014. The dependent variable, *Public Acquirer*, is an indicator variable that equals one if a target frim chooses a public bidder. A detailed description of each variable is included in Appendix B. All specifications control for year fixed effects. t-statistics based on standard errors clustered by the Fama-French 12 industry classifications are in parentheses. ***, **, and * represent significance at the 1%, 5%, and 10% level, respectively.