Incentives for Innovation: Bankruptcy, Corporate Governance, and Compensation Systems*

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1 Introduction

Across all of the social sciences, researchers often model the innovation process as the cumulative, interactive recombination of existing bits of knowledge in novel ways to improve over existing ways of doing things (Schumpeter (1934), Weitzman (1998)). But how do these novel recombinations that generate innovation come about? One view is that from time to time inventors, either by luck or talent, stumble upon new combinations that are superior to conventional ways of doing things. Of course, if luck and talent are all that is needed for innovation, then much of the innovation process is essentially uncontrollable and there is little that economists could contribute to the debate.

However, an extensive literature in economics and finance argues that the intensity and direction of people's innovative activities are influenced by incentives in the form of laws, institutions, customs, regulations, and compensation systems. In this chapter, we describe and discuss some of the theoretical and empirical contributions to this literature. Our focus is primarily on papers that study the problem from an optimal contracting perspective, and on applications to bankruptcy, corporate governance, and compensation systems.

The chapter is organized as follows. Section 2 discusses the literature on incentive problems in economics with a particular emphasis on incentives for innovation, and relates the main results to some of the findings of the psychology literature on this topic. Section 3 discusses applications of these ideas to bankruptcy laws, corporate governance, and compensation systems. Finally, in Section 4 we present concluding remarks and directions for future research.

*The focus of this chapter is by its very nature limited in its scope and, inevitably, we have left out many important papers. We apologize to those who feel that their research has been ignored or misrepresented.

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2 Foundations

This section reviews the literature on incentive problems in economics, in particular as they concern incentives for innovation and tasks that require more inputs than simple effort provision. We discuss the main results of this literature in light of the experimental literature in psychology and economics on incentives and innovation.

2.1 Economics of Incentives

Economists have long studied incentive problems under asymmetric information and have shown that a problem of moral hazard may arise.[1] The canonical model used to study these incentive problems is a principal-agent relationship in which the agent provides a productive input (e.g., effort) that cannot be observed by the principal directly. This approach has proved very successful both for theoretical analysis and empirical applications and has also strongly influenced corporate and public policy.

At a very basic level this strand of research argues that rewarding an agent more strongly for his performance induces the agent to exert more effort thereby improving productivity. For example, in dynamic principal-agent models of repeated effort, such as Rogerson (1985), Holmstrom and Milgrom (1987) and Sannikov (2008), incentive contracts that do not reward high output throughout all periods will lead to lower effort provision and hence lower output in times when an agent's reward is not tied to his performance. There is ample data supporting the thesis of a direct positive link between incentives and productivity. This evidence comes from a variety of studies including quasi-experimental data as well as laboratory and field experiments investigating the effect of financial incentives on effort exertion and performance in simple routine tasks, in which effort is the main determinant of productivity. In a study of agricultural workers in the Philippines, Foster and Rosenzweig (1994) show that conditional on calory intake, workers on piece-rates lose more weight than workers on fixed salaries thus suggesting that they exerted more effort when working on the job. Such increased effort provision should also have repercussions for performance. For example, Lazear (2000) shows that the productivity of windshield installers in Safelite Glass Corporation increased when management changed their compensation from fixed wages to piece-rate pay. Shearer (2004) finds similar evidence in a randomized field experiment with Canadian tree planters while Ehrenberg and Bognanno (1990) document increased performance for professional golf players when monetary incentives are higher. Dickinson (1999) shows that subjects in a controlled laboratory experiment type more letters when their compensation is more sensitive to performance.

These theoretical models and empirical studies primarily focus on settings where the only tension in the principal-agent relationship arises from the agent's decision to either work or shirk and where effort is the sole determinant of output and productivity. While this common modeling assumption may be a good fit for routine tasks, it appears considerably less compelling when workers are confronted with creative, open-ended problems

that require innovative solutions.

Early principal-agent models that attempt to capture this tension between several competing work aspects, therefore study settings in which the action choices of the agent are not solely limited to the level of effort. Lambert (1986) analyzes the provision of incentives when the agent expends effort to generate information about project profitability and selects among several risky projects. The conflict of interest between principal and agent about which project to select can result in under- or overinvestment in risky projects. Holmstrom and Milgrom (1991) develop a multi-task principal- agent model in which the agent allocates effort among multiple tasks and the principal observes a performance measure for each of these tasks. In particular, they show that paying fixed wages can be optimal to prevent agents from shifting their entire effort to tasks where output can be easily measured and highly rewarded. Dewatripont and Maskin (1995) and Von Thadden (1995) analyze incentives for the agent to select between short-term and long-term investments.

2.2 Incentives for Innovation

There are two noteworthy early contributions that explicitly study the provision of incentives for innovation from an organizational perspective. Holmstrom (1989) proposes an explanation for why incentives schemes that motivate innovation must exhibit tolerance for failures. He argues that performance measures for innovative activities are noisier, and that therefore in order to motivate innovation the principal should rely on compensation schemes that are less sensitive to performance. In the same vein, Aghion and Tirole (1994) argue that the outcomes of innovation activities are unpredictable and, therefore, hard to contract ex ante. In an incomplete contract framework, they derive the optimal allocation of control rights that motivates innovation. These papers focus on measurability and contractability aspects of the innovation activity. Related to this approach are two more recent papers by Hellmann (2007) and Hellmann and Thiele (2008). The authors also study incentives for innovation using a multi-task principal-agent model in which contracts are left incomplete.

In all of these models, however, the agent does not learn about the distribution of payoffs, a feature that is central to the process of exploration. Moreover, the agent takes an action in the first period and cannot change it later on. Therefore, these models do not incorporate experimentation, learning, and adaptation, all of which are important features of innovation.

Yet, there is no shortage of theoretical contributions that model the innovation process explicitly and focus on the central trade-off that arises in innovation activities, the trade-off between exploration and exploitation. This model of the innovation process follows a long tradition in the study of innovation. Schumpeter (1934) argues that innovation results from the experimentation with new combinations of existing resources. Arrow (1969) associates innovation with the production of knowledge and proposes the use of Bayesian decision models to study innovation. Bandit problems are Bayesian decision

models that allow for knowledge acquisition through experimentation. Weitzman (1979) applies a simple bandit problem to study the innovation process and March (1991) is the first to use the terms exploration and exploitation to describe the fundamental tension that arises in learning through experimentation. The literature in industrial organization, including Roberts and Weitzman (1981), Jensen (1981), Battacharya, Chatterjee, and Samuelson (1986), and Moscarini and Smith (2001), has relied extensively on bandit problems and related models of learning through experimentation to study the innovation process. Also, recent papers on growth theory, such as Jovanovic and Rob (1990), Jovanovic and Nyarko (1996) and Aghion (2002), develop quite detailed models of innovation as the result of learning from the exploration of new technologies.

Following this approach, a number of models have been developed that apply Bayesian decision models to study the interplay of incentives and innovation. Bolton and Harris (1999) study strategic experimentation in a setting where multiple players face the same experimentation problem. Each agent learns from the experimentation of the other players. Since information is a public good, there is free riding and under-experimentation in equilibrium. However, they assume that payoffs are exogenously given thus making their model less applicable to the study of innovation in organizational settings where the rewards are endogenously determined by the setting of wages. To study the financing of innovation, Bergemann and Hege (2005) develop a principal-agent model in which there is learning about the quality of the project and which allows for the endogenous determination of rewards. The tension between exploration and exploitation does not arise in their model though, as the agent can only choose one type of project. Moreover, their paper only considers implementation with a sequence of short-term contracts.[2]

Manso (2009) is the first to incorporate this tension between exploitation and exploration into a principal-agent model to study incentives for creativity and innovation. He shows that the optimal incentive scheme that motivates innovation exhibits substantial tolerance for early failure and reward for long-term success. Moreover, inefficient continuation may be optimal to induce exploration since the threat of termination may prevent the agent from exploring new untested approaches. Finally, commitment to a long-term compensation plan and timely feedback on performance are essential ingredients in inducing exploration. The institution of tenure, debtor-friendly bankruptcy laws, and golden parachutes are examples of schemes that protect the agent when failure occurs and thereby encourage exploration. Ederer (2009) extends the analysis to settings where several workers or teams explore new work methods in parallel. To prevent under-exploration that results as workers attempt to free-ride on the new ideas generated by co-workers, optimal incentives should tolerate early failure and provide workers with long-term group incentives for joint success.

As we shall see in the following sections, many of the theoretical results of the papers discussed here are in accordance with a large literature in psychology and a growing set of contributions in economics that also finds that a significant tolerance for early failure is vital in motivating agents to undertake innovation.

2.3 Experimental Research in Economics and Psychology

In the last decades, researchers in economics and psychology started to challenge the view that pay-for-performance has unambiguously positive effects on productivity by providing experimental evidence that pay-for-performance may actually undermine performance, especially for tasks that require creativity and exploration.

Amongst the earliest contributions in the psychology literature on the interplay between incentives and innovation is Glucksberg (1962) who asked subjects to mount a candle on a vertical screen, using only the screen, the candle, a book of matches, and a box of thumbtacks. To solve the problem, subjects had to ascertain that they could use the box of thumbtacks not only as a container but also as a platform for the candle. Perhaps surprisingly, subjects who were offered no reward solved the problem significantly faster than subjects who were offered rewards.

McCullers (1978), McGraw (1978), Kohn (1993) and Amabile (1996) survey subsequent research, which replicated the findings of Glucksberg (1962) for different tasks. The main conclusion of this line of research is that pay-for-performance improves performance in tasks that require simple, routine, unchanging responses, but can undermine performance in tasks that require flexibility, conceptual and perceptual openness, and creativity. Paying the agent in terms of current performance may make the agent inclined to exploit, because the agent thinks that the likelihood of success with a conventional work method is higher than the likelihood of success with a new work method. However, if the task requires exploration, such as the task in Glucksberg's experiment, then pay-for-performance may undermine performance, as pay-for-performance induces the agent to exploit and not to explore.

There are a number of papers in economics that have found that pay-for-performance does not always increase performance. Most recently, Ederer and Manso (2009) show in a controlled laboratory experiment that compensation schemes that tolerate early failure and reward long-term success encourage innovation. Subjects under such an incentive scheme explore more and are more likely to discover a novel business strategy than subjects under fixed-wage and standard pay-for-performance incentive schemes. The threat of termination can undermine incentives for innovation, while golden parachutes can alleviate these innovation-reducing effects. These results suggest that appropriately designed incentives are useful in motivating creativity and innovation. They also indicate that experimentation and learning should be taken into account when designing compensation schemes for innovative tasks.[3]

As we shall see in the next section, the results of this relatively new literature on innovation and incentives are not limited to abstract theoretical models and experimental laboratory settings, but can be applied to a variety of real-world settings.

3 Applications

In this section we discuss how the central insights of the theoretical and experimental literature on incentives for innovation have been fruitfully applied to bankruptcy laws, executive compensation and corporate governance, and the management of knowledge workers.

3.1 Bankruptcy

Early bankruptcy laws dictated a severe treatment towards insolvent debtors.[4] For example, the ancient Roman law determined that insolvent debtors became slaves of the creditor, who could either sell or kill them. Britain's first bankruptcy laws, passed in 1542 and 1570, determined that insolvent debtors could go to prison, or have an ear cut off while attached to a pillory in a public place. Given the dangers of going bankrupt in these societies, it is unlikely that entrepreneurs borrowed money to pursue exploratory projects.

Today, the treatment towards insolvent debtors is less severe. However, bankruptcy laws are still the subject of controversy as evidenced by a recent debate involving bankruptcy laws in Europe and in the United States. In response to a widening of the productivity gap between the United States and Europe and a broad consensus that entrepreneurship is a major driver of innovation, competitiveness, and growth, the European Union is investigating why it is failing to take full advantage of its entrepreneurial potential. In a recent survey, Europeans and Americans were asked if they agree with the statement "one should not start a business if there is a risk it might fail."[5] While 50% of the Europeans respondents agree with the statement, only 33% of their American counterparts do so. To better understand the reasons for this difference, the survey investigates the most feared risks by Europeans and Americans when starting a new business. The main concerns Europeans have when they start their own business are the risk of losing their property and the possibility of going bankrupt. In contrast, Americans' main concern is the uncertainty of their income. These differences are not surprising since European bankruptcy laws are tougher towards debtors than American bankruptcy laws.

To attack this problem, the European Council issued the European Charter for Small Enterprises.[6] The Charter states that

> ... failure is concomitant with responsible initiative and risk-taking and must be mainly envisaged as a learning opportunity.

The Charter declares that bankruptcy law reforms should become a clear priority for the Member States and that new bankruptcy laws should allow failed entrepreneurs a fresh start.

For the past two centuries, American bankruptcy laws have been known for their tolerance toward insolvent debtors.[7] However, more recently, after eight years of discussion, the U.S. Congress passed a new creditor-friendly bankruptcy law,[8] which makes it more

difficult for insolvent debtors to obtain exemptions and discharge obligations. The main objective of the law is to hold Americans more responsible for paying off their personal debt. Since many entrepreneurs finance their startups with personal debt, the recently passed law may have unintended consequences for entrepreneurship.

There is a large literature on the design of bankruptcy laws. Based on standard models of incentives Jensen (1991) and Aghion, Hart, and Moore (1992) are strong proponents of bankruptcy laws that respect the absolute priority of claims. Other papers have found beneficial effects of deviations from absolute priority. For example, Bebchuk and Picker (1993), and Berkovitch, Israel, and Zender (1997, 1998) show that deviations from absolute priority may encourage investments in firm-specific versus general human capital. Baird (1991), Heinkel and Zechner (1993), Povel (1999), and Berkovitch and Israel (1998, 1999) show that deviations of absolute priority induce the entrepreneur to reveal private information to creditors.

Recent models in the theory of incentives and innovation provide a framework for analyzing the incentive effects of different bankruptcy laws. If the entrepreneur borrows money to undertake some project and the project fails, then the entrepreneur will not have the funds to pay his debts and will be insolvent. As mentioned before, in the model of Manso (2009) the optimal contracts that motivate exploration and exploitation are quite different in the way they treat insolvent debtors. In particular, the optimal contract that motivates exploration rewards the agent after early failure. One can interpret this as a bankruptcy law based on the principle of a fresh start. The bankruptcy law based on the principle of fresh start provides the entrepreneur with generous exemptions and an immediate full discharge of debt, so that the entrepreneur earns an extra surplus after early failure. By protecting the entrepreneur against early failure, these bankruptcy laws make the entrepreneur more inclined to explore. On the other hand, the optimal contract that implements exploitation does not reward the agent after failure. We interpret this as a bankruptcy law based on the principle of absolute priority. The creditor seizes the goods owned by the entrepreneur and discharge takes several years. The creditor may allow the entrepreneur to keep working after default if it is still profitable to do so, but the entrepreneur earns just enough money so that he does not shirk.

The model of Manso (2009) thus prescribes different bankruptcy laws depending on whether the objective is to encourage exploration or exploitation. To motivate exploration, a bankruptcy law that is based on the principle of fresh start is optimal, while to motivate exploitation, a bankruptcy law that is based on the principle of absolute priority is optimal. Why then is a single bankruptcy law mandatory? Schwartz (1997) and Povel (1999) study this question and conclude that it is inefficient to have a single mandatory bankruptcy law.

By considering the incentives for exploration, the recent literature on incentives for innovation provides an explanation for this puzzle. Nelson (1959) argues that exploration cannot fully appropriate the economic value it generates due to knowledge spillovers and imperfect intellectual-property-rights (IPR) protection. This leads to under-exploration

when compared to the socially efficient level of exploration. To alleviate the under-exploration problem, governments should offer debtor-friendly bankruptcy laws instead of a menu of bankruptcy laws. Debtor-friendly bankruptcy laws reward failure and therefore induce exploration.

Thus, according to these theoretical models social gains could be made from a bankruptcy law based on the principle of fresh start. By protecting entrepreneurs against failures, the bankruptcy law based on the principle of a fresh start encourages exploration, generating knowledge that may benefit society.

Recently, several papers have provided fresh evidence and support for the importance of lenient bankruptcy laws in spurring innovation. Most notably, Acharya and Subramanian (2009) analyze the effect of bankruptcy laws on entrepreneurship using time-series changes within a country and cross-country variation in creditor rights. They find that when a country's bankruptcy code is creditor-friendly, excessive liquidations cause levered firms to shun innovation, whereas by promoting continuation upon failure, a debtor-friendly code induces greater innovation. Employing patent filings and patent citations as proxies for innovation, they show that a creditor-friendly code leads to a lower absolute level of innovation by firms. In particular, countries that underwent a creditor rights increase (decrease) generated 9.7% less (10.7% more) patents, 13.3% less (15.4% more) citations to these patents, and 8.4% less (9.2% more) patenting firms. Furthermore, their results suggest a causal interpretation since the decrease in patent filings and citations following a strengthening of creditor rights is particularly more pronounced in technologically innovative industries. Finally, Acharya and Subramanian (2009) also provide evidence on how the strengthening in creditor rights influences the innovation activity. In response to stronger creditor rights, innovative industries take on relatively less leverage compared to other industries and also grow disproportionately more slowly.

3.2 CEO Compensation and Corporate Governance

Top executive compensation is routinely criticized by the press, investors, government agencies and academics as excessive and not related to performance. This public outcry creates pressure for regulations that limit stock options, golden parachutes, entrenchment, and option repricing.[9]

In an article on the state of U.S. corporate governance, Holmstrom and Kaplan (2003) point to the risk of a regulatory overreaction by stating that

> ... an effort to regulate the system so that such outrage will never again occur would be overly costly and counterproductive. It would lead to inflexibility and fear of experimentation. In today's uncertain climate, we probably need more organizational experimentation than ever. The New Economy is moving forward and, in order to exploit the potential efficiencies inherent in the new information technologies, new business models and new organizational structures are likely to be desirable and valuable. Enron was an

> experiment that failed. We should take advantage of its lessons not by withdrawing into a shell, but rather by improving control structures and corporate governance so that other promising experiments can be undertaken.

In light of the recent outcry against common features of executive compensation and such cautious remarks about their immediate regulation it is natural to ask what would be the best way of motivating managers to undertake experimentation and innovation.

There are a number of notable contributions that develop static principal-agent models to analyze how to provide incentives for managers to undertake risky investments including Lambert (1986), Feltham and Wu (2001) and Lambert and Larcker (2004)). These studies find that the optimal contract that encourages risk-taking is convex, resembling a stock option. Indeed, as we shall see the use of stock options is particularly widespread in innovation-intensive industries that rely on experimentation.

In addition, optimal executive contracts are shown to include golden parachutes, entrenchment, or option repricing, in particular in theoretical models that involve situations where an agent's incentives need to be realigned after a bad outcome. In a setting in which the manager observes a private signal about the future prospects of the firm, Inderst and Mueller (2006) show that stock options and golden parachutes may be optimal to induce the manager to reveal information to the board after bad outcomes. In a similar vein, Acharya, John, and Sundaram (2000) find that option repricing can be optimal because it motivates the agent to exert effort after poor performance when the only instruments available to the principal are at-the-money call options. Finally, employing an incomplete contracting framework, Almazan and Suarez (2003) show that a contract consisting of a bonus and severance pay may be optimal to induce the incumbent manager to invest in firm-specific human capital when there is the threat that a better rival manager will become available.[10]

Manso (2009) explicitly analyzes incentive contracts that encourage exploration and shows that the optimal contract for exploration (with termination) can be implemented by a combination of stock options, option repricing, golden parachutes, and entrenchment. This optimal contract motivates exploration through stock options maturing in the long term and golden parachutes to be paid upon termination. The role of golden parachutes is to protect the agent against early failure. The optimal contract that encourages exploration can also be implemented by granting the agent a stock option that matures in the long term and by repricing the option in case of early failure. The role of repricing is not just to induce the agent to work in the long term after an early failure, but also to induce the agent to explore early on by protecting the agent against early failures. Finally, inefficient continuation is sometimes optimal when the manager is supposed to engage in exploratory activity. This feature is akin to the often observed phenomenon of entrenchment, since the manager may keep his job even though it is ex-post optimal for the firm to terminate the work relationship with the manager. An entrenched manager is protected against early failures and is more likely to explore new business strategies. These results suggest that regulations that limit the use of stock options, option repricing,

golden parachutes, and entrenchment may just make it harder to implement exploration, and can potentially have adverse effects on innovation and long-term growth.

Rayo, Sapra, and Diaz Sr. (2009) also note that insider protection in the form of the transfer of control rights over a sale decision to insiders can be desirable when the firm's objective is to innovate. In their model, insider protection such as poison pills, golden parachutes, and managerial entrenchment can arise endogenously as an optimal contracting device to induce insiders to carry out innovative projects that have a high risk/high return and generate high information asymmetry between insiders and external shareholders.

The theoretical models naturally give rise to cross-sectional predictions about managerial compensation. For example, firms operating in industries with higher innovation rates should use more stock options, option repricing, golden parachutes, and entrenchment, since they are more likely to be pursuing exploration. There is indeed empirical evidence that high technology firms use more stock options and option repricing than traditional firms. Ittner, Lambert, and Larcker (2003) find that the media CEO in high technology "new economy firms" receives 86.9% of compensation from stock options and restricted stock, versus only 19.3% in large "old economy firms." Guay (1999) shows that firms with greater growth opportunities provide more option-like incentives in the form of convex compensation. Carter and Lynch (2001) and Ittner, Lambert, and Larcker (2003) find that option repricing is substantially more common in high technology "new economy firms" than in large "old economy" firms. Using compensation data from 237 firms in the high-technology industry, Yanadori and Marler (2006) find that greater emphasis on innovation activities is positively associated with a greater reliance on long-term incentives and longer stock option vesting period lengths. Similarly, Lerner and Wulf (2007) show that long-term incentives to the heads of research and development departments are associated with more heavily cited patents, while short-term incentives are unrelated to measures of innovation.

However, innovation activity is also influenced by aspects of corporate governance other than compensation contracts, such as takeover pressure and monitoring intensity. Sapra, Subramanian, and Subramanian (2008) develop a theory of the effects of external corporate governance mechanisms and internal mechanisms on innovation. Most importantly, they show that innovation varies non-monotonically in a U-shaped manner with takeover pressure and that innovation increases with monitoring intensity. Using the variation created by the sequential passage of anti-takeover laws across different states they also find empirical support for their predictions. They conclude that either a completely unhindered market for corporate control or severe anti-takeover laws are best at fostering innovation.

Atanassov (2007) explores a related question by examining how strong corporate governance, as proxied by the threat of hostile takeovers, affects innovation. He uses the enactment of state antitakeover laws as an exogenous decrease in the threat of hostile takeovers and finds that stronger antitakeover laws lead to fewer patents and patent cita-

tions and that the presence of alternative governance mechanisms such as large shareholders, pension fund ownership, high financial leverage, as well as the presence of financial constraints mitigate this innovation-reducing effect.

In light of this theoretical and empirical evidence that provides both positive and normative evidence for the use of options, option repricing, golden parachutes, entrenchment, and corporate governance mechanisms when executives are encouraged to explore and innovate, it may be necessary to reconsider the introduction of strict limits on the use of such instruments, in particular in innovation-intensive industries. The adverse effects of these restrictions may end up blunting otherwise optimal incentives and stifling innovation.

3.3 Management of R & D Workers and Labor Laws

From the beginning of the twentieth century until the last few decades, scientific management (also known as "Taylorism") was the dominant model of management. Scientific management emphasizes centralized authority and ex ante optimization where the central authority plans and controls every detail of the production process. Because of this hierarchic form of planning and control, there is little scope for the worker to experiment with new work methods.

The last few decades, however, have seen a shift from scientific management towards more flexible forms of management. The new forms of management introduce a substantial degree of decentralization. Instead of ex ante optimization, the new forms of management rely on a continuous improvement approach in which workers are responsible for discovering new and better ways to do their jobs.

Naturally, this shift has been particularly pronounced in industries that rely on continuous improvement and innovation. As a result there has been a considerable change in the way R & D workers are managed. A large practical business management literature that provides an abundance of anecdotal evidence on how innovative corporations attempt and succeed in motivating innovation, bears witness to this change. There seems to be a developing consensus and a widespread wisdom among business consultants that tolerance for failure is important in motivating innovation and that incentives that reward agents for long-term success are particularly important in knowledge-intensive organizations, such as in firms that heavily rely on research and development. Sutton (2002), Farson and Keyes (2002) are among the several business books that defend the importance of a corporate culture that tolerates (or even rewards) failures and rewards long-term success to motivate innovation.

Considered to be one of the most innovative corporations, 3M is well-known for having a corporate culture that provides freedom to experiment, tolerance for failures, and rewards for successful innovations. William L. McKnight, who joined 3M in 1907 as an assistant bookkeeper and served as a chairman of the board from 1949 to 1966, crafted the management principles that are still in place. His basic rule of management was the following:[11]

> Mistakes will be made. But if a person is essentially right, the mistakes he or she makes are not as serious in the long run as the mistakes management will make if it undertakes to tell those in authority exactly how they must do their jobs. Management that is destructively critical when mistakes are made kills initiative. And it's essential that we have many people with initiative if we are to continue to grow.

In addition to providing freedom to experiment and tolerance for failures, 3M builds its reputation by celebrating its successful innovators. The invention of Post-it-Notes by Art Fry, a 3M employee, is one of its most famous stories. It was only twelve years after Fry conceived the idea that Post-it-Notes proved to be a huge success. Fry was then named a corporate scientist, the highest rung on the technical side of 3M, and became a legend in the corporation.

Another corporation that has relied on its culture to implement exploration is IBM. Bennis and Nanus (1997) discuss a well-known tale among IBM employees. According to legend, Thomas Watson, the founder of IBM, was once discussing a ten million dollar mistake one of his executives had just made. "I guess you want my resignation" said the executive. Watson replied, "You can't be serious. We have just spent ten million dollars educating you."

Innovative organizations also rely on explicit contracts to induce risk-taking and experimentation. For example, research departments in business or academic organizations often grant tenure to their senior employees. Job security makes these employees willing to take risks on new research directions that are likely to fail, but may lead to breakthroughs. Explicit contracts may also produce the long-term incentives that are needed to induce exploration. One way to provide long-term incentives through explicit contracts is to promise employees who develop successful new products a percentage of the resulting sales revenues. For example, in 1989, Applied Materials Inc. paid the physicist who led the team that developed an especially successful product more than $\$800,000$. The team-leading physicist ended up earning more than the corporation's chief executive officer.[12]

More recently, in addition to anecdotal evidence provided by popular business and management books there is also significant academic interest, both theoretically and empirically, in the management of R & D workers.

Manso (2009) shows that in addition to the tolerance for early failure, the provision of feedback to workers and ability to commit to a long-term contract is essential to encourage exploration. Modern corporations rely on corporate cultures and explicit contracts to overcome the commitment problem and encourage exploration. Promises made in the form of a corporate culture are often enforced through reputation.

In a similar vein, Ederer (2009) shows that incentives for innovation should also have a clear group component that rewards workers for long-term joint success. This normative finding has direct empirical implications for the compensation structure of R & D workers. Indeed, Harden, Kruse, and Blasi (2008) find that shared compensation systems such as

profit sharing, employee ownership, and broad-based stock option plans, are consistently positive predictors of both an innovation culture and a willingness to engage in innovative activity. Similarly, Tushman and O'Reilly (1997) argue that "individual-based awards may be less effective in promoting innovation than group-based recognition and rewards". Thus, various financial incentives that reward a large group of people for their long-term group performance are shown to go hand in hand with innovation.

A corporate culture that tolerates failure may indeed spur corporate innovation and increase firm value as shown by Tian and Wang (2009) who study a sample of venture capital (VC) backed IPO firms. Using a measure of VC investors' failure tolerance they find that IPO firms backed by more failure-tolerant VC investors are significantly more innovative, in particular in industries where innovation is more difficult to achieve, and that this increased innovation activity is also reflected by higher firm value. Interestingly, the authors also document that the failure tolerance effect persists long after VC investors exit the IPO firms, suggesting that tolerance is likely to have been internalized by the startup firms and become part of the firms' culture.

A firm's ability to innovate is also influenced by the competitive environment it operates in and by the failure tolerance of its shareholders. While Tian and Wang (2009) show that the type of investors is critical in fostering innovation within companies at an early stage, Aghion, Reenen, and Zingales (2008) document the interplay of competition and institutional ownership and its effect on innovation for more established public companies. Using inclusion in the S&P500 as an exogenous increase in the share of institutional owners they find that an increase in institutional ownership has a sizeable economic and statistically significant effect in the quantity and quality of innovation as measured by patents and patent citations. Their results further point toward the fact that career and risk concerns might be at the heart of this finding. By insulating the manager from being punished for innovation failures, institutional ownership is found to be particularly effective in more competitive product markets and when managers are less entrenched.

The same failure tolerance is also a driving force for innovation in organizational settings outside of the corporate world. Azoulay, Graff-Zivin, and Manso (2009) study incentives for innovation in the context of the funding of life sciences academic research. They compare the output of researchers under the two most important sources of funding in the life sciences: the National Institute of Health (NIH) R01 grants and the Howard Hughes Medical Institute (HHMI) Investigator Program. The HHMI Investigator Program stated goal is to "push the bounds of knowledge" in some of the most important areas of biological research. In order to achieve this goal, the HHMI program has adopted practices and rewards that according to Manso (2009) should provide strong incentives for breakthrough scientific discoveries: initial appointments typically last five years, there is a two-year phase-down upon non-renewal, the first review for reappointment is rather lax, but at the same time provides detailed feedback to the researcher. This evaluation policy stands in sharp contrast with the incentives faced by most life scientists funded by the NIH. The typical NIH RO1 grant cycle lasts only three years, funding is immediately

cancelled upon non-renewal, the review for reappointment is not as forgiving and does not provide much feedback to the researcher. Controlling for selection issues, the paper shows that HHMI-funded researchers are indeed more innovative than NIH-funded researchers as measured by publication and citation count and variability, prizes and awards, as well as a combination of successful keywords in published papers.

The results of the aforementioned papers further highlight that factors other than funding and compensation influence innovation activity. For example, Aghion, Reenen, and Zingales (2008) find that the positive relationship between innovation and institutional ownership is stronger when executives are more protected from hostile takeovers and they enjoy higher job security. Their finding hints at the fact that the legal system, in particular as it pertains to labor relations, can play a particularly important role in determining an organization's innovation performance. Acharya, Baghai-Wadji, and Subramanian (2009) examine this question in greater detail and argue that stringent labor laws can provide firms with an ex-ante commitment device not to punish employees' short-run failure. They show that an increase in the employee dismissal law index leads to an increase in the number of annual patents and subsequent citations in a patent class by 14.9% and 25.5% respectively. In addition, this innovation-fostering effect of stringent dismissal laws is more pronounced in more innovation-intensive sectors of the economy.

However, restrictive labor laws may also have a dark side. While Acharya, Baghai-Wadji, and Subramanian (2009) document a beneficial ex-ante effect of strict labor laws, there may also be adverse ex-post effects. Non-compete clauses are a particular feature of labor laws and their impact on innovation has received considerable attention in the public press and in academic research. Much of the debate centers around the claim that restrictive non-compete clauses decrease worker mobility, hinder the transfer of knowledge that is necessary in spurring innovation and impede the reallocation of resources towards firms with superior innovations. On the other hand, this decreased mobility and turnover may also act as a powerful incentive for firms to invest in their more easily retainable human capital.

Non-compete clauses are indeed very prevalent among technology companies whose most valuable assets consist of their highly mobile human capital. For example, Kaplan and Stromberg (2003) find that venture capital firms required 90 percent of the founders of the companies they financed to sign non-compete agreements. Among others, Gilson (1999) argues that Silicon Valley's entrepreneurial growth can be attributed to California's proscription of non-competes. Although their evidence does not allow a causal interpretation, Sorenson and Stuart (2003) document that more startups appear in regions that do not enforce non-competes. Using a formal model of innovation Fallick, Fleischman, and Rebitzer (2006) identify conditions where the innovation benefits of job-hopping exceed the costs from reduced incentives to invest in human capital and argue that these are more likely to hold for the computer industry. Consistent with their model they find higher rates of job-hopping for college-educated men in Silicon Valley's computer industry than in computer clusters located outside of California where non-compete

covenants are enforceable. Outside of the computer industry, California's mobility rates are no higher than elsewhere. Marx, Strumsky, and Fleming (2009) exploit Michigan's reversal of its non-compete enforcement policy as a natural experiment. In accordance with the previous papers they find that the enforcement of non-competes attenuates mobility and that non-compete enforcement decreases mobility more sharply for inventors with firm-specific skills and for those who specialize in narrow technical fields.

4 Concluding Remarks

Despite its recognized status as the engine of growth (Romer (1986) and Mokyr (2002)), much still needs to be learned about business practices and policies that encourage innovation. In addition to luck and talent, people's innovative activities are influenced by laws, institutions, customs, regulations, and compensation systems, whose design is fundamental to promoting growth. In this chapter we discussed several studies that contribute to our understanding of incentives for innovation, focusing on issues related to bankruptcy, corporate governance, and compensation systems.

Although the papers discussed here have enlightened our understanding of policies that promote innovation, more research on the topic is warranted. For example, current research only provides broad guidelines about how to structure incentives in different settings. Models that are able to quantify the impact of different policies in particular contexts would thus be extremely valuable in shaping management practices and economic policy in the future.

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Notes

[1]See for instance Arrow (1970), Zeckhauser (1970), Ross (1973), Pauly (1974), Mirrlees (1974), Harris and Raviv (1979), and Holmstrom (1979).

[2]Two other recent papers, Lewis and Ottaviani (2008) and Gerardi and Maestri (2008), study incentive problems with learning about some fundamental parameter of the model. Both papers are more closely related to Bergemann and Hege (2005) as there is no tension between exploration and exploitation.

[3]There are a few other papers that study the tension between exploitation and exploration in an experimental setting, including Meyer and Shi (1995) and Banks, Olson, and Porter (1997) who study bandit problems. Using a single-agent tournament game Merlo and Schotter (1999) find results that are in accordance with the beneficial effects of a tolerance for failure. They show that learning and performance are lower in a setting where subjects are learning while they receive compensation than in a setting where subjects are learning before they receive compensation.

[4]For discussions of early bankruptcy laws, see Levinthal (1917–1918) and Tabb (1995).

[5]Flash Eurobarometer 160: "Entrepreneurship", European Commission, June 2004.

[6]The "European Charter for Small Enterprises" was approved by European Union leaders at the Feira European Council on 19–20 June 2000.

[7]See, for example, Balleisen (2001) and Tabb (1995).

[8]"Bankruptcy Abuse and Consumer Protection Act," April 14, 2005.

[9]See, for example, Bebchuk and Fried (2004) and "Rewards for Failure," *British DTI Consultation*, June 2003. Edmans and Gabaix (2009) survey the recent literature on incentives that justifies the use of some of these instruments. In contrast to Bebchuk and Fried (2004)'s critique that CEOs are stealing from shareholders they argue that executive executive compensation is efficient.

[10]Rewards for failure are also advocated by the theoretical analysis of Simester and Zhang (2009) where compensation for failure is necessary to prevent managers from persisting with bad product ideas.

[11]See `http://solutions.3m.com/wps/portal/_l/en_US/_s.155/123521/_s.155/123521`.

[12]This example is discussed by Milgrom and Roberts (1992, pp. 399–400). The primary source is Valerie Rice, "Tying Pay to Sales Puts Inventor at the Top," San Jose Mercury News (July 16, 1990), D–1.