Innovation and Corporate Governance

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ABSTRACT

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We examine the impact of corporate governance on firms' innovation. We find that the presence of more anti-takeover provisions impedes firms' innovation efforts, and thereby, is associated with lower levels of innovation. We also find that boards that have a majority of outside directors or female directors are positively and significantly associated with innovation. Our results show that firms with female CEOs or concentrated ownership structures tend to undertake smaller innovative projects and generate fewer patents, which could be the result of risk aversion. Finally, our results also show that the presence of anti-takeover provisions not only decreases innovative activities directly, but also impedes the efficiency of the monitoring by directors and strengthens the degree of risk aversion of blockholders.

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I. Introduction

What causes firms to innovate? This is an interesting question and has attracted a fair amount of interest from researchers. In this thesis, we look at a specific aspect of this issue: the role of governance. Several researchers have addressed this issue. For example, Baranchuk, Kieschnick, and Moussawi (2014) analyze a sample of IPO firms and find that managers are better motivated to pursue innovation when they are protected by anti-takeover provisions. Hirshleifer, Low, and Teoh (2012) find that firms with overconfident CEOs obtain more patents and patent citations, and receive greater innovative success. Torchia, Calabro, and Huse (2011) use survey data on Norwegian firms and suggest that an increasing number of female directors make it possible to enhance the level of firm innovation. O'Connor and Rafferty (2012) examine the relation between control provisions and corporate innovation. However, each of these studies has examined in detail a limited aspect of the relation between corporate governance and innovation. In this thesis we adopt the opposite strategy – we consider a comprehensive sample of US firms and examine the relation between various facets of corporate governance and innovation for these firms.

We find that the presence of more anti-takeover provisions is associated with lower levels of innovation. Our findings suggest that managers who are protected in this fashion tend to perform poorly, at least as measured in terms of innovation. We also find that boards that have a majority of outside directors or a large number of female directors are associated with more innovative firms. A possible explanation is that such boards are better able to monitor managers and thereby improve firm performance, including the firm's ability to innovate. Additionally, our results show that firms with female CEOs (chief executive officers) neither generate many patents nor undertake relatively larger innovative projects. They appear to prefer smaller and safer projects. A possible explanation is that female CEOs are more risk averse and less confident (or less likely to be overconfident) than their male counterparts (Barber and Odean, 2001; Galasso and Simcoe, 2011). Our results also indicate that a concentrated ownership structure is negatively and significantly related to innovation. This could also be the result of risk aversion, considering the fact that the blockholders holding a large undiversified position in the firm may not want the company to undertake risky projects. Finally, we also conclude that the presence of anti-takeover

provisions not only reduces innovative activities, but also impedes the efficiency of the monitoring by directors, and enhances the degree of risk aversion of blockholders.

Our findings are related to and contribute to the following streams of literature. First: the earlier literature on innovation tended to use research and development (R&D) expenses as the variable of interest. This resulted in two problems. First, for innovation R&D refers to the expense akin to input but not to the output. It is interesting to know how the results are affected – recent research, such as Baranchuk, Kieschnick, and Moussawi (2014), Gao and Chou (2015), Hsu, Tian, and Xu (2014), etc., suggests the use of patent variables. Specifically, an examination of the patents earned by a firm has the potential to give us a better measure of the extent of innovation by a firm.

Second: our thesis also contributes to the growing literature that examines the relation between innovation and governance. A number of more recent studies have analyzed the relationship between anti-takeover provisions and innovation in recent years (Baranchuk, Kieschnick, and Moussawi, 2014; O'Connor and Rafferty, 2012; Chemmanur and Tian, 2013). These provisions protect managers from takeovers and essentially impede shareholders' ability to monitor the behaviors of the managers. Researchers have also questioned whether the presence of anti-takeover provisions brings about a negative or positive effect on a firm's innovative activities. Agency theory suggests that managers that are not adequately monitored by shareholders tend to waste funds on pet projects or engage in other activities which can destroy the firm's value. Due to career concerns, the managers may also prefer to avoid riskier investments (Atanassov, 2013). This suggests that firms with more anti-takeover provisions will innovate less.

An alternative perspective on the relation between anti-takeover provisions and innovation suggests that under certain conditions anti-takeover provisions could, in fact, result in greater innovation. The Managerial Myopia Hypothesis of Stein (1988) states that the threat of takeover could lead managers to focus on the short-term and less risky investments. This is because shareholders tend to pay more attention to short-term performance, as a result of asymmetric information. Alternatively, Manso (2011) states that greater pressure on innovators and a lower

tolerance for mistakes could also bring about less innovation. Consequently, the presence of anti-takeover provisions will encourage managers to undertake more and larger innovations.

Prior literature has also explored the relationships between innovation and other types of corporate governance (CG), such as the characteristics of CEOs, the composition of the Board of Directors, and ownership structure (Baranchuk, Kieschnick, and Moussawi, 2014; Galasso and Simcoe, 2011; Pascual and Jordi, 2007). Because of the different functions and mechanisms, such as the strength of monitoring and the impact of being risk averse, CG could bring about a negative or positive effect on innovative activities. Using options and press-based proxies for CEO overconfidence, Hirshleifer, Low, and Teoh (2012) find that firms with overconfident CEOs invest more in innovation, obtain more patents and patent citations, and receive greater innovative success as a result of their R&D. Hung and Mondejar (2005) state that the fraction of outsiders and the number of shares owned by the Board of Directors are significantly positively related to innovative activities in firms. Additionally, the ownership structure of firms plays an important role in its general investment policy and its R&D expenses (Lee and O'Neill, 2003; Porter and Trifts, 2014). Pascual and Jordi (2007) find a negative relation between the number of blockholders and R&D investment. Minetti, Murro, and Paiella (2012) illustrate that ownership concentration, measured by the number of shares owned by the primary shareholders, negatively affects the probability of innovation.

Although a large number of studies have investigated the relationship between innovation and CG, few have put many CG aspects together to explore their combined influence on innovative activities. Barring a few exceptions, most extant studies of innovation and governance focus on a very specific aspect of governance, usually based on a small and focused sample.[1] In this paper, we fill that gap. More specifically, we analyze a relatively large sample of firms to examine the impact of an extensive set of CG measures on innovation; these include anti-takeover provisions, characteristics of CEOs, the composition of the Board of Directors, and the ownership structure. In a similar fashion, prior studies have largely focused on individual measures of innovation to study the effect of CG. In our thesis, we follow the recommendations of Hsu, Tian, and Xu

[1] For example, O'Connor and Rafferty (2012) are one of the few researchers who focus on a more comprehensive sample. However, they focus on control provisions – one specific aspect of corporate governance, and R&D – one specific aspect of innovation.

(2014) and Gao and Chou (2015) and consider several measures of innovation that capture the quantity, quality, and efficiency of innovation.

The remainder of the paper is organized as follows. Section II describes the development of the six hypotheses. Section III describes the data used in this study. In this section, we also introduce the variables and the methodology. Section IV illustrates the results for the basic statistics, univariate, multivariate, and interaction tests. Section V concludes.

II. Prior research and hypotheses

In this section, we review the literature and provide our innovation and CG hypotheses. For each effect of CG on firms' innovation efforts, we provide some prior evidence and introduce the specific hypotheses.

2.1 Innovation and anti-takeover provisions

Innovation is likely to bring about benefits in the long term, rather than the short term. If managers are not protected by anti-takeover provisions, one possibility is that they will be swayed by the possibility of a takeover in the short term with the associated negative effects on their career. As a result, they may prefer to focus on projects that bring about short-term benefits, rather than participate in innovative activities. Under these conditions, the presence of anti-takeover provisions has a positive influence on innovation. Their protection provides managers with the opportunity to make long-term riskier investments without concerns over acquisition attempts driven by short-term mispricing. This is the prediction of the Managerial Myopia Hypothesis (Stein, 1988). Brown, Martinsson, and Petersen (2013) indicate that strong shareholder protection, measured by laws (e.g., the anti-self-dealing index), leads to higher long-run rates of R&D investment. Chemmanur and Tian (2013) and Baranchuk, Kieschnick, and Moussawi (2014) state that managers are better motivated to pursue innovation when they are protected by anti-takeover provisions.

The view is not universal. As the "Quiet Life Hypothesis" predicts, managers could use the protection provided by anti-takeover provisions to reduce their managerial efforts, especially in terms of risky projects (e.g., long-term innovation efforts) (Bertrand and Mullainathan, 2003). O'Connor and Rafferty (2012) suggest that provisions protecting managers will increase agency

costs, which brings about a negative influence on innovative activities. Consequently, we propose the following hypothesis:

H1: Anti-takeover provisions are related to innovative activities.

We test our hypotheses using the following specification:

$$\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{Anti} - \text{takeover provisions}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon \quad (1)$$

In the above model (1), the dependent variable is innovation, and we employ eight proxies for innovative quantity, quality, and efficiency.[2] We describe these dependent variables in detail in Data and Methodology section below. The independent variable of interest is anti-takeover provisions that are measured by E-index, Ati-index, and G-index. The higher the index is, the better protection managers receive. See Appendix I for a description of all dependent and independent variables for this as well as subsequent hypotheses.

2.2 Innovation and female CEOs

In this investigation, we focus on the effect of a CEO's gender on innovation. Barber and Odean (2001) state that males are more overconfident than females. Danes and Olson (2003) believe that the entrepreneurial role is more often associated with men than women. Innovative projects are risky. Hence, if a project is not successful, the CEO may be regarded as a low talent manager and can be fired by the Board of Directors. Overconfident CEOs prefer to take more risks and generate more innovation than non-overconfident CEOs on the ground that they underestimate the probability of a failure (Galasso and Simcoe, 2011). Hirshleifer, Low, and Teoh (2012) find that firms with overconfident CEOs have higher R&D expenditures, obtain more patents and patent citations, and finally receive greater innovative success. Torchia, Calabro, and Huse (2011) indicate that a CEO's gender influences the organization's innovations. Consequently, a male CEO contributes to a proxy for overconfidence, and thereby, may bring about an effect on innovation. Therefore, our second hypothesis is as follows:

[2] These proxies are defined in Appendix I. We use these as our standard measures of the dependent variable throughout this study.

H2: Female CEOs will bring about a negative effect on innovation.

We test our hypothesis using the following equation:

$$\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{CEO\_female}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon \quad (2)$$

As in model (1), the dependent variable is innovation. The independent variable of interest is CEO_female, a variable taking on a value of one if CEO is female in a firm, otherwise zero.

2.3 Innovation and CEO/chairman duality

Donaldson and Davis (1991) argue that the combination of the positions of chair and CEO maximizes shareholder interests. In addition, it prevents internal competition among senior executives and improves efficiency in decision-making. Hung and Mondejar (2005) empirically confirm that CEO/chairman duality is positively related to the development of new initiatives of firms.

Based on the research of Mallette and Fowler (1992), however, it is determined that the Board of Directors tends to be more independent and more efficient in monitoring management under the condition that the CEO and chairman are different people. If a person holds both positions (i.e., CEO and chairman of the Board of Directors), he or she may have the power to choose projects that are consistent with his or her own benefits. Consequently, they generate less innovation. As such, we develop the following hypothesis:

H3: CEO/chairman duality is related to innovation.

We test our hypotheses using the following model:

$$\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{CEO/chairman duality}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon \quad (3)$$

In the above model (3), the dependent variable is innovation, and we employ our usual eight proxies for innovative quantity, quality, and efficiency. Our variable of interest is the indicator

variable CEO/chairman duality, a variable taking on a value of one if the positions of CEO and chair of board are held by the same person, otherwise zero.

2.4 Innovation and female directors

We make distinction between our earlier discussion on the gender of the CEO and the gender composition of the board of directors. While decision making of CEOs could be affected by their risk aversion, the working of a group such as the board of directors may not necessarily have as clear a link personal risk aversion of its constituents and its decision making. On the other hand, Jurkus, Park, and Woodard (2011) and Adams and Ferreira (2009) show that a greater percentage of female directors may reduce agency costs on the ground that female directors tend to pay more attention to monitoring managers. O'Connor and Rafferty (2012) state that the executive may reduce innovative activities when agency problems are severe. Terjesen, Sealy, and Singh (2009) draw the conclusion that gender diversification on the Board of Directors contributes to a more effective CG and firm value. Torchia, Calabro, and Huse (2011) suggest that an increasing number of female directors make it possible to enhance the level of firm innovation. Therefore, we conjecture that a greater percentage of female directors induces more innovations.

Nevertheless, extending the logic we applied to risk aversion of CEOs, it is possible that boards where female directors are an overwhelming majority will begin to exhibit similar risk aversion. As a result, such boards may, in a similar fashion, reduce innovation in the firm. In order to maintain stable performance for firms, female directors may push managers to undertake more routine and less risky projects, which could decrease innovative activities. Therefore, a large number of female directors on a Board of Directors may damage firm innovation efforts. Accordingly, we develop the following hypothesis:

H4: The presence of more female directors will affect the extent on innovation.

We test our hypotheses using the following specification:

$$\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{NumFemale} + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon \quad (4)$$

In the above model (4), the dependent variable is innovation, and we employ eight proxies for

innovative quantity, quality, and efficiency. Our variable of interest is the indicator variable NumFemale, which is the number of female directors in a board.

2.5 Innovation and the Board of Directors

Continuing with our discussion of the board of directors, a board with more independent directors contributes to the monitoring of managers' behavior, reducing the agency cost, and making managers select projects in the interest of shareholders (Byrid and Hickman, 1992; Peng, 2004). Linck, Netter and Yang (2008) show that larger boards are likely to provide the resources and expertise to perform more and better monitoring that are demanded by the regulators or the general public. Additionally, a larger Board of Directors size, or more independent directors, also allows firms to easily access a larger pool of external resources, including technological and financial resources, which are important for innovation (Shapiro, Tang, Wang, and Zhang, 2013, Hillman and Dalziel, 2003).

However, Jensen (1993) argues that boards with more than about seven to eight directors are unlikely to be effective on the ground that large boards lead to less effective communication and decision-making. Empirical findings by Yermack (1996), Eisenberg, Sundgren, and Wells (1998), and Mak and Kusnadi (2005) support Jensen's hypothesis and find that larger boards are associated with lower firm value. Consequently, we hypothesize:

H5a: The number of independent directors on the Board of Directors is positively related to innovation activities.[3]
H5b: The Board of Directors size is associated with innovation activities.

We test our hypothesis 5a using the following one:

$$\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{NumOutsider}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon \quad (5)$$

[3] We also study the effect of the percent of outsiders on innovation. We hypothesize that the percent of outsiders on the Board of Directors is positively associated with innovation activities. Our findings are qualitatively unchanged in this alternate specification.

We also test our hypothesis 5b using the following model:

$$\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{Board size}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon \quad (6)$$

In the above models, the dependent variable is innovation, and we employ our usual eight proxies for innovative quantity, quality, and efficiency. Our variables of interest are NumOutsider and Board size. NumOutsider is the number of independent directors in a board and Board size is the total amount of directors in a board.

2.6 Innovation and ownership structure

Prior literature shows that large shareholders often have an important influence on corporate strategy. These large shareholders, or blockholders, are defined as having 5% or more of the firm's equity (Atanassov, 2013; Driver and Coelho, 2012). Hence, it is important to study the relationship between innovation and blockholders. Pascual and Jordi (2007) argue that a large number of blockholders could weaken the degree of monitoring of management, which increases managerial discretion and agency costs.[4] As a result, managers prefer to waste money for their own benefits, rather than invest funds on R&D or receive patents for shareholder interests. Sapra and Subramanian (2014) conclude that monitoring intensity is significantly positively related to innovation. They determine this by using the number of institutional blockholders and the total percentage of shares owned by blockholders as proxies for monitoring intensity.

On the contrary, Morck and Yeung (2003) illustrate that ownership concentration will reduce diversification, which depresses the manager's incentive to innovate. Additionally, a high concentration of ownership is an undiversified position, such that the largest blockholder becomes more risk averse and tends to innovate less with their increasing number of shares. Large and undiversified shareholders may distort a firm's investments because of their risk averse behavior (Bolton and Thadden, 1998). As a result, we hypothesize:

[4] Admati and Pfleiderer (2009) and Edmans and Manso (2011) argue that under certain conditions, blockholders could exert their influence by the threat of exit rather than activism. However, in our case the variable of interest is innovation and not market value. As such, our perspective aligns more closely with a situation where long-term large blockholders exert direct influence on management to focus on innovation.

H6a: The number of blockholders is negatively related to innovation.
H6b: The number of shares owned by all blockholders is negatively related to innovation.
H6c: The number of shares owned by the largest blockholder is negatively related to innovation.

We test our hypotheses using the following one:

$$\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{Ownership structure}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon \quad (7)$$

In the above model (7), the dependent variable is innovation, and we employ usual eight proxies for innovative quantity, quality, and efficiency. Our variables of interest are NumBlks, SumBlks, and Largest_B, which are expressed by the variable Ownership structure in the model above. NumBlks is the number of blockholders in a firm. SumBlks is the amount of shares held by all blockholders in a firm. Largest_B is the amount of shares owned by the largest blockholder in a firm.

III. Data and Methodology

3.1 Data

Our patent dataset includes data over the period of 1990-2003. Our data is from the National Bureau of Economic Research (NBER). The database contains detailed information on all of the patents awarded by the U.S. Patent and Trademark Office (USPTO) between 1976 and 2006 (Hall, Jaffe, and Trajtenberg, 2001). Patents are only included in the NBER if they are granted. There is a two-year lag between patent applications and patent grants. The latest year in the NBER database is 2006. Hence, we may not find the patents applied for in 2004 and 2005. As suggested by Hall, Jaffe, and Trajtenberg (2001), we choose 2003 as the last year to address potential time truncation issues. In the meanwhile, we choose 1990 as the first data year to analyze, since the governance data is only available starting in 1990. Our control variables dataset comes from Compustat, our CEO dataset from Execucomp, our information on boards and anti-takeover provisions from Riskmetrics, and our data on blockholders are obtained from the dataset provided by Dlugosz, Fahlencrach, Gompers, and Metrick (2006).

There are 22,668 patent observations from the NBER during the period of 1990-2003. Of these, 22,628 observations are available on Compustat. The number of observations that are missing is 40. The reason of loss is that the firm applying for a patent in that year may have disappeared in the same year, because of bankruptcy, restructuring, or an acquisition. Therefore, we are not able to locate these firms on Compustat. In addition, we regard that firms which are not found in the NBER do not own any patent and that patent counts for that kind of firms equals to zero. As a result, we get 123,049 patent observations for the companies with or without patents.

For the anti-takeover provisions variables, there are 10,279 observations from Riskmetrics; the data covers the period of 1990-2003. Of these, 9,611 observations are available on Compustat. The number of observations lost is 668. For the CEO variables, there are 20,466 observations obtained from the Execucomp of Compustat; the data covers the period of 1992-2003. Of these, 20,457 observations are available on Compustat. The number of observations lost is 9. For the director variables, there are 13,222 observations obtained from Riskmetrics; the data covers the period of 1996-2003. Of these, 12,897 observations are available on Compustat. The number of observations lost is 325. For the blockholder variables, there are 7,649 observations; the data covers the period of 1996-2001. Of these, 7,433 observations are available on Compustat. The number of observations lost is 216. All of the missing observations mentioned above are results of an acquisition, restructuring, or bankruptcy.

Furthermore, we delete the observations if firm assets, leverage, R&D expenditures, or common shares outstanding is less than zero. We obtain 120,441 observations on the patent section, 8,995 observations on the anti-takeover provisions section, 19,642 observations on the CEO section, 12,306 observations on the director section, and 7,177 observations on the blockholder section. Since we lag all independent variables by one year in all of the regressions, we lose one year for each CG data observation. In the regressions, therefore, we analyze 8,553 observations for the anti-takeover provisions, 17,209 observations for the CEO, 10,210 observations for the director, and 6,705 observations for the blockholders.

3.2 Variables and methodology

3.2.1 Dependent variables

We construct eight innovation measures. The first innovation measure is the number of patents. This variable is widely used in the previous literature to measure innovation performance (Hirshleifer, Low, and Teoh, 2012; Baranchuk, Kieschnick, and Moussawi, 2014).

Since patent innovations change widely in their economic and technological importance, however, patent counts cannot measure the success of innovation perfectly (Griliches, Pakes, and Hall, 1987). Hence, we use patent citations, which is the number of forward patents citing the patent, as the second measure. Aghion, Reenen, and Zingales (2013) and Hsu, Tian, and Xu (2014) argue that patent citations could account for the quality and influence of patent innovations. In addition, since the patents created near the ending year of the sample have not enough time to accumulate citations, the number of patent citations is subject to the truncation bias, following Hsu, Tian, and Xu (2014) and Hirshleifer, Low, and Teoh (2012). Therefore, each patent citation is multiplied by the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005), which is obtained directly from the NBER[5]. We utilize the adjusted citation as the third innovation measure.

Based on Hsu, Tian, and Xu (2014), patent originality and generality could account for the fundamental importance of the innovation being patented. The wider array of technology classes of patents that a patent cites, the greater originality the patent has. Likewise, the wider the range of technology covered by patents that cite a patent, the greater the generality the patent has. Therefore, we also use originality and generality as innovation measures. Amore, Schneider, and Zaldokas (2013) state that the NBER patent database includes 400 main (three-digit) technology classes, as defined by the USPTO. As a result, we use the originality and generality indexes calculated by Hall, Jaffe, and Trajtenberg (2001) as two complementary innovation measures. Another innovation measure used widely in the literature is R&D expenses.

In order to study risk aversion of CEOs, therefore, we use citation counts scaled by patent counts to measure the degree of risk-taking. In addition, Gao and Chou (2015) evaluate innovative

[5] Hall, Jaffe, and Trajtenberg (2005) estimates the total citations of any patent for which they observe a portion of its citation life simply by dividing the observed citations by the fraction of the population distribution that lies in the time interval for which citations are observed. In the case of patents for which they observe the prime citation years (roughly years 3–10 after the grant), this should give relatively accurate estimates of lifetime citations.

efficiency by the ability of a firm to create patents per dollar of R&D expense. We employ one measure of innovative efficiency as our dependent variable: patent counts scaled by R&D expenditures (Prd). To study the future effects of the CG on innovation, we lag all independent variables by one year to run the regressions (Gao and Chou, 2015).

3.2.2 Independent variables

The Gompers, Ishii, and Metric (2001) governance index (G-index) is a proxy for anti-takeover provisions. However, recent research also questions whether all of the provisions in the G-index may affect firm performance. Hence, an increasing number of studies prefer to use the Bebchuk, Cohen, and Ferrell (2009) entrenchment index (E-index) and the Cremers and Nair (2005) alternative anti-takeover index (Ati-index) as proxies. The E-index only contains six provisions: staggered boards, limits to shareholder bylaw amendments, poison pills, golden parachutes, and supermajority requirements for mergers and charter amendments. The Ati-index includes three provisions: staggered boards, poison pill, and restrictions on shareholder voting to call special meetings or act through written consent. To obtain a more robust understanding of the relationship between innovation and anti-takeover provisions, we utilize each index separately as an independent variable in our tests.

We also explore the impact of CEO characteristics and the Board of Directors structure, including female CEO, CEO/chairman duality, the number of female directors, the number of independent directors, and the Board of Directors size, on firm innovation efforts. Additionally, to study the relationship between ownership structure and innovation, we employ three proxies for ownership concentration: the number of blockholders, shares owned by all blockholders, and shares held by the largest blockholder. A detailed explanation of the independent variables is provided in Appendix I.

3.2.3 Control variables

Cohen and Klepper (1992) indicate that firm size and industry can bring about a significant effect on R&D intensity. Bhagat and Welch (1995) find that leverage ratio is significantly negatively correlated with current R&D expenditures for U.S. firms, and positively for Japanese firms. Hall (1989), Elliott (1971), and Giudici and Paleari (2000) regard debt financing as having a negative

effect on R&D investments. Atanassov (2013) and Baranchuk, Kieschnick, and Moussawi (2014) use firm size and firm age as control variables. Except for the control variables above, Becker-Blease (2011) also adds return on asset (ROA) and the ratio of the market value to the book value (MB ratio) into the regressions.

Following prior literature, we also include commonly used firm characteristics as control variables: firm size, leverage, ROA, market to book value, and firm age. Additionally, we also control industry and year fixed effects in the regressions. A detailed summary of the variable definitions is provided in Appendix I.

IV. Results

4.1 Univariate test

In the first test, we want to examine whether there exist some differences in the basic characteristics of firms which have a large number of patents and firms which do not generate too many patents. We divide firms into two samples, based on the patent counts: 1) firms generating patent counts equal to, or less than, three, and 2) firms owning more than three patent during a given year. We choose three patents as the boundary since the median of patents counts in the Univariate test is three. All firms studied in univariate test have at least one patent.

Table 3 reports the mean of the firm characteristics across the two samples and tests for the significance of the differences between them. The firms with more patents differ significantly from the firms with less patents, in many aspects. More specifically, compared to firms with less patents, firms owning a large number of patents are larger, older, and more profitable. They also have a higher leverage, lower MB ratio, more independent directors, and larger Board of Directors size. In addition, we observe that firms with more patents tend to invest more in R&D. In the following section, we provide more detailed evidence on these preliminary trends

4.2 Multivariate test

In the multivariate test, we examine the effects of CG on innovation. All regressions employ White's (1980) correction for heteroscedasticity. For each dependent variable, we do two

regressions: with and without control variables. In the regressions with control variables, we also control the year and industry fixed effects.

4.2.1 Anti-takeover provisions

In Table 5, we regress the E-index, Ati-index, and G-index separately on seven measures of innovation: patent, citation, ad_citation, originality, generality, R&D, and Prd. We also control for firm age, firm size, MB ratio, leverage, ROA, year, and industry.

The results show the coefficient estimates for all of the indexes and five measures of innovation: patent, citation, ad_citation, originality, and generality, are statistically significant and negative at the 0.01 level and are economically meaningful. Thus, Panel A indicates that an increase in one unit in the E-index separately results in a reduction of 4.21 units in patent, a reduction of 39.37 units in citation, a reduction of 27.93 units in ad_citation, a reduction of 1.23 units in originality, and a reduction of 1.25 units in general, after controlling for the other effects of firm characteristics.

The impacts of the Ati-index and G-index on innovation are similar to the impacts of the E-index (Panels B and C). Furthermore, the E-index and G-index are negatively associated with the Prd, at a significant level, and Prd, which equals the patents per dollar of R&D expenses; this may measure the efficiency of innovation. No indexes are found to have a significant influence on R&D expenses. We conclude that the anti-takeover provisions of firms impede the innovative activities, reduce the innovative quality and efficiency.

For the control variables, our results illustrate that larger firms have more patents and generate a higher quality innovation (Atanassov, 2013). Firm age is positively related to innovation, implying that older companies tend to innovate more, possibly as a result of their greater experience and potentially larger pool of available funds. Firms with a high leverage ratio tend to be involved in relatively higher innovative activities. We also find that profitability is positively and significantly related to innovation.

4.2.2 CEO characteristics

In Table 6, we regress the CEO_female variable on our seven measures of innovation and our

standard control variables. The results show that the coefficient estimates between the CEO_female variable and the six measures of innovation, except for Prd, are statistically significant and negative at the 0.01 level; and are economically meaningful. The presence of a female CEO results in a reduction of 6.82 units in patent, a reduction of 57.94 units in citation, a reduction of 58.71 units in ad_citation, a reduction of 2.6 units in originality, a reduction of 2.52 units in generality, and a reduction of 0.21 units of R&D after controlling for the other effects of the firm characteristics. Overall, our results are consistent with Hypothesis 2. Hence, we conclude that female CEOs tend to invest less funds on innovative projects and innovate less than male CEOs

Additionally, we regress the CEO/chairman duality on the seven measures of innovation with the control variables. We find that the CEO/chairman duality is positively and significantly related to four measures of innovation: patent, citation, originality, and generality. In this way, the presence of a CEO/chairman duality brings about an increase of 7.83 units in patent, an increase of 86.52 units in citation, an increase of 3.03 units in originality, and an increase of 2.98 units in generality, after controlling for the other effects of the firm characteristics. Our results refer to the positions of when the CEO and chairman of the Board of Directors is the same person. This contributes to improving the efficiency in decision-making, maximizing the interest of shareholders, and innovating more patents that are of a higher quality. Panel B in Table 6 also shows that the presence of a CEO/chairman duality also reduce R&D intensity, without controlling for the other variables. The result indicates that CEOs under undiversified positions do not invest too much money in R&D expenditures.

4.2.3 Director Characteristics

In Table 7, we regress NumFemale on the seven measures of innovation with the control variables. Panel A illustrates the coefficient estimates between NumFemale and the five measures of innovation, including patents, citations, ad_citation, originality, and generality. These estimates are statistically positive and significant at the 0.01 level and are economically meaningful. From the results in Panel A, we find that an increase of one unit in NumFemale leads to an increase of 8.89 units in patent, an increase of 27.61 units in citation, an increase of 78.29 units in ad_citation, an increase of 1.96 units in originality, and an increase of 1.94 units in generality, after controlling for the other effects of the firm characteristics. Nevertheless,

NumFemale is negatively and significantly related to Prd, a variable that measures the innovation efficiency. Overall, these results suggest that boards with more female directors are better able to foster innovation, which is contrary to the impact of female CEOs on innovation. One possible reason for this difference is that the CEO is an individual and therefore bears sole responsibility for executive decision-making. In contrast, the board of directors is a group and as such the impact of risk on their decision-making is not as clear as in the case of the CEO. The negative relation for innovation efficiency is puzzling. One possibility is that the relation between R&D expenditure and innovation is a nonlinear one and this drives increasingly higher R&D expenditure to achieve incremental innovation. However, a detailed analysis of this relationship is beyond the scope of our study.

In addition, we separately regress NumOutsider and Board size on the seven measures of innovation with the control variables. The results show that the coefficient estimates between NumOutsider and the five measures of innovation, including patent, citation, ad_citation, originality, and generality, are statistically positive and significant at the 0.01 level and are economically meaningful.[6] In the meanwhile, the effect of Board size on innovation is the same as those of the NumOutsider.

Panel B illustrates that an increase of one unit in NumOutsider results in an increase of 4.40 units in patent, an increase of 21.33 units in citation, an increase of 34.78 units in ad_citation, an increase of 1.1 units in originality, and an increase of 1.05 units in generality, after controlling for the other effects of firm characteristics. Panel C indicates that, moreover, an increase of one unit in Board size results in an increase of 2.56 units in patent, an increase of 13.15 units in citation, an increase of 17.66 units in ad_citation, an increase of 0.75 units in originality, and an increase of 0.74 units in generality, after controlling for the other effects of firm characteristics.

Overall, we conclude that a large number of outsiders, or directors in a Board of Directors, contribute to monitoring manager behaviors, reducing agency costs, accessing more resources, and generating more innovation.

4.2.4 Ownership structure

[6] The results also show that the coefficient estimates between the percent of outsiders and the six measures of innovation, including patent, citation, ad_citation, originality, generality, and Prd are statistically positive and significant at the 0.01 level and are economically meaningful.

In Table 8, we regress NumBlks on the seven measures of innovation with the control variables. We find that the relationship between NumBlks and the five measures of innovation: patent, citation, ad_citation, originality, and generality, are statistically negative and significant at the 0.01 level. Panel A shows that an increase of one unit in NumBlks results in a reduction of 5.77 units in patent, a reduction of 26.39 units in citation, a reduction of 43.15 units in ad_citation, a reduction of 1.48 units in originality, and a reduction of 1.44 units in generality, after controlling for the other effects of firm characteristics. Overall, these results indicate that an increasing number of blockholders in a firm may lead to a negative effect on firm innovation efforts, which provides some support for Hypothesis 6a.

Furthermore, we separately regress SumBlks and Largest_B on those seven measures of innovation with control variables. The results show the coefficient estimates between SumBlks and the five measures of innovation (i.e., patent, citation, ad_citation, originality, and generality) are statistically negative and significant at the 0.01 level; they are also economically meaningful.

The effects of the Largest_B on innovation are the same as the ones for SumBlks. Panel B illustrates that an increase of one unit in SumBlks results in a reduction of 0.45 units in patent, a reduction of 2.15 units in citation, a reduction of 3.17 units in ad_citation, a reduction of 0.12 units in originality, and a reduction of 0.12 units in generality, after controlling for the other effects of firm characteristics.

Panel C indicates that an increase of one unit in Largest_B results in a reduction of 0.62 units in patent, a reduction of 3.12 units in citation, a reduction of 4 units in ad_citation, a reduction of 0.18 units in originality, and a reduction of 0.17 units in generality, after controlling for the other effects of firm characteristics. The results are consistent with Hypotheses 6b and 6c, indicating that a concentrated ownership structure impedes innovative activities as a result of a person being risk averse.

4.2.5 Risk aversion

Our results till this point indicate risk aversion as a possible reason for the link between CEOs, blockholders and innovation. Barber and Odean (2001) state that males are more overconfident than females. Galasso and Simcoe (2011) regard that overconfident CEOs prefer to take more

risks on the ground that they underestimate the probability of a failure. Additionally, Morck and Yeung (2003) illustrate that ownership concentration will reduce diversification, which depresses the manager's incentive to innovate. Bolton and Thadden (1998) indicate that large and undiversified shareholders may distort a firm's investments because of their risk averse behavior. Hence, we predict that female CEOs and blockholders are more risk averse. We employ Citation_Pat to measure the degree of risk, since a patent receiving many citations is regarded as a larger, riskier, more valuable innovation,

Our results are reported in Table 9. The results show the coefficient estimates between CEO_female and Citation_Pat are statistically negative and significant at the 0.01 level; they are also economically meaningful. It shows that the presence of female CEOs results in a reduction of 2.26 units in Citation_Pat after controlling for the other effects of firm characteristics. The result means that female CEOs tends to avoid undertaking riskier and larger projects as well as innovate patents with less citation counts. As such, our evidence is consistent with risk aversion driving the lower innovation levels by female CEOs. Columns 7-12 in Table 9 illustrate that NumBlks, SumBlks, and Largest_B are statistically and negatively associated with Citation_Pat at a significant level. This implies that blockholders prefer to avoid risky projects, and instead, choose a smaller scale of innovative projects because of them being a risk averse person.

4.2.6 All corporate governance together

We choose one or two variables from the four CG sections, separately, and use them as independent variables in one regression to study their combined effect. The choosing standard is that all selected independent variables (e.g., the E-index, the CEO_female variable, CEO/chairman duality, NumFemale, NumBlks, and Largest_B) are not significantly correlated with each other (Table 4). Table 10 shows that the effects of anti-takeover provisions, female directors, and a concentration of ownership on innovation are consistent with the results we obtained previously. The impacts of the CEO characteristics on innovative activities are weakened by other CGs.

4.3 Interaction test

To examine whether the presence of anti-takeover provisions weakens or strengthens the influence of other CG on innovation, we conduct an interaction test. According to the results of

the multivariate tests, the effects of the CEO/chairman duality, number of female directors, number of outsiders, and Board of Directors size on innovation are significant and positive. Table 11 illustrates that their positive effects on innovation become weak at higher levels of anti-takeover provisions.[7] For example, Panel A shows that an increase of one unit in the E-index mitigates the positive impact of CEO/chairman duality on patent by 27.73%, on citation by 28.22%, on originality by 25.58%, and on generality by 25.87%. Panel B illustrates that an increase of one unit in the E-index mitigates the positive impact of NumFemale on patent by 24.45%, on citations by 22.46%, on ad_citation by 27.19%, on originality by 20.37%, and on generality by 20.19%. Based on the results, we conclude that the efficiency of monitoring managers from the Board of Directors is severely damaged by an augment of anti-takeover provisions.

Furthermore, the results, reported in Table 11, also suggest that an increase in the E-index enhances the negative effects of SumBlks and NumBlks on innovation. Panel F, for example, shows that an increase of one unit in the E-index strengthens the negative effect of SumBlks on patent by 25.4%, on citation by 17.28%, on ad_citation by 28.93, on originality by 16.01%, and on generality by 15.1%. Consequently, we conclude that the blockholder preference of avoiding to investing in risky projects, as well as innovating less, is enhanced by the presence of anti-takeover provisions.

V. Conclusions

While a large number of studies have investigated the relationship between innovation and CG (Hung and Mondejar, 2005, and Baranchuk, Kieschnick, and Moussawi, 2014), they did not explore the combined impact of many CGs on innovative activities. In this paper, we fill that gap in the literature. More specifically, we examine the combined impact of a comprehensive set of measures of CG on innovation, including anti-takeover provisions, characteristics of CEOs, the composition of the Board of Directors, and ownership structure. Furthermore, we use an exhaustive set of measures of innovation to test the effect of CG on innovation quantity, quality, and efficiency, following Hsu, Tian, and Xu (2014) and Gao and Chou (2015).

[7] Our results also indicate that the positive impact of the percent of outsiders on the Board of Directors is significantly weaken by the presence of more anti-takeover provisions.

We find that anti-takeover provisions are negatively related to innovation, possibly due to their raising agency costs. We also find that female CEOs tends to invest less on innovative projects and impede firm innovation efforts. Combining the roles of the CEO and chairman, tends to result in greater innovation. Our results also illustrate that the positive impacts of the number of female directors, number of outsiders, and Board size on innovation are weakened by an increase in anti-takeover provisions, which means the presence of anti-takeover provisions damages the efficiency of monitoring by the Board of Directors.

Additionally, anti-takeover provisions could protect managers from the discipline exerted by the market for corporate control and managers who are protected in this fashion could misuse funds for their own benefits. Blockholders, under these conditions, would not want to provide too much discretion for managers, while innovative activities could give managers such discretionary funds. Therefore, blockholders could want less innovation with an increasing number of anti-takeover provisions. We also conclude that female CEOs and large blockholders tend to reduce firms' innovation efforts, possibly as a result of their risk aversion. Overall, our results provide a comprehensive perspective of the many ways in which corporate governance appears to affect the innovative activities of the firm.

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Appendix I: Variable Definitions

Variables	Definitions	Function
Dependent variables		
patent	Number of patents applied for during the year.	Quantity of innovation
citation	Number of citations summed across all patents applied for.	Quality of innovation
ad_citation	Total number of citations summed across all patents applied for during the year. Each patent's number of citations is multiplied by the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005).	Quality of innovation
originality	It equals to one minus H-index that is three-digit tech class distribution of all patents it cites. Originality can be derived from NBER directly.	Importance of innovation
generality	An array of technology classes of patents that the patents being cited. It equals to one minus H-index that is three-digit tech class distribution of all patents that cites it. Generality can be derived from NBER directly.	Importance of innovation
Citation_Pat	Citation counts received by per patent.	Degree of risk-taking
Prd	Patent counts per a dollar of R&D expense.	Efficiency of innovation
R&D intensity	R&D expenditures scaled by sale.	Input of innovation
Independent variables		
E-index	Staggered boards, limits to shareholder bylaw amendments, poison pills, golden parachutes, and supermajority requirements for mergers and charter amendments.	
Ati-index	Staggered boards, poison pill, and restrictions on shareholder voting to call special meetings or act through written consent.	
G-index	Governance index following Gompers, Ishii, and Metrick (2001).	
CEO_female	A variable that takes on a value of one if CEO is female, otherwise, takes on a value of zero.	
CEO/chairman	A variable that takes on a value of one if the CEO and chairman is the same person, otherwise, takes on a value of zero.	
NumFemale	Number of female directors.	
NumOutsider	Number of independent directors.	
Board size	Number of directors in the board.	
NUMBLKS	Number of blockholders.	
SUMBLKS	Shares held by all blockholders.	
Largest_B	Shares held by the largest blockholder.	
Interaction		
Eindex_female	E-index is multiplied by NumFemale.	
Eindex_director	E-index is multiplied by Board size.	

Eindex_outsider	E-index is multiplied by NumOutsider.
Eindex_cc	E-index is multiplied by CEO/chairman duality.
Eindex_NumBlks	E-index is multiplied NumBlks.
Eindex_SumBlks	E-index is multiplied SumBlks.
Control variables	
Firm size	Market value of equity plus total asset subtract common equity
Leverage	Total debt divided by total asset
ROA	Ratio of EBITDA to total asset
MB ratio	Firm size subtract deferred taxes, then divided by total asset
Firm age	Logarithm of 1 plus the number of years a firm has been in Compustat

Appendix II: Tables

Table 1: Data description

DATA BASE	Selected period	Obs	Obs after merged into Compustat	Missing obs	Description	Obs after deleting invalid obs
Patent	1990-2003	123089	123049	40	The reason of lose is that the firm applying a patent in that year was disappeared in the same year because of bankruptcy, restructuring, or acquisition.	120441
Director	1996-2003	13222	12897	325	Losing observations as a result of acquisition, restructuring, bankruptcy.	12306
Governance	1990-2003	10279	9611	668	Losing observations as a result of acquisition, restructuring, bankruptcy.	8995
Blockholder	1996-2001	7649	7433	216	Losing observations as a result of acquisition, restructuring, bankruptcy.	7177
Execucomp	1992-2003	20466	20457	9	Losing observations as a result of acquisition, restructuring, bankruptcy.	19642

Table 2: Descriptive statistic

	Selected period	Number of observations	mean	Median
Dependent variables				
Patent	1990-2003	120441	5.941764	0
Citation	1990-2003	120441	41.7050174	0
Ad_citation	1990-2003	120441	34.3919818	0
Originality	1990-2003	120441	1.7239322	0
Generality	1990-2003	120441	1.7587308	0
R&D intensity	1990-2003	120441	0.8366302	0
Independent variables				
E-index	1990-2003	8995	2.0657	2
Ati-index	1990-2003	8995	1.5675	2
G-index	1990-2003	8995	9.0356	9
CEO_female	1992-2003	19642	0.0108	0
CEO/chairman	1992-2003	19642	0.5482	1
NumFemale	1996-2003	10926	0.8407	1
NumOutsider	1996-2003	12306	6.0488	6
Board size	1996-2003	12306	9.6335	9
NUMBLKS	1996-2001	7177	2.3421	2
SUMBLKS	1996-2001	7177	23.5537	20.9
Largest_B	1996-2001	7177	12.5147	10.13
Control variables				
Firm age	1990-2003	120441	2.1905259	2.1972246
Firm size	1990-2003	108278	4.6320049	0.2120983
MB ratio	1990-2003	96285	2.6337112	1.3236784
Leverage	1990-2003	120441	0.373093	0.3439962
ROA	1990-2003	117652	0.0210454	0.0862553

Table 2 illustrates summary statistics. Patent is the total awarded patents applied for during a given year. Citation is total number of citations summed across all patents applied for during a given year. Ad_citation is total number of citations summed across all patents applied for during the year. Each patent's number of citations is multiplied by the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005). Originality equals to one minus H-index which is three-digit tech class distribution of all patents it cites. Generality equals to one minus H-index that is three-digit tech class distribution of all patents citing it. R&D intensity equals to research and development expenditure scaled by sale. CEO_female is a variable that takes on a value of one if CEO is female, otherwise, takes on a value of zero. CEO/chairman duality is a variable that takes on a value of one if the CEO and chairman is the same person, otherwise, takes on a value of zero. NumFemale equals to number of female directors. NumOutsider is the number of outsiders; Board size is the total number of directors. NumBlks is number of blockholders. SumBlks is shares owned by all blockholders. Largest_B is shares held by the largest blockholder. Firm age equals to logarithm of 1 plus the number of years a firm has been in Compustat. Firm size is the natural logarithm of total assets. ROA is the ratio of operating income to total assets. Leverage is the ratio of total debt to total assets. Mb ratio equals to the ratio of market value to book value.

Table 3: Univariate test

VARIABLE	PATENT =<3	PATENT>3	DIFFERENCE	P-VALUE
Variable name	Mean (NOP)	Mean (P)	Mean (NOP)-Mean(P)	P-value
E-index	2.1129	2.1108	0.00215	0.9646
Obs	1089	2148		
Ati -index	1.6327	1.7328	-0.1001	0.0097
Obs	1089	2148		
G-index	9.0523	9.4693	-0.4169	<.0001
Obs	1089	2148		
CEO_female	0.0146	0.00670	0.00786	0.0040
Obs	2405	4479		
CEO/chairman	0.5385	0.6086	-0.0702	<.0001
Obs	2405	4479		
NumFemale	0.6915	0.8724	-0.1809	<.0001
Obs	1313	2657		
NumOutsider	5.7332	6.3253	-0.5921	<.0001
Obs	1473	2991		
Board size	9.0964	9.4363	-0.3399	0.0002
Obs	1473	2991		
NumBlks	2.4825	2.0954	0.3871	<.0001
Obs	856	1855		
SumBlks	24.0775	20.0320	4.0455	<.0001
Obs	856	1855		
Largest_B	12.3838	10.8715	1.5123	<.0001
Obs	856	1855		
Firm age	2.3181	2.6497	-0.3316	<.0001
Obs	10380	9640		
Firm size	3.6997	13.4415	-9.7417	<.0001
Obs	9775	9209		
Leverage	0.2608	0.2701	-0.00934	0.0006
Obs	10380	9640		
ROA	-0.0109	0.0788	-0.0896	<.0001
Obs	10336	9609		
MB	2.8837	2.7116	0.1721	0.0147
Obs	9424	8546		
R&D intensity	3.3883	1.3477	2.0405	<.0001
Obs	10380	9640		

Table 3 presents the comparison of the mean of independent variables and control variables between firms owning patents counts equals or less than three and firms having patent counts larger than three. All observations studied in table 3 own at least one patent during a given year, and all variables, except patent, are lagged by one year. The variables are defined as follows (see Appendix I for detailed definitions): CEO_female is a variable that takes on a value of one if CEO is female, otherwise, takes on a value of zero; CEO/chairman duality is a variable that takes on a value of one if the CEO and chairman is the same person,

otherwise, takes on a value of zero; NumFemale equals to number of female directors; NumOutsider is the number of outsiders; Board size is the total number of directors; NumBlks is number of blockholders; SumBlks is shares owned by all blockholders; Largest_B is shares held by the largest blockholder; firm age equals to logarithm of 1 plus the number of years a firm has been in Compustat; firm size is the natural logarithm of total assets; ROA is the ratio of operating income to total assets; leverage is the ratio of total debt to total assets; Mb ratio equals to the ratio of market value to book value. The comparison of means is based on a two-sided t-test.

Table 4: Pearson correlation matrix

Variables	e index	ati index	g index	ceo female	CEO chairman	Num female	Num outsider	Board size	Num Blks	Sum Blks	Largest B
E-index	1										
Ati-index	0.7797	1									
G-index	0.7360	0.7183	1								
CEO_female	-0.002	-0.0000	-0.015	1							
CEO/chairman	0.0872	0.0772	0.1258	-0.011	1						
NumFemale	0.1179	0.1101	0.2109	0.106	0.161	1					
NumOutsider	0.2535	0.2345	0.3370	-0.034	0.1581	0.491	1				
Board size	0.1239	0.1044	0.2297	-0.043	0.10145	0.488	0.7587	1			
NUMBLKS	-0.057	-0.0713	-0.139	0.047	-0.08355	-0.220	-0.2788	-0.277	1		
SUMBLKS	-0.198	-0.2250	-0.264	0.0586	-0.11496	-0.238	-0.365	-0.263	0.76409	1	
Largest_B	-0.231	-0.2614	-0.262	0.0356	-0.11908	-0.168	-0.2972	-0.153	0.26112	0.78594	1

Table 4 shows the Pearson correlation matrix of all independent variables. The variables are defined as follows (see Appendix I for detailed definitions): CEO_female is a variable that takes on a value of one if CEO is female, otherwise, takes on a value of zero; CEO/chairman duality is a variable that takes on a value of one if the CEO and chairman is the same person, otherwise, takes on a value of zero; NumFemale equals to number of female directors; NumOutsider is the number of outsiders; Board size is the total number of directors; NumBlks is number of blockholders; SumBlks is shares owned by all blockholders; Largest_B is shares held by the largest blockholder. The values above are product moment correlation coefficient.

Table 5: The impact of antitakeover provisions on innovation

Panel A: E-index

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
E-index	-5.8727***	-4.2125***	-50.0238***	-39.3719***	-42.0328***	-27.9262***	-1.6527***	-1.2329***	-1.6353***	-1.2529***	-0.0068	0.0008	-0.0214*	-0.036**
	(-5.7892)	(-4.8645)	(-5.3182)	(-4.0905)	(-4.0666)	(-3.1346)	(-5.9353)	(-4.8531)	(-5.9249)	(-4.8334)	(-0.331)	(0.0449)	(-1.6654)	(-2.0542)
Firm age		17.4753***		129.988***		112.428***		4.8498***		4.923***		0.0068		-0.0163
		(6.587)		(5.0672)		(4.2885)		(6.4087)		(6.5441)		(0.128)		(-0.6056)
Firm size		0.7744***		3.6679***		6.8908***		0.1823***		0.1799***		-0.0006*		-0.0004
		(4.6458)		(4.1412)		(3.9126)		(4.3056)		(4.3351)		(-1.802)		(-1.2568)
MB ratio		2.014**		-12.6855		39.0464***		0.1124		0.0203		0.1017		-0.0069
		(2.0033)		(-1.5932)		(3.2033)		(0.4117)		(0.0777)		(1.1809)		(-1.3985)
Leverage		10.4809*		80.5938		28.4195		3.3295*		3.3561*		-0.4277		0.1668
		(1.6672)		(1.6075)		(0.4528)		(1.8411)		(1.8498)		(-1.2882)		(1.6375)
ROA		42.3191***		503.412***		120.2856		13.4164***		13.154***		-5.8747		0.1922
		(4.3156)		(4.3375)		(1.2493)		(4.5353)		(4.579)		(-1.6255)		(1.6292)
Constant	31.307***	-57.292***	238.787***	-488.178***	219.881***	-227.632**	8.8227***	-17.308***	8.7853***	-17.250***	0.13**	0.6977***	0.4034***	0.4721**
	(9.8947)	(-4.7393)	(8.1709)	(-4.5907)	(6.8765)	(-2.0237)	(10.0571)	(-4.6013)	(10.1368)	(-4.5911)	(2.0385)	(2.6457)	(9.319)	(2.4392)
R-Square	0.0047	0.1426	0.0042	0.0713	0.0025	0.1183	0.0043	0.1103	0.0043	0.111	0	0.0326	0.0007	0.0426
obs	8553	7283	8553	7283	8553	7283	8553	7283	8553	7283	8552	7282	3344	3058
year FE		YES		YES		YES		YES		YES		YES		YES
industryFE		YES		YES		YES		YES		YES		YES		YES

Panel B: Ati-index

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
Ati-index	-4.0426***	-5.1916***	-45.1945***	-47.7268***	-20.1748*	-33.505***	-1.2801***	-1.4763***	-1.2478***	-1.4491***	-0.0136	-0.0249	-0.0139	-0.0213
	(-2.9147)	(-3.514)	(-3.464)	(-3.2494)	(-1.7141)	(-2.5902)	(-3.1826)	(-3.4562)	(-3.1629)	(-3.4617)	(-0.283)	(-0.503)	(-1.1062)	(-1.6314)
Firm age		17.1628***		126.953***		110.227***		4.7521***		4.8165***		0.0105		-0.0242
		(6.4253)		(4.9535)		(4.2568)		(6.2103)		(6.3417)		(0.201)		(-0.799)
Firm size		0.7801***		3.7222***		6.9298***		0.184***		0.1817***		-0.0007*		-0.0002
		(4.6825)		(4.1862)		(3.9277)		(4.3487)		(4.3789)		(-1.8717)		(-0.8539)
MB ratio		2.1677**		-11.2378		40.0782***		0.158		0.0673		0.1013		-0.006
		(2.1529)		(-1.441)		(3.2986)		(0.5784)		(0.2588)		(1.1797)		(-1.289)
Leverage		10.0376		76.0689		25.0434		3.179*		3.1787*		-0.4152		0.1466
		(1.5653)		(1.4941)		(0.3937)		(1.731)		(1.7321)		(-1.2929)		(1.5373)
ROA		41.8192***		498.624***		116.8393		13.2638***		12.9915***		-5.8709		0.1892
		(4.2598)		(4.295)		(1.2201)		(4.4723)		(4.5107)		(-1.6244)		(1.6332)
Constant	25.527***	-57.317***	206.446***	-489.102***	164.754***	-228.5897**	7.4196***	-17.353***	7.3674***	-17.340***	0.1375	0.7202***	0.3819***	0.4467**
	(7.9452)	(-4.8989)	(6.8354)	(-4.7362)	(5.9096)	(-2.0436)	(7.9936)	(-4.7449)	(8.0976)	(-4.7334)	(1.4515)	(2.6375)	(11.8561)	(2.4912)
R-Square	0.0014	0.1425	0.0021	0.0712	0.0004	0.1182	0.0016	0.1101	0.0015	0.1107	0	0.0326	0.0002	0.0414
obs	8553	7283	8553	7283	8553	7283	8553	7283	8553	7283	8552	7282	3344	3058
year FE		YES		YES		YES		YES		YES		YES		YES
industryFE		YES		YES		YES		YES		YES		YES		YES

Panel C: G-index

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
G-index	-1.068**	-2.0015***	-13.1389***	-22.7663***	-7.5989**	-9.4496*	-0.3335***	-0.6917***	-0.3209***	-0.7006***	-0.0156	-0.0037	-0.0032	-0.0152*
	(-2.5549)	(-3.48)	(-3.1221)	(-3.5781)	(-1.9603)	(-1.7096)	(-2.7018)	(-3.9672)	(-2.6324)	(-4.0232)	(-1.330)	(-0.3768)	(-0.4501)	(-1.6904)
Firm age		19.1018***		150.6264***		118.098***		5.4677***		5.5477***		0.0119		-0.0057
		(6.1098)		(4.7915)		(3.8712)		(6.0708)		(6.2064)		(0.2469)		(-0.2349)
Firm size		0.7803***		3.71***		6.9431***		0.1837***		0.1813***		-0.0007*		-0.0002
		(4.6785)		(4.1815)		(3.9297)		(4.34)		(4.3696)		(-1.7662)		(-0.9974)
MB ratio		2.1355**		-11.7689		40.0568***		0.1423		0.0507		0.1015		-0.0063
		(2.1154)		(-1.4908)		(3.2966)		(0.5186)		(0.194)		(1.1826)		(-1.3096)
Leverage		10.3062		84.5589		21.9968		3.4244*		3.4493*		-0.4221		0.1593
		(1.5787)		(1.6329)		(0.3321)		(1.8478)		(1.8624)		(-1.2787)		(1.5556)
ROA		42.4794***		507.7816***		118.6483		13.5382***		13.2761***		-5.8719		0.1993*
		(4.3231)		(4.3677)		(1.2424)		(4.5509)		(4.594)		(-1.6246)		(1.6628)
Constant	28.8531***	-54.271***	254.4865***	-444.596***	201.9033***	-222.0358**	8.43***	-16.023***	8.3144***	-15.953***	0.2572*	0.7125***	0.3882***	0.4868**
	(6.0809)	(-4.8674)	(5.3777)	(-4.6891)	(4.5924)	(-2.0945)	(6.046)	(-4.5714)	(6.0495)	(-4.5395)	(1.9433)	(2.6531)	(4.7636)	(2.5303)
R-Square	0.0007	0.1424	0.0013	0.0721	0.0004	0.1178	0.0008	0.1109	0.0007	0.1116	0.0002	0.0326	0.0001	0.0422
obs	8553	7283	8553	7283	8553	7283	8553	7283	8553	7283	8552	7282	3344	3058
year FE		YES		YES		YES		YES		YES		YES		YES
industryFE		YES		YES		YES		YES		YES		YES		YES

Table 5 reports the results for multivariate tests using various forms of $\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{Anti} - \text{Takeover provisions}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon$. The dependent variables include seven measures of innovation. Patent is the total awarded patents applied for during a given year. Citation is total number of citations summed across all patents applied for during a given year. Ad_citation is total number of citations summed across all patents applied for during the year. Each patent's number of citations is multiplied by the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005). Originality equals to one minus H-index which is three-digit tech class distribution of all patents it cites. Generality equals to one minus H-index that is three-digit tech class distribution of all patents that cites it. Those measures of innovation above are in year t+1 and R&D which is research and development expense scaled by sale is in year t. In addition, Prd_{t+1}equals to $Patent_{t+1}\ scaled\ by\ R\&D_t$, which evaluates innovative efficiency. The independent variables include three measures of takeover provisions: E-index, Anti-index, and G-index. Control variables include Logarithm of 1 plus the number of years a firm has been in Compustat (Firm age), the natural logarithm of total assets (firm size), the ratio of operating income to total assets (ROA), the ratio of total debt to total assets (Leverage), and the ratio of market value to book value (MB ratio). Additionally, all regressions control for year and industry fixed effects. The statistical inferences are based on White's heteroscedasticity consistent standard errors (reported in parentheses). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6: The impact of CEO characteristic on innovation

Panel A: CEO_female

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
CEO_female	25.3716	-6.8216***	-84.7816***	-57.9378**	518.7702*	-58.7058**	-1.5249	-2.5978***	-1.9412	-2.5213**	-0.106***	-0.207***	-0.1303**	-0.0147
	(1.3131)	(-2.6153)	(-3.673)	(-2.3857)	(1.7346)	(-2.1978)	(-0.7385)	(-2.625)	(-1.0888)	(-2.5321)	(-3.9431)	(-2.5778)	(-2.5738)	(-0.2731)
Firm age		15.172***		120.405***		76.6304***		4.6655***		4.6406***		-0.0502**		-0.0312*
		(9.5662)		(7.6023)		(6.3025)		(9.2856)		(9.2954)		(-2.4384)		(-1.7403)
Firm size		0.8894***		4.0891***		7.3557***		0.2167***		0.2127***		-0.0004*		-0.0002
		(6.7621)		(5.8774)		(5.6195)		(6.4126)		(6.4571)		(-1.6822)		(-1.0052)
MB ratio		0.5593**		-1.0681		9.8909***		0.0888		0.0726		-0.0051		0.0014
		(2.3892)		(-0.5628)		(3.6655)		(1.3363)		(1.1529)		(-0.4688)		(0.8143)
Leverage		5.5681		51.5527		-18.4715		1.978		2.0857		-0.792***		-0.0337
		(1.2361)		(1.5467)		(-0.4358)		(1.524)		(1.6319)		(-3.8486)		(-0.7186)
ROA		31.770***		296.790***		138.649***		9.1256***		8.6755***		-4.438***		0.0373
		(6.4129)		(5.2382)		(3.4911)		(5.8462)		(5.7963)		(-2.7241)		(0.8119)
Constant	19.014***	-57.727***	129.255***	-552.661***	120.4032***	-121.2321*	5.54***	-19.985***	5.4736***	-19.814***	0.135***	1.096***	0.347***	0.479***
	(21.2428)	(-7.2266)	(16.2626)	(-7.3908)	(15.9107)	(-1.735)	(20.2725)	(-7.865)	(20.402)	(-7.9078)	(5.1066)	(3.734)	(31.6046)	(3.9732)
R-Square	0.0004	0.1406	0.0001	0.0655	0.0024	0.1202	0	0.1101	0	0.1122	0	0.0334	0.0001	0.0389
obs	17209	14678	17209	14678	17209	14678	17209	14678	17209	14678	17208	14677	7008	6357
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Panel B: CEO/chairman duality

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
CEO/chairma	15.904***	7.8322***	99.7362***	86.5197***	86.0443***	10.2745	4.5869***	3.0314***	4.4709***	2.9801***	-0.1197**	-0.0456	0.0162	0.0008
	(9.2944)	(5.1059)	(6.7361)	(5.952)	(5.5073)	(0.5889)	(8.9692)	(6.3303)	(8.8864)	(6.3082)	(-2.1723)	(-0.6937)	(0.7697)	(0.0311)
Firm age		14.229***		109.960***		75.4731***		4.3005***		4.2817***		-0.0443**		-0.0313
		(9.3145)		(7.3837)		(6.0509)		(9.0075)		(9.0362)		(-1.992)		(-1.5564)
Firm size		0.8837***		4.0269***		7.3469***		0.2145***		0.2106***		-0.0004*		-0.0002
		(6.7235)		(5.8343)		(5.5963)		(6.3652)		(6.4095)		(-1.7727)		(-0.9961)
MB ratio		0.5506**		-1.1684		9.8893***		0.0854		0.0692		-0.005		0.0013
		(2.3503)		(-0.613)		(3.666)		(1.286)		(1.0994)		(-0.4589)		(0.8091)
Leverage		4.4495		38.849		-18.9458		1.5442		1.6587		-0.780***		-0.0337
		(0.9991)		(1.193)		(-0.4485)		(1.2035)		(1.3114)		(-3.7989)		(-0.7368)
ROA		30.958***		287.874***		137.439***		8.8115***		8.3668***		-4.434***		0.037
		(6.2491)		(5.1007)		(3.4172)		(5.6666)		(5.6131)		(-2.7281)		(0.8165)
Constant	10.603***	-59.057***	74.085***	-567.072***	78.6884***	-123.7932*	3.0264***	-20.500***	3.0189***	-20.319***	0.199***	1.099***	0.338***	0.479***
	(14.1882)	(-7.297)	(12.3522)	(-7.4414)	(8.6375)	(-1.7601)	(13.826)	(-7.9586)	(13.412)	(-8.0023)	(4.1229)	(3.6903)	(31.4162)	(3.9364)
R-Square	0.0044	0.1415	0.0023	0.0669	0.0016	0.1202	0.0041	0.1115	0.0041	0.1136	0.0003	0.0334	0.0001	0.0389
obs	17209	14678	17209	14678	17209	14678	17209	14678	17209	14678	17208	14677	7008	6357
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Table 6 reports the results for multivariate tests using various forms of $\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{CEO characteristic}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon$. The dependent variables include seven measures of innovation. Patent is the total awarded patents applied for during a given year. Citation is total number of citations summed across all patents applied for during a given year. Ad_citation is total number

of citations summed across all patents applied for during the year. Each patent's number of citations is multiplied by the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005). Originality equals to one minus H-index which is three-digit tech class distribution of all patents it cites. Generality equals to one minus H-index that is three-digit tech class distribution of all patents that cites it. Those measures of innovation are in year t+1 and R&D which is research and development expense scaled by sale is in year t. In addition, Prd_{t+1}equals to $Patent_{t+1}\ scaled\ by\ R\&D_t$, which evaluates innovative efficiency. The independent variables include two measures of CEO characteristics: a variable that takes on a value of one if CEO is female, otherwise, takes on a value of zero (CEO_female), a variable that takes on a value of one if the CEO and chairman is the same person, otherwise, takes on a value of zero (CEO/chairman duality). Control variables include Logarithm of 1 plus the number of years a firm has been in Compustat (Firm age), the natural logarithm of total assets (firm size), the ratio of operating income to total assets (ROA), the ratio of total debt to total assets (Leverage), and the ratio of market value to book value (MB ratio). Additionally, all regressions control for year and industry fixed effects. The statistical inferences are based on White's heteroscedasticity consistent standard errors (reported in parentheses). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 7: The impact of board structure on innovation

Panel A: The number of female directors

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
NumFemale	14.1742***	8.8945***	28.9765***	27.6061***	149.4733***	78.2867***	2.3583***	1.9626***	2.2702***	1.9433***	-0.1008**	-0.0331	-0.0427**	-0.051***
	(6.1957)	(4.604)	(3.3142)	(3.3457)	(5.742)	(4.2136)	(4.9162)	(3.9946)	(5.1552)	(4.1212)	(-2.0724)	(-0.8858)	(-2.1239)	(-3.1725)
Firm age		13.5751***		34.2617**		131.1864***		2.1801***		1.9572***		0.007		-0.0165
		(5.1904)		(2.5744)		(5.0429)		(3.2171)		(2.9471)		(0.1139)		(-0.5614)
Firm size		0.7443***		2.0044***		7.4809***		0.1438***		0.1358***		-0.0004		0
		(5.6008)		(4.3343)		(5.1756)		(4.6937)		(4.6517)		(-1.2239)		(-0.0181)
MB ratio		1.9659***		5.2391*		26.2087***		0.3784**		0.3401**		0.0572		0.0074
		(2.8537)		(1.887)		(3.213)		(2.3496)		(2.3425)		(1.3484)		(1.2662)
Leverage		5.9225		40.8898		-14.6295		1.5728		1.6609		-0.5951*		0.0997*
		(0.8601)		(1.3335)		(-0.196)		(0.9921)		(1.1264)		(-1.8324)		(1.7592)
ROA		37.886***		180.835***		240.3966**		8.8934***		8.0343***		-5.0798*		0.1786**
		(4.0965)		(4.1217)		(2.5678)		(3.8808)		(3.7794)		(-1.6888)		(2.373)
Constant	10.6109***	-59.9575***	46.3064***	-228.988***	87.0093***	-380.929***	2.6445***	-12.9092***	2.4234***	-11.8869***	0.2219***	0.6357***	0.3481***	0.5016***
	(7.4162)	(-4.5575)	(7.2231)	(-3.6079)	(5.7635)	(-2.8748)	(8.0529)	(-3.8896)	(8.3525)	(-3.7903)	(2.672)	(3.0064)	(11.0401)	(2.812)
R-Square	0.0082	0.1432	0.0017	0.066	0.008	0.1332	0.0041	0.1063	0.0044	0.1098	0.0004	0.0222	0.001	0.0325
obs	8910	7617	8910	7617	8910	7617	8910	7617	8910	7617	8910	7617	3616	3239
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Panel B: The number of independent directors

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
NumOutsider	4.3308***	4.4046***	15.8137***	21.3324***	35.7797***	34.7799***	0.981***	1.0965***	0.9496***	1.0511***	-0.0256**	-0.0061	0.0047	0.0001
	(7.3086)	(6.1207)	(4.4547)	(4.2169)	(5.8683)	(4.7426)	(6.6192)	(5.3705)	(6.7671)	(5.3437)	(-2.0802)	(-0.4265)	(1.0754)	(0.0298)
Firm age		10.9874***		30.0933**		96.9138***		1.9124***		1.8035***		0.0003		-0.0308
		(5.1667)		(2.0943)		(5.3462)		(3.1306)		(3.003)		(0.004)		(-1.0502)
Firm size		0.7761***		2.4931***		7.3097***		0.1627***		0.1562***		-0.0004		-0.0003
		(5.8998)		(4.6329)		(5.2697)		(5.144)		(5.1309)		(-1.6171)		(-1.3586)
MB ratio		1.7386**		1.0914		26.6407***		0.2715		0.235		0.0596		0.0055
		(2.5308)		(0.2756)		(3.3989)		(1.5591)		(1.4739)		(1.4169)		(0.97)
Leverage		1.7545		16.1697		-42.357		0.5028		0.6838		-0.5911*		0.0852
		(0.2831)		(0.5105)		(-0.6484)		(0.328)		(0.4685)		(-1.9411)		(1.5278)
ROA		44.5564***		313.2209***		218.333***		12.4206***		11.5599***		-4.8644*		0.1679**
		(4.8113)		(4.2068)		(2.5827)		(4.7035)		(4.6616)		(-1.7361)		(2.2572)
Constant	-3.2463	-71.256***	-1.302	-347.368***	-23.4446	-399.619***	-0.5985	-17.5851***	-0.6532	-16.6911***	0.2797**	0.6414***	0.3037***	0.5427***
	(-1.1826)	(-5.3433)	(-0.081)	(-4.2346)	(-0.8188)	(-3.1218)	(-0.8868)	(-4.8534)	(-1.0231)	(-4.8074)	(2.5132)	(2.8821)	(7.8621)	(3.0021)
R-Square	0.0082	0.1457	0.003	0.0634	0.0057	0.1331	0.0062	0.1092	0.0065	0.1118	0.0004	0.0218	0.0001	0.0325
obs	10210	8734	10210	8734	10210	8734	10210	8734	10210	8734	10210	8734	4106	3679
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Panel C: Board size

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
Board size	2.6994***	2.5623***	10.0034***	13.1485***	18.8222***	17.661***	0.6902***	0.7484***	0.6837***	0.7355***	-0.032***	-0.0109	-0.002	-0.0126
	(6.6501)	(4.2576)	(4.224)	(2.6912)	(4.3127)	(3.3991)	(6.3234)	(3.8854)	(6.4831)	(3.9672)	(-2.7014)	(-1.4294)	(-0.2513)	(-1.2936)
Firm age		13.3056***		40.3736**		118.5144***		2.3478***		2.1978***		0.0065		-0.0141
		(4.7109)		(2.0446)		(5.0568)		(2.9785)		(2.8916)		(0.1295)		(-0.627)
Firm size		0.7788***		2.4976***		7.3611***		0.1621***		0.1554***		-0.0003		-0.0001
		(5.7564)		(4.3639)		(5.2141)		(4.9927)		(4.9874)		(-0.9895)		(-0.4382)
MB ratio		1.8312***		1.5659		27.2815***		0.2985*		0.2615		0.0592		0.0051
		(2.6513)		(0.3995)		(3.4702)		(1.7138)		(1.641)		(1.4096)		(0.9035)
Leverage		2.7782		19.8628		-29.8716		0.5684		0.7158		-0.5798*		0.103*
		(0.4168)		(0.5411)		(-0.4451)		(0.3395)		(0.4513)		(-1.9271)		(1.7358)
ROA		44.1351***		310.2507***		218.2413**		12.1767***		11.3033***		-4.8545*		0.1828**
		(4.7436)		(4.2344)		(2.5618)		(4.638)		(4.5786)		(-1.7303)		(2.2749)
Constant	-3.3687	-76.8105***	-3.1711	-377.18***	9.2349	-433.323***	-1.3886	-19.4044***	-1.5686*	-18.5066***	0.4365***	0.6783***	0.3489***	0.5703***
	(-1.0019)	(-6.0146)	(-0.1597)	(-4.8771)	(0.2532)	(-3.3942)	(-1.5526)	(-5.4936)	(-1.8219)	(-5.4344)	(2.8556)	(2.9057)	(4.1249)	(2.9553)
R-Square	0.0039	0.1428	0.0015	0.0618	0.0019	0.1308	0.0038	0.1072	0.0041	0.1099	0.0007	0.0219	0	0.033
obs	10210	8734	10210	8734	10210	8734	10210	8734	10210	8734	10210	8734	4106	3679
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Table 7 reports the results for interaction tests using various forms of $\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{board structure}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon$. The dependent variables include seven measures of innovation. Patent is the total awarded patents applied for during a given year. Citation is total number of citations summed across all patents applied for during a given year. Ad_citation is total number of citations summed across all patents applied for during the year. Each patent's number of citations is multiplied by the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005). Originality equals to one minus H-index which is three-digit tech class distribution of all patents it cites. Generality equals to one minus H-index that is three-digit tech class distribution of all patents that cites it. Those measures of innovation are in year t+1 and R&D which is research and development expense scaled by sale is in year t. In addition, Prd_{t+1}equals to $Patent_{t+1}$ $scaled\ by\ R\&D_t$, which evaluates innovative efficiency. The independent variables include number of female directors (NumFemale), number of independent directors (NumOutsider), and number of directors (Board size). Control variables include Logarithm of 1 plus the number of years a firm has been in Compustat (Firm age), the natural logarithm of total assets (firm size), the ratio of operating income to total assets (ROA), the ratio of total debt to total assets (Leverage), and the ratio of market value to book value (MB ratio). Additionally, all regressions control for year and industry fixed effects. The statistical inferences are based on White's heteroscedasticity consistent standard errors (reported in parentheses). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 8: The impact of ownership structure on innovation

Panel A: The number of blockholders

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
NumBlks	-11.594***	-5.7706***	-52.127***	-26.3915***	-85.5738***	-43.1474***	-2.8914***	-1.4797***	-2.7831***	-1.4389***	-0.014	-0.0571	-0.005	-0.0021
	(-8.2007)	(-5.0008)	(-5.9305)	(-3.5865)	(-7.0066)	(-4.7449)	(-7.597)	(-4.4438)	(-7.7862)	(-4.714)	(-0.605)	(-1.032)	(-0.7897)	(-0.2984)
Firm age		19.252***		68.926***		126.4169***		4.2016***		4.0041***		-0.067**		0.0045
		(5.1009)		(2.8318)		(4.08)		(4.1692)		(4.1902)		(-2.0676)		(0.279)
Firm size		0.9584***		3.2937***		7.9492***		0.2115***		0.2008***		-0.0011		-0.0002
		(5.1787)		(4.1037)		(4.6584)		(4.6918)		(4.6731)		(-1.2047)		(-0.8561)
MB ratio		1.3115		-6.7315		34.8817***		0.0014		-0.0325		0.1218		-0.0015
		(1.1632)		(-0.892)		(2.8727)		(0.0044)		(-0.1145)		(1.556)		(-0.5067)
Leverage		9.6382		49.1936		-1.5338		2.1648		2.2181		-0.5555		0.1005
		(0.9797)		(0.9213)		(-0.0171)		(0.876)		(0.9533)		(-1.4755)		(1.4754)
ROA		54.5335***		414.6694***		257.1981**		15.7139***		14.8748***		-7.4763		0.1093
		(4.1128)		(3.377)		(2.4522)		(3.91)		(3.9016)		(-1.3623)		(1.5806)
Constant	54.9063***	-59.299***	249.7848***	-304.671***	391.862***	-266.4538**	13.8711***	-14.83***	13.2992***	-14.004***	0.1361	1.6637	0.3462***	0.5627***
	(11.1062)	(-3.4553)	(8.0609)	(-2.89)	(9.0321)	(-1.9683)	(10.5223)	(-3.1669)	(10.6059)	(-3.1667)	(1.4025)	(1.3849)	(21.757)	(3.4565)
R-Square	0.0144	0.1666	0.0072	0.0763	0.0107	0.1543	0.0124	0.1314	0.0128	0.1339	0	0.0367	0.0003	0.1239
obs	6705	5725	6705	5725	6705	5725	6705	5725	6705	5725	6705	5725	2671	2370
year FE		YES		YES		YES		YES		YES		YES		YES
IndustryFE		YES		YES		YES		YES		YES		YES		YES

Panel B: Shares owned by all blockholders

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
SumBlks	-1.0785***	-0.4515***	-4.8378***	-2.1502***	-7.8523***	-3.1675***	-0.2696***	-0.1207***	-0.2597***	-0.1188***	-0.0019	-0.0062	-0.0007	-0.0005
	(-8.9185)	(-4.9659)	(-6.3623)	(-3.7543)	(-7.5905)	(-4.6405)	(-8.2564)	(-4.5148)	(-8.4483)	(-4.8682)	(-0.819)	(-1.1172)	(-1.3023)	(-0.6885)
Firm age		19.3774***		69.0388***		128.4778***		4.207***		4.0017***		-0.075**		0.0036
		(5.0502)		(2.8065)		(4.0479)		(4.1284)		(4.1432)		(-2.0616)		(0.223)
Firm size		0.9638***		3.3135***		8.0008***		0.2126***		0.2018***		-0.0012		-0.0002
		(5.1843)		(4.1032)		(4.6606)		(4.7015)		(4.6831)		(-1.2283)		(-0.9507)
MB ratio		1.3994		-6.4008		35.7133***		0.0197		-0.0158		0.1213		-0.0016
		(1.2364)		(-0.8528)		(2.9289)		(0.0644)		(-0.0557)		(1.553)		(-0.5436)
Leverage		7.0907		37.2382		-19.8402		1.4939		1.5606		-0.5869		0.0989
		(0.7292)		(0.7075)		(-0.2247)		(0.6082)		(0.6754)		(-1.4521)		(1.4428)
ROA		54.8965***		415.4278***		262.1091**		15.7546***		14.8993***		-7.491		0.1081
		(4.1292)		(3.3732)		(2.4911)		(3.9136)		(3.9032)		(-1.3628)		(1.5642)
Constant	53.0883***	-61.242***	241.3544***	-308.819***	375.9276***	-292.5313**	13.4325***	-15.058***	12.8811***	-14.142***	0.1478	1.7408	0.3511***	0.5778***
	(11.7141)	(-3.4267)	(8.4588)	(-2.8425)	(9.5108)	(-2.0466)	(11.1025)	(-3.1264)	(11.1808)	(-3.1143)	(1.5077)	(1.3909)	(23.9353)	(3.5162)
R-Square	0.0151	0.1659	0.0074	0.076	0.0108	0.1535	0.013	0.1309	0.0135	0.1334	0.0001	0.0368	0.0006	0.124
obs	6705	5725	6705	5725	6705	5725	6705	5725	6705	5725	6705	5725	2671	2370
year FE		YES		YES		YES		YES		YES		YES		YES
industryFE		YES		YES		YES		YES		YES		YES		YES

Panel C: Shares owned by the largest blockholder

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
Largest_B	-1.3163***	-0.619***	-5.7768***	-3.1254***	-9.5392***	-4.0035***	-0.3316***	-0.1775***	-0.3173***	-0.1725***	-0.0025	-0.0062	-0.0005	-0.0001
	(-8.2705)	(-5.3893)	(-5.9253)	(-4.233)	(-6.8269)	(-4.3064)	(-7.9004)	(-5.3813)	(-7.9274)	(-5.4362)	(-1.245)	(-1.34)	(-0.6499)	(-0.1495)
Firm age		20.5386***		74.2037***		137.3236***		4.4928***		4.2876***		-0.0544*		0.0053
		(5.225)		(2.9449)		(4.218)		(4.3105)		(4.344)		(-1.8769)		(0.3279)
Firm size		0.9726***		3.3509***		8.0716***		0.2146***		0.2039***		-0.001		-0.0001
		(5.2371)		(4.137)		(4.7049)		(4.7515)		(4.7353)		(-1.2849)		(-0.8285)
MB ratio		1.6425		-5.2816		37.4927***		0.0821		0.0461		0.1251		-0.0014
		(1.4346)		(-0.7101)		(3.0491)		(0.2668)		(0.1617)		(1.5335)		(-0.4697)
Leverage		6.7467		35.0403		-21.1832		1.364		1.4399		-0.5843		0.1
		(0.6942)		(0.6678)		(-0.2403)		(0.5556)		(0.6231)		(-1.464)		(1.4598)
ROA		56.8262***		423.8057***		277.2031***		16.2156***		15.3635***		-7.4539		0.1097
		(4.2257)		(3.4074)		(2.6131)		(3.9791)		(3.9775)		(-1.3649)		(1.5779)
Constant	44.168***	-69.750***	199.7635***	-344.598***	310.4366***	-361.2888**	11.2345***	-17.012***	10.7386***	-16.126***	0.1339*	1.5617	0.3408***	0.5561***
	(11.9446)	(-3.8674)	(8.6746)	(-3.1104)	(9.5916)	(-2.5045)	(11.4494)	(-3.4959)	(11.4875)	(-3.4992)	(1.9184)	(1.4595)	(26.2432)	(3.4775)
R-Square	0.0086	0.1654	0.0041	0.0759	0.0061	0.153	0.0076	0.1307	0.0077	0.1332	0.0001	0.0365	0.0001	0.1238
obs	6705	5725	6705	5725	6705	5725	6705	5725	6705	5725	6705	5725	2671	2370
year FE		YES		YES		YES		YES		YES		YES		YES
Industry FE		YES		YES		YES		YES		YES		YES		YES

Table 8 reports the results for interaction tests using various forms of $\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{Ownership structure}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon$. The dependent variables include seven measures of innovation. Patent is the total awarded patents applied for during a given year. Citation is total number of citations summed across all patents applied for during a given year. Ad_citation is total number of citations summed across all patents applied for during the year. Each patent's number of citations is multiplied by the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005). Originality equals to one minus H-index which is three-digit tech class distribution of all patents it cites. Generality equals to one minus H-index that is three-digit tech class distribution of all patents that cites it. Those measures of innovation are in year t+1 and R&D which is research and development expense scaled by sale is in year t. In addition, Prd_{t+1}equals to $Patent_{t+1}$ $scaled\ by\ R\&D_t$, which evaluates innovative efficiency. The independent variables include number of blockholders (NumBlks), amount of shares held by all blockholders (SumBlks), and amount of shares held by the largest blockholder (Largest_B). Control variables include Logarithm of 1 plus the number of years a firm has been in Compustat (Firm age), the natural logarithm of total assets (firm size), the ratio of operating income to total assets (ROA), the ratio of total debt to total assets (Leverage), and the ratio of market value to book value (MB ratio). Additionally, all regressions control for year and industry fixed effects. The statistical inferences are based on White's heteroscedasticity consistent standard errors (reported in parentheses). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9: The impact of risk averse on innovation

Variable	(1) Citation_Pat	(2) Citation_Pat	(3) Citation_Pat	(4) Citation_Pat	(5) Citation_Pat	(6) Citation_Pat	(7) Citation_Pat	(8) Citation_Pat	(9) Citation_Pat	(10) Citation_Pat	(11) Citation_Pat	(12) Citation_Pat
CEO_female	-4.4982***	-2.2596***										
	(-7.8479)	(-3.0757)										
CEO/chairman			-2.472***	-0.2103								
			(-8.5379)	(-0.8253)								
NumFemale					-0.4049***	0.0103						
					(-5.3764)	(0.1604)						
NumBlks							-0.2658***	-0.1471***				
							(-4.7021)	(-2.9174)				
SumBlks									-0.026***	-0.0162***		
									(-4.9026)	(-3.6007)		
Largest_B											-0.0221**	-0.0185**
											(-2.4274)	(-2.2496)
Firm age		-1.2305***		-1.2103***		-0.1809**		-0.6011***		-0.6098***		-0.5713***
		(-6.5109)		(-6.435)		(-2.0307)		(-4.1309)		(-4.1553)		(-3.8809)
Firm size		0.0025		0.0024		-0.0025		-0.0023*		-0.0024**		-0.002*
		(1.5423)		(1.4872)		(-1.3244)		(-1.8908)		(-2.0403)		(-1.7967)
MB ratio		-0.0025		-0.0025		0.0698**		0.0104		0.0119		0.018
		(-0.087)		(-0.0869)		(2.5006)		(0.3575)		(0.399)		(0.6141)
Leverage		-2.3426***		-2.2236***		-0.4536		-0.5568		-0.612		-0.614
		(-2.7755)		(-2.5874)		(-1.2209)		(-0.8618)		(-0.9477)		(-0.9549)
ROA		1.1467		1.1389		0.4555		1.2938		1.2331		1.3256
		(1.0172)		(1.0108)		(0.5884)		(1.3193)		(1.2628)		(1.364)
Constant	6.8364***	5.8399***	8.2265***	5.8843***	2.9097***	6.0771*	4.338***	5.0638***	4.3019***	5.1605***	4.0038***	4.8267***
	(49.5178)	(3.1002)	(33.388)	(3.1092)	(26.3561)	(1.8086)	(26.2501)	(3.0596)	(27.5576)	(3.1912)	(28.1534)	(3.035)
R-Square	0.0014	0.3	0.013	0.2998	0.0075	0.327	0.0074	0.37	0.0076	0.3706	0.0019	0.3692
obs	6119	5496	6119	5496	3223	2863	2549	2252	2549	2252	2549	2252
year FE		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES

Table 9 reports the results for risk averse tests using Citation_Pat which equals to citation scaled by patent as dependent variable. The regression formula is $\text{Citation\_Pat}_{t+1} = \beta_0 + \beta_1 * \text{Independent variables}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon$. The independent variables include a variable that takes on a value of one if CEO is female, otherwise, takes on a value of zero (CEO_female), a variable that takes on a value of one if the CEO and chairman is the same person, otherwise, takes on a value of zero (CEO/chairman duality), number of female directors in a board (NumFemale), number of blockholders (NumBlks), amount of shares owned by all blockholders (SumBlks), and amount of shares owned by the largest blockholder (Largest_B). Control variables include Logarithm of 1 plus the number of years a firm has been in Compustat (Firm age), the natural logarithm of total assets (firm size), the ratio of operating income to total assets (ROA), the ratio of total debt to total assets (Leverage), and the ratio of market value to book value (MB ratio). Additionally, all regressions control for year and industry fixed effects. The statistical inferences are based on White's heteroscedasticity consistent standard errors (reported in parentheses). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 10: The combined impact of corporate governance on innovation

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
E-index	-18.01***	-7.8305**	-57.602***	-24.039***	-155.480***	-65.3643*	-3.774***	-1.5042***	-3.5083***	-1.4042***	-0.0148*	-0.0096	-0.0006	-0.0093
	(-3.9764)	(-2.5169)	(-3.8064)	(-2.6813)	(-3.3515)	(-1.8699)	(-4.0659)	(-2.732)	(-4.1172)	(-2.7909)	(-1.8207)	(-1.1262)	(-0.0507)	(-0.7019)
CEO_female	108.4644	-14.0458	130.4573	-66.036	1260.128	-187.7796	12.5646	-5.7436	10.2158	-5.9017	0.0213	-0.0799	-0.0626	0.0227
	(1.0985)	(-1.0335)	(0.9297)	(-0.9992)	(1.0403)	(-1.4406)	(0.9346)	(-1.4227)	(0.8959)	(-1.5223)	(1.2726)	(-1.1041)	(-0.7515)	(0.3141)
CEO/chair	10.219*	6.713	38.085*	31.255	43.0196	20.8402	2.6472**	1.9333	2.4215*	1.6975	-0.0511	-0.0532	0.0247	0.0039
	(1.8676)	(1.3433)	(1.7285)	(1.425)	(0.8263)	(0.4435)	(1.9623)	(1.4772)	(1.9144)	(1.3718)	(-1.4406)	(-1.3382)	(0.7954)	(0.1311)
NumFemale	18.337***	10.7709**	32.8035*	29.9268*	165.949***	83.2491**	2.9702***	2.4248**	2.7982***	2.3797**	-0.0262**	0.0005	-0.0172	-0.0404*
	(3.4961)	(2.368)	(1.8888)	(1.8718)	(3.4011)	(2.2161)	(2.7774)	(2.0934)	(2.8902)	(2.1444)	(-2.3475)	(0.0817)	(-1.0463)	(-1.8896)
NUMBLKS	-9.965***	-6.071***	-34.433***	-20.948***	-79.3396***	-45.817***	-2.2711***	-1.3994***	-2.1224***	-1.294***	0.0003	-0.0061	-0.0181**	-0.024***
	(-5.0002)	(-3.5693)	(-4.1837)	(-3.0758)	(-4.5502)	(-3.0341)	(-4.6803)	(-3.3523)	(-4.6627)	(-3.2784)	(0.1565)	(-1.2975)	(-1.995)	(-2.7141)
Largest_B	-1.429***	-0.9261***	-4.7477***	-3.178***	-11.0565***	-6.9797***	-0.3352***	-0.2264***	-0.3124***	-0.2112***	-0.001***	-0.0013**	-0.0011	-0.0005
	(-4.201)	(-3.5214)	(-3.5284)	(-3.1251)	(-3.5786)	(-2.7746)	(-4.1826)	(-3.645)	(-4.2018)	(-3.6838)	(-2.6641)	(-2.0506)	(-0.7417)	(-0.3306)
Firm age		13.235*		37.9157		86.3378		2.1975		1.8925		-0.0055		0.0216
		(1.9559)		(1.2586)		(1.5626)		(1.2593)		(1.1299)		(-0.3883)		(0.9269)
Firm size		0.9307***		2.5853**		7.8784***		0.1948***		0.1841***		-0.0001		-0.0004*
		(3.4257)		(2.5099)		(3.4047)		(2.8765)		(2.8406)		(-1.1781)		(-1.7519)
MB ratio		0.3624		-1.0743		21.6621		-0.123		-0.1379		0.0213**		0.0011
		(0.2322)		(-0.1896)		(1.2278)		(-0.3444)		(-0.4176)		(1.9658)		(0.3143)
Leverage		15.9536		68.409		44.8265		2.7252		2.5841		-0.3132		0.1137
		(0.738)		(0.7922)		(0.2196)		(0.5728)		(0.5974)		(-1.5276)		(0.9474)
ROA		67.019***		186.747**		551.221**		12.4986**		10.776**		-1.7527		0.1275
		(2.8796)		(2.0544)		(2.4318)		(2.1795)		(1.9859)		(-1.3729)		(1.1827)
Constant	85.471***	-15.9592	301.861***	-80.282	695.232***	-64.1812	19.772***	-0.997	18.466***	-0.1316	0.1537**	0.4779*	0.3617***	0.9748***
	(5.1261)	(-0.6029)	(4.7586)	(-0.6292)	(4.2776)	(-0.3608)	(5.1096)	(-0.1342)	(5.1152)	(-0.0186)	(2.3701)	(1.655)	(7.4849)	(6.8649)
R-Square	0.0516	0.1862	0.029	0.1114	0.0472	0.1706	0.0407	0.1636	0.0409	0.1689	0.0044	0.0758	0.0066	0.1849
obs	2090	1793	2090	1793	2090	1793	2090	1793	2090	1793	2090	1793	859	769
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Table 10 reports the results for interaction tests using various forms of $\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{Independent variables}_t + \beta_2 * \text{firm age}_t + \beta_3 * \text{firm size}_t + \beta_4 * \text{MB}_t + \beta_5 * \text{Leverage}_t + \beta_6 * \text{ROA}_t + \varepsilon$. The dependent variables include seven measures of innovation. Patent is the total awarded patents applied for during a given year. Citation is total number of citations summed across all patents applied for during a given year. ad_citation is total number of citations summed across all patents applied for during the year. Each patent's number of citations is multiplied by the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005). Originality equals to one minus H-index which is three-digit tech class distribution of all patents it cites. Generality equals to one minus H-index that is three-digit tech class distribution of all patents that cites it. Those measures of innovation are in year t+1 and R&D which is research and development expense scaled by sale is in year t. In addition, Prd_{t+1}equals to $Patent_{t+1}\ scaled\ by\ R\&D_t$, which evaluate innovative efficiency. The independent variables include a variable that takes on a value of one if CEO is female, otherwise, takes on a value of zero (CEO_female), a variable that takes on a value of one if the CEO and chairman is the same person, otherwise, takes on a value of zero (CEO/chairman duality), number of female directors in a board (NumFemale), number of blockholders (NumBlks), and amount of shares owned by the largest blockholder (Largest_B). Control variables include Logarithm of 1 plus the number of years a firm has been in Compustat (Firm age), the natural logarithm of total assets (firm size), the ratio of operating income to total assets (ROA), the ratio of total debt to total assets (Leverage), and the ratio of market value to book value (MB ratio). Additionally, all regressions control for year and industry fixed effects. The statistical inferences are based on White's heteroscedasticity consistent standard errors (reported in parentheses). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 11: The impact of interaction between antitakeover provisions and other corporate governance on innovation

Panel A: interaction of CEO/chairman and E-index

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
CEO/chairman	38.911***	20.184***	274.170***	195.275***	232.441***	69.1714	11.041***	6.7541***	10.748***	6.6136***	0.0832	0.0828	0.0611	0.0963
	(5.0864)	(3.3529)	(4.2429)	(3.25)	(3.0957)	(0.9957)	(5.399)	(4.0579)	(5.4407)	(4.0799)	(0.4424)	(0.3994)	(0.8192)	(0.9199)
eindex_cc	-11.197***	-5.598***	-83.2426***	-55.795***	-75.1171***	-27.0688	-3.0873***	-1.728***	-2.9966***	-1.711***	-0.0582	-0.0277	-0.0176	-0.0401
	(-4.8285)	(-3.028)	(-4.2122)	(-2.9222)	(-3.3937)	(-1.461)	(-5.0285)	(-3.4042)	(-5.0531)	(-3.4266)	(-1.2542)	(-0.714)	(-0.8268)	(-1.2808)
Firm age		19.543***		115.954***		148.873***		4.7702***		4.7194***		0.0034		-0.025
		(5.2914)		(3.6972)		(3.9254)		(4.6917)		(4.74)		(0.0716)		(-0.5976)
Firm size		0.7856***		3.151***		7.3993***		0.1751***		0.1701***		-0.0007		-0.0004
		(4.6428)		(3.9007)		(3.9529)		(4.1298)		(4.1358)		(-1.4256)		(-1.2977)
MB ratio		1.7239		-11.4012		37.917***		0.0263		-0.0475		0.1271		-0.0017
		(1.5677)		(-1.3956)		(2.8109)		(0.0892)		(-0.1697)		(1.1547)		(-0.494)
Leverage		16.1081		127.6757*		45.2875		4.8462*		4.7287*		-0.7594		0.1315
		(1.6032)		(1.6621)		(0.4319)		(1.7579)		(1.7558)		(-1.5028)		(1.4369)
ROA		53.964***		542.631***		193.8277		16.404***		15.630***		-7.8148		0.1523
		(3.7092)		(3.3727)		(1.3695)		(3.8731)		(3.8706)		(-1.475)		(1.3427)
Constant	14.333***	-84.680***	81.8834***	-629.07***	139.629***	-435.2637**	3.4063***	-23.44***	3.3335***	-22.85***	0.1507*	1.0179*	0.3207***	0.6676***
	(8.0202)	(-4.3627)	(6.9243)	(-3.8893)	(4.9291)	(-2.4142)	(8.3797)	(-4.1559)	(8.302)	(-4.1451)	(1.8096)	(1.8556)	(18.1605)	(2.9713)
R-Square	0.0103	0.1497	0.008	0.073	0.0039	0.1262	0.0104	0.1166	0.0104	0.1173	0.0003	0.0375	0.0005	0.0443
obs	5755	4936	5755	4936	5755	4936	5755	4936	5755	4936	5754	4935	2332	2112
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Panel B: interaction of NumFemale and E-index

VARIABLES	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
NumFemale	34.979***	20.206***	70.0601***	43.9713**	421.283***	248.715***	5.3126***	3.1406***	5.0212***	3.0691***	-0.0888	-0.0521	-0.0607*	-0.0598**
	(3.9146)	(3.3139)	(2.8608)	(2.3776)	(3.8095)	(3.3678)	(3.4115)	(2.6775)	(3.558)	(2.815)	(-1.4147)	(-1.1067)	(-1.9366)	(-2.1592)
eindex_female	-8.9631***	-4.9401***	-20.6189***	-9.8783*	-106.414***	-67.6242***	-1.4487***	-0.6397**	-1.3637***	-0.6197**	0	0.0157	0.0077	0.0029
	(-3.4069)	(-2.5796)	(-3.0053)	(-1.9207)	(-3.2951)	(-2.7619)	(-3.2188)	(-1.9732)	(-3.3317)	(-2.0756)	(0.0248)	(1.2179)	(1.3605)	(0.3759)
Firm age		14.938***		35.514**		157.417***		2.3048**		2.0844**		-0.0197		-0.0049
		(3.7853)		(2.209)		(3.5878)		(2.522)		(2.4153)		(-1.3969)		(-0.1207)
Firm size		0.6525***		1.5618***		7.1522***		0.1175***		0.1106***		0.0001		0
		(3.9744)		(2.7814)		(3.8077)		(3.0443)		(2.9838)		(0.5281)		(0.1768)
MB ratio		2.6555**		7.7787*		32.808**		0.4804*		0.423*		0.0198*		0.0024
		(2.2602)		(1.9375)		(2.2087)		(1.8172)		(1.7788)		(1.708)		(0.7503)
Leverage		12.6504		49.2189		66.4347		2.6084		2.5673		-0.8228		0.091
		(1.1509)		(1.2015)		(0.5108)		(1.137)		(1.2274)		(-1.266)		(1.0729)
ROA		50.900***		172.801***		325.6169		11.501***		9.9593***		-2.7863*		0.2384*
		(2.8171)		(2.9438)		(1.641)		(2.937)		(2.927)		(-1.7558)		(1.6588)
Constant	9.9897***	-65.255***	36.5388***	-212.696**	90.6029***	-493.3806**	2.3508***	-12.83***	2.1402***	-11.651**	0.1869*	0.5474*	0.332***	0.4886**
	(4.7165)	(-3.1965)	(5.4241)	(-2.5621)	(3.6035)	(-2.2891)	(5.3373)	(-2.6487)	(5.5088)	(-2.5711)	(1.6724)	(1.8104)	(7.5694)	(2.0206)
R-Square	0.0202	0.147	0.0066	0.0752	0.021	0.139	0.0103	0.1087	0.0108	0.113	0.0004	0.0098	0.0013	0.0379
obs	4151	3553	4151	3553	4151	3553	4151	3553	4151	3553	4151	3553	1678	1505
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Panel C: interaction of NumOutsider and E-index

VARIABLES	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
NumOutsider	10.093***	7.8095***	24.3893***	19.6716***	110.646***	90.193***	1.7601***	1.3142***	1.6411***	1.2208***	-0.0079	0.0171	0.0114*	0.0188
	(4.6963)	(3.6083)	(3.4197)	(3.028)	(4.2671)	(3.1994)	(4.2521)	(3.2641)	(4.3811)	(3.2892)	(-1.2256)	(1.6142)	(1.81)	(1.2155)
eindex_outsider	-1.9933***	-1.229***	-5.2938***	-2.8523**	-22.0623***	-15.5984***	-0.3532***	-0.1739**	-0.3262***	-0.161***	-0.0046	-0.0027	-0.0019	-0.0055
	(-4.2263)	(-2.867)	(-3.5865)	(-2.5697)	(-3.8912)	(-2.7626)	(-3.9637)	(-2.5455)	(-4.0395)	(-2.5911)	(-1.3359)	(-1.3292)	(-0.7292)	(-1.1339)
Firm age		12.129***		27.4249*		126.281***		1.7876**		1.6293**		-0.035**		-0.0231
		(3.5644)		(1.894)		(3.6488)		(2.1265)		(2.0322)		(-2.1948)		(-0.5034)
Firm size		0.639***		1.5141***		7.0144***		0.115***		0.1086***		-0.0001		-0.0005
		(3.8881)		(2.7349)		(3.6843)		(2.9842)		(2.9305)		(-1.2585)		(-1.1802)
MB ratio		2.6327**		7.6719*		32.483**		0.4798*		0.4248*		0.0183		0.0009
		(2.1736)		(1.8855)		(2.111)		(1.7867)		(1.7552)		(1.5176)		(0.3041)
Leverage		10.897		43.855		47.7869		2.2384		2.2419		-0.8282		0.0913
		(1.0049)		(1.0866)		(0.3696)		(0.9846)		(1.0785)		(-1.2721)		(1.014)
ROA		54.273***		180.104***		360.7747*		12.126***		10.604***		-2.8015*		0.2042
		(3.0782)		(3.1219)		(1.8453)		(3.1542)		(3.1502)		(-1.7528)		(1.5381)
Constant	-11.214**	-78.554***	-18.3006	-245.99***	-122.7726*	-640.7147**	-1.713	-15.18***	-1.6607*	-13.88***	0.223	0.5302*	0.2594***	0.5652**
	(-2.0865)	(-3.3992)	(-0.9962)	(-2.6841)	(-1.8597)	(-2.5711)	(-1.6409)	(-2.8187)	(-1.7451)	(-2.7562)	(1.5875)	(1.7937)	(6.0106)	(2.0715)
R-Square	0.024	0.1513	0.0117	0.0778	0.0206	0.1427	0.0161	0.1115	0.0165	0.1156	0.0003	0.0098	0.0004	0.0382
obs	4151	3553	4151	3553	4151	3553	4151	3553	4151	3553	4151	3553	1678	1505
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Panel D: interaction of Board size and E-index

VARIABLES	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
Board size	5.5195***	3.7778***	13.5023***	9.6373**	55.5177***	40.2544***	1.0631***	0.7724***	1.0026***	0.7258***	-0.0264	-0.0099	0.0028	-0.0024
	(4.9322)	(3.3737)	(3.9869)	(2.5347)	(4.017)	(3.0814)	(4.41)	(3.0228)	(4.4518)	(3.2251)	(-1.494)	(-0.7554)	(0.3359)	(-0.2893)
eindex_director	-0.9692***	-0.4907***	-2.6414***	-1.0473**	-10.5572***	-6.4884***	-0.1788***	-0.0669**	-0.1658***	-0.0624**	-0.0024	-0.0008	-0.0012	-0.0032
	(-4.3571)	(-2.8881)	(-3.9278)	(-2.505)	(-3.9592)	(-2.8412)	(-3.9439)	(-2.3518)	(-3.9438)	(-2.3863)	(-1.2765)	(-1.0682)	(-0.9543)	(-1.2862)
Firm age		14.518***		33.3614*		156.75***		2.0608*		1.8765*		-0.007		-0.003
		(3.1052)		(1.6821)		(3.4232)		(1.8782)		(1.8473)		(-0.3735)		(-0.0927)
Firm size		0.6525***		1.5476***		7.2075***		0.1157***		0.1092***		0.0001		-0.0003
		(3.803)		(2.5976)		(3.6951)		(2.9172)		(2.8826)		(0.3804)		(-1.0084)
MB ratio		2.8935**		8.3452**		35.4115**		0.5262*		0.4679*		0.0183		0.001
		(2.4252)		(2.0478)		(2.3608)		(1.9516)		(1.9247)		(1.4974)		(0.337)
Leverage		12.5029		47.4353		70.7978		2.3431		2.334		-0.7963		0.112
		(1.0664)		(1.0577)		(0.5293)		(0.9466)		(1.0354)		(-1.2759)		(1.1467)
ROA		52.6057***		175.289***		348.5852*		11.590***		10.095***		-2.7713*		0.2244
		(3.0323)		(3.0748)		(1.7932)		(3.0831)		(3.0396)		(-1.7633)		(1.5235)
Constant	-10.4195*	-82.340***	-18.285	-256.48***	-70.4959	-669.340***	-2.412*	-16.38***	-2.3977**	-15.02***	0.4156	0.5874*	0.3002***	0.5558**
	(-1.8397)	(-3.8262)	(-1.0702)	(-3.1132)	(-0.9768)	(-2.7611)	(-1.9256)	(-3.2628)	(-2.0219)	(-3.1939)	(1.5596)	(1.6734)	(2.7134)	(2.0524)
R-Square	0.014	0.1454	0.0074	0.075	0.0108	0.1366	0.0111	0.1087	0.0115	0.1128	0.0008	0.0098	0.0002	0.0383
obs	4151	3553	4151	3553	4151	3553	4151	3553	4151	3553	4151	3553	1678	1505
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Panel E: interaction of NumBlks and E-index

Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
NumBlks	-9.9497***	-5.5155***	-31.2524***	-21.275***	-73.9363***	-39.9052***	-2.2816***	-1.495***	-2.1534***	-1.408***	0.0094	0.0005	-0.0196*	-0.0147
	(-4.1798)	(-3.1289)	(-3.2621)	(-2.8517)	(-3.5866)	(-2.7346)	(-4.0638)	(-3.1802)	(-4.1285)	(-3.1305)	(1.1669)	(0.1137)	(-1.8153)	(-1.262)
eindex_NumBlks	-1.2172***	-0.5803*	-4.7855***	-1.2328	-10.8791**	-4.4818	-0.2713***	-0.0716	-0.2447***	-0.0581	-0.0029	-0.002	0.0008	-0.0023
	(-2.9313)	(-1.7733)	(-3.5626)	(-1.0984)	(-2.5701)	(-1.5536)	(-3.1323)	(-0.9602)	(-3.1325)	(-0.8291)	(-0.9614)	(-0.6077)	(0.1916)	(-0.5641)
Firm age		15.814***		46.1376*		102.3732**		2.9991**		2.6989*		-0.0137		0.0193
		(2.591)		(1.7246)		(2.0474)		(1.9674)		(1.8663)		(-0.8449)		(0.9034)
Firm size		0.9468***		2.6473**		7.954***		0.1984***		0.1876***		-0.0001		-0.0002
		(3.4169)		(2.5644)		(3.3596)		(2.9513)		(2.9296)		(-1.5874)		(-0.9118)
MB ratio		0.8844		0.7717		25.0059		0.0005		-0.017		0.024**		-0.0003
		(0.6184)		(0.1482)		(1.5555)		(0.0014)		(-0.0552)		(2.4013)		(-0.0926)
Leverage		16.5983		68.4134		56.6077		3.4534		3.3596		-0.2526		0.0554
		(0.9328)		(0.9596)		(0.3441)		(0.8683)		(0.9247)		(-1.4871)		(0.5271)
ROA		64.063***		175.5597**		524.970***		12.1005**		10.6497**		-1.629		0.0879
		(3.2426)		(2.2359)		(2.7737)		(2.4204)		(2.2426)		(-1.5044)		(0.911)
Constant	56.528***	-39.9726	184.818***	-146.1442	429.762***	-263.5069	12.946***	-6.6442	12.114***	-5.7014	0.045***	0.3642**	0.341***	0.5797**
	(6.3638)	(-1.5942)	(5.1862)	(-1.2574)	(5.4959)	(-1.4214)	(6.2057)	(-0.9907)	(6.2442)	(-0.8966)	(5.983)	(1.9821)	(15.295)	(2.477)
R-Square	0.0175	0.1711	0.0129	0.1015	0.0132	0.1572	0.017	0.1495	0.0172	0.1542	0.0004	0.071	0.0047	0.1636
obs	2447	2090	2447	2090	2447	2090	2447	2090	2447	2090	2447	2090	989	883
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Panel F: interaction of SumBlks and E-index														
Variables	(1) Patent	(2) Patent	(3) Citation	(4) Citation	(5) ad_citation	(6) ad_citation	(7) Originality	(8) Originality	(9) Generality	(10) Generality	(11) R&D	(12) R&D	(13) Prd	(14) Prd
SumBlks	-0.8693***	-0.3627***	-2.7143***	-1.4078***	-6.4437***	-2.4813***	-0.1996***	-0.102***	-0.1878***	-0.097***	0.0003	-0.0003	-0.0017*	-0.0012
	(-5.0552)	(-3.2694)	(-3.8884)	(-3.053)	(-4.3524)	(-2.7571)	(-4.8934)	(-3.3647)	(-4.9452)	(-3.3055)	(0.5001)	(-0.87)	(-1.9538)	(-1.2358)
eindex_SumBlks	-0.1774***	-0.0921***	-0.6424***	-0.2433**	-1.4908***	-0.7178**	-0.04***	-0.0164**	-0.0367***	-0.0146**	-0.0002	-0.0002	0	-0.0003
	(-4.4596)	(-2.8024)	(-4.5173)	(-2.2821)	(-3.8205)	(-2.3729)	(-4.6424)	(-2.3143)	(-4.6603)	(-2.2124)	(-0.6659)	(-0.6222)	(-0.1188)	(-0.9437)
Firm age		16.0456**		47.2016*		104.6532**		3.055**		2.7514*		-0.0158		0.0215
		(2.5718)		(1.7282)		(2.04)		(1.9755)		(1.8812)		(-0.9907)		(1.0256)
Firm size		0.9507***		2.6633**		7.9877***		0.1993***		0.1884***		-0.0001*		-0.0002
		(3.4098)		(2.5594)		(3.354)		(2.9469)		(2.9259)		(-1.8555)		(-0.9292)
MB ratio		0.9441		1.0178		25.47		0.0129		-0.0059		0.0238**		0
		(0.6631)		(0.1966)		(1.5907)		(0.0386)		(-0.0191)		(2.3773)		(0.0038)
Leverage		13.9733		59.1565		38.0553		2.807		2.759		-0.2558		0.0495
		(0.796)		(0.8397)		(0.2351)		(0.7134)		(0.7678)		(-1.492)		(0.4712)
ROA		65.413***		180.5859**		535.645***		12.4037**		10.9283**		-1.6312		0.0885
		(3.3131)		(2.3064)		(2.8232)		(2.4851)		(2.3037)		(-1.5074)		(0.9208)
Constant	55.81***	-43.1228	181.308***	-159.1348	422.887***	-292.3324	12.792***	-7.3206	11.965***	-6.3228	0.0538***	0.383**	0.3394***	0.5868**
	(6.6628)	(-1.615)	(5.4651)	(-1.2919)	(5.6746)	(-1.4556)	(6.5409)	(-1.0478)	(6.5858)	(-0.9609)	(6.7523)	(2.0714)	(15.4715)	(2.4594)
R-Square	0.0187	0.17	0.0133	0.1006	0.0139	0.1564	0.0183	0.1484	0.0185	0.1531	0.0001	0.0711	0.0049	0.1632
obs	2447	2090	2447	2090	2447	2090	2447	2090	2447	2090	2447	2090	989	883
year FE		YES		YES		YES		YES		YES		YES		YES
industry FE		YES		YES		YES		YES		YES		YES		YES

Table 11 reports the results for interaction tests using various forms of $\text{Innovation}_{t+1} = \beta_0 + \beta_1 * \text{corporate governance}_t + \beta_2 * \text{interaction}_t + \beta_3 * \text{firm age}_t + \beta_4 * \text{firm size}_t + \beta_5 * \text{MB}_t + \beta_6 * \text{Leverage}_t + \beta_7 * \text{ROA}_t + \varepsilon$. The dependent variables include seven measures of innovation. Patent is the total awarded patents applied for during a given year. Citation is total number of citations summed across all patents applied for during a given year. Ad_citation is total number of citations summed across all patents applied for during the year. Each patent's number of citations is multiplied by the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005). Originality equals to one minus H-index which is three-digit tech class distribution of all patents it cites. Generality equals to one minus H-index that is three-digit tech class distribution of all patents that cites it. Those measures of innovation are in year t+1 and R&D which is research and development expense scaled by sale is in year t. In addition, Prd_{t+1}equals to $Patent_{t+1}$ $scaled\ by\ R\&D_t$, which evaluate innovative efficiency. Corporate governance variables include CEO/chairman duality, number of female directors, number of outsiders, Board size, number of blockholders, and amount of shares held by all blockholders. The interaction variables are following ones. Eindex_cc is E-index multiplied CEO/chairman duality. Eindex_female is E-index multiplied number of female directors. Eindex_outsider is E-index multiplied number of outsiders. Eindex_director is E-index multiplied number of directors. Eindex_NumBlks is E-index multiplied number of blockholders. Eindex_SumBlks is E-index multiplied amount of shares held by all blockholders. Control variables include Logarithm of 1 plus the number of years a firm has been in Compustat (Firm age), the natural logarithm of total assets (firm size), the ratio of operating income to total assets (ROA), the ratio of total debt to total assets (Leverage), and the ratio of market value to book value (MB ratio). Additionally, all regressions control for year and industry fixed effects. The statistical inferences are based on White's heteroscedasticity consistent standard errors (reported in parentheses). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.