Corporate Governance and Innovation

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Abstract

A fundamental concern emerging from the corporate literature is the agency problem of innovation. While shareholders regard innovation as a value-enhancing investment strategy, CEOs have an intrinsic reluctance to pursue innovation projects. The thrust of this paper is to identify the mechanisms of corporate governance which help attenuate this problem, thereby encouraging the CEO to have the propensity to innovate. Using count data panel models that control for heterogeneity bias, I find that firms with a concentration of minority shareholders are less likely to engage the CEO to innovate. The likelihood of innovating appears to increase, however, in the presence of a large minority shareholder. I also find a positive association between innovation and board independence. Boards predominated by independent directors appear to be better able to induce the CEO to pursue innovation than those otherwise. The same result is supported in firms in which the CEO has equity ownership and in which the CEO is not also the Board Chairman. I use a sample of domestically owned Australian firms over the period 1994-2003.

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1. Introduction

The central theme underlying corporate agency theory is the potential divergence of interest between the stockholders and the chief executive officer or CEO. As the company's manager and chief strategist, the CEO has a wide latitude and discretion to make decisions that alter corporate policies and strategic directions. Theory establishes that these decisions do not necessarily coincide with the collective interest of the stockholders. The literature documents evidence of managerial decisions at variance with the pursuit of shareholder value maximization (Shleifer and Vishny, 1997). Empirical manifestations include misappropriating funds through gratuitous perquisites and transfer pricing by setting prices that exclusively benefit the CEO's personal affairs.

A main concern is that the investment projects that the CEO chooses are not optimal in the sense that they do not have the potential to generate positive net present value returns in the long run; rather, these choices simply reflect a predisposition towards overly safe projects that bolster managerial career and reputation. The CEO chooses suboptimal projects in the interest of entrenching his position in the company and elevating his prestige in the labor market, which implies that he will provide insufficient attention to risky, but potentially value-enhancing projects. For instance, Jensen (1986) argues that CEOs in the oil industry chose to pursue investments that allowed them to expand their control and dominion, but nevertheless yielded inferior returns. Similarly, Poterba and Summers (1995) report that CEOs in the United States have a myopic investment horizon which dissuades them from making long-term, value enhancing investments.

The focus of this paper is the identification of mechanisms, collectively called as corporate governance, which encourage the CEO to pursue innovation. Innovation is a prime example of a value-enhancing investment decision. In its 2006 Senior Executive Innovation Survey, the Boston Consulting Group reports that innovative companies (which included Apple Computer, Google, and 3M) generated a median annualized shareholder return of 14.3 percent over the period 1996-2005, which is 300 basis points higher than that of the benchmark Standard and Poor's (S&P) Global 1200 median. These companies also generated a median annualized increase of 3.4 percentage points in their profit margins, compared with 0.4 percent of the S&P benchmark companies. Innovation is a major driver of company growth and profitability; however, it is also a risky venture. While the financial rewards benefit stockholders, the intrinsic risk can negatively affect the CEO's future career. The survey identifies the CEO as the person most responsible for implementing innovation. Its development and sustainability depends on the commitment and leadership of the CEO. Nonetheless, the survey also reveals a perceived lack of commitment by the CEO, stemming in large part on a risk-averse culture. The American Management Association (2006) highlights this overly conservative attitude, noting the generalized absence of corporate structures that foster innovation; only less than a third of US companies surveyed had structures formally in place that indicate a commitment to innovation.

The research intent and main contribution of this paper is to provide empirical evidence for corporate governance as a structure that encourages the CEO to innovate. Corporate governance is a nexus of incentive schemes and monitoring devices designed to align the interest of the CEO with that of the shareholders. While there is a multiplicity of studies that analyze corporate agency problems, the empirical evidence that specifically focuses on innovation and corporate governance is sparse and suffers from problems of reverse causality and unobserved firm heterogeneity. These problems essentially invalidate any characterization as to what corporate governance mechanisms can resolve the agency problem of innovation. At the core of corporate governance is the efficient monitoring of the CEO's activities. Identifying an efficient system of monitoring managerial behavior is important because incentive schemes in the form of executive compensation cannot solely mitigate the preference incongruity in innovation between the CEO and the stockholders (Holmstrom, 1989). The corporate governance of innovation particularly matters when ownership shares are widely dispersed, such as those observed in Australia, the United Kingdom, and the United States. Unless the appropriate governance structures are in place, the CEO can virtually make investment decisions unwarranted by stockholders. I test whether the facets of corporate governance such as ownership structure, the composition of the board of directors, and CEO-Chair duality can characterize an efficient structure of incentives and supervision of the CEO's innovation decisions.

My empirical specification employs panel models of count data. I use patent applications to measure innovation. The data come from the IBIS-Melbourne Institute database where I also collect other firm-level information such as research and development (R&D) expenditures and the number of employees. I use a sample of 197 firms over the period 1994-2003. The data consist of domestically-owned Australian firms listed on the

Australian Stock Exchange. The sample is drawn from across all sectors, using the classification scheme of the Global Industry Classification Standard. Industry groups which do not reasonably engage in innovation in the sense that it lends itself to measurement are excluded. These include the media, banking, insurance, and retailing, among others. The corporate governance data are hand-collected from each firm's annual reports sourced from AspectHuntley's DatAnalysis. These include information on equity ownership, the number and independence of board members, and CEO compensation, among others.

I initially estimate a Poisson model which does not control for unobserved firm effects. However, the results suggest that there is substantial cross-sectional heterogeneity that needs to be accounted for. This heterogeneity is also exhibited through overdispersion in the sample data, with the variance greatly exceeding the mean. A fixed effects negative binomial specification appears to provide a better fit.

I find that firms with a concentration of minority shareholders are less likely to engage the CEO to innovate. The likelihood of innovating appears to increase, however, in the presence of a large minority shareholder. This finding suggests that shareholder activism is best achieved through a single large minority shareholder, rather than several substantial minority shareholders. I also find a positive association between innovation and board independence. Boards which are predominated by independent directors appear to be better able to induce the CEO to pursue innovation than those otherwise. The same result is supported in firms in which the CEO has equity ownership and in which the CEO is not also the Board Chairman. Looking at controls, I find evidence of decreasing returns to R&D expenditures. Competition and firm size are positively associated with innovation.

The rest of the paper is outlined as follows. I review the literature in Section 2, providing background theory and the associated empirical studies. In Section 3, I present a conceptual framework which motivates the importance of corporate governance in innovation. The hypotheses are explained in Section 4. I describe the construction of the variables and the dataset in Section 5. The estimation technique and results are discussed in Section 6. The paper concludes in Section 7.

2. Review of Literature

The idea that the CEO will shun investments in innovation, if left on his own volition, is a straightforward application of the principal agent problem in its moral hazard form. Stockholders delegate control of the firm to the CEO with the contractual expectation that managerial decisions will advocate shareholder interests. There is, however, no guarantee that the CEO will fulfill his obligations because the pursuit of shareholder value maximization does not necessarily complement the CEO's inherent desire to enhance his own utility. Maximization of utility involves the CEO mitigating risk exposures to his career and reputation, which necessitates him to provide insufficient attention to innovation or entirely abandon projects associated with it. His decision not to pursue innovation is a hidden action that shareholders cannot fully observe and contravenes their interest.

Ideally, the contract between the CEO and the stockholders should resolve this agency problem. However, even with the most appropriate design and intent, a contract which details the CEO's fiduciary duties and the permissible boundaries of his actions is ultimately second-best. Contracts involve substantial transactions costs which render them incomplete or incomprehensive; no contract can account for all future states of the world and the actions that the CEO may take. The divergence in interest and the inability to create a perfect contract provide a rationale for corporate governance (Hart, 1995). It creates a system that impels the CEO to choose strategies that boost shareholder value, in general, and that an optimal strategy would involve the pursuit of innovation, in particular. Corporate governance incorporates the provision of incentives in the form of executive compensation (Murphy, 1999) and the supervision of managerial behavior through the board of directors (Hermalin, 2004) and ownership structure (Becht, et.al, 2003). It evaluates whether providing the CEO stockownership rights will align his interest with those of the shareholders, and if such can similarly be achieved through board supervision and equity concentration.

Managerial resistance to innovation is well recognized in theory. Holmstrom (1989) sums up the basis for viewing innovation within an agency framework. Innovation is (i) risky, (ii) unpredictable, (iii) long-term and multi-stage, (iv) labor-intensive, and (v) idiosyncratic. A divergence of risk attitude and incentive between the stockholder and the

CEO will therefore lead to a divergence of interest. On the one hand, a generic stockholder is risk neutral. He has a diversified portfolio of investments which effectively immunizes him from the risks he bears. Accordingly, he would be interested in exploiting risk-reward strategies associated with investments in innovation. These are inherently risky and long-term, but carry expectations of wealth maximization. A generic CEO, on the other hand, is risk averse. He has a firm-specific risk-reward behavior, contingent on what benefits he can accumulate from his job now and in the near future. Accordingly, concerns for job security and enhancement of career and reputation will dampen his inclination to innovate.

The corporate governance of innovation revolves mainly on the reputational and career concerns of the CEO. In essence, if the CEO innovates, he faces the prospect of risky ventures whose commercial exploitations may well in fact go beyond his incumbency. Innovation is costly and entails several stages of market testing to evaluate its commercial viability. These include meeting quality standards, in the case of product innovation and searching for the most efficient technique, in the case of process innovation. Its implementation can be hindered by the lengthy process of applying for a patent and the indeterminacy of being a granted a patent. Moreover, its subsequent disclosure allows competitors the potential to imitate or re-engineer the innovation. In all, innovation requires a high degree of tolerance for error and possibilities of commercial failure. This creates an insecure job status for the CEO which he would most likely try to avoid.

Holmstrom (1999) and Holmstrom and Ricart i Costa (1986) point out that the CEO's investment behavior is contingent on how the market evaluates his performance. The CEO wants to be viewed as an effective decision maker, skilled in selecting projects and nurturing them with success. Concerns for such status will therefore make him decide against undertaking innovation projects. In a model of learning, the CEO knows that his ability is being inferred over time based on past performance. Although he cannot manipulate project outcomes, he can mask potential signals of low ability by selecting projects that suit him best. The choice of project is a hidden action by the CEO and so he can refrain from choosing innovation. Hirshleifer and Thakor (1992) support the postulate of reputation building by the CEO. They postulate a model of managerial conservatism in the CEO's choice of investment. The CEO identifies the safe projects from the risky ones, and the choice is private knowledge. The stockholders can only observe the success or failure of the project. Although they yield lower financial returns, safe projects have a higher probability of success. Since the CEO's reputation is built on project outcomes, he will therefore prefer the safe projects. The model highlights the distortion in investment policy arising from misaligned interests; the stockholders main interest is financial gain, whereas the CEO's main interest is the perceived value of his human capital.

Zwiebel (1995) demonstrates that CEOs will particularly avoid innovation projects which have the potential to become an industry standard, favoring instead those which are less original and less complicated. Conventional projects are preferred because they have a low probability of failure and the yardstick in which the CEO's competence is assessed is easier to understand. Therefore, evaluations of his reputation are more likely to be comparable and positive. The model suggests a herd-like mentality by CEOs in that no one wants to deviate from doing industry standards.

Along similar lines, Narayanan (1989) develops a model of managerial reputation which explains the CEO's myopic corporate behavior. In the interest of enhancing his career quickly in order to earn higher wages, the CEO will choose short-term investment projects over those which actually increase long-run shareholder wealth. The short-term preference diminishes, however, with CEO experience. This happens because the market continually updates its inferences about the CEO's competence and a seasoned CEO has already established a distinct reputation. The model also shows that corporate myopia is inversely related to the CEO's length of contract. Providing the CEO a long-term contract gives him the incentive to value more highly the benefits from future cash flows than those obtainable from short-term earnings. Such assertion complements Stein's (1989) version of myopic behavior. In his model, the CEO attempts to window-dress the firm's performance by focusing on activities which boost current earnings. The incentive arises because high current earnings translate to high future earnings. In equilibrium, the market detects the earnings manipulation and correctly revises the firm's actual performance. Nonetheless, the CEO persists in its attempt to fool the market.

Jensen (1986) documents evidence that CEOs elevate their status by building "empires." CEOs have a penchant for managing large projects to showcase their managerial flair, rather than those that actually increase net present value returns in the long run. Also, by running projects beyond their optimal size, the CEO can claim higher wages because he has more resources under his control. In their survey of Fortune 100 companies, Poterba and Summers (1995) report that CEOs have a short investment horizon, which is suggestive of the theory of corporate myopia. CEOs set hurdle rates higher than the required standard which implies the tendency to reject long term projects that improve shareholder wealth.

Using a longitudinal database of plant creations and destructions in the manufacturing sector, Bertrand and Mullainathan (2003) suggest that CEOs may prefer to have the "quiet life." CEOs are not interested in building empires, in the sense of creating new plants nor destroy existing ones, in the sense of shutting down old plants, with the net effect that firm size is unchanged. This implies that CEOs do not have the inclination to venture into new lines of business. They simply prefer to be a CEO with an uncomplicated lifestyle.

Empirical evidence illuminating the relationship between corporate governance and innovation is scanty. Using stepwise regression on a cross section of 94 Fortune 500 research-intensive firms, Hill and Snell (1988) find that concentrated ownership is positively associated with innovation and see no support for the benefits of greater board independence. They measure innovation in terms of R&D expenditures per employee. Baysinger, Kosnik, and Turk (1991) obtain similar results. Their sample size is expanded to 176 Fortune 500 firms spread across industries. They attribute the positive influence of concentrated ownership on R&D expenditures to institutional investors. They also show that innovation increases with greater insider board representation. Francis and Smith (1995) show that the dispersion of equity shares does not lead companies to have the propensity to innovate. In contrast, providing the CEO stock ownership rights leads to higher innovation, a result that is also supported by Zahra (1996). Graves (1988), however, contradicts the positive association between equity concentration and innovation. Using data on 22 computer-manufacturing companies over the period 1976-1985, he finds that a high concentration of institutional ownership suppresses R&D spending. Contrary to expectations from the theoretical literature, Czarnitzki and Kraft (2004) assert that manager-led firms have a higher propensity to innovate compared to their owner-led counterparts. Their study uses probit and Tobit to estimate pooled data of manufacturing firms over the period 1992-96.

3. Conceptual Motivation

I draw upon the structure of the agency model developed in Aggarwal and Samwick (1999) to motivate the importance of corporate governance in innovation. The model is meant to convey the idea that corporate governance can potentially be employed to create an environment where the CEO is motivated and effectively supervised to innovate.

Consider an agency problem where the stockholders appoint a CEO to pursue investments in innovation. The payoff from innovating depends on the CEO's dedication or effort and a random component for which both the stockholders and the CEO have the same prior distribution. This takes the form

$$I(e,\varepsilon) = em - \frac{1}{2}e^2 + \varepsilon \tag{1}$$

where I is the payoff from innovation, e is managerial effort, and ε is a normally distributed error term with mean zero and variance σ^2. The parameter m scales the efficiency or intensity of effort.

The specification implies that innovation is not a deterministic function of effort alone. The random component represents uncertainty in the outcome of the innovation projects due, say, to technology shocks; it generates the differential attitude towards risk by the CEO and the stockholders. Having the same prior distribution means that the CEO and the stockholders have the same information set over all the possible states of nature innovation takes. The stockholders offer the CEO a take-it-or-leave contract, and both parties know that innovation not only carries the possibility of high reward (greater wealth for the shareholders, prestige for the CEO) but also great risk (commercial failure, CEO gets replaced). Both parties know the payoff from innovating. The CEO cannot hide nor misrepresent information on projected earnings. However, stockholders cannot fully observe the CEO's choice of effort or level of dedication to innovate. This creates the problem of hidden action. The stockholders must design an incentive scheme so that the CEO puts forth the appropriate effort.

I assume that a representative stockholder has a well-diversified portfolio of investments which makes for an attitude of risk neutrality. As such, their collective objective is to maximize the expected value of the innovation projects, regardless of the risk involved.

The CEO, however, is risk averse. This stems from the assumption that his income and utility are obtained from his job and status as a CEO. It is therefore to his interest to secure his position by suppressing risky project ventures – in this case, those involving innovation – and instead directing his effort on projects which generate sufficient returns, reveal his productivity, and avoid failure. In other words, since his career and reputation are tied solely on project returns, his behavioral preference would be to choose safe investments with more certain outcomes.

As a useful benchmark, consider the ideal scenario where the CEO's actions are fully observable and that he actually prefers to innovate, such that he does not incur any disutility from doing so. This will enable us to assess the degree of the agency problem. Maximizing equation (1) with respect to effort yields

$$e_1 = m \tag{2}$$

which implies that the CEO exerts the optimal effort to the extent dictated by his efficiency to innovate. Therefore, it is optimal that the stockholders offer him a fixed remuneration contract commensurate to the level of effort he provides.

Given the maintained assumption that the CEO is risk averse and that his choice of effort is not verifiable, the optimal contract cannot be contingent on effort. The stockholders will not offer him a fixed wage because it does not give him the incentive to innovate.

Instead, the compensation scheme will have to depend on the payoff from innovating, which is verifiable. The wage scheme is a linear incentive

$$w = w_F + \alpha I \tag{3}$$

such that the CEO's income is attributable not only to his fixed wage w_F but also to the returns generated by the innovation projects I. Since innovation depends on effort, high returns on innovation signal a high propensity to innovate. The CEO's propensity to innovate is denoted by α.

In order to obtain closed-form results, we assume that the CEO has constant absolute risk aversion represented by a negative exponential utility function

$$u(w,e) = -\exp\left[-\eta\left(w + c(e)\right)\right] \tag{4}$$

His coefficient of absolute risk aversion is $\eta = -\frac{u''}{u'} > 0$. His cost of innovation is linearly increasing in effort $c(e) = \lambda e$, where $\lambda < 0$. The reason for this disutility is two-fold. First, the more he innovates, the more he exposes himself to the possibilities of failure and revelation of managerial incompetence. Second, there is the opportunity lost in enhancing his reputation. It means his effort is directed towards innovation, instead of safe projects.

The CEO's problem is to maximize his utility expressed by the program

$$\underset{e}{Max}\; E\left\{u\left[w_F + \alpha\left(em - \frac{1}{2}e^2 + \varepsilon\right) + \lambda e\right]\right\} \tag{5}$$

The following results are useful

$$E\left[w_F + \alpha\left(em - \frac{1}{2}e^2 + \varepsilon\right) + \lambda e\right] = w_F + \alpha\left(em - \frac{1}{2}e^2\right) + \lambda e$$

(6)

$$Var\left[w_F + \alpha\left(em - \frac{1}{2}e^2 + \varepsilon\right) + \lambda e\right] = \alpha^2\sigma^2$$

Using the fact that $E\left[u(x)\right] = u\left(u_x - \frac{1}{2}\eta\sigma_x^2\right)$ if $x \sim N(u_x,\, \sigma_x^2)$, then the CEO's problem can be rewritten as

$$\underset{e}{Max}\; E\left[w_F + \alpha\left(em - \frac{1}{2}e^2\right) + \lambda e - \frac{1}{2}\eta\alpha^2\sigma^2\right] \tag{7}$$

where $\frac{1}{2}\eta\alpha^2\sigma^2$ is the cost of risk aversion. The expression in brackets represents the CEO's certainty equivalent, the minimum amount of riskless compensation that gives him the same level of utility as under the risky contract. Taking the first order condition and solving for effort yields

$$e_2 = m + \frac{\lambda}{\alpha} \tag{8}$$

Compared with the benchmark case, there is suboptimal effort in that $e_1 > e_2$. The CEO chooses to innovate less because he incurs disutility $\lambda < 0$ from doing so. Of interest is α, the CEO's propensity to innovate. Since $\frac{\partial e_2}{\partial \alpha} = -\frac{\lambda}{\alpha^2} > 0$, this pay-to-innovate parameter can mitigate the suboptimality. The CEO exerts greater effort to innovate, the higher is α.

The stockholders face the problem of offering a contract to the CEO that maximizes the investment returns from innovating net of compensation costs. They do so by solving the following program

$$\underset{\alpha}{Max}\ E(I - w) = em - \frac{1}{2}e^2 - (w_F + \alpha I) \tag{9}$$

$$\text{s.t.} \quad \text{(IRC)} \quad E\left[u\left(w_F + \alpha I + \lambda e\right)\right] \geq \underline{u}$$

$$\text{(ICC)} \quad e_2 = m + \frac{\lambda}{\alpha}$$

The stockholders must satisfy two constraints. First is the participation or individual rationality constraint (IRC). The CEO has a reservation utility $\underline{u}$ which denotes an outside opportunity that he can benefit from by working somewhere else. Therefore, the stockholders must offer him a contract that provides no less than this utility. Second is the incentive compatibility constraint (ICC). Given the compensation scheme, the CEO will maximize his utility by selecting the optimal effort e_2. Recognizing this, stockholders need to ensure that the contract they offer is compatible with the CEO's maximization problem.

Because the stockholders can always adjust the CEO's compensation without affecting the incentive compatibility constraint, the participation constraint binds and can be rewritten as

$$w_F + \alpha I + \lambda e - \frac{1}{2}\eta\alpha^2\sigma^2 = \underline{u} \tag{10}$$

Substituting equation (10) and the incentive compatibility constraint into the objective function simplifies the problem into

$$\underset{\alpha}{Max}\ E(I-w) = \left(m + \frac{\lambda}{\alpha}\right)\left[m + \lambda - \frac{1}{2}\left(m + \frac{\lambda}{\alpha}\right)\right] - \frac{1}{2}\eta\alpha^2\sigma^2 + \underline{u} \tag{11}$$

The first order condition yields

$$\frac{1}{\alpha^3}\left(\lambda^2 - \lambda^2\alpha - \eta\sigma^2\alpha^4\right) = 0 \tag{12}$$

The incentive solution α^* is bounded between 0 and 1. The solution reflects a tradeoff between risk sharing and the effort to innovate. Optimal risk sharing implies $\alpha = 0$, but the CEO will not be inclined to innovate. Optimal innovation implies $\alpha = 1$, but the CEO bears all risk.

The second order condition is

$$(2\alpha - 3)\frac{\lambda^2}{\alpha^4} - \eta\sigma^2 < 0 \tag{13}$$

which satisfies a maximum for $\alpha \in (0,1)$.

Implicit differentiation of equation (12) yields

$$\begin{aligned}
\frac{\partial\alpha^*}{\partial\eta} &= -\frac{\sigma^2\alpha^4}{\lambda^2 + 4\eta\sigma^2\alpha^3} < 0 \\
\frac{\partial\alpha^*}{\partial\sigma^2} &= -\frac{\eta\alpha^4}{\lambda^2 + 4\eta\sigma^2\alpha^3} < 0 \\
\frac{\partial\alpha^*}{\partial\lambda} &= \frac{2\lambda(1-\lambda)}{\lambda^2 + 4\eta\sigma^2\alpha^3} < 0
\end{aligned} \tag{14}$$

The power of the pay-to-innovate parameter α^* to induce the CEO to innovate depends on η, σ^2, and λ. The incentive solution weakens as risk aversion η, the randomness of innovation σ^2, and cost of effort λ increases. Concomitantly, the CEO chooses to innovate less. With limited observability, the CEO innovates optimally if $\alpha^* = 1$, but this occurs only if innovation were risk-free (such that $\eta = 0$) or predictable (such that $\sigma^2 = 0$). The contrary fact exacerbates the reluctance to innovate. This suggests that incentive compensation schemes may not be sufficient to mitigate the agency problem.

A form of monitoring scheme must be implemented to complement the incentive solution which, taken together, forms the basis for the corporate governance of innovation. While the idea of incentives – getting paid to innovate – encourages the CEO, monitoring ensures that the CEO does just that. As echoed by Hermalin (2003), corporate governance mitigates the incentive problem that "wanting to be seen as doing the right thing and doing the right thing are not always the same." Monitoring managerial behavior may involve obtaining more information over the CEO's decisions and activities, eliminating marginal tasks to induce focus, and tolerating mistakes, in recognition of the fact that innovation is an unconventional investment (Holmstrom, 1988). Corporate governance encourages the CEO and makes him accountable for his actions. I identify in this paper the mechanisms of corporate governance that are associated with this behavior.

4. Hypotheses

Corporate governance helps mitigate the agency problem of innovation essentially in two ways: (i) incentivizing the CEO through an appropriate compensation scheme and (ii) monitoring his performance. The key goal is to identify the governance mechanisms that foster innovation. To systematize the analysis, I group these mechanisms into three themes: (i) ownership structure, (ii) board of directors, and (iii) CEO compensation and duality.

4.1 Ownership Structure

Ownership structure pertains to the dispersion or concentration of equity shares and the resultant incentive and ability of the stockholder to monitor the CEO. A distinct feature of market-oriented economies such as Australia, the United Kingdom, and the United States is the widespread dispersion of equity shares. In this situation, each shareholder owns a small fraction of outstanding stock. Dispersion conveys the economic merit of risk diversification and liquidity. However, when shares are widely dispersed, collective shareholder action becomes a problem. Although shareholders have the collective interest to enforce innovation as a value-maximizing strategy, the collective action to evaluate the CEO's performance is ultimately an individual decision that benefits everyone. Monitoring the CEO is a public good that is likely to lead to a free-rider problem. Monitoring is costly because a stockholder expends his own time, money, and effort to understand corporate affairs and voice his concerns at his own cost. With a small ownership in the company, he has little or no incentive to supervise managerial behavior. Widespread dispersion creates a situation wherein each stockholder rationally thinks and hopes that somebody else will monitor the CEO, which results in understated or practically zero supervision. The CEO, in effect, become unaccountable to the stockholders and is not effectively controlled.

A governance mechanism that potentially remedies the free-rider problem is concentrated ownership. A large shareholder has the motivation to acquire information, verify performance, and enforce value-based innovation strategies. His significant ownership rights imbue him voice and power in the decision-making process. Shleifer and Vishny (1986) motivate the importance of equity concentration in a model in which firm value increases in the presence of a large shareholder. Claessens, et. al. (2002) provide evidence that firm performance is enhanced when shares are concentrated under reasonable threshold levels. Moreover, firms governed by large shareholders are better able to design a compensation scheme that reflects CEO performance. The CEO is less able to set his own pay and extract rents (Core, 1999; Bertrand and Mullainathan, 2001). Value-based management is therefore reinforced when stockholders can exert adequate control and supervision. The hypothesis is:

Hypothesis 1: Concentrated ownership or the presence of a large shareholder encourages the CEO to have the propensity to innovate.

4.2 Board of Directors

Another corporate mechanism that stockholders can use to govern the innovation behavior of the CEO is the board of directors. The board of directors acts as a middle man between shareholders and the CEO. Since the directors are elected by stockholders, they are supposed to represent their rights and interests. It is through the board where managerial decisions are evaluated and strategic shifts specified. The board, in short, establishes the rules of the game advocated by shareholders that guide CEO behavior.

An element crucial to the board's effectiveness in supervising the CEO is its independence. A typical board consists of insiders and outsiders. An insider is a director-executive who is a current or former employee of the company. An outsider is a non-executive director who is not working for the company. Apart from his directorship, an outsider practically does not have any financial ties and vested interests in the company. Outsiders are usually university professors or well-respected civic leaders. An outsider is viewed as an epitome of the virtues of independence: disinterested and probing. On this basis, outsiders are also called as independent directors and insiders as non-independent directors. The expectation is that a board predominated by or composed entirely of outsiders would have no preferential treatment towards managerial interests. They are not working for management and so the CEO cannot influence their judgment. However, one could also argue that outsider representation poses no significant advantage. Outsiders are essentially what they are – outsiders. Because they derive no marketable financial gain except perhaps prestige, not only can they be disinterested in the affairs of the business, but can be uninterested as well.

Corporate best practice guidelines in Australia and the United States espouse the benefits of board independence. The Australian Council of Super Investors (2004) report that independent directors constitute majority of the board seats in the top 100 publicly-listed Australian firms in 2003. Klein (1998) show a similar predominance for US firms listed in the S&P 500 for 1992-1993, with almost 60% of board seats considered as independent.

Hermalin (2004) presents a theory of board supervision and its impact on managerial behavior. The board monitors the CEO to evaluate his effectiveness in advocating shareholder interest. In equilibrium, the greater the intensity of monitoring, the stronger is the incentive for the CEO to do well. In this model, monitoring corresponds to the board's independence. The empirical evidence linking board independence and firm performance is, however, mixed. Hermalin and Weisbach (1991) cast doubt on the association, suggesting that insiders and outsiders are equally likely to provide good or bad supervision. Klein (1998) and Bhagat and Black (2001) also report the absence of any systematic relationship; firms with a greater proportion of independent directors do not exhibit higher valuation than others. Nonetheless, Weisbach (1988) finds that independent directors are more likely to remove the CEO following poor performance, suggesting the idea that board independence can improve firm value through CEO replacement.

Apart from independence, I also examine the relevance of board size and diversity. As in any other group, the number and diversity of board members can have an effect on overall cohesion and group dynamics. Board size may matter because directors must collaborate with each other when evaluating the CEO. A large board poses two potential problems. First, it impairs the coordination and implementation of decisions. Second, it creates an internal free-rider problem in that some directors might tacitly prefer to dodge responsibility, delegating it to the board as a whole. These imply that the quality and intensity of monitoring may weaken when boards become large. In contrast, a board of few directors might be able to examine issues more carefully, make more informative decisions, and better supervise the CEO. Jensen (1993) typifies this idea, advocating small boards of no more than eight directors to improve performance.

Yermack (1996) and Eisenberg, et. al. (1998) document an improvement in firm value when boards are small. Aggarwal and Nanda (2004) also support this finding, taking the view that a board with several directors imposes multiple tasks on the CEO which weakens his focus. Beiner, et. al. (2004), on the other hand, report no relationship between board size and performance, a result suggestive of Hermalin and Weisbach's (2003) equilibrium interpretation that firms determine their optimal number of directors.

I also test whether a diverse board instigates the CEO to innovate. A mix of directors with different backgrounds, for example, in terms of academic or industry expertise, opens up a variety of individual perspectives and experiences which possibly promote creativity and responsiveness to new ideas. In addition, the quality and intensity of CEO supervision may be enhanced because performance issues are viewed more broadly and problems are confronted with alternative solutions. In contrast, a grouping of people with common values, attitudes, and beliefs can become quite resistant to change and lead to stagnation.

Carter, et.al. (2002) examine diversity in terms of the gender and ethnicity of board members, finding a positive association between firm value and diversity. Adams and Ferreira, (2004) also find that gender diversity in the boardroom appears to enhance the effectiveness of the board in decision-making insofar as the directors become more involved. Ancona and Caldwell (1992), on the other hand, caution against an unwavering reliance on diversity, noting that while group heterogeneity encourages creativity, it can also hamper the implementation process because of greater dissonance among members.

Hypothesis 2: Boards which are small, diverse, and independent are better able to monitor the CEO to innovate.

4.3 CEO Compensation and Duality

A distinct board characteristic exhibited by some firms is CEO duality, wherein the CEO is also Chairman of the Board. This creates a potential problem in that it invalidates the premise of the board supervising the CEO. The CEO is being monitored by a board presided over by the very same person being monitored. While the Chairman supposedly protects the interests of the stockholders, the CEO embodies his own vested interests. A duality in function leads one to question the impartiality of actions or decisions made by the board. Such is the case observed by Jensen (1993) who argues that any potential divergence of views between the board and CEO-Chairman almost always gets tilted in favor of a dual CEO. A separation of roles might therefore enhance board independence, which leads to better supervision and firm performance.

The empirical evidence on duality is mixed. While Rechner and Dalton (1991) support the separation of roles, Brickley, et.al. (1997) view duality as advantageous. Combining the role of the CEO and Chairman into one facilitates the transfer of information between the CEO-Chairman and the rest of the directors.

The corporate governance of innovation use monitoring schemes to reinforce the CEO's interest in value-maximization. In conjunction with supervision, a straightforward aspect of governance is to incentivize the CEO by tying his compensation with the firm's performance. I test whether the CEO will take a value-based approach to innovation if part of his compensation is equity-based. Providing the CEO equity rights might help attenuate the agency costs of innovation because he assumes co-ownership of the firm. On this basis, the CEO is then inclined to innovate, viewing it as an appropriate strategy to increase not only the shareholders' wealth but his own as well.

Jensen and Murphy (1990) estimate the CEO's share of value creation, finding that CEOs in the United States receive about $3.25 for every $1,000 increase in shareholder wealth. Although the pay-performance sensitivity appears to be low, Haubrich (1994) contends that the incentive mechanism need not be expensive and is not necessarily inconsistent with a CEO who is sufficiently risk averse. Holmstrom and Kaplan (2003) report an increasing trend in the use of equity-based compensation in US companies, which resulted in a more than ten-fold increase in the pay-performance sensitivity over the period 1980-1999. The trend is exhibited worldwide, but more modest compared to US levels (Murphy, 1999; Becht, et. al. 2003). In Australia, equity incentives accounted for about a quarter of total compensation received by CEOs in the top 100 firms in 2003, a four-fold increase from previous 1980s levels (Australian Council of Super Investors, 2004).

The evidence linking firm performance and equity compensation is mixed, with Mehran (1995) and Hall and Liebman (1998) reporting a positive association. The incentive solution is particularly strong when the CEO initially has low ownership (Ofek and Yermack, 2000). In contrast, Loderer and Martin (1997) and Himmelberg, et.al (1999) report no systematic association.

Hypothesis 3: Innovation is increasing in CEO equity compensation. A separation of CEO-Chairman roles makes for better control of managerial tasks conducive to innovation.

5. Variables and Data Description

5.1 Innovation

I use patent applications as my measure of innovation. Patent applications provide a direct representation of the outcome of the innovation process. I use the variable *Patent applications* to designate the number of patents applied for by a firm at a given year.

5.2 Corporate Governance Variables

5.2.1 Ownership Structure

I characterize a firm's ownership structure by measuring the (i) concentration of equity shares and the (ii) stockholder's incentive and ability to monitor the CEO.

I use the *Herfindahl equity index* to measure equity concentration. Given data on all *N* equity holdings, then the Herfindahl index H_N can be computed straightforwardly as

$$H_N = \sum_{i=1}^{N} \left(\frac{S_i}{T_N} \right)^2 = \frac{1}{N} + N\sigma^2 \tag{15}$$

where S_i = equity holding of stockholder *i*, $T_N = \sum_{i=1}^{N} S_i$, and $\sigma^2 = \frac{1}{N} \sum_{i=1}^{N} \left(\frac{S_i}{T_N} - \frac{1}{N} \right)^2$

The index ranges from a value of $\frac{1}{N}$, in which firms have symmetric shares, to 1, which indicates maximum concentration. A value close to zero indicates that ownership is widely dispersed. Because equity shares are squared before summing them up, the index achieves convergence quickly and stockholders with large holdings are weighted more heavily.

However, I can only get data on equity shares for the top 20 stockholders and the sum of all *N* holdings. A potential problem exists in that the *N-20* shares need to be accounted for and ignoring them would likely produce biased estimates of the Herfindahl index. I circumvent this problem by adjusting the computation for the index using the method prescribed by Cubbin and Leech (1983).

My data is an ordered sequence

$$S_1 \geq S_2 \geq \ldots \geq S_{20} \geq \ldots \geq S_N \tag{16}$$

If all *N* holdings are available, then I can rewrite equation (15) as

$$H_N = \sum_{i=1}^{20} \left(\frac{S_i}{T_N} \right)^2 + \left(1 - C_{20}\right)^2 H_{N-20} \tag{17}$$

where $C_{20} = \sum_{i=1}^{20} \left(\frac{S_i}{T_N} \right)$ and $H_{N-20} = \sum_{i=21}^{N} \left(\frac{S_i}{T_{N-20}} \right)^2$

The absence of data on the remaining *N-20* shares requires calculating a lower and upper bound to estimate H_{N-20}, and hence obtain an estimate for H_N.

H_{N-20} reaches its upper bound if T_{N-20}, the sum of the remaining shares, is concentrated or held by as few stockholders as possible. To obtain this, we let $S_{21} = S_{20}$ and assume

$S_{22}, S_{23}, ..., S_N$ are negligible such that $S_{21} = S_{20} = T_{N-20}$. Therefore, $H_{N-20} = 1$ and $(1 - C_{20})^2 = \frac{S_{20}}{T_N}$. An upper bound on H_N is thus

$$H_{Upper\ Bound} = \sum_{i=1}^{20} \left(\frac{S_i}{T_N} \right)^2 + \frac{S_{20}}{T_N} \tag{18}$$

H_{N-20} reaches its lower bound if the T_{N-20} shares are widely dispersed or held by as many stockholders as possible. In the limit, $H_{N-20} = 0$. A lower bound on H_N is thus

$$H_{Lower\ Bound} = \sum_{i=1}^{20} \left(\frac{S_i}{T_N} \right)^2 \tag{19}$$

I then take the average of the lower and upper bounds to obtain an approximation of the Herfindahl equity index on the whole distribution.

Apart from equity concentration, I verify whether the presence of a large shareholder can help mitigate the agency problem of innovation. A large shareholder is usually defined in terms of a stockholder owning an arbitrary, fixed percentage of shares, such as 5% or 20% which gives him voting rights to control the CEO's behavior. However, a fixed criterion does not incorporate variations in equity holdings. While a substantial shareholding is required for a highly concentrated ownership, a smaller proportion may just as well be sufficient for control when shares are widely dispersed. I use this insight in gauging the power or the ability and incentive of the largest shareholder to supervise the CEO. I use the Banzhaf index to measure the ability of the largest shareholder to influence the voting outcome. The power index explicitly takes into account the idea that stockholders strategically form coalitions in order to pass a motion. They do so because as is typical in most publicly traded companies with widely dispersed ownership, no particular shareholder has enough voting stock to win in a simple majority. Moreover, as Leech (2002) argues, a coalition may still be necessary even when shares are highly concentrated. For example, a company with three shareholders in which two each has 49% of outstanding shares and the third with 2% will still need to have at least two stockholders supporting each other in order to pass a motion.

The Banzahf power index is given by

$$Banzahf_i = \frac{\beta_i}{\sum_{i=1}^{N} \beta_i} \tag{20}$$

where β_i counts the number of times that stockholder *i* is able to win a motion in a simple majority rule by forming a coalition with others and *N* is the total number of possible winning coalitions. Also, $Banzahf_i \in [0,\ 1]$. Shareholder power increases the closer is the index to 1.

As an example, consider the case of the company with three stockholders $s_1 = 49\%$, $s_2 = 49\%$, and $s_3 = 2\%$. There are $N = 4$ possible winning coalitions in a simple majority rule in which shareholders decide whether to accept or reject the CEO's proposal. These are $\{s_1, s_2\}$, $\{s_1, s_3\}$, $\{s_2, s_3\}$, and $\{s_1, s_2, s_3\}$. In these coalitions, stockholder s_1 is a critical voter in that he is needed three times to pass a decision in tandem with either s_2 or s_3. The same reasoning applies to s_2 and s_3. Therefore, each stockholder has a Banzhaf index of 33%.

My use of the Banzahf index substantiates the important point that shareholder power is not necessarily based on the percentage of shares owned. In this example, the stockholder with only 2% of the shares has, in fact, the same power as those with 49%. This implies that stockholders need to take into account the strategic, and not the absolute, advantage of their ownership rights, and there is evidence to suggest that stockholders do so (Maug and Rydqvist, 2004).

Because I only have data on the 20 largest shareholders, I compute for the index by assuming an oceanic setup of voting, following Leech (2002). This means that there are only a few large shareholders and the rest are infinitesimally small shareholders. This assumption fits my data quite well in that the shareholdings are widely diffused. The same procedure for calculating the index is used and the idea of making the unknown holdings negligible appears innocuous. I use a program made available online by Leech (2002), http://www.warwick.ac.uk/~ecaae/, which automates the calculation of the power index. This eases the burden of manually computing for the index, as the procedure can get very cumbersome. I use the variable *Largest Banzhaf* to designate the Banzhaf index of the largest shareholder.

5.2.2 Board of Directors

I use the variable *Board independence* to estimate the hypothesized relationship between board independence and innovation. Board independence is measured by the proportion of directors that are independent. I follow Becht, et.al. (2003, p. 31) to verify independence. A director is independent if he is "not employed by the corporation, is not engaged in business with the corporation, and is not a family member." Also, I do not consider as independent a director who holds substantial shares in the company, which is at least 5% as defined in Australia's Corporations Act of 2001. To explain how the number of directors can affect the CEO's innovation decision, I create the variable *Board Size*, which is the (log) number of directors. I use the variable *Board diversity*, which is an entropy-based diversity index to capture functional diversity on the board. I classify each director into three categories, which represent the director's distinct industry expertise and academic background. These are business, science, and the arts. I use Teachman's (1980) index to measure diversity

$$Board\ diversity = \sum_{i=1}^{3} p_i(\ln p_i) \qquad (21)$$

where p_i is the proportion of directors classified into a particular category *i*. The index ranges from 0 to approximately 1. The greater the distribution of directors across categories, the higher is the index.

5.2.3 CEO Compensation and Duality

To test the hypothesis that a separation of CEO-Chairman roles is associated with a higher propensity to innovate, I define the variable $CEO/\{Chairman\} = 1$, if the CEO is not the Chairman of the Board. The idea of incentivizing the CEO to innovate through the provision of equity ownership is represented by the variable *CEO stockholdings*, which is the fraction of outstanding equity held by the CEO.

5.3 Control Variables

I consider the effect of product market competition on innovation using the industry Lerner index. I do this by calculating the index at the firm level and averaging them out to obtain an estimate at the industry level, following Aghion, et.al. (2002). The approximation at the firm level is

$$Firm\ Lerner\ Index_{it} = \frac{EBITDA_{it} - financial\ \text{cost}_{it}}{sales_{it}} \tag{22}$$

where *EBITDA* is earnings before interest, taxes, and depreciation of firm *i* at time *t*. The financial cost of capital is obtained by multiplying the cost of capital with the capital stock. I assume a fixed cost of capital of 8.5%, which is the same value used by Aghion, et.al. (2002). Capital stock is calculated using the perpetual inventory system, using the framework of Salinger and Summers (1981). This is meant to transform the book value of capital into its replacement value. In essence, the perpetual inventory system works by iteratively adding this year's capital expenditures to previous year's capital stock, to obtain current capital stock, adjusted for inflation and depreciation. I use the book value of capital stock in 1994 as my starting value.

The perpetual inventory system is given by

$$K_{it} = \left[K_{it-1} \left(\frac{p_t}{p_{t-1}} \right) + I_{it} \right] (1-d) \tag{23}$$

where K_{it} is gross property, plant, and equipment for firm i at time t, p_t is the deflator for gross fixed capital formation, I_{it} is capital expenditures, and d is the depreciation rate. I use depreciation rates of 4% and 8%. Values for capital stock, however, do not appear to be sensitive to different rates of depreciation.

The Lerner index at the industry level is

$$Industry\ Lerner\ Index_{jt} = 1 - \frac{1}{N_{jt}} \sum_{i \in j} Firm\ Lerner\ Index_{it} \tag{24}$$

I obtain this by taking the average of firm-level Lerner indices associated with industry *j* at time *t*, using all the *N* firms listed on the Australian Stock Exchange, and subtracting it from 1 to get a more direct interpretation of the index. The index ranges from 0, which characterizes a monopoly, to 1, which is perfect competition. I refer to the variable *Lerner Index* to indicate its industry-level estimate.

The idea that large firms innovate more is captured by the variable *Firm size*, which is the number of employees a firm has. I use the variable (log) *R&D expenditures* to account for the patent-R&D relationship posited by Hausman, et.al., (1984) and Cincera (1997). I obtain this variable by dividing a firm's R&D spending by its employment size, so as not to confound its effect with firm size. Stein (2003) documents the idea that firms with more cash and less debt invest more. I examine this proposition in the case of investments in innovation using the variables *Cash flow* = cash flow before interest expense/total assets and *Debt* = total liabilities/total assets.

5.3 Data

I use a panel of 197 firms drawn from the IBIS World database, provided by the Melbourne Institute of Applied Economic and Social Research. It covers the period 1994-2003, giving a total of 1,970 observations. The IBIS dataset supplies information on patent applications, R&D expenditures, and number of employees for both domestic and multinational firms. From this, I draw a representative sample of locally-owned Australian companies listed on the Australian Stock Exchange. The firms are mostly large in that 77% have at least 200 employees. Corporate governance data on equity shares, board size and composition, and CEO profile are assembled from company annual reports, downloaded from Aspect Huntley Annual Reports Online. Company financial data are sourced online from Aspect Huntley FinAnalysis. These include EBITDA, cash flow, assets, debt, investments, and property, plant and equipment. These are then matched with the IBIS dataset. All nominal variables are deflated using implicit GDP price deflators, culled from the Australian Bureau of Statistics Australian System of National Accounts, 5204.0, 1999-00 and 2003-04. I specifically use the deflator for private gross fixed capital formation to calculate capital stock at replacement value.

The classification scheme of the Global Industrial Classification Standard is used to group the firms into 16 industries (Table 1). Almost 60% of the firms come from the Materials (31%), Capital Goods (16%), and Food, Beverage, and Tobacco Industries (12%). Figure 1 shows the frequency distribution of patent applications. The distribution is skewed towards a few small values, with 76% of observations recording zero patent applications. This high proportion of zeroes is commonly observed in the literature. On average, firms apply for one patent per year (Table 2). The highest number recorded is 97 patent applications in the Healthcare Equipment & Services Industry. Figure 2 shows that over the period 1994-2003, firms in the Consumer Services Industry accounted for more than 40% of the total number of patent applications, followed by those in the Pharmaceutical & Biotechnology (18%) and Household & Personal Products (7%)

Tables 3A and 3B provide some descriptive statistics on the variables. The mean Herfindahl equity index is 0.12, which indicates that the shares are widely dispersed; there are several stockholders owning minority shares. The largest stockholder owns 24% of outstanding stock, on average. This translates to a Banzhaf power index of 48%. More than half of the total observations recorded stockholders owning less than 20% of company shares. The wide dispersion of shares and the paucity of majority shareholders complement the finding that more than 60% of observations indicate a lack of effective shareholder control over the CEO's decisions. The number of directors ranged from 2 to 15, with a mean of 7. Independent directors constitute 61% of the board, reflective of the Australian corporate best practice guideline to have majority independent directors. The typical board is fairly diverse, with a mean functional diversity of 0.68. The average Australian CEO owns 8% of outstanding shares. Less than a fifth of total observations reported a dual CEO-Chairman.

Figure 3 plots the movement over time of the corporate governance variables. Over the last decade, equity shares have become more dispersed, with the concomitant effect of reducing the ownership of the largest stockholder by almost 10%. On the other hand, there is a marked upward trend in the percentage of independent directors which is reflective, presumably, of the regulatory calls for greater board vigilance and supervision of CEO activities. Such perception of an effective, reliable board is mirrored by the decrease in board size and an increase in board diversity Also, there is a pronounced downward trend in the shares owned by the CEO.

Because I have longitudinal information on firms, it would be informative to look at the decomposition of variation of the corporate governance variables into between and within components (Table 4). The within-variance is positive, which indicates that the variables vary over time. However, for all variables, most of the total variation is accounted for by the between-variance. Relative to the variation over time for a firm, the variation between firms explains more than three times of the total variation. The fraction explained by the between-variance is higher for the Herfindahl equity index and CEO stockholdings.

6. Empirical Framework and Analysis of Results

6.1 The Poisson Regression Model

The economic thrust of this paper is to identify the mechanisms of corporate governance that potentially alleviate the agency problem of innovation, thereby encouraging the CEO to have the propensity to innovate. Empirically, this involves analyzing the propensity to innovate, which is measured by the number of patent applications, in terms of ownership structure, the profile of the board of directors, and CEO compensation and duality, which constitute my thematic set of corporate governance variables.

A fundamental characteristic of the propensity to innovate is that it is an event count. As a response variable, it is a count of the number of times that a firm, as directed by the CEO, innovates by applying for a patent. This carries two implications in the analysis. First, the patent applications are inherently nonnegative. Second, as the summary statistics indicate, there is a predominance of zero patent counts. I therefore use an econometric framework that accommodates these features.

I begin with a setup that explicitly models the probability distribution of the patent applications at nonnegative integer values. A natural assumption would be to consider that the number of patents y applied for by firm i at year t is Poisson distributed with density

$$f(y_{it} \mid \lambda_{it}) = \frac{e^{-\lambda_{it}} \lambda_{it}^{\ y_{it}}}{y_{it}!}$$
$$(i = 1,\ldots,N;\ t = 1,\ldots,T) \tag{25}$$

The parameter $\lambda_{it} > 0$ represents the rate of occurrence or the expected number of patent applications. To frame this into a regression model, I parameterize λ_{it} as a conditional mean function of the corporate governance variables such that

$$\lambda_{it} = E(y_{it} \mid x_{it}) = \exp(x_{it}'\beta) \tag{26}$$

The intent is to determine changes in the conditional expectation of y_{it} that can be causally linked to changes in the corporate governance variables x_{it}, given the vector of β parameters that I estimate. Because $y_{it} \geq 0$, the exponential function ensures the nonnegativity of the mean function for all possible values of the explanatory variables.

Characterizing the patent applications as Poisson distributed imposes the condition that the conditional variance and mean are the same. That is,

$$E(y_{it} \mid x_{it}) = Var(y_{it} \mid x_{it}) \tag{27}$$

This equidispersion necessarily implies that the Poisson regression model is heteroskedastic.

Parameter estimation is carried out by via maximum likelihood. Given equations (25) and (26), the log-likelihood function is

$$\ln L = \sum_{i=1}^{N}\sum_{t=1}^{T}(-\exp(x_{it}'\beta) + y_{it}x_{it}'\beta + \ln y_{it}!) \tag{28}$$

Differentiating equation (28) yields the first-order conditions

$$\frac{1}{N}\sum_{i=1}^{N}\sum_{t=1}^{T} x_{it}(y_{it} - \exp(x_{it}'\beta)) \tag{29}$$

for which the parameter estimates are calculated iteratively. Convergence is assured because the log-likelihood is globally concave.

Assuming that the Poisson mean-variance equality holds, the estimator is consistent and asymptotically efficient. When this assumption is incorrect, the standard errors are concomitantly incorrect, and statistical inference becomes invalid. The Poisson estimator however is still consistent, provided that the conditional mean is correctly specified. The patent applications need not necessarily be Poisson distributed as long as the functional form of the conditional mean and the covariates are those of the data generating process. This implies that the Poisson model is robust to distributional misspecification (Cameron and Trivedi, 1998). However, the standard errors need to be adjusted in accordance with the correct variance structure. This approach is the Poisson quasi-maximum likelihood estimation; we maintain the consistency of the estimators with an appropriately adjusted covariance matrix. The considerable number of zero patent applications in the sample data is symptomatic of overdispersion, which means that the variance exceeds the mean. Taken together, the zero counts and overdispersion are suggestive of the heterogeneity among firms.

As a starting point for assessing the sensitivity of parameter estimates, I estimated a Poisson regression that simply pools the data together, not taking into account the longitudinal information contained in the observations. The estimates are reported in Table 5. I ran regressions under various variable specifications. Estimates are reported with the default maximum likelihood standard errors in parentheses and the robust standard errors in brackets. The default standard errors assume equidispersion; the robust standard errors allow for possible variance misspecification. Rather than impose a parametric form for the variance function that may be possibly misspecified, I use a robust covariance matrix estimator that yields standard errors that are generally valid for all variance specifications. By definition, the parameter estimates are equivalent to those obtained from the Poisson quasi-maximum likelihood.

The first column of estimates reports base results from running a regression of the corporate governance variables only. Assuming correct specification of the conditional mean and equidispersion, the estimate for ownership structure show support for hypothesis 1, to the extent that a large shareholder, as denoted by the Banzhaf index, who has the ability and incentive to influence corporate management, can supervise the CEO to innovate. The negative sign of the Herfindahl index suggests that ownership concentration, or the supervision of a few large shareholders, negates the CEO's keenness to innovate. The estimate is statistically significantly different from zero at the 1% level. At face value, this complements broad-brush presumptions about organizational dynamics and delegation. A CEO who receives instructions singularly from a monitoring large shareholder is better able to process the information, carry out the assigned task, and avoid the dissonance associated with having several shareholder-supervisors. The estimate for board diversity supports the second hypothesis that functional diversity among directors enhances the board's effectiveness in supervising the CEO. The coefficient for board independence, however, rejects the hypothesis that emphasizes the importance of having independent directors. Moreover, large boards appear to be better able to monitor the CEO to innovate. The estimates for the third hypothesis on CEO compensation and duality substantiate the idea of separating the functional roles of the CEO and the Chairman of the Board, but discount the incentive effect of providing the CEO equity ownership. The parameter for CEO stockholdings is negative and statistically significant. Results do not qualitatively change when robust standard errors are used, except for the parameter on the Banzaf index which loses its significance.

Column 2 adds estimates from the control variables. Basing inference from robust standard errors, the inclusion of these variables deemphasized the importance of a large shareholder and an independent, small, and diverse board. The control covariates, on the other hand, report that large, R&D-spending firms operating in a competitive environment are more likely to innovate and apply for a patent. The final three regressions in the table add industry dummies (column 3) to allow for differences in the industry in which the firm operates, year dummies (column 4) to account for aggregate time effects, and both industry and year dummies (column 5). Estimates for the industry and time effects are suppressed for brevity. The last row in the table reports joint hypotheses tests of the overall significance of the dummy variables. The p-values are practically zero, rejecting the null that the model does not need to take into account industry and time effects. Focusing on the estimates from column 5, the CEO's propensity to innovate remains to be negatively affected by a concentration of equity shares and surprisingly unaffected by the presence of a large monitoring shareholder. These results invalidate hypothesis 1. In support of hypothesis 2, an independent board appears positively influential. Board size and diversity are not statistically significant. Providing the CEO company ownership does not incentivize him to innovate (as the estimate is negative and insignificant), but excluding him from the role as Board Chairman reinforces the third hypothesis that a dual CEO is not conducive to innovation.

6.2 Fixed Effects and Random Effects Poisson Estimation

The conclusion that a large shareholder serves no monitoring role in the CEO's pursuit of innovation and that the provision of equity rights does not encourage the CEO to do so as well seems disconcerting, but the results may be misleading due to possible unobserved firm heterogeneity. The pooled Poisson estimator essentially attributes all changes in the conditional mean to the observed explanatory variables. However, there may be firm-specific differences which are inherently unobservable or difficult to measure but nevertheless play an important role in inciting the CEO to innovate. These include the CEO's managerial aptitude and work ethic and the organizational structure and dynamics of the company. Some companies, for instance, may have a corporate structure that facilitates monitoring by a large shareholder, while others may not. Neglecting these attributes creates an omitted variables problem that weakens the statistical validity of the results.

Because I have longitudinal data on firms, I can extend the Poisson analysis by framing it into an unobserved effects model. These firm effects c_i enter the conditional expectation multiplicatively so that

$$E(y_{it} \mid x_{it},\ c_i) = \exp(x_{it}'\beta + c_i) \tag{30}$$

Under a random effects Poisson model, the unobserved effects do not vary systematically with the explanatory variables in that $E(c_i \mid x_{it}) = E(c_i)$. To invoke consistent parameter estimation, the unobserved effects are assumed to be gamma distributed with $E(c_i) = 1$ and $Var(c_i) = \theta$. The gamma heterogeneity permits a tractable way to remove c_i and obtain a density for y_{it} that is conditional on just the explanatory variables. The parameters are then estimated via maximum likelihood. The variance parameter θ is estimated as well, and we can then compare the pooled Poisson estimator with the panel estimator. An unobserved effects model is preferred if θ is significantly different from zero.

In contrast, a fixed effects Poisson model allows for correlation between c_i and x_{it}. Following Hausman, et.al. (1984), I use conditional maximum likelihood to obtain a consistent estimator for the parameters. This employs the observed counts $\sum_{t=1}^{T} y_{it} = T\,\overline{y}$ as a sufficient statistic to eliminate the firm effects. As a result, the distribution of y_{it} depends only on x_{it} and the observed counts.

Assuming that the conditional mean is correctly specified, the Poisson unobserved effects model yields consistent estimators that are robust to distributional misspecification. The standard errors, however, still need to be adjusted for possible variance misspecification. To do so, I use panel robust standard errors, obtained from bootstrapping. I use bootstrapping to avoid imposing an otherwise inappropriate parametric variance function. Moreover, Cameron and Trivedi (1998) report that bootstrapping performs reasonably well as a small-sample corrected estimate of the standard error. This attenuates the potential limitation of my small sample. The boostrap resamples my data with replacement over firm i and calculates parameter estimates for each bootstrap sample. An estimate of the covariance matrix is then calculated using all the parameter values obtained from the bootstrap samples. Following recommended practice, I use 200 bootstrap samples to estimate the standard error.

Since I am interested in assessing the causal link between corporate governance and innovation, it would be useful to have a sense not only of the statistical significance of the variables but, equally important, their economic significance as well. The marginal effect of a change in the *j* explanatory variable on the conditional expectation of y_{it} is given by

$$\frac{\partial E(y_{it} \mid x_{it})}{\partial x_{itj}} = \beta_j \exp(x'_{it}\beta) \tag{31}$$

which implies that the sign of the effect depends on the sign of β_j. The magnitude of the response, however, depends on how $\exp(x'_{it}\beta)$ is evaluated. One can obtain an average marginal response by aggregating the effect over all firms or obtain the response of a "typical" firm with the regressors held at their sample means. To systematize the analysis and provide a straightforward parameter interpretation, I use a semi-elasticity expression.

Equation (35) can be rewritten as

$$\beta_j = \frac{\partial E(y_{it} \mid x_{it})}{\partial x_{itj}} \cdot \frac{1}{E(y_{it} \mid x_{it})} = \frac{\partial \ln[E(y_{it} \mid x_{it})]}{\partial x_{itj}} \tag{32}$$

so that $100\beta_j$ gives the percentage change in y_{it} if the *j* explanatory variable changes by one unit. The response becomes an elasticity is the regressor appears in logs. For a dummy variable, the response is a factor change. For a 0 to 1 change in the *j* dummy variable and holding the other variables x_{it}^* constant, then

$$\frac{E(y_{it} \mid x_{it} = 1,\ x_{it}^*)}{E(y_{it} \mid x_{it} = 0,\ x_{it}^*)} = \exp(\beta_j) \tag{33}$$

which means that the expected number of patent applications changes by a factor of $\exp(\beta_j)$ when the dummy variable changes from 0 to 1.

Estimates for both the random effects and fixed effects models are summarized in Table 6. To compare the precision of estimates, I report the default maximum likelihood standard errors in parentheses and the robust standard errors in brackets. However, my conclusions are based on the robust standard errors. The first column of estimates reports a random effects regression of the corporate governance variables only, while the second column includes the control variables. I also report a test for the presence of firm-specific effects using the variance component. In a likelihood ratio test comparing the pooled

Poisson and random effects estimator, $\chi_1^2 = 5,182$ (column 1) and $\chi_1^2 = 3,422$ (column 2); for both estimates, the significance level of the test is practically zero, rejecting the null that θ is zero. This implies that a panel estimator is appropriate.

When inference is based on the default standard errors, the corporate governance variables in the first column of estimates are all statistically significant, except for board size. When robust standard errors are used, the coefficient for board size remained insignificant, as well as for CEO stockholdings. The inclusion of the control covariates in the second column reinforces the result that ownership concentration negatively affects the CEO's propensity to innovate. A percentage point increase in equity concentration reduces the expected number of patent applications by 4%. On the other hand, contrary to previous estimates, the estimate for the Banzahf index now provides support for the hypothesis that a large shareholder can monitor the CEO to innovate. While the size and diversity of the board do not appear to be influential factors, the positive and statistically significant coefficient of board independence seems encouraging, as a matter of corporate policy. We expect the CEO to increase his propensity to innovate by 1.3% for a percentage point increase in the number of independent directors. Notable also is the CEO/{Chairman} variable which is positive and significant. The estimate suggests that the CEO's propensity to innovate increases by a factor of $\exp(0.8713) = 2.39$ when the CEO is not the Chairman of the Board. This is equivalent to saying that the number of patent applications is $[\exp(0.8713) - 1] \cdot 100 = 139\%$ higher compared to a dual CEO. Unlike the previous result from the pooled estimates, the sign for CEO stockholdings is now positive, yet the equity incentive does not appear as a motivating factor for the CEO to innovate.

The fixed effects estimates are given in columns (3), which reports estimates for the corporate variables only and (4), which adds the control covariates. The results are qualitatively similar to the random effects model, except that the coefficient for CEO stockholdings is now statistically significant at the 10% level. It indicates that a 1% increase in the CEO's equity holdings raises his propensity to innovate by 0.09%. Comparing the precision of estimates, the use of the robust standard errors suggests that there is a considerable downward bias in the default standard errors, which can lead to erroneous inference. On average, the robust standard errors are about three larger than their default counterparts. This holds for both the fixed effects and random effects models.

While both models generally report the same economic result, they are statistically different in their treatment of unobserved heterogeneity. The fixed effects model allows for the arbitrary correlation between c_i and x_{it}, whereas the random effects model imposes mean independence of c_i. This distinction carries the implication that the fixed effects estimator is consistent when there is indeed a correlation, and that the random effects estimator is inconsistent and therefore misleading. I use Hausman's test to discriminate between the two models. Under the null of zero correlation between c_i and x_{it}, the random effects model is consistent. A statistically significant difference between the two estimators is an indication that the null is incorrect, and that the fixed effects estimator is consistent. Comparing the estimates in columns (2) and (4) using robust standard errors, the Hausman test statistic is $H = 20.80$ with p-value 0.0534. This rejects the null at the 10% level, implying that the results from the fixed effects estimator are appropriate to use.

6.3 Fixed Effects and Random Effects Negative Binomial Estimation

I also consider the negative binomial model as an alternative way to characterize the distribution of the patent applications. This explicitly takes into account overdispersion in the sample data, as manifested by the high proportion of zeros. It relaxes the restrictive Poisson assumption of equidispersion by imposing an overdispersion parameter in the variance. Following Hasuman, et.al. (1984), the patent applications have a negative binomial density, with mean $\frac{c_i \lambda_{it}}{\phi_i}$ and variance $\left(\frac{c_i \lambda_{it}}{\phi_i}\right)\left(1 + \frac{c_i}{\phi_i}\right)$. The overdispersion parameter is denoted by ϕ_i.

Under random effects estimation, the variance component $\left(1 + \frac{c_i}{\phi_i}\right)^{-1}$ is assumed to be beta distributed, as a tractable way to consistently estimate the parameters via maximum likelihood. In similar spirit to the fixed effects Poisson model, the fixed effects negative binomial model is estimated via conditional maximum likelihood, using the observed sum of patent applications as sufficient statistic.

The negative binomial estimates are presented in Table 7. The associated standard errors allow for overdispersion. Column 1 reports estimates for the corporate governance variable under a random effects specification. The Herfindahl index and board independence are the only variables that registered statistical significance, the latter being significant at the 10% level. There is a considerable change when the control covariates are added in column 2. The estimates are now essentially in accord with the previous Poisson panel result. The Banzahf index is now significant. In addition, enhancing the independence of the board and separating the CEO and Board Chairman roles remain as instruments of corporate governance that foster innovation. While increasing the size and diversity of the board appears to negate the CEO's inclination to innovate, the estimates are not statistically conclusive. The statistical and economic significance of the variables carry over when a fixed effects negative model is used (columns 3 and 4), with the added result that, as in the Poisson fixed effects model, the estimate for CEO stockholdings is positive and statistically significant at the 10% level. The elasticity estimate indicates a modest percentage increase of 0.05 (compared with 0.09 for the Poisson) for a 1% increase in the CEO's shares of stock

Overall, the negative binomial results are confirmatory of the Poisson panel conclusion identifying the presence of a large shareholder, board independence, separation of CEO-Chairman roles, and CEO equity ownership as corporate governance instruments that encourage the CEO to have propensity to innovate, thereby attenuating the agency problem of innovation. The choice between the two models is suggested by Figure 4, where I compare the actual sample frequency of each patent application with those predicted by the Poisson and Negative Binomial. The predictions are fitted frequencies calculated by averaging over firms the predicted probability for each patent application. The graphical comparison shows that the Poisson model underpredicts the zero patents and overpredicts the positive counts. In contrast, the negative binomial matches quite well the observed frequencies, sufficiently predicting the large number of zeros in the data.

7 Conclusion

The goal of this paper is to identify the mechanisms of corporate governance that encourage the CEO to innovate. There is an agency problem in innovation in that while shareholders view innovation as a value-enhancing investment strategy, the CEO regards it as a risky venture that can potentially tarnish his career and reputation. The contribution of this paper is to empirically establish the importance of corporate governance in innovation. I examine ownership structure, the profile of the board of directors, and CEO compensation and duality as potential mechanisms. My use of panel data allows me to control for heterogeneity bias that can lead to misleading results.

I find that firms with a concentration of minority shareholders are less likely to engage the CEO to innovate. The likelihood of innovating appears to increase, however, in the presence of a large minority shareholder. I also find a positive association between innovation and board independence. Boards predominated by independent directors appear to be better able to induce the CEO to pursue innovation than those otherwise. The same result is supported in firms in which the CEO has equity ownership and in which the CEO is not also the Board Chairman. These results are robust to the inclusion of control variables. Accordingly, I find evidence that large, R&D-spending firms in competitive markets innovate more.

A future goal of this research is to expand the sample size of firms to include foreign-owned firms, and compare their governance structure with those of their domestic counterparts. It would be interesting to find out the profile of the CEOs they hire and how their boards are organized. Would domestic and foreign-owned companies of similar financial structure and operating in the same environment have different approaches to innovation? Are there differences across industries? A related research would be to establish the kind of innovation CEOs would be inclined to pursue. Would they be more persuaded to do process, cost-reducing innovation or would they prefer product, market-expanding innovation?

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Table 1: Industry Distribution of Firms

Industry	% of Obs
Automobiles & Components	3.05
Capital Goods	15.74
Commercial Services & Supplies	6.09
Consumer Durables & Apparel	4.57
Consumer Services	0.51
Energy	4.57
Food Beverage & Tobacco	12.18
Healthcare Equipment & Services	4.57
Household & Personal Products	0.51
Materials	30.96
Pharmaceutical & Biotechnology	1.02
Software & Services	7.61
Technology Hardware & Equipment	2.54
Telecommunications Services	2.54
Transportation	2.54
Utilities	1.02
Total	100

Table 2: Industry Distribution of Patent Applications

Industry	% of Obs	Mean	Std. Dev.	Min	Max
Automobiles & Components	3.05	2.48	4.99	0	23
Capital Goods	15.74	1.07	2.53	0	20
Commercial Services & Supplies	6.09	0.25	1.20	0	12
Consumer Durables & Apparel	4.57	0.90	2.64	0	22
Consumer Services	0.51	21.10	22.73	5	74
Energy	4.57	1.23	3.51	0	21
Food Beverage & Tobacco	12.18	0.44	1.59	0	17
Healthcare Equipment & Services	4.57	3.11	12.45	0	97
Household & Personal Products	0.51	0.00	0.00	0	0
Materials	30.96	1.50	6.35	0	87
Pharmaceutical & Biotechnology	1.02	5.45	3.15	1	10
Software & Services	7.61	0.31	1.32	0	12
Technology Hardware & Equipment	2.54	0.90	1.83	0	9
Telecommunications Services	2.54	1.92	5.01	0	26
Transportation	2.54	0.00	0.00	0	0
Utilities	1.02	0.50	0.76	0	2
Total	100	1.28	5.34	0	97

Table 3A: Descriptive Statistics

Variable (Obs=1,970)	Mean	Std. Dev.	Min	Max
Patent Applications	1.28	5.34	0	97
Ownership Structure				
Herfindahl Equity Index	0.12	0.14	0.002	0.79
Largest Banzhaf (%)	48.23	33.65	9.17	100
Largest Control	0.38	0.49	0	1
Board of Directors				
Board Independence (%)	60.52	20.10	0	100
Board Size	6.59	2.13	2	15
Board Diversity	0.68	0.30	0.002	1.10
CEO Compensation & Duality				
CEO/{Chairman}	0.85	0.35	0	1
CEO Stockholdings (%)	8.00	15.12	0	70
Controls				
Lerner Index	0.98	0.02	0.85	1
Firm Size	2,807	7,723	13	88,995
R&D Expenditures	7.17	2.08	0.63	13.22
Debt	0.22	0.16	0.0002	0.93
Cash flow	0.02	0.11	-0.93	0.85

Table 3B: Descriptive Statistics

Variable	% of Obs
Herfindahl Equity Index	
0.002-0.05	43.81
0.06-0.19	36.25
0.20-0.69	18.28
0.70-0.79	0.25
Largest Banzhaf	
9-19%	18.00
20-39	41.13
40-69	10.30
70-100	29.46
Largest Control	
1	38.02
0	61.98
Board Independence	
0-20%	3.80
22-40	15.47
43-57	23.90
60-100	56.79
Board Size	
2-4	14.87
5-7	57.36
8-10	23.55
11-15	4.22
Board Diversity	
0.002-0.04	9.18
0.33-0.59	27.58
0.60-0.76	21.77
0.80-1.10	41.41
CEO/{Chairman}	
1	85.23
0	14.77
CEO Stockholdings	
0-0.48%	49.57
1-29	40.31
30-57	6.41
60-70	2.94

Table 4: Variance Decomposition

Variable	Total	Between	Within
Herfindahl Equity Index	0.018	0.015	0.003
Largest Banzhaf	0.113	0.087	0.027
Largest Control	0.236	0.168	0.068
Board Independence	0.040	0.031	0.010
Board Size	4.556	3.542	1.031
Board Diversity	0.088	0.067	0.021
CEO/{Chairman}	0.126	0.093	0.033
CEO Stockholdings	0.023	0.019	0.004

Table 5: Poisson Pooled Estimates

Dependent Variable: Patent applications

Explanatory Variables	(1)	(2)	(3)	(4)	(5)
Herfindahl Equity Index	-0.062	-0.054	-0.051	-0.041	-0.037
	(0.004)***	(0.005)***	(0.005)***	(0.004)***	(0.004)***
	[0.228]***	[0.196]***	[0.017]**	[0.149]*	[0.013]***
Largest Banzhaf	0.005	0.009	0.009	0.003	0.002
	(0.001)***	(0.001)***	(0.001)***	(0.001)***	(0.001)**
	[0.006]	[0.006]	[0.005]*	[0.005]	[0.004]
Board Independence	0.001	0.005	0.016	0.001	0.012
	(0.001)	(0.001)***	(0.001)***	(0.001)	(0.001)***
	[0.004]	[0.004]	[0.003]***	[0.003]	[0.003]***
Board Size	1.605	-0.200	0.108	0.145	0.412
	(0.078)***	(0.099)**	(0.103)	(0.102)	(0.106)***
	[0.269]***	[0.268]	[0.311]	[0.286]	[0.347]
Board Diversity	0.012	0.004	0.002	0.004	0.002
	(0.001)***	(0.001)***	(0.001)**	(0.001)***	(0.001)
	[0.002]***	[0.002]	[0.003]	[0.002]	[0.0038]
CEO/{Chairman}	0.554	0.345	0.716	0.058	0.397
	(0.115)***	(0.117)***	(0.120)***	(0.118)	(0.124)***
	[0.263]**	[0.242]	[0.192]***	[0.247]	[0.220]*
CEO Stockholdings	-0.164	-0.086	-0.036	-0.109	-0.057
	(0.009)***	(0.010)***	(0.011)***	(0.010)***	(0.012)***
	[0.269]***	[0.033]**	[0.041]	[0.353]***	[0.401]***
Lerner Index		0.177	0.299	0.112	0.052
		(0.019)***	(0.039)***	(0.019)***	(0.044)
		[0.067]***	[0.119]*	[0.589]*	[0.104]
Firm Size		0.604	0.656	0.588	0.635
		(0.019)***	(0.021)***	(0.019)***	(0.021)***
		[0.055]***	[0.067]***	[0.048]***	[0.624]
R&D Expenditures		0.416	0.432	0.439	0.444
		(0.015)***	(0.019)***	(0.015)***	(0.019)***
		[0.059]***	[0.078]***	[0.057]***	[0.071]***
Debt		-0.002	-0.006	-0.005	-0.008
		(0.002)	(0.002)***	(0.002)**	(0.002)***
		[0.005]	[0.005]	[0.005]	[0.005]
Cash flow		0.005	0.010	0.005	0.009
		(0.002)**	(0.003)***	(0.002)**	(0.003)***
		[0.008]	[0.102]	[0.006]	[0.008]
Constant	-4.326	-25.194	-37.631	-19.336	-13.879
Industry dummies?	No	No	Yes	No	Yes
Year dummies?	No	No	No	Yes	Yes
Observations	1,780	1,780	1,780	1,780	1,780
Joint Hypothesis Test			11,155.79	45.35	1,474
χ^2 (p-value)			(0.000)	(0.000)	(0.000)

Default standard errors in parentheses; robust standard errors in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 6: Fixed Effects and Random Effects Poisson Estimates

Dependent Variable: Patent applications				
Explanatory Variables	Random Effects		Fixed Effects	
	(1)	(2)	(3)	(4)
Herfindahl Equity Index	-0.044	-0.044	-0.040	-0.043
	(0.007)***	(0.007)***	(0.007)***	(0.007)***
	[0.023]*	[0.019]**	[0.025]	[0.021]*
Largest Banzhaf	0.015	0.016	0.016	0.016
	(0.002)***	(0.002)***	(0.002)***	(0.002)***
	[0.004]***	[0.004]***	[0.005]***	[0.004]***
Board Independence	0.013	0.012	0.013	0.013
	(0.002)***	(0.002)***	(0.002)***	(0.002)***
	[0.006]**	[0.005]**	[0.006]*	[0.006]*
Board Size	0.229	0.085	0.160	0.147
	(0.173)	(0.180)	(0.179)	(0.185)
	[0.691]	[0.563]	[0.717]	[0.582]
Board Diversity	-0.008	-0.009	-0.010	-0.011
	(0.002)***	(0.002)***	(0.002)***	(0.002)***
	[0.0111]	[0.009]	[0.101]	[0.009]
CEO/{Chairman}	0.809	0.871	0.835	0.935
	(0.191)***	(0.188)***	(0.194)***	(0.199)***
	[0.322]**	[0.328]**	[0.337]**	[0.368]*
CEO Stockholdings	0.075	0.060	0.112	0.091
	(0.021)***	(0.021)***	(0.022)***	(0.022)***
	[0.585]	[0.050]	[0.056]**	[0.0513]*
Lerner Index		0.306		0.298
		(0.039)***		(0.040)***
		[0.111]***		[0.126]**
Firm Size		0.364		0.274
		(0.054)***		(0.057)***
		[0.239]		[0.309]
R&D Expenditures		0.226		0.199
		(0.033)***		(0.035)***
		[0.101]**		[0.112]*
Debt		-0.003		-0.003
		(0.003)		(0.003)
		[0.006]		[0.007]
Cash flow		0.006		0.005
		(0.003)**		(0.003)*
		[0.006]		[0.006]
Constant	-1.195	-35.417		
Observations	1,780	1,780	837	837
Log likelihood	-1,797	-1,731	-1,310	-1,262
$H_o: \theta=0\ \chi_1^2$ (p-value)	5,181.59 (0.000)	3,422.04 (0.000)		

Default standard errors in parentheses; robust standard errors in brackets
significant at 10%; ** significant at 5%; *** significant at 1%

Table 7: Fixed Effects and Random Effects Negative Binomial Estimates

Dependent Variable: Patent applications				
Explanatory Variables	Random Effects		Fixed Effects	
	(1)	(2)	(3)	(4)
Herfindahl Equity Index	-0.025	-0.021	-0.025	-0.022
	(0.012)**	(0.011)*	(0.013)**	(0.012)*
Largest Banzhaf	0.005	0.007	0.006	0.008
	(0.003)	(0.003)**	(0.004)	(0.003)**
Board Independence	0.006	0.009	0.005	0.008
	(0.004)*	(0.004)***	(0.004)	(0.004)**
Board Size	0.243	-0.093	0.182	-0.024
	(0.234)	(0.241)	(0.243)	(0.255)
Board Diversity	0.001	-0.002	-0.001	-0.004
	(0.003)	(0.003)	(0.003)	(0.003)
CEO/{Chairman}	0.358	0.467	0.427	0.544
	(0.258)	(0.246)*	(0.277)	(0.270)**
CEO Stockholdings	-0.020	0.032	0.005	0.050
	(0.027)	(0.027)	(0.028)	(0.029)*
Lerner Index		0.286		0.267
		(0.062)***		(0.067)***
Firm Size		0.378		0.288
		(0.063)***		(0.068)***
R&D Expenditures		0.107		0.096
		(0.040)***		(0.043)**
Debt		-0.004		-0.004
		(0.005)		(0.005)
Cash flow		0.003		0.003
		(0.005)		(0.005)
Constant	-0.835	-31.830	-0.549	-29.193
Observations	1,780	1,780	837	837
Log likelihood	1,508	-1,483	-1,028	1,012

standard errors in parentheses allow for overdispersion
* significant at 10%; ** significant at 5%; *** significant at 1%

Figure 1: Frequency Distribution of Patent Applications

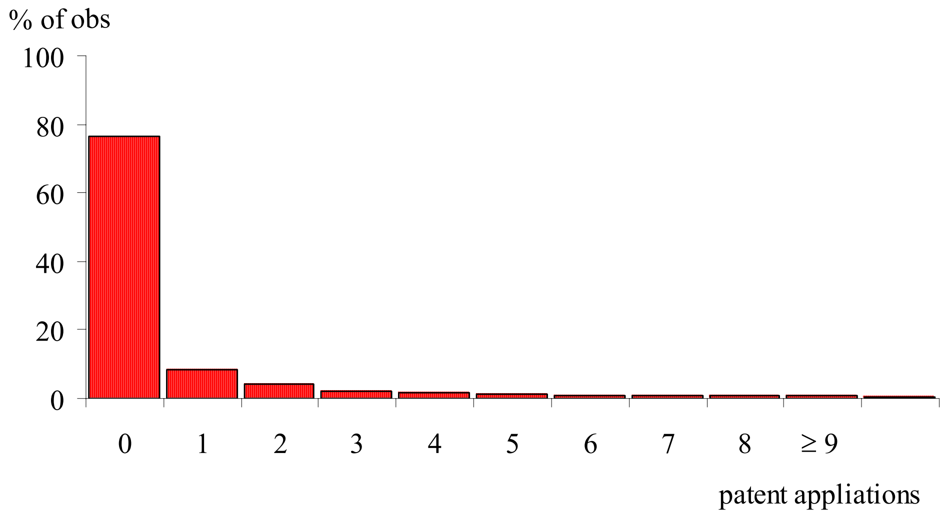


Figure 2: Industry Share of Patent Applications, 1994-2003

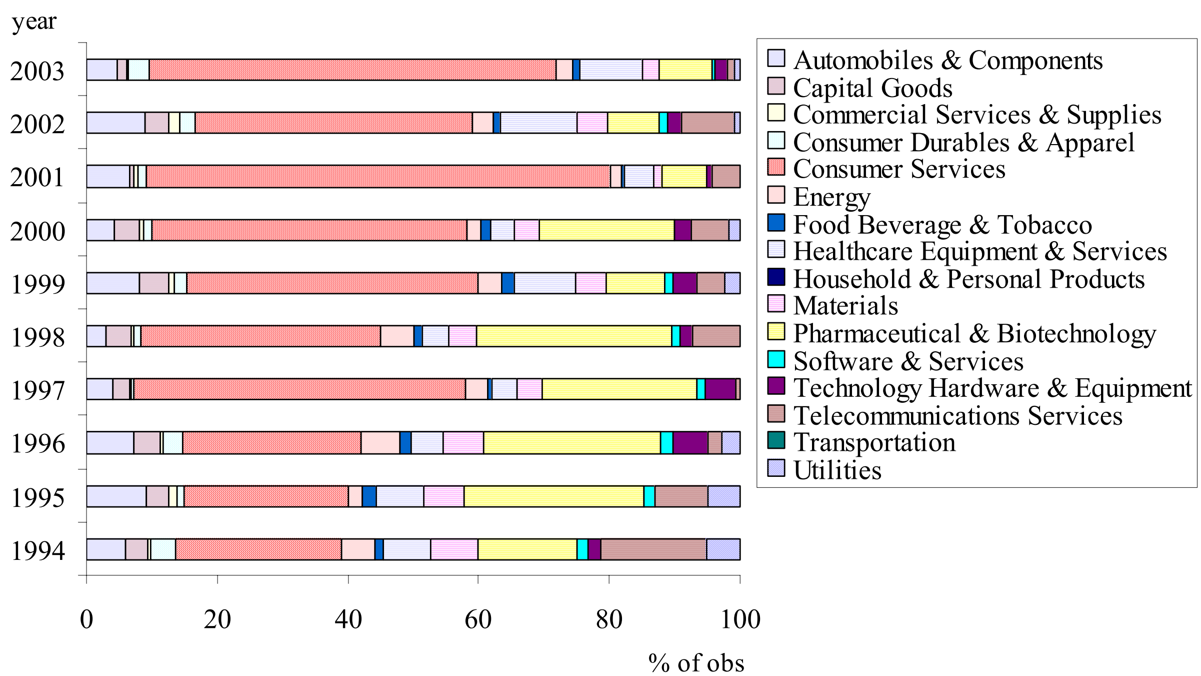
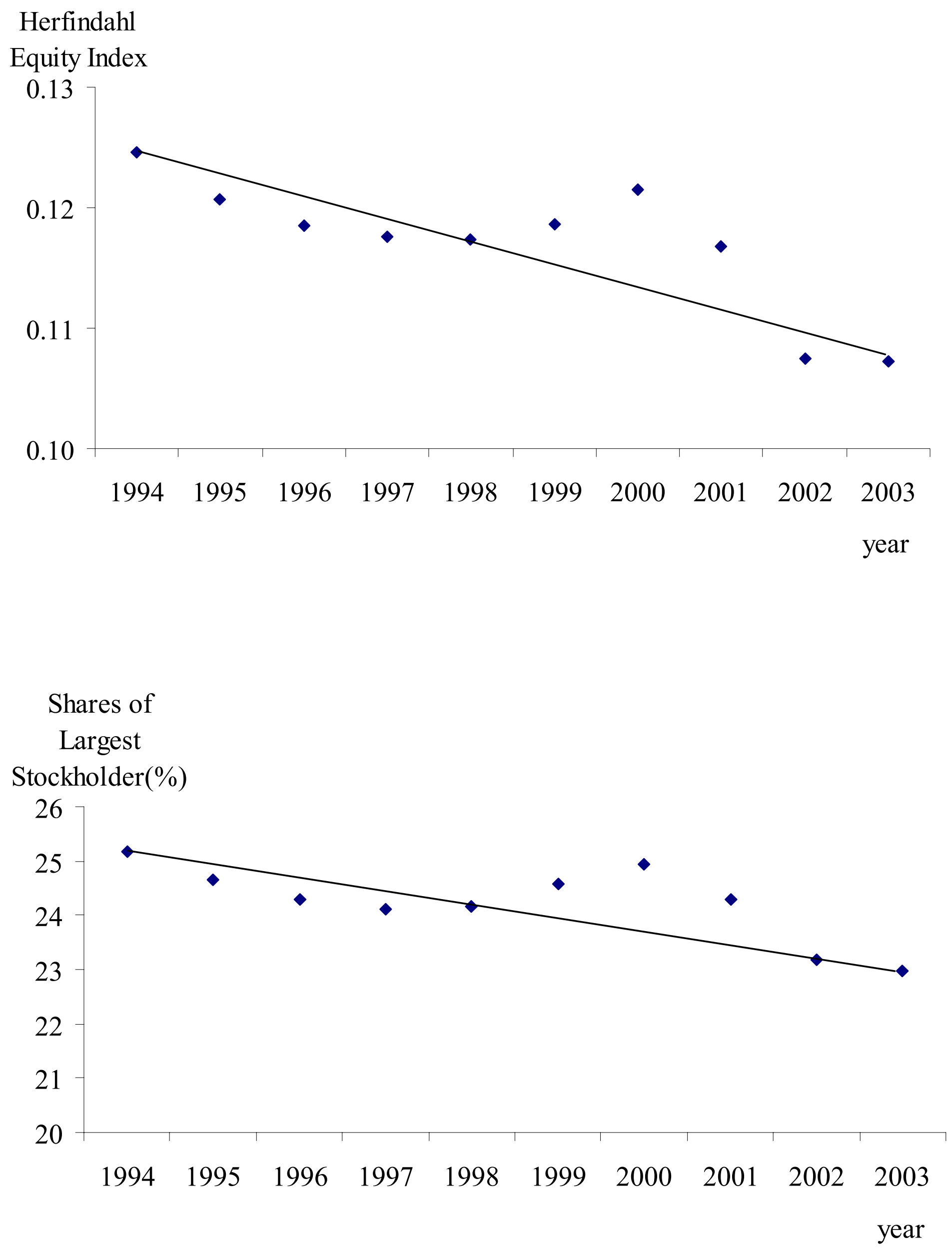
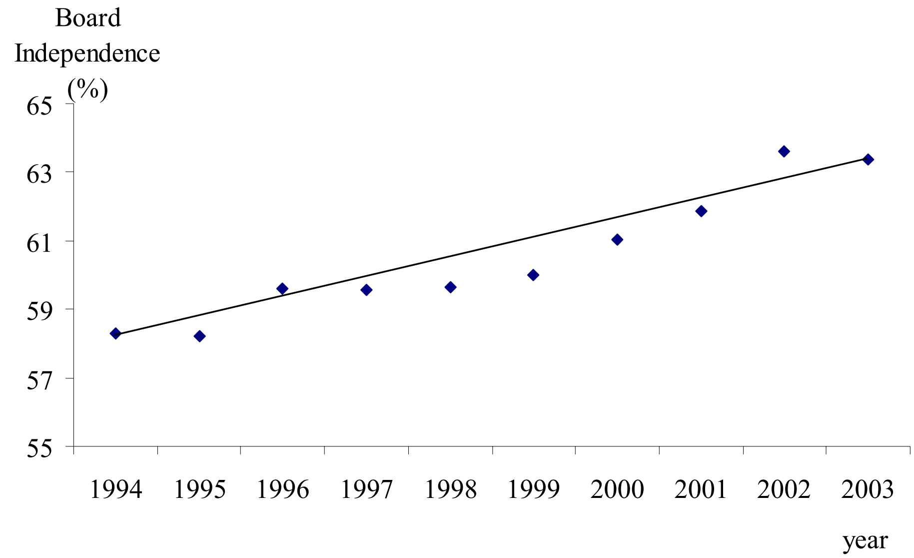
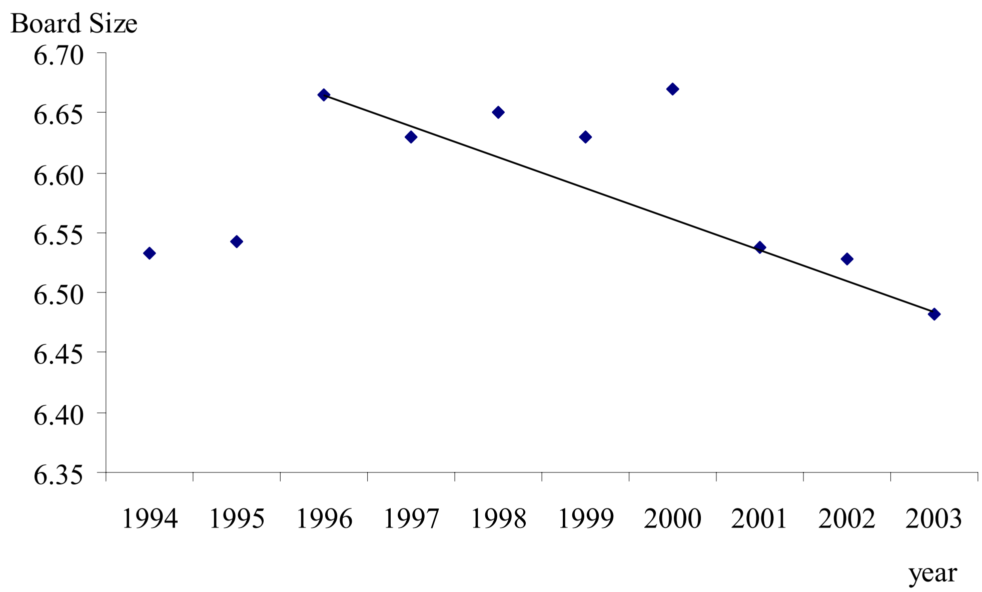
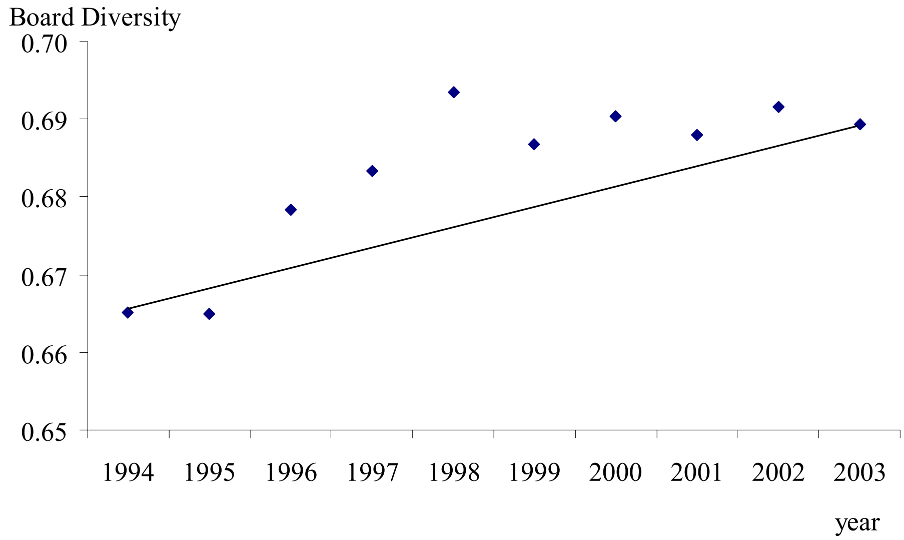


Figure 3: Corporate Governance Variables, 1994-2003




Board Independence (%)
65
63
61
59
57
55
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
year


Board Size
6.70
6.65
6.60
6.55
6.50
6.45
6.40
6.35
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
year


Board Diversity
0.70
0.69
0.68
0.67
0.66
0.65
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
year

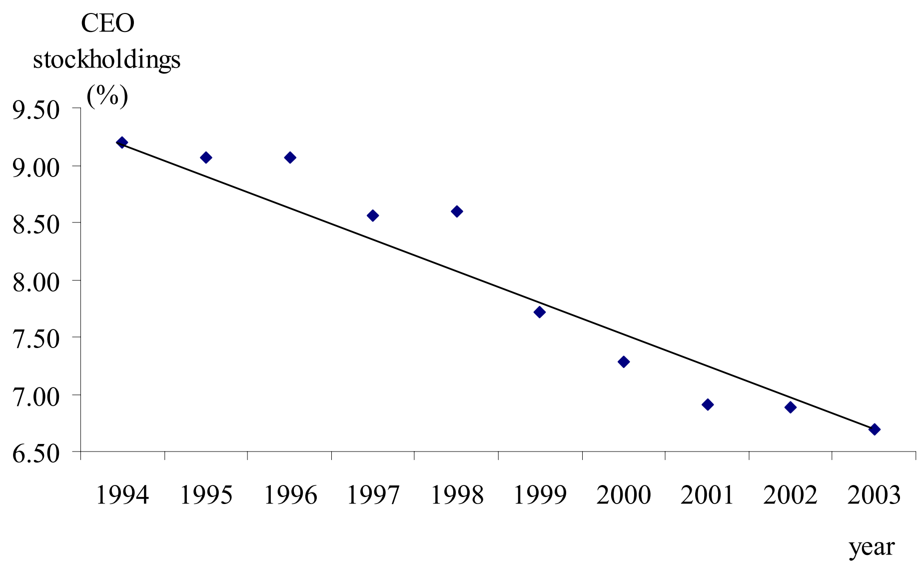

CEO
stockholdings
(%)
9.50
9.00
8.50
8.00
7.50
7.00
6.50
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
year

Figure 4: Observed and Predicted Probabilities from Poisson and Negative Binomial