Innovation, Governance and Competition

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15 January 2015

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ABSTRACT. We consider a two period career concern model where corporate governance is a decisive factor for innovation efforts by a manager. In the beginning of the first period, a manager decides whether to innovate. Prior to the innovation decision, the ability of the manager is unknown to the firm but known to the manager and an expected wage is paid based on a probability distribution of managerial abilities. The success of the innovation is both a function of the managerial ability and the product market competition and the beliefs about the managerial ability is updated if the manager innovates and the wage is set for the second period accordingly. Our model predicts that the rate of innovation would be higher under a more democratic governance structure and relatively low product market competition. Using a panel dataset from 1990s, compiled from Aghion et al.(2013*b*) and Gompers, Ishii, and Metrick (2003), containing time-varying information of patent citations, R&D, product market competition, and Governance index, we show that there is a robust association between innovation and the quality of governance and this relationship is strongest in industries with relatively low competition.

1. INTRODUCTION

Innovation activities in industries, especially oligopolistic industries, are common. Such activities often have different purposes, e.g. cost reduction for the existing line of production, generating a better quality product,gain comparative advantage, etc. All these, however, lead to the common objective : establishing a competitive edge over competitors or maintaining own competitive strength in order to do well in the industry. Therefore, many firms, in order to capture the market better, be it in terms of lower costs leading to offering of lower prices or in terms of better products, engages itself in innovation oriented R&D activities.

In a firm, the innovation decisions are largely taken by corporate managers. These managers may enjoy higher benefits, e.g. in the form of promotions, higher compensation, etc. following successful innovations. If an innovation succeeds, a manager is generally assessed as one with high abilities. But the failure of an innovation might result from these possibilities: either the manager has lower ability or the manager did not put in enough effort or bad luck (noise). Unless there is any provision for observing the managerial action or efforts actually put in by a manager, no definite inference can be drawn about the exact cause of an innovation failure.

If a firm has strong shareholder rights and minimal takeover defenses then a manager could be risk-averse and may only select low return-low risk projects especially in presence of high competition. This might lead to under-investment in R&D and innovation (Shlifer and Vishny, 1989). Corporate governance mechanisms such as fewer anti-takeover provisions, activist and institutional shareholders, or effective boards may reduce this moral hazard problem. However, the justification for takeover threats (i.e. less anti-takeover provisions) is often seen as the strongest form of managerial discipline (Jensen, 1986). Bertrand and Mullainathan (2003) have found that when managers are insulated from takeovers, they may exploit the opportunity to avoid difficult and risky investments, especially if these could reveal managers to be of low ability. As a result, the firm's propensity to innovate may be negatively associated with the level of takeover protection.

At the other extreme, there are firms where the shareholders have very few rights. If there are stiff anti-takeover provisions, so that the firm is impregnable to outside takeovers, it becomes difficult or costly to replace a manager. As a result, managers may feel more secured and be willing to invest in long term risky projects (Stein, 1988). At the same time, with increased job security, managers may put in less effort, shirk, extract private benefits (Jensen, 1986), or invest in inefficient projects (Williamson, 1964; Masulis, et al., 2007) or even be content to lead a "quiet life" (Bertrand and Mullainathan, 2003).

As noted widely in most literature on R&D, innovations are risky and there is always some element of noise (luck) involved. In any governance structure, if the manager does not innovate or make failed innovation attempts, she could be *removed* from her position either by the board of directors, activist shareholders, bankruptcy or takeover. With an autocratic governance structure with more managerial power, it would be at least as difficult to "remove" a manager than if the governance structure was more democratic. The "lazy manager hypothesis" (Hart, 1983) predicts that in industries with high product market competition, the governance structure should not matter much as the manager is disciplined by the threat of bankruptcy or takeover to work hard. Conversely, if the product market competition is low then managers could shirk and content with living a "quiet life".

Under any governance structure, managers know that failure in some innovation activity or undertaking no innovation can be interpreted either as a lack of effort on her part, or her low ability. In both the cases a manager knows that the threat of removal is higher under democratic i.e. stronger governance structure. Since the projection of higher ability entails a prospect of higher lifetime income, and a successful innovation is generally interpreted as an indicator of high ability, every manager has an incentive to project herself as a high ability manager.

We consider a two period career concern model where corporate governance is a decisive factor for innovation efforts by a manager. Our model predicts that at any given level of product market competition, the innovation efforts made by a manager under a stronger or democratic governance structure (following Gompers, Ishii, and Metrick (GIM, 2003) this would imply stronger shareholder rights, less anti-takeover provisions and "less" entrenched managers) is not *lower* than innovation efforts made under a weaker or autocratic governance structure (characterized by weak shareholder rights, high number of anti-takeover provisions and "more" entrenched managers). If the product market competition is low, the same manager will strictly make more innovative efforts in a democratic democratic governance structure than in an autocratic governance structure. Using an innovative dataset compiled by Aghion et. al (2013*b*) and the *G*-index constructed by GIM, 2003, we find strong empirical evidence supporting our claims. Our model provides support to the two widely used models of governance; the "lazy manager hypothesis" which posits that the managers prefer a $quietlife$ and with shareholders having more power will force the managers to innovate, and the "career" concerns model where managers try to avoid innovation due to concerns about their future earnings when the risk of failure is high.

Homström (1999) analyzes the case where manager have career concerns – concerns about the effects of current performance on future consumption.This impacts her decision on making innovation efforts in her current job. In his model, the expected output in each period is a function of the assessed ability as calculated from outputs observed in earlier periods. In that case, the manager might try to influence the present performance and thus future income by involving unobserved actions. The individual manager's objective is to maximize returns to human capital, while the firm's objective is to maximize returns to financial capital. Depending on how well these two kinds of capital are related, the career concerns of the managers can be beneficial or detrimental to the firm. Aghion et al. (2013) uses this model in a context where institutional ownership is associated with more innovation. In their model, institutional owners, through reducing career risks of managers, can increase innovation incentives. Empirically they find complementary relationships between institutional ownership and product market competition in deciding the level of innovation.

Our model, though shares some common features with both these papers, marks a departure in analysis in certain ways. First, we consider *ability* to be private information to the managers, unknown to the employers initially, only revealed through observed performances over time, as opposed to the assumption that ability of managers is unknown to both, the managers as well as the firms. Second, we introduce governance as a decisive factor regarding innovation effort levels in the scenario. In low competition, the higher probability of success of an innovation effort reduces the reputational risk attached with undertaking a risky investment under any governance structure. But as the manager's will have a less ability to slack when the governance is strong than when the governance is weak, our model predicts strictly more innovation associated with stronger governance. In presence of high competition, the manger has less ability to slack under any governance structure, though we would still that the governance structure still matters where manager's under a democratic governance structure do not make any less innovation efforts than the manager's under relatively autocratic governance structure.

There have been few empirical papers which directly deal with the broad based governance index and innovation and so far the empirical evidence has been mixed. Roychoudhury and Egorov (2009) find a negative relationship between innovation and the GIMs G-Index from 1990-2004 for US firms, where higher values of the G-index imply higher anti-takeover provisions and more restrictive shareholder rights. They measure corporate innovation as firm level total factor productivity estimated from a modified Solow (1956) model. Becker-Blease (2011) found a positive relationship between proxies of innovation (using R&D expenditures and Patent data) and his reconstructed G-Index over 1984 and 1997. Sapra et al. (2014) show that there is a U-shaped relation between innovation and external takeover pressure, which arises from the interaction between expected takeover premia and private benefits of control. They find that innovation is fostered either by an unhindered market for corporate control, or by anti-takeover laws that are severe enough to effectively deter takeovers. We contribute to this discussion by showing that there is a negative association between the G-Index and innovations (as measured by future cite weighted patents) but for firms which are characterized by industries with relatively low product market completion.

The rest of this paper is structured as follows: Section 2 describes our model, Section 3 shows the main results from the model, Section 4 describes the data, Section 5 reports and analyzes our empirical results. Section 6 concludes the paper.

2. Description of the model

We consider a two period career concern model similar to that in Homström(1999) and Aghion et al.(2013). Our model involves two sectors[1], denoted by $S = \{S_1, S_2\}$. A firm in sector S_1 is run by our representative manager whose ability is unknown to the market and also to the concerned manager. We denote the set of abilities by $\Theta = \{\theta_1, \theta_2, \theta_3\}$, where $\theta_3 \succ \theta_2 \succ \theta_1$ and $\theta_i \succ \theta_j$ indicate that the type θ_i is higher than the type θ_j. In the first period, she decides whether to innovate. Note that the outcome of an innovative activity may either be a success or a failure. The income of the manager is determined by a function[2] $f : \Theta \to \mathbb{R}_+$, where

$$f(\theta_3) \geq f(\theta_2) \geq f(\theta_1) \text{ and } f(\theta_3) > f(\theta_1).$$

Note that we allow the manager with the intermediate ability θ_2 to have the same income as that of the manager with either high or low ability[3]. Denoting the revenue realizations of an innovation by $\{0, 1\}$, where 0 (respectively 1) indicates the failure (respectively success) of an innovation, the set of *states* is defined by

$$\Omega := \Theta \times \{0, 1\} = \{(\theta_i, j) : 1 \leq i \leq 3,\ j = 0, 1\}.$$

It is assumed that θ_i and j are unknown in the first period to both the market as well as the managers. However, the realization of j will be observable in the second period. But the same is not true for θ_i. Normalizing (ex post) perfect competition in the market to 1, the degrees of competition are denoted by $(0, 1]$. Since the revenue realizations depend on the managerial ability and the market competition, the probability of occurrence of an outcome of Ω also depends on the market competition. Let $(\Omega, \mathscr{F}, \mathbb{P}_c)$ be a probability space of states, where $\mathscr{F}$ is the algebra generated by all subsets of Ω representing the family of all events and $\mathbb{P}_c$ is a probability measure for any competition level $c \in (0, 1]$. We assume that $\mathbb{P}_c(\theta_i) = \frac{1}{3}$ for all $1 \leq i \leq 3$. Thus, the managerial abilities are equally likely in the first period.

For a given degree of competition c, let $\mathbb{P}_c(1|\theta_i) = p_i(c)$. This means that for a given type θ_i and a competition level c, the probability of success of an innovation is $p_i(c)$. Consequently, for a given type θ_i and a competition level c, the probability of failure of an innovation is given by $\mathbb{P}_c(0|\theta_i) = 1 - p_i(c)$. Note that

[1]For simplicity, we assume only two sectors in our model. Allowing multiple sectors of any number in our model does not change our analysis.

[2]Note that the income of the manager is sector-specific, that is, the income of the manager in S_1 and S_2 are determined by possibly different functions.

[3]This is very natural if one considers many different types of abilities. For simplicity, we consider three types of abilities in our model. A general model containing $m(\geq 2)$ many types of abilities is studied in the appendix.

$p_i : (0,1] \to [0,1]$ is a monotonically decreasing function for all $1 \le i \le 3$, that is, the success of an innovation goes higher with lower degrees of competition. This is a common prediction shared by models of endogeneous growth (e.g,, Romer, 1990 and Grossman and Helpman, 1991), where product market competition is modeled as a probability of imitation, in which an increase in imitation probability will reduce the monopoly rents that reward new innovation. This also has support from the IO models of Salop (1977) and Dixit and Stiglitz (1977) which suggest that higher competition will reduce postentry rents. Note, our model predicts that the number of innovations under low product market competition will unambiguously be no lower than that under high competition.

Since abilities are directly related to the result of an innovation, let $p_3 > p_2 > p_1$[4]. This means that the higher the ability, the higher is the chance to get the successful innovation for any competition level. Using the formula of conditional probability, one has

$$\mathbb{P}_c(\theta_i, 1) = \mathbb{P}_c(1|\theta_i)\mathbb{P}_c(\theta_i) = \frac{p_i(c)}{3} \text{ and } \mathbb{P}_c(\theta_i, 0) = \mathbb{P}_c(0|\theta_i)\mathbb{P}_c(\theta_i) = \frac{1-p_i(c)}{3}.$$

Since there is an uncertainty regarding the managerial ability, the probabilities of success and failure of an innovation are given by

$$\mathbb{P}_c(1) = \sum_{i=1}^{3} \mathbb{P}_c(\theta_i, 1) = \frac{1}{3}\sum_{i=1}^{3} p_i(c) \text{ and } \mathbb{P}_c(0) = 1 - \frac{1}{3}\sum_{i=1}^{3} p_i(c),$$

respectively. We use the following assumptions in our model.

($\mathbf{A}_1$) The markets for managers are fully competitive and the second period income is equal to the value of the income function conditional upon the information acquired in the first period;

($\mathbf{A}_2$) Managerial ability is sector-specific in the sense that the information of the current job is uncorrelated with the manager's ability if she moves to another sector.

($\mathbf{A}_3$) The value $p_3(c)$ is very close to 1 when c is very close to 0. Suppose also that $p_2(c_0) > \frac{1}{2}$ and $p_1(c_0) \neq 0$ for some $c_0 \in (0,1]$.

It is worth pointing out that ($\mathbf{A}_1$) and ($\mathbf{A}_2$) are similar to Assumption 1 and Assumption 3, respectively, in Aghion et al. (2013). Assumption ($\mathbf{A}_3$) will be used to show that the success of innovation is higher at a lower product market competition.

In general, most of a manager's payoff is determined not by explicit contracts, but the effect her reputation has on her ability to renegotiate her contract (see Xu, 2013 and Aghion et al., 2013). In our model, there are no explicit output contingent contracts, but since manager's income in each period is based on expected output and expected output depends on assessed ability, an implicit contract links her first period performance to her second period income. If the manager takes an innovation decision, then the market updates belief about the manager's ability from observing the first period's revenue realizations. Thus, given a successful innovation, the probability of type θ_i is given by

$$\mathbb{P}_c(\theta_i|1) = \frac{\mathbb{P}_c(\theta_i, 1)}{\mathbb{P}_c(1)} = \frac{p_i(c)}{\sum_{i=1}^{3} p_i(c)}.$$

[4]The ordering is taken pointwise, that is, $p_3(c) > p_2(c) > p_1(c)$ for all $c \in (0,1]$.

Similarly, given failure of an innovation, the probability of type θ_i is given by

$$\mathbb{P}_c(\theta_i|0) = \frac{\mathbb{P}_c(\theta_i, 0)}{\mathbb{P}_c(0)} = \frac{1 - p_i(c)}{3 - \sum_{i=1}^{3} p_i(c)}.$$

So, $\mathbb{P}_c(\theta_i|1)$ and $\mathbb{P}_c(\theta_i|0)$ are market's belief in the second period about the manager's ability θ_i whenever the first period revenue realizations are 1 and 0, respectively. Since $p_3(c) > p_2(c) > p_1(c)$, one obtains

$$\mathbb{P}_c(\theta_3|1) > \mathbb{P}_c(\theta_2|1) > \mathbb{P}_c(\theta_1|1) \text{ and } \mathbb{P}_c(\theta_3|0) < \mathbb{P}_c(\theta_2|0) < \mathbb{P}_c(\theta_1|0).$$

As a result, a successful (failed) innovation leads to a belief that assigns higher probability to the high (low) managerial ability. Thus, we assume that the manager is not removed from S_1 at the beginning of the second period if the revenue realization in the first period is 1. Consequently, for successful innovation in the first period, the manager's income[5] in the second period if she remains in S_1 is

$$\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f) = \sum_{i=1}^{3} f(\theta_i)\mathbb{P}_c(\theta_i|1) = \frac{\sum_{i=1}^{3} f(\theta_i)p_i(c)}{\sum_{i=1}^{3} p_i(c)}.$$

The role of governance can be justified if the first period revenue realization is 0 or the manager decides not to make an innovation effort. In both these situations, there are possibilities that the manager would be removed from S_1. In case that the first period revenue realization is 0 and the manager retains the same job, her income in the second period will be

$$\mathbb{E}^{\mathbb{P}_c(\cdot|0)}(f) = \sum_{i=1}^{3} f(\theta_i)\mathbb{P}_c(\theta_i|0) = \frac{\sum_{i=1}^{3} f(\theta_i)(1 - p_i(c))}{3 - \sum_{i=1}^{3} p_i(c)}.$$

If the manager decides not to innovate in the first period, then no information is revealed about the manager's ability. Consequently, if she remains in S_1 in the second period, then her income will be

$$\mathbb{E}^{\mathbb{P}_c}(f) = \sum_{i=1}^{3} f(\theta_i)\mathbb{P}_c(\theta_i) = \frac{1}{3}\sum_{i=1}^{3} f(\theta_i).$$

For a proof of the following theorem, refer to the proof of Theorem 6.1 for $m(\geq 2)$ many abilities in the Appendix.

Theorem 2.1. $\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f) > \mathbb{E}^{\mathbb{P}_c}(f) > \mathbb{E}^{\mathbb{P}_c(\cdot|0)}(f)$.

It is assumed that relocation of the manager to another sector incurs a switching cost δ satisfying

$$\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f) > \mathbb{E}^{\mathbb{P}_c}(f) - \delta > \mathbb{E}^{\mathbb{P}_c(\cdot|0)}(f). \tag{2.1}$$

It follows from $(\mathbf{A}_2)$ that the information about the current job is uncorrelated with the manager's ability if she moves to S_2. Thus, she has a new draw of distribution of talent in S_2 and the income of the manager in S_2 in the second period is $\mathbb{E}^{\mathbb{P}_c}(g)$ for some income function $g : \Theta \to \mathbb{R}_+$. The above inequality says that the value $\delta := \mathbb{E}^{\mathbb{P}_c}(f) - \mathbb{E}^{\mathbb{P}_c}(g)$ is small enough so that the income of the manager in S_2 is no better than $\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f)$ and worse than $\mathbb{E}^{\mathbb{P}_c(\cdot|0)}(f)$, refer to Aghion et. al. (2013).

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[5]Here, we use the standard notation of expectation, that is, for the random variable $f : \Theta \to \mathbb{R}_+$ and the probability measure $\mathbb{P}_c(\cdot|1) : \Theta \to [0, 1]$, the expression $\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f)$ denotes the expected value.

We now introduce governance into the model. The innovation decision in the first period is denoted by $i \in \{0,1\}$, where $i = 0$ means no innovation effort and $i = 1$ means an innovation effort. Following GIM (2003), we define two types of governance structures: the autocratic or dictatorial governance structure, where the firm has high takeover provisions and weak shareholder rights and the democratic governance, where there are fewer anti-takeover provisions and shareholders have more power. We take a convention that each governance structure wants to keep a manager whose ability is higher than some threshold value of types and the threshold value in the case of democratic governance structure is not lower than that in the case of autocratic governance structure. Suppose, g_a stands for the autocratic governance and g_d represents the democratic governance. Let q_a and q_d represent the probabilities of removing from S_1 for failure of an innovation under the autocratic governance and the democratic governance, respectively. If there is no innovation effort, r_a and r_d denote the probabilities of removing a manager from S_1 when the governance structures are autocratic and democratic, respectively. We introduce two other assumptions to our model.

($\mathbf{A}_4$) Under the democratic governance regime, if the innovation fails, then the probability, q_d, of the manager getting *removed* is not less than the probability, q_a, of getting *removed* under the autocratic regime, i.e., $q_d \geq q_a$;

($\mathbf{A}_5$) If the manager decides not to innovate, the probability of being *removed* is higher in the democratic governance regime, i.e., $r_d > r_a$.

This information is known to the manager. Since removal from S_1 is uncertain, the *ex-ante* expected income of the manager for the second period is probabilistic. The notation $\mathbb{E}(W(i = 0, g = g_k))$ is employed to represent the ex ante income of the manager in the second period for the case of no innovation in the first period and the governance structure g_k for $k = a, d$. Analogously, the symbol $\mathbb{E}(W(i = 1, g = g_k))$ is used to denote the ex ante income of the manager in the second period when she takes an innovation decision in the first period and the governance structure is g_k for $k = a, d$. Thus, under the governance structure g_k, the manager decides to take an innovation decision if and only if

$$\mathbb{E}(W(i = 1, g = g_k)) - I > \mathbb{E}(W(i = 0, g = g_k)),$$

where I is the innovation cost.

3. The Main Result

In this section, we show that the number of an innovation decision is higher under the democratic governance and lower market competition.

To establish that number of innovation decisions increases if the market competition decreases, note from (2.1) that the manager is willing to take an innovation decision whenever she has some hope for the success of an innovation decision. Given ($\mathbf{A}_3$), we can assume that $\sum_{i=1}^{3} p_i(c_*) > \frac{3}{2}$ for some $c_* \in (0,1]$ satisfying $c_* \leq c_0$. Consequently, $\mathbb{P}_{c_*}(1) > \frac{1}{2}$. Note that the value $P_c(1)$ becomes larger as c becomes smaller. Thus, $\mathbb{P}_{c_*}(1) > \frac{1}{2}$ for all $c \in (0, c_*]$. So, if the manager takes an innovation decision in some point $c_1 \in (0, c_*]$ then she must take the innovation decision at any point $c \in (0, c_1]$. Hence, the number of innovation decisions is higher with respect to lower competition.

Now, we show that the number of an innovation decision under the democratic governance is not lower than that under the autocratic governance. Formally, we prove that

$$\begin{aligned}&\mathbb{E}(W(i=1,g=g_a))-I>\mathbb{E}(W(i=0,g=g_a))\\ \Rightarrow\ &\mathbb{E}(W(i=1,g=g_d))-I>\mathbb{E}(W(i=0,g=g_d)).\end{aligned}$$

This means that if the manager takes an innovation decision under the autocratic governance structure then she must take an innovation decision under the democratic governance structure.

3.1. **The Case When $\delta \geq 0$.** If the manager does not take an innovation decision then her income will be high in S_1 than that in S_2 since $\mathbb{E}^{\mathbb{P}_c}(f) \geq \mathbb{E}^{\mathbb{P}_c}(g)$ for $\delta \geq 0$. In this case, either she will retain her job in S_1 or she will be removed from S_1 in the second period. In that event, she will join S_2. Recall that the probability of retaining the same job in S_1 is $1-r_k$ and that of being removed from S_1 is r_k whenever the governance structure is g_k. So, the ex ante expected income of the manager conditional upon not taking an innovation decision is

$$\mathbb{E}(W(i=0,g=g_k))=r_k\mathbb{E}^{\mathbb{P}_c}(g)+(1-r_k)\mathbb{E}^{\mathbb{P}_c}(f)=\mathbb{E}^{\mathbb{P}_c}(f)-r_k\delta.$$

We now consider the situation when the manager takes an innovation decision. It follows from (2.1) that the failure of an innovation results in the manager's higher income from joining S_2 than that if she retains the same job in S_1 in the second period. However, she might have some incentive to stay in S_1 if the difference between these two incomes is sufficiently small. Consider now the possibility when the manager is willing to switch to S_2 for the failure of an innovation. In this situation, she will get the wage $\mathbb{E}^{\mathbb{P}(\cdot|1)}(f)$ for successful innovation and the wage $\mathbb{E}^{\mathbb{P}}(g)$ for the failure of innovation. Thus, her ex ante expected income[6] is

$$\mathbb{E}(W(i=1,g=g_k))=\mathbb{P}_c(1)\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f)+\mathbb{P}_c(0)\mathbb{E}^{\mathbb{P}_c}(g)$$

for $k=a,d$. We now take the possibility when the manager is willing to stay in S_1. However, this decision depends not only on her, but it also depends on the governance structure. Since the probability of removal from S_1 is q_k for the governance structure g_k, her ex ante expected income is

$$\mathbb{E}(W(i=1,g=g_k))=\mathbb{P}_c(1)\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f)+\mathbb{P}_c(0)\left(q_k\mathbb{E}^{\mathbb{P}_c}(g)+(1-q_k)\mathbb{E}^{\mathbb{P}_c(\cdot|0)}(f)\right)$$

for $k=a,d$. Consequently, for both of these possibilities, one obtains

$$\mathbb{E}(W(i=1,g=g_d))\geq\mathbb{E}(W(i=1,g=g_a)).$$

Note that

$$\mathbb{E}(W(i=0,g=g_d))\leq\mathbb{E}(W(i=0,g=g_a)).$$

So,

$$\begin{aligned}&\mathbb{E}(W(i=1,g=g_a))-I>\mathbb{E}(W(i=0,g=g_a))\\ \Rightarrow\ &\mathbb{E}(W(i=1,g=g_d))-I>\mathbb{E}(W(i=0,g=g_d)).\end{aligned}$$

Hence, the number of innovation efforts under the democratic governance is not lower than that under the autocratic governance.

[6]Note that this possibility does not depend on the governance structure, and the ex ante expected income is same across two governance structures.

3.2. **The Case When $\delta < 0$.** In this case, the manager's income for no innovation decision is higher[7] in S_2 than S_1. Thus, if the manager moves to S_2 in the second period then her income will be $\mathbb{E}(W(i=0, g=g_k)) = \mathbb{E}^{\mathbb{P}_c}(g)$. However, if the switching is small then she might have some incentive to stay in the same sector. Since this decision depends on her as well as on the governance, her ex ante expected income is

$$\mathbb{E}(W(i=0, g=g_k)) = r_k \mathbb{E}^{\mathbb{P}_c}(g) + (1-r_k)\mathbb{E}^{\mathbb{P}_c}(f) = \mathbb{E}^{\mathbb{P}_c}(f) - r_k\delta.$$

Note that for the failure of innovation, manager must move to S_2 as the wage $\mathbb{E}^{\mathbb{P}_c}(g)$ is sufficiently higher than $\mathbb{E}^{\mathbb{P}_c(\cdot|0)}(f)$. Thus, the manager's ex ante expected income for an innovation decision is

$$\mathbb{E}(W(i=1, g=g_k)) = \mathbb{P}_c(1)\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f) + \mathbb{P}_c(0)\mathbb{E}^{\mathbb{P}_c}(g)$$

for $k = a, d$. Since $\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f) > \mathbb{E}(W(i=0, g=g_k))$ and $\mathbb{E}^{\mathbb{P}_c}(g) \geq \mathbb{E}(W(i=0, g=g_k))$ irrespective of the fact that whether the manager will retain her job or move to S_2, one has

$$\mathbb{E}(W(i=1, g=g_k)) > \mathbb{E}(W(i=0, g=g_k))$$

for $k = a, d$. Thus, for $\delta < 0$, the manager always takes an innovation decision in both the governance structure.

4. Data and Methodology

4.1. **Governance Data.** GIM's 'G-Index' is possibly the most widely used broad based measure of corporate governance in the US. It is a proxy for the balance of power between shareholders and managers. It was created on the basis of how many restrictive governance provisions are imposed on shareholder rights; the more restrictive the governance, the weaker the shareholder rights. These anti-takeover provisions range from bylaws that restrict shareholder voting to whether companies are subject to state-level anti-takeover laws. Their primary data source is the Investor Responsibility Research Center (IRRC). The governance index is constructed by adding one point for every provision(out of a total of 24) that restricts shareholder rights and correspondingly increases managerial power; thus, the higher the score, the weaker the shareholder rights.The firms with weak shareholder rights (or higher G-index)are more likely to experience a wider divergence of ownership and control.Additionally, such firms are also more likely to have high agency costs and hence, poor corporate governance. Since the IRRC does not publish volumes for every year, Aghion et al. (2013*b*) dataset does not include G-index values for years where the IRRC data was missing. We fill the missing years assuming that the governance provisions reported in any given year were also in place in two years preceding the volume's publication. This procedure is consistent with all the major studies involving the G-index(e.g., Fishman et al. (2014).

4.2. **Innovation.** Following standard literature on proxies of innovation, we measure innovation by future cite weighted patents following Hall, Jaffe and Trajtenberg (2005)and Aghion et. al (2013). The patent related data is obtained from Aghion et al. (2013*b*). They obtain patents data from the NBER and match them with the USPTO data for patents that were ultimately granted, dated by year of application

[7]This does not mean that the manager's income for successful innovation is higher in S_2 than S_1. For instance, $f(\theta_3) > g(\theta_3)$, $f(\theta_2) = g(\theta_2)$, $f(\theta_1) < g(\theta_1)$ and $f(\theta_1) + f(\theta_3) = g(\theta_1) + g(\theta_3)$ imply $\mathbb{E}^{\mathbb{P}_c}(g) > \mathbb{E}^{\mathbb{P}_c}(f)$ and $\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(g) < \mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f)$.

from 1963 to 1999. Since the value of these patents differs greatly, to capture their importance they weight them by the number of future citations between 1975 and 2002. To deal with censoring they estimate only until 1999, allowing for a three-year window of future citations for the last cohort of patents in the data. They also include a full set of time dummies, which controls for the fact that patents taken out later in the panel have less time to be cited than patents taken out earlier in the panel.

4.3. **Firm Specific Accounting Data.** The capital and labor data is obtained from Aghion et al. (2013) data set and cross-checked with the COMPUSTAT data. The capital stock of a firm is measured by the Net Property, Plant, and Equipment (PPEN, COMPUSTAT industrial annual data item 8).The book value of total assets is used to account for the size factor (ASSETS, COMPUSTATindustrial annual data item 6). The capital stock in a firm is difficult to measure with time series of investments required along with composition issues. However, Bailey, et al., (1992), find that in the productivity model, the use of sophisticated measures of capital instead of crude measures based on book values of capital stock do not change the results qualitatively. For labor input, there is no way to distinguish between "blue collar" and "white collar" workers and hence the labor input is simply the number of its employees (EMP, COMPUSTAT industrial annual data item 29). We use the R&D stock available in Aghion et. al. (2013*b*) dataset which is estimated using a perpetual inventory method described by Hall, Jaffe, and Trajtenberg (2005).

4.4. **Competition.** Following Aghion et. al (2013), we employ the inverse Lerner (i.e., 1- Lerner index) as a measure of the intensity of competition. Consistent with our theoretical model, a value close to 1 implies perfect competition. Lerner is estimated as the median gross margin from entire Compustat database in the firms three-digit industry. There is some (weak) evidence of an inverted U relationship between innovation and competition. If we run a regression of Innovation on the inverse Lerner and the square of the inverse Lerner, the linear term is positive whereas the squared term is negative but insignificant. See Aghion et al. (2005) for a discussion on why the inverse Lerner is appropriate in these kinds of models.

4.5. **Descriptive Statistics.** By restricting the Aghion et al. (2013*b*) dataset to firms which have a G-index value associated with them, our baseline sample reduces to 285 firms, 1669 firm years spanning a period from 1990-1999. We consider a range of control variables suggested by the existing literature. For example, we condition on Sales, R&D stock and the capital-labor ratio (Aghion et al., 2013, Hall, Jaffe, and Trajtenberg, 2005, and Gompers and Metrick, 2001). In all our regressions we account for the full set of four digit industry and time dummies. As different industries are likely to have different observed levels of patenting activity due to institutional features of the industry that may have no direct link with product market competition or governance, it is imperative to use industry fixed effects in all our regressions. The time effects control for common macroeconomic shocks. Table 1 reports the descriptive statistics for the variables used in our regressions. The firms in our sample are large with mean (and median) sales of little more than 1.6 billion dollars. Our sample of firms spend, on average, about 275 million on R&D per year. The patent series is highly skewed with a mean of about 55, standard deviation of 159 and a median of 10 patent counts. The corresponding numbers for forward citations shows an even larger skew with a mean of 410, standard deviation

Table 1: Descriptive Statistics

Variable	Mean	Standard deviation	Median	Min	Max
Governance Index	10.1	2.7	10	3	18
Cite Weighted Patents	410	1494	52	1	23,121
Patent Counts	54.75	158.7	10	1	2,405
Competition	0.86	0.038	0.871	0.632	0.973
Institutions (%)	54.83	17.87	57.4	0	99.99
Capital Stock ($m)	3,800	10,631	793.27	4.363	121,160
Employees (1000s)	28.9	68.2	8.62	0.05	711
Sales ($m)	1,601	16,782.6	1,600.9	5.68	174,694
R&D ($m)	274.73	845.19	30.89	0	8,900.00

Notes: Governance Index is obtained from Joy Ishii. The data on rest of the variables is from Aghion et al. (2013). "Innovation and Institutional Ownership: Dataset." *American Economic Review* (http://dx.doi.org/10.1257.aer.103.1.277). *'Institutional'* is the data on the share of institutional ownership in a firm. *'Competition'* is measured by *1- Lerner Index* for the relevant industry. The number of firms in our sample is 285 and number of observations is 1669.

of 1494 and a median of 52 cite-weighted patents. The G-index has a median value of 10 and a mean value of 10.1 with a standard deviation of 2.7. The proxy for competition as measured by the inverse Lerner index has a mean of 0.86 and a median of 0.871.

5. Results and Analysis

It is worthwhile to look at the relationship between our proxies for innovation and governance. Figure 1 shows the non-parametric relationship between log of raw patent counts and the G-index using a locally weighted regression estimated by lowess smoother[8] (with a bandwith of 0.8). Figure 2 replaces log patent counts with the Log of future citation-weighted patents measure. For both figures, there is a negative relationship between innovation and the Governance Index as shown by the shape of the fitted curve. The curve becomes steeper at higher levels of the G-index implying this negative association is stronger at higher levels of the G-index.

Our base parametric model is the Poisson regression model because of the count-based nature of the dependent variable. The Poisson distribution is entirely determined by its mean, so we only need to specify $E(y|\mathbf{x})$ in order to estimate the effect of explanatory variables on our dependent variable. As we are primarily interested in the effect of G-Index on y_{jt} (i.e., future cite-weighted patents of firm j in period t), we will specify the conditional expectation of y_{jt} as

[8]Lowess is an acronym for "Locally weighted Scatter plot Smoother. The smoothing process is considered local because each smoothed value is determined by neighboring data points defined within the span. A regression weight function is defined for the data points contained within the span.

Figure 1: Patent Counts

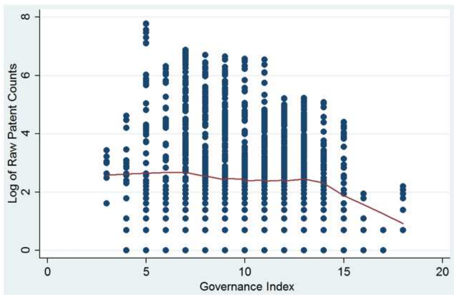
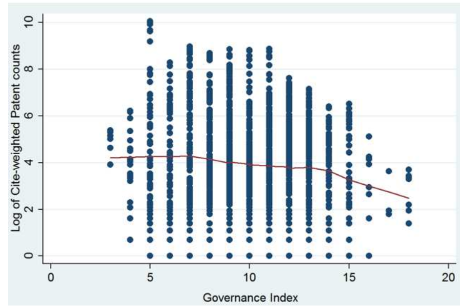


Figure 2: Future Cite-weighted Patent Counts



$$E(y_{jt}|\mathbf{x}_{jt}, \gamma_{jt}) = e^{(\alpha G_{jt} + \beta \mathbf{x}_{jt} + \gamma_{jt})}, \tag{5.1}$$

where $\mathbf{x}_{jt}$ are other control variables, and γ_{jt} represents a complete set of time and four digit industry dummies. We also consider negative binomial model which relaxes the assumption in Poisson that the conditional mean and variance are equal. As all these models allow the standard errors to have arbitrary heteroskedacity and autocorrelation (e.g., clustering the standard errors by firm), the exact functional form of the error distribution is not so important (Aghion et al., 2013). We also adopt the log-link formulation because of the count based nature of the dependent variable. Table 2 reports the baseline results. Columns (1)-(3) from Table 2 presents the estimates from the Poisson count data regressions of future-cite weighted patents on the G-index with controls for capital, labor, sales,four digit industry dummies and year dummies (column 1), additional controls of R&D stock (column 2) and *institutional* ownership (column 3). Across columns (1) and (3), the coefficient on the G-index is negative and significant with a magnitude of about -0.08. A coefficient of -0.08 implies that an increase of 1 standard deviation in the G-index (about 2.7 points) is associated with a 21.6 percent decrease in the probability of obtaining an additional cite-weighted patent. The coefficient on the firms R&D stock (columns 2 and 3) and the institutional ownership(column 3) is positive but insignificant. Columns (4)-(6) of Table 2 repeat the specifications of the first three columns but use the more general Negative Binomial model. Across columns (4)-(6), the coefficient on the G-Index is negative and significant. The coefficient on the R&D stock is positive and significant and reduces the coefficient on the G-Index from -0.067 to -0.054. The coefficient on institutional ownership however remains insignificant.

A major problem faced while creating an empirical model for governance studies is endogeneity. The variables that represent levels of corporate governance may be also determined simultaneously with dependent variables related to innovation activity. Firms with better and worse governance probably also differ on other, unobserved, dimensions. So comparing managerial behavior between firms with autocratic and democratic governance may capture the effect of these unobservable differences rather than the effect of governance. Similarly, changes in governance within a firm may be accompanied by other unobservable changes. The simultaneous equations bias makes it difficult to determine the direction of causality. The problem of simultaneous equation bias could be empirically treated by the use of

Table 2: Corporate Governance and innovation

	Poisson			Negative Binomial		
	(1)	(2)	(3)	(4)	(5)	(6)
Governance Index	-0.081***	-0.084***	-0.088***	-0.067**	-0.054**	-0.055**
	(0.029)	(0.030)	(0.028)	(0.030)	(0.027)	(0.026)
Ln (*K/L*)	0.544***	0.553***	0.568***	0.445***	0.389***	0.390***
	(0.168)	(0.205)	(0.196)	(0.135)	(0.130)	(0.128)
Ln (Sales)	0.698***	0.424**	0.410**	0.646***	0.389***	0.387***
	(0.054)	(0.180)	(0.196)	(0.046)	(0.084)	(0.087)
Ln (R&D)		0.289	0.290		0.298***	0.299***
		(0.217)	(0.225)		(0.083)	(0.084)
Institutional			0.004			0.000
			(0.005)			(0.004)
Observations	1669	1669	1669	1669	1669	1669

Notes: Dependent variable is Future cite weighted patents. Column (1) - (3) are Poisson count data regressions and (4) - (6) are Negative Binomial regressions. All regressions control for a full set of year and four digit industry dummies. '*Institutional*' is the data on the share of institutional ownership in a firm. R&D stock is estimated using a perpetual inventory method used by Halle, Jaffe, and Trajtenberg (2005). Estimation period is 1991-1999 over 285 firms. The standard errors (in parenthesis) are clustered by firm. ***, **,* are significance at 1%, 5% and 10% levels, respectively.

an instrumental variables or the Arellano-Bond (1991) approach, but such an instrument for G-index is not easily identified. GIM (2003) report their inability to come up with a suitable instrument for G-index to use as an instrumental variable. Another way of reducing this endogeneity problem is the use of panel data fixed effect models. A combined time and firm fixed effect regression model eliminates omitted variables arising both from unobserved variables that are constant over time and unobserved variables that are constant across firms. With firm fixed effects, the regression coefficient on the G-index is driven by the extent of variation over time within each firm. Since the G-index for a firm is largely invariant over time, the fixed effects regression coefficient on the G-index is mostly attributed to the variation of G-index of the firms for which the index values does change over time. If a firms governance is sticky over time, that firm would not contribute to the coefficient estimation but will only introduce noise and lower test power (Chi, 2005).

An alternative solution to implement fixed effects suggested by Blundell, Griffith, and Van Reenen (1999) is to use the pre-sample mean scaling method in such models involving count data. Aghion et. al (2013) uses a long history on patenting behavior (up to 25 years per firm) to construct the pre-sample mean of cite-weighted patents for each firm. This can then be used as an initial condition to proxy for unobserved heterogeneity under certain conditions. We use Aghion et. al (2013) dataset to obtain the pre-sampled and scaled means of cite weighted patents and raw patents for each firm.

To incorporate the effect of governance and competition on innovation we split our sample into observations with high and low competition based on the median (0.871) of the inverse Lerner index. Including the firm fixed effects and competition into our baseline Poisson model, we estimate

$$E(y_{jt}|\mathbf{x}_{jt}, c_j, \mu_j, \gamma_{jt}) = e^{(\alpha G_{jt}+\beta \mathbf{x}_{jt}+c_j+\mu_j+\gamma_{jt})}, \tag{5.2}$$

where $\mathbf{x}_{jt}$ are other control variables, c_j is our measure of competition based on 3 digit industry for firm j, μ_j is a firm fixed effect, and γ_{jt} represents a complete set of time and industry dummies.

Table 3 reports Poisson count data regressions of future cite-weighted patents on the G-index accounting for product market competition (as measured by 1-Lerner) and the usual controls. Column (1) and (2) report estimates adding the Competition variable to our baseline regression which include usual set of controls and the R&D stock. The coefficient on G-Index in Column (1) of table 3 is negative and significant at 1% with a value of -0.084. However, including fixed effects using the pre-sample mean scaling estimator in Column (2) brings the coefficient on the G-index down to -0.026 but still significant but at the 10% level. A coefficient of -0.026

Table 3: Corporate Governance, innovation and Competition

	All		High Competition		Low Competition	
	(1)	(2)	(3)	(4)	(5)	(6)
Governance Index	-0.084***	-0.026*	-0.065	-0.009	-0.118***	-0.060***
	(0.027)	(0.015)	(0.049)	(0.012)	(0.028)	(0.023)
Competition	1.709	0.494	7.183**	8.681***	6.110	2.362
	(2.440)	(3.056)	(3.193)	(3.347)	(5.933)	(6.207)
Ln (R&D)	0.289***	-0.108	0.276*	-0.133*	0.319*	-0.014
	(0.106)	(0.082)	(0.142)	(0.079)	(0.167)	(0.085)
Ln (*K/L*)	0.553***	0.722***	0.545***	0.855***	0.544***	0.474**
	(0.061)	(0.220)	(0.039)	(0.167)	(0.155)	(0.184)
Ln (Sales)	0.424***	0.199***	0.434***	0.199***	0.371**	0.132*
	(0.109)	(0.057)	(0.142)	(0.042)	(0.187)	(0.076)
Fixed Effects	No	Yes	No	Yes	No	Yes
Observations	1669	1669	808	808	861	861

Notes: Dependent variable is Future cite weighted patents. All regressions are Poisson regressions and control for a full set of year and four digit industry dummies. *'Competition'* is the *(1- Lerner Index)* where Lerner is estimated as the median gross margin from entire Compustat database in the firm's three-digit industry. High or Low competition is the subsample where the industry (1- Lerner) is larger or smaller than the sample median of .871. The fixed effects use the pre-sample mean scaling estimator using Blundell, Griffith, and Van Reenen (1999) method. Estimation period is 1991-1999 over 285 firms. The standard errors (in parenthesis) are clustered at the three-digit industry level in columns (3) - (6) and by firms in (1) and (2). ***,**,* are significance at 1%, 5% and 10% levels, respectively.

implies that an increase of 1 standard deviation in the G-index (about 2.7 points) is associated with a 7 percent decrease in the probability of obtaining an additional cite-weighted patent (e.g., from the mean of 410 cite weighted patents to about 380)for a given level of competition. The coefficient on competition is positive as expected but insignificant in (1) and (2). In Column (3) and (4) where competition is high, the coefficient on the G-index is still negative but now insignificant while the coefficient on *competition* becomes positive and highly significant. For low competition (columns (5) and (6)), the coefficient on the G-index is negative and highly significant for both the non-fixed and fixed effects model specifications. The magnitude of the coefficient on the G-index in presence of low competition is larger than the corresponding values for high competition. However, the coefficient on *competition*, though positive, is insignificant for the low competition firms. The results from table 3 imply that the relationship between governance and innovation is strongest in industries with relatively low competition. In the columns where we include fixed effects, the coefficient on the R&D stock and $ln(Sales)$ drops significantly. This could be due to the fact that both these variables will have very little within-firm variation hence their effects are muted.

Table 4: Using Raw Patent Counts

	All		High Competition		Low Competition	
	(1)	(2)	(3)	(4)	(5)	(6)
Governance Index	-0.048*	-0.038**	-0.008	-0.011*	-0.086***	-0.071***
	(0.025)	(0.019)	(0.053)	(0.007)	(0.020)	(0.016)
Competition			13.182**	14.500***	4.000	2.316
			(4.692)	(4.954)	(5.927)	(5.757)
Ln (R&D)	0.343***	0.114	0.390	0.125**	0.274*	0.116
	(0.134)	(0.074)	(0.237)	(0.052)	(0.146)	(0.091)
Ln (*K/L*)	0.415***	0.535***	0.225***	0.546***	0.596***	0.542**
	(0.182)	(0.113)	(0.091)	(0.160)	(0.103)	(0.100)
Ln (Sales)	0.430***	0.212***	0.401*	0.184***	0.435***	0.218***
	(0.120)	(0.065)	(0.217)	(0.050)	(0.163)	(0.056)
Fixed Effects	No	Yes	No	Yes	No	Yes
Observations	1669	1669	808	808	861	861

Notes: Dependent variable is raw patent counts. All regressions are Poisson regressions and control for a full set of year and four digit industry dummies. *'Competition'* is the *(1- Lerner Index)* where Lerner is estimated as the median gross margin from entire Compustat database in the firm's three-digit industry. High or Low competition is the subsample where the industry (1- Lerner) is larger or smaller than the sample median of .871. The fixed effects use the pre-sample mean scaling estimator using Blundell, Griffith, and Van Reenen (1999) method. Estimation period is 1991-1999 over 285 firms. The standard errors (in parenthesis) are clustered at the three-digit industry level in columns (3) - (6) and by firms in (1) and (2). ***,**,* are significance at 1%, 5% and 10% levels, respectively.

Aghion et al.(2013) as a robustness exercise use unweighted patent counts as a dependent variable.We use the raw patent count from their dataset and repeat the some of the specifications used in Tables 2 and 3. We include firm fixed effects using the pre-sample mean scaling estimator based on raw patents. Table 4 reports the results. Column (1) and Column (2) shows the baseline regression with the usual controls. The results for columns (3)-(6)where we include competition are qualitatively similar to the corresponding columns in Table 3[9].

6. Conclusions

One possible explanation for the variation in innovations across firms in similar industries can be found in terms of the relationship between the type of governance structure and the extent of innovative activities. Our paper has made an attempt to explore this relationship with a simple theoretical model as well as an empirical investigation. The model provides support to the two widely used models of governance; the "lazy manager hypothesis" which posits that the managers prefer

[9]We also ran Poisson regressions with additional controls such as Tobin's q as well as used OLS (we used natural log of future cite weighted patents as the dependent variable)in base regressions. Our main results and significance remained unchanged. We do not report the results for brevity but they can be obtained from the author's upon request.

a *quiet* life and with shareholders having more power will force the managers to to innovate, and the "career concerns model" where managers try to avoid innovation due to concerns about their future earnings when the risk of failure is high such as in high competition. Our model predicts that corporate governance is a decisive factor for innovation efforts by a manager especially in industries where product market competition in low. This is possibly because highly competitive industries preclude the need for additional monitoring provided by the governance as the manager is disciplined by the threat of bankruptcy or take-over to work hard. Our empirical results strongly support most of our model's predictions. The relationship between the G-index and innovation is robust when firms belong to relatively less competitive industries. However, we find only weak evidence of this managerial behavior in highly competitive industries.

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APPENDIX

We consider a general model where the set of managerial abilities containing $m(\geq 2)$ many elements, denoted by $\Theta = \{\theta_1, \cdots, \theta_m\}$. Put,

$$\Omega := \Theta \times \{0,1\} = \{(\theta_i, j) : 1 \leq i \leq m, j = 0, 1\},$$

where $\theta_m \succ \cdots \succ \theta_1$. As in Section 2, let $(\Omega, \mathscr{F}, \mathbb{P}_c)$ be a probability space and $\mathbb{P}_c(\theta_i) = \frac{1}{m}$ for all $1 \leq i \leq m$. Thus,

$$\mathbb{P}_c(\theta_i, 1) = \mathbb{P}_c(1|\theta_i)\mathbb{P}_c(\theta_i) = \frac{p_i(c)}{m} \text{ and } \mathbb{P}_c(\theta_i, 0) = \mathbb{P}_c(0|\theta_i)\mathbb{P}_c(\theta_i) = \frac{1 - p_i(c)}{m}.$$

Assume that $f : \theta \to \mathbb{R}_+$ denote the income function of the manager in S_1 such that

$$f(\theta_m) \geq \cdots \geq f(\theta_1) \text{ and } f(\theta_m) > f(\theta_1).$$

Consequently, the probabilities of success and failure of an innovation are given by

$$\mathbb{P}_c(1) = \sum_{i=1}^{m} \mathbb{P}_c(\theta_i, 1) = \frac{1}{m}\sum_{i=1}^{m} p_i(c) \text{ and } \mathbb{P}_c(0) = 1 - \frac{1}{m}\sum_{i=1}^{m} p_i(c),$$

respectively. Hence,

$$\mathbb{P}_c(\theta_i|1) = \frac{\mathbb{P}_c(\theta_i, 1)}{\mathbb{P}_c(1)} = \frac{p_i(c)}{\sum_{i=1}^{m} p_i(c)} \text{ and } \mathbb{P}_c(\theta_i|0) = \frac{\mathbb{P}_c(\theta_i, 0)}{\mathbb{P}_c(0)} = \frac{1 - p_i(c)}{m - \sum_{i=1}^{m} p_i(c)}.$$

Manager's income in the second period in S_1 for success and failure of innovation in the first period are

$$\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f) = \sum_{i=1}^{m} f(\theta_i)\mathbb{P}_c(\theta_i|1) = \frac{\sum_{i=1}^{m} f(\theta_i)p_i(c)}{\sum_{i=1}^{m} p_i(c)}$$

and

$$\mathbb{E}^{\mathbb{P}_c(\cdot|0)}(f) = \sum_{i=1}^{m} f(\theta_i)\mathbb{P}_c(\theta_i|0) = \frac{\sum_{i=1}^{m} f(\theta_i)(1 - p_i(c))}{m - \sum_{i=1}^{m} p_i(c)}.$$

Her income in the second period in S_1 for no innovation effort is given by

$$\mathbb{E}^{\mathbb{P}_c}(f) = \sum_{i=1}^{m} f(\theta_i)\mathbb{P}_c(\theta_i) = \frac{1}{m}\sum_{i=1}^{m} f(\theta_i).$$

We now present the relationship among the above three income levels.

Theorem 6.1. $\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f) > \mathbb{E}^{\mathbb{P}_c}(f) > \mathbb{E}^{\mathbb{P}_c(\cdot|0)}(f)$.

Proof. Obviously,

$$\mathbb{E}^{\mathbb{P}_c(\cdot|1)}(f) > \mathbb{E}^{\mathbb{P}_c}(f) \Leftrightarrow m\sum_{i=1}^{m} f(\theta_i)p_i(c) > \sum_{i=1}^{m} f(\theta_i)\sum_{i=1}^{m} p_i(c)$$

and

$$\mathbb{E}^{\mathbb{P}_c}(f) > \mathbb{E}^{\mathbb{P}_c(\cdot|0)}(f) \Leftrightarrow m\sum_{i=1}^{m} f(\theta_i)p_i(c) > \sum_{i=1}^{m} f(\theta_i)\sum_{i=1}^{m} p_i(c).$$

Thus, it only remains to prove that

$$m\sum_{i=1}^{m} f(\theta_i)p_i(c) > \sum_{i=1}^{m} f(\theta_i)\sum_{i=1}^{m} p_i(c). \tag{6.1}$$

We prove the inequality (6.1) by mathematical induction. If $m = 2$ then $f(\theta_2) > f(\theta_1)$. Using $(p_2(c) - p_1(c))(f(\theta_2) - f(\theta_1)) > 0$, it can be verified that

$$2\sum_{i=1}^{2} f(\theta_i)p_i(c) > \sum_{i=1}^{2} f(\theta_i)\sum_{i=1}^{2} p_i(c).$$

Thus, (6.1) is true for $m = 2$. Assume that (6.1) holds for $m = k \geq 2$. We now show that it is true for $m = k + 1$. Since $f(\theta_{k+1}) > f(\theta_1)$, at least one of the inequalities in $f(\theta_{k+1}) \geq \cdots \geq f(\theta_1)$ must be strict. Let $1 \leq k_0 \leq k$ be the largest integer such that $f(\theta_{k_0+1}) > f(\theta_{k_0})$. The rest of the proof is decomposed into two cases.

Case 1. $k_0 = k$. Then

$$\sum_{i=1}^{k+1} f(\theta_i)\sum_{i=1}^{k+1} p_i(c) = \left(\sum_{i=2}^{k+1} f(\theta_i) + f(\theta_1)\right)\left(\sum_{i=2}^{k+1} p_i(c) + p_1(c)\right)$$

By induction hypothesis, since $f(\theta_{k+1}) > f(\theta_2)$, one has

$$k\sum_{i=2}^{k+1} f(\theta_i)p_i(c) > \sum_{i=2}^{k+1} f(\theta_i)\sum_{i=2}^{k+1} p_i(c).$$

Since $f(\theta_1) \leq f(\theta_i)$ for all $2 \leq i \leq k+1$, one concludes

$$\sum_{i=2}^{k+1}(p_i(c) - p_1(c))f(\theta_1) \leq \sum_{i=2}^{k+1}(p_i(c) - p_1(c))f(\theta_i).$$

This implies that

$$f(\theta_1)\sum_{i=2}^{k+1} p_i(c) + p_1(c)\sum_{i=2}^{k+1} f(\theta_i) \leq \sum_{i=2}^{k+1} f(\theta_i)p_i(c) + kf(\theta_1)p_1(c).$$

Thus,

$$\sum_{i=1}^{k+1} f(\theta_i)\sum_{i=1}^{k+1} p_i(c) < (k+1)\sum_{i=2}^{k+1} f(\theta_i)p_i(c) + (k+1)f(\theta_1)p_1(c).$$

Hence,

$$\sum_{i=1}^{k+1} f(\theta_i)\sum_{i=1}^{k+1} p_i(c) < (k+1)\sum_{i=1}^{k+1} f(\theta_i)p_i(c)$$

and thus, (6.1) is true for $m = k + 1$.

Case 2. $k_0 \neq k$. Applying an argument similar to that in *Case 1* with the fact that $f(\theta_k) > f(\theta_1)$, $f(\theta_{k+1}) \geq f(\theta_i)$ for all $1 \leq i \leq k$ and

$$\sum_{i=1}^{k+1} f(\theta_i)\sum_{i=1}^{k+1} p_i(c) = \left(\sum_{i=1}^{k} f(\theta_i) + f(\theta_{k+1})\right)\left(\sum_{i=1}^{k} p_i(c) + p_{k+1}(c)\right),$$

one can verify that (6.1) is true for $m = k + 1$.

By the principle of mathematical induction, it follows from *Case 1* and *Case 2* that (6.1) holds for all integer $m \geq 2$. $\square$

Analogous to our main result, it can be shown that for a model with $m(\geq 2)$ many abilities, the number of innovation decisions is high under the democratic governance structure and lower market competition.

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