Essays on Financial Markets and Regulations

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by

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- To my parents -

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Abstract

Recent developments in the economics of information have revolutionized the way policy-makers think about how financial markets affect real economic activity. Many of the policy initiatives undertaken now are aimed at alleviating informational frictions in financial markets and ensuring financial stability. This thesis analyzes the effects of two distinct policy initiatives on the way financial markets function, and the resultant effects on real economic activity.

The first essay of this dissertation analyzes the effects of the 1979 amendment to the "prudent man rule" in the United States. This policy shift has spurred commitments to the venture capital industry, which has been associated with an explosion of innovation ever since. Nonetheless, a major chunk of innovation still occurs within large companies. To better understand the role of policy, I investigate the factors that determine when innovation is performed by VC-backed firms and when by large companies. To this end, I develop a novel theoretical framework in which development of new technologies and products requires the collaboration of researchers, executives, and suppliers of capital. I focus on the two-tier agency problem designed to provide simultaneously the right kinds of incentives for researchers and executives. I find that if capital markets function perfectly, it is optimal for innovation to be conducted by VC-backed firms: Specialization implicit in VC form of organization mitigates two-tier agency problems. If capital markets are sufficiently imperfect, however, it is optimal for innovation to be performed by large companies: they can use cheaper internal funds to finance innovation. The analysis suggests that the 1979 policy shift played a key role in improving financial markets which in turn has been responsible for a significant share of the surge in innovation.

The second essay examines the effect of the introduction of explicit deposit insurance on bank risk-taking using Korean bank data from 1994 through 2004. Estimating a fixed effects panel model by instrumental variable estimation as well as OLS, we find strong evidence that explicit deposit insurance increases bank risk-taking. We also find some evidence that risk-taking increases with (i) the extent of insurance coverage; and (ii) bank size. Our results are consistent with the strand of literature that emphasizes the moral hazard effects of deposit insurance.

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Chapter 1

Introduction

The effects of financial factors and markets on real economic activity has historically been a highly debated issue among economists. In the early post-World War II period, economists generally downplayed the importance of finance as an important determinant of real activity. As a result, it was commonplace in the profession to isolate real firm decisions from purely financial factors (such as leverage). The justification for this approach was in large part provided by the Modigliani-Miller capital structure irrelevance theorem which stated a firm's financial structure would not affect its market value in "frictionless" capital markets. Lacking a thorough understanding of these "frictions" (or imperfections), it was convenient -both theoretically and empirically- to abstract from financial considerations altogether.[1]

More recently, the controversy has not been so much about "whether" financial factors affect real economic activity but rather "how". That is, economists now largely agree that financial factors do indeed have important consequences for real activity, but there seems to be some controversy about

[1] Abstracting from capital market imperfections in economic modeling could also have been due to an inclination to view the U.S. capital markets as being relatively "frictionless".

the particular mechanism(s) through which this is supposed to happen. For example, there was a debate in the late 1980s and early 1990s about the implications of the then recent large increases in U.S. corporate debt. While some economists, such as Henry Kaufman (1986) and Benjamin Friedman (1986), argued that the build up of debt posed significant dangers which may lead to an epidemic of financial distress or to inflation when the next recession arises; others, such as Jensen (1988), argued that increased leverage is necessary to improve managerial performance and the efficiency of U.S. corporations.[2]

The change from "whether" to "how" financial factors are significant for real economic activity has come about largely as a result of improvements in our understanding of the nature of these frictions. In particular, breakthroughs in the economics of imperfect and asymmetric information (beginning with the seminal work of Akerlof (1970)) in the past three decades have made possible more rigorous theoretical analyses of capital market imperfections. As noted by Bernanke, Gertler, and Gilchrist (1999), it is now well-understood that asymmetries of information play a key role in borrower-lender relationships; that lending institutions and financial contracts take the forms they do in order to reduce the costs of gathering information and to mitigate principal-agent problems in credit markets; and that the common features of most of the diverse problems that can occur in credit markets is a worsening of informational asymmetries and increases in associated agency costs. Because credit-market crises (and less dramatic malfunctions) increase the real cost of extending credit and reduce the efficiency of the process of matching lenders and potential borrowers, these events may have widespread real effects. The implication was that seemingly purely financial factors such as the "creditworthiness" of borrowers or the "soundness" of banks may indeed have significant real consequences.

This shift in the understanding of the economic effects of financial factors has had implications

[2]See Bernanke and Gertler (1990) for more on this.

for government policy and regulations. In particular, policy-makers nowadays appear to believe more than ever that the introduction of policies and regulations that have the potential to ameliorate capital market frictions can improve the allocation and utilization of resources across space and time, thereby increasing economic efficiency.[3] Indeed, many of the policy initiatives undertaken in the U.S. (and in many other countries around the world) are aimed at this very goal. Of particular interest are the policy initiatives aimed at fostering innovation[4], as innovation is viewed by economists as being the main "engine" of economic growth. Examples of such policy initiatives include the reductions in capital gains taxes in the late 1970s and early 1980s, the establishment of small business investment funds during the same period, and, perhaps more prominently, the 1979 amendment to the so called "prudent man rule" governing pension fund investments.

In the next chapter of this thesis, titled "Corporate R&D, Venture Capital, and Capital Markets", I focus on one particular policy initiative -the 1979 amendment to the so called "prudent man rule" governing pension fund investments- in order to shed more light on the mechanisms through which it effects the allocation of resources, and more specifically, the effectiveness of innovative activities in the U.S.[5] I argue that one key effect of this policy shift has been to improve the functioning of U.S. capital markets, and that these improvements have made possible a greater number of positive

[3]Incidentally, policy-makers, somewhat unlike academic economists, appear to have always believed in the importance of financial factors, especially financial stability, for real economic activity. This seems to be motivated in large part by the experiences of Great Depression and earlier episodes of financial crises. As noted by Bernanke and Gertler (1990), preservation of financial stability has also been an important goal of monetary policy (as when the stock market crash of 1987 induced the Federal Reserve to supply extra liquidity) and fiscal policy (as in the "bailout" of Chrysler).

[4]The literature sometimes distinguishes between "discrete innovation" whereby improvements in products and processes are brought about as a result of R&D, and "continuous innovation" whereby improvements naturally occur as a by-product of learning-by-doing. See, for example, Solow (1997). In this thesis, innovation refers to "discrete innovation".

[5]Previous work on this topic include Gompers and Lerner (1998) and Poterba (1989).

net present value innovative projects to find financing, thereby increasing efficiency. The change has also allowed greater specialization in innovative activities by shifting part of R&D away from established, large companies to young, specialized ones. An important finding in the chapter is that, under certain conditions, specialization in research environments can be efficiency improving. In particular, I show that if capital markets are sufficiently perfect (to be defined momentarily), then specialization in innovative activities is optimal; and that if capital markets are not sufficiently perfect, then it is not. The degree of perfection of capital markets refers to the degree of ease (i.e. cost) with which specialized research firms can find (external) financing for their activities. Thus, if capital markets are sufficiently perfect, then it is sufficiently easy for such firms to raise funds from external sources. To understand this result, the chapter carefully analyzes the costs and benefits of specialization in research environments.

The first part of the chapter is devoted to the analysis of benefits of specialization in research environments. The main result of this first part of the chapter is that specialization in research environments can be valuable as it has the potential to alleviate (if not eliminate) multi-level agency problems (stemming from informational asymmetries) that commonly characterize these environments. Differently from the existing literature on the topic[6], the multi-level agency problems encountered in many research environments is given special attention. Multi-level agency relationships are indeed quite prevalent in research environments. In most situations, there is at least three parties to a given transaction: those who provide funds (investors), those who are responsible for using those funds on behalf of the investors (e.g. executives of financial and industrial companies), and those who do the actual work (scientists, production engineers, etc.). The key problem is that once investors have provided funds, executives, scientists/engineers, or both may have access to some critical information that benefit themselves while at the same time hurting investors. For example, investors may not

[6]Previous work on this topic includes, among others, Rotemberg and Saloner (1994).

be able to tell whether the executives are "working hard" in hiring talented scientists and engineers, or whether employed scientists are working hard to generate new inventions. In the absence of mechanisms that alleviate these multi-level informational concerns, investors will be less willing to supply their capital, causing many profitable businesses to go unfunded. It is argued in the chapter that specialization is one such mechanism. Specifically, when an executive is responsible for many different activities at the same time (as would be in a large firm), it is more difficult for investors to ensure that both the executives and their subordinates are doing a good job. Specialization reduces the extent of information asymmetries between the investors on one hand, and the executives and scientists/engineers on the other, by making performance measurement easier.

The second part of Chapter 2 then analyzes the costs of specialization in research environments. It is argued that the main cost of specialization in research is that this makes a firm dependent on external capital markets, and this dependence may increase the cost of funds to these firms. There is a variety of factors that make it more difficult for specialized research firms to raise funds from external sources. First, specialized research ventures are typically surrounded by substantial uncertainty concerning their potential outcomes. Second, insiders of such firms typically possess critical information that cannot be observed or verified by suppliers of capital (outsiders). It is well-known that in the presence of informational asymmetries, the informationally disadvantaged party may find it less appealing to transact with the other party, as this exposes them to potential manipulation by the latter. Third, most of the assets of a research venture is intangible and hence cannot be used as collateral. All of these issues potentially reduce the willingness of suppliers of capital to provide financing to research enterprises. In extreme situations, these problems may even cause credit-rationing (Stiglitz and Weiss, 1981).

The situation is very different for large firms. First, their built-up reputation and ability to offer physical collateral makes it easier for them to secure external funds. Second, even when rasing external funds is difficult, large firms can rely on internally generated earnings, and this makes them less dependent on external funds. This implies that large firms are less affected by adverse conditions that may characterize markets for financial capital. That is, while viability of young, specialized research firms depend critically on the existence of a well-functioning capital market, large firms may be able to survive even in the absence of such a market. Therefore, an important prediction of the model is that we should observe the dominance of established large corporations in innovation when capital markets are sufficiently imperfect, but this dominance should fade out as capital markets improve.[7] This prediction of the model is in line with the empirical finding of Rajan and Zingales (1998) who show, in a cross-section of countries in the 1980s, that the growth in the number of new establishments is significantly higher in industries dependent on external finance when the economy is financially developed.

Finally, a few words must be said about how the above story relates to the 1979 policy shift. Before doing this, however, it is helpful to provide a little background information on this policy change. Prior to 1979, the Employee Retirement Income Security Act (ERISA) obstructed pension fund investment in high-risk start-up ventures (young, specialized firms), as investments in such ventures were deemed to be "imprudent". The Department of Labor's clarification of the rule stated that investments will be judged prudent not by their individual risk but by their contribution to portfolio risk. Following this policy shift, venture capital organizations -a relatively new type of financial intermediary whose distinctive feature was providing early stage capital to high-risk, high-potential start-up firms- have been able to raise substantial amounts of funds without concern over the perceived riskiness for pension funds.[8] As a result, the cost of external funds for such ventures

[7]An immediate corollary to this statement is that developments in capital markets pose a threat to large corporations, a point also argued by Rajan and Zingales (2003a,b).

[8]Gompers and Lerner (2006) found that in 1978, when $481 million was invested in new venture capital funds, individuals accounted for the largest share (32 percent). Pension funds supplied just 15 percent. Eight years later, when

went down dramatically, making it possible for many such firms to be established.

In my view, the shift in policy caused by improvements in economists' understanding of how various financial issues (such as the way in which investments are judged to be prudent or imprudent) represents an improvement in the functioning of financial markets. Of course, there were other developments that have led the financial markets to function in a more frictionless way. For example, Rajan and Zingales (2003a) note that more data on potential borrowers is now available and is more timely, and that there have been improvements in accounting disclosure which have resulted in greater borrower transparency. Consequently, the ability of financial institutions in assessing and spreading risks has increased, resulting in lower costs for potential borrowers.

In the third chapter of this thesis, which is a joint work with Junghee Park and is titled "Does Deposit Insurance Increase Bank Risk Taking? Evidence from Korean Bank Panel", the focus is on a different side of financial markets, namely the banking sector. We are interested in the effects of the introduction of explicit deposit insurance on bank risk-taking. In particular, we analyze the effect of the introduction of explicit deposit insurance on bank risk-taking in South Korea. Korean banking sector adopted deposit insurance in 1997, but its economic impact has been rarely explored thus far. To the best of our knowledge, this is the first attempt to investigate the existence of risk-taking incentives due to deposit insurance using bank-level data of Korea.[9] In addition, considering that the system has experienced various changes in terms of insurance coverage[10], analyzing their

more than $4.8 billion was invested, pension funds accounted for more than half of all contributions.

[9]Demirguc-Kunt and Detragiache (2002) use Korean macro data. It is difficult to find studies using a country's bank-level data except the U.S.. Gueyie and Lai (2001) examine 5 Canadian banks and fail to detect the presence of moral hazard in the Canadian banking industry.

[10]The insurance coverage was 20 million won in 1997 when the deposit insurance was first introduced. The banking authorities implemented an extraordinary full protection scheme between 1998 and 2000 to prevent possible bank-runs during the East Asian economic crisis period. Beginning 2001, the insurance coverage was reduced to 50 million won.

effect will also provide valuable insights. More specifically, we test the following two hypotheses:

· Introduction of explicit deposit insurance increases bank risk-taking [H1], and

· Bank risk-taking increases with insurance coverage [H2].

In order to empirically analyze these hypotheses, we collected panel data on 27 Korean commercial banks from 1994 through 2004. The sample period begins with 1994 as this is the first year for which data on the dependent variable is available. Most data are from FSS (Financial Supervisory Service) of Korea, and some other data, such as the stock market variables and GDP, are from KSE (Korea Stock Exchange) and the BOK (Bank of Korea). We then estimated a fixed effects panel model by instrumental variable estimation as well as OLS. Our regression results indicate there is a strong association between deposit insurance and bank risk-taking, which we interpret as a strong evidence for moral hazard effect of deposit insurance. We also find some evidence that risk-taking increases with (i) the extent of insurance coverage; and (ii) bank size. Therefore, our results are consistent with the strand of literature that emphasizes the moral hazard effects of deposit insurance on bank risk-taking.

In order to put our findings in perspective, a little background on the varying views on the effects of deposit insurance on bank risk-taking is helpful. The effect of deposit insurance on bank risk-taking has been one of the most controversial issues in banking literature. On one hand, there is a literature arguing that the existence of deposit insurance increases moral hazard of market participants and bank failure. The contention is that the existence of an explicit safety net induces depositors to exert less effort in monitoring a bank's investment behavior, which then leads to selection of a riskier portfolio by the bank and causes a deterioration of the bank's asset quality (Thies and Gerlowski (1989), Wheelock (1992), and Demirguc-Kunt and Detragiache (1998)). On the other hand, some economists argue that the effect of deposit insurance on bank risk-taking is insignificant, and hence can safely be ignored (see, for example, Wheelock and Wilson (1999), Karels and McClatchey (1999)). Meanwhile, Gropp and Vesala (2001) find that the establishment of explicit deposit insurance significantly reduces the risk-taking of banks using the panel data of EU banks. They argue that when there is a comprehensive implicit safety net, the introduction of explicit deposit insurance limits the coverage of bank loss, thus reducing banks' moral hazard incentives.

To briefly summarize the discussion so far, this thesis argues that financial factors play a key role in shaping real economic activities, and that prudential regulations and policies can improve the effectiveness with which financial markets function, which then translates into better allocation and utilization of resources. Policies with the greatest potential to improve economic outcomes are those that increase the informational efficiency with which financial markets function.

Chapter 2

Corporate R&D, Venture Capital, and Capital Markets

2.1 Introduction

The U.S. venture capital (henceforth VC) industry has grown dramatically since the late 1970s. While the amount of funds committed to VC was roughly half a billion in 1978, it has risen over \$100 billion by 2000.[1] An important factor contributing to this change was the Department of Labor's 1979 decision to relax the "Prudent Man Rule", which had previously obstructed pension funds from investing substantial amounts of money in high-risk start-up ventures. Since then venture funds have been behind many of the exceptionally innovative companies, including Cisco, Genentech, and Google. Nonetheless, substantial amount of innovation still occurs within corporations such as IBM, Merck, and Microsoft. These observations raise the following questions that are the focus of this paper: First, what are the forces that determine when innovation is undertaken by small

[1] The amount of commitments has declined since 2000, but is still well above the levels in the 1960s and 1970s.

companies backed by VC and when by large corporations? Second, what is the role of policy in spurring innovation? In particular, how does policy affect whether capital is allocated by financial markets to venture organizations or large corporations?

In order to answer these questions, one must first determine what makes venture organizations different from large corporations at funding innovative ventures. This will, in turn, determine how capital will be allocated by investors between venture organizations and large corporations. It is important to note that, in both situations, investors must delegate the responsibility of making use of their money to top executives of these institutions, whose interests may not be perfectly aligned with those of the investors. Moreover, the severity of agency problems that arise as a result of delegation is determined in large part by the organizational features of these institutions. The differential incentives provided to the suppliers of capital by each of these institutions are therefore a major theme of this paper.

Then, how are venture organizations different from traditional corporations at funding innovation? In my view, a key function and a distinctive feature of venture financing is that it allows *specialization* in innovative activities. Put differently, venture financing makes the establishment of specialized research companies, which would otherwise make substantial short-run losses, possible. By contrast, large corporations are *diverse*: they conduct many productive activities at the same time, such as manufacturing and sales, in addition to innovative activities. Both specialization and diversity have their bright as well as dark sides. In this paper, I focus on two key dimensions. On the bright side, diversity may allow a corporation to overcome capital market imperfections as the headquarters have the ability to redistribute funds from units with surplus funds to those units that are in need of funds. This mechanism may be especially valuable in the context of innovation, as R&D requires substantial financial resources early on without generating cash flows for a long time.[2] On the dark side, the proliferation of activities under the same roof may introduce additional agency problems between investors and the top managers of a corporation, as managers may inflate costs and shift revenues across activities. While specialization in the form of small firms carrying out stand-alone projects has the potential to mitigate the agency problems that may plague diverse organizations, it requires that capital markets be sufficiently developed in the sense of allowing firms to make short-run losses as long as they promise to generate satisfactory returns in the future.

To formalize these ideas, I develop a theoretical model in which development of new technologies and products requires the collaboration of investors, managers, and workers. Investors provide funds. Managers have the ability to find talented workers and supervise them, but lack funds. Therefore, investors are assumed to delegate this task to managers. Workers are either research workers (*scientists*) or ordinary production workers (*production engineers*), have no wealth, but have the ability to perform research and ordinary production activities, respectively. Managers and scientists (but not production engineers) are subject to moral hazard: they must be given incentives so as to be induced to "work hard" or "exert effort". Managers are also potentially subject to a hidden information problem stemming from their direct involvement in the productive activities -which can only be imperfectly observed by the investors. As a result, investors face a two-tier agency problem: They must design appropriate incentive contracts for managers so as to induce them to exert the right amount of effort, to write appropriate incentive contracts with their subordinates, and to reveal the true state of nature once outcomes are realized.

To understand the costs and benefits of specialization, I then consider two alternative organizational structures in which the investors can allocate tasks to individuals. In the first, each manager undertakes both research and ordinary production activities ("Integrated Structure"). In the second,

[2] There is considerable evidence that corporations do indeed operate such cross-subsidies. See, for example, Stein (1997).

managers are specialized: some managers undertake research activities while others undertake ordinary production activities ("Specialized Structure"). Thus, while there is only one type of firm in the integrated structure, there are two different types of firms in the specialized structure: research firms and ordinary production firms. It is important to note that the technological structures and agents' attitudes towards risk are identical across the two modes of organization.

To identify the benefits of specialization, I abstract from imperfections in capital markets and focus on the extent of agency problems generated by each of these organizational structures. To identify the costs of specialization, I then introduce capital market imperfections into the model. Following Bernanke and Gertler (1989) and Kiyotaki and Moore (1997), among others, I model these imperfections as a *wedge* between the cost of external funds and the opportunity cost of funds generated internally by a firm. In the presence of imperfections, different types of firms face different costs of external finance. In particular, it is assumed that specialized research firms face a higher cost of external finance than other types of firms, due to, for instance, lack of collateral, greater informational problems surrounding their activities, or difficulties investors face in enforcing repayment of loans.

I derive two main conclusions. First, in the absence of capital market imperfections, investors' preferred mode of organization is the specialized structure. Second, if capital markets are "sufficiently" imperfect, then integrated structure is the preferred arrangement.

The conclusions stem from the interplay of costs and benefits of specialization. The benefit of specialization is that it mitigates two-tier agency problems. When a manager is responsible for both research and ordinary production activities, he has an incentive to distort reporting of productivity across activities, and this exposes investors to more severe agency problems. Therefore, absent capital market imperfections, specialized structure is preferred. On the other hand, specialization has costs if there are capital market imperfections. This is because research firms can raise funds only at a higher cost. If capital markets are "sufficiently" imperfect, then specialization becomes sufficiently costly, outweighing its benefits due to reduced agency problems. By contrast, integrated firms are less dependent on costly external finance as they can use production revenues to subsidize research activities. Consequently, integrated structure is the preferred structure if capital markets are sufficiently imperfect. The precise nature of these issues is detailed in Section 3.

These results have an interesting implication: All else equal, the division of innovation between established companies and young, specialized firms will be determined by the extent of imperfections in capital markets. Specifically, the more perfect the capital markets, the greater will be the share of innovation conducted by young firms.

The above conclusions also shed light on the role of the policy in improving capital markets and innovative efficiency. In particular, I argue that policies that reduce informational asymmetries in capital markets can improve the functioning of those markets, and that better functioning capital markets can increase innovative output. The Department of Labor's 1979 policy shift has done exactly this: It has freed pension funds to invest in VC and this has translated into a surge in the supply of funds to specialized research firms. The increase in the supply of funds, in turn, has reduced the cost of external finance, and as a result it has become easier to establish such firms. To the extent that specialization in innovative activities is efficiency-enhancing, the policy shift has improved innovation outcomes.

The remainder of the paper is organized as follows. Section 2 discusses the relevant theoretical and empirical literature. Section 3 lays out the basic model. Section 4 presents the characterization of optimal contracts under integrated and specialized structures, and Section 5 states the main results. Section 6 extends the model in several dimensions. The paper concludes in Section 7. All proofs are in the Appendix.

2.2 Related Literature

This paper is related to several strands of literature. Rather than attempting a comprehensive survey, I will briefly mention the most direct linkages. Kortum and Lerner (2000) provide empirical evidence on the relationship between innovation and venture capital (see, also, Hellmann and Puri (1998)). In particular, they find that while the ratio of venture capital to industrial R&D averaged less than 3% from 1983 to 1992, venture capital has accounted for 8% of industrial innovations in that period. Gompers and Lerner (1998) provide empirical evidence that the Department of Labor's 1979 clarification of the prudent man rule has spurred commitments to the VC industry. On the other hand, Jensen (1993) argued that agency problems have hampered the effectiveness of major corporate industrial research facilities over the past several decades.

To develop the model, I draw on the literatures on corporate finance/governance and the economics of agency. A key aspect of my model is the incentives investors face in providing their capital to various types of institutions -a major theme in corporate finance/governance (see Shleifer and Vishny (1997) for an excellent survey). This literature highlights the agency problems that arise as a result of "separation of financing and management" of firms-a main theme in this paper. The severity of agency problems, in turn, may itself be endogenous and depend crucially on the organizational features of firms (see, for example, Aghion and Tirole (1997)).[3] Melumad, Mookherjee, and Reichelstein (1995) and Macho-Stadler and Perez-Castrillo (1998), among others, examine some of the informational problems that may arise in environments with multi-tier agency relationships. The present paper contributes to this literature by providing a theoretical framework that can be used to analyze the costs and benefits of specialization in research environments with multi-tier agency

[3]There is a related strand of literature that takes the perspective that firms are organized so as to be maximally efficient at the processing and communication of various types of information (see, for example, Sah and Stiglitz (1986) and Radner (1993)). These papers, however, abstract from agency problems within the firm, which is central to my paper.

relationships.[4]

My paper is more closely related to yet another paper in the theory of the firm. **?**) argue that firms may wish to avoid being too broad in scope as this may inhibit the provision of incentives to firms' employees. For if there are "synergies" between different activities within a firm, such narrowness can help senior management of a firm commit to rewarding employees for any ideas they may generate, thereby strengthening employees' *ex ante* research incentives. Their model, however, abstracts from agency problems between the suppliers of capital and managers, which is a main concern in my model. Also, narrowness is valuable in their model because contracts are incomplete, whereas in my model it is desirable because it helps investors overcome informational frictions.

Also closely related is the stream of literature that studies the financing of innovation from a theoretical perspective. Aghion and Tirole (1994) analyze the organization of R&D in an incomplete-contracts framework. Anand and Galetovic (2000) study the importance of the strength (or weakness) of intellectual property rights for a new venture's choice of financing between VC and corporations. Like them, I highlight the difficulties corporations may face in funding research ventures, but the mechanisms at work are different. In their model, corporations are unable to commit to sharing profits created by the innovation with their research employees. By contrast, corporations are fully committed to compensating their employees duely in my model. Rather, it is the inability of top managers (e.g. a CEO) of a corporation to commit to truthfully reveal the true state of nature to the suppliers of capital. On the other hand, Hellmann (1998) emphasizes the importance of a

[4]By making managers responsible for multiple tasks (e.g. for research as well as ordinary production), the present model also builds on Holmstrom and Milgrom (1991), who examine the provision of incentives in environments with multi-task considerations. See also Laffont and Martimort (2002) for a nice textbook exposition of multi-task considerations.

corporation's strategic motive for making investments in entrepreneurial ventures. In his model, corporate financing is preferred when new projects complement the "core business" of a corporation, and VC financing is preferred if they are substitutes. In contrast with Hellman, considerations of complementarity or substitutability play no role in my model. I depart from both of these papers by focusing on the incentives provided by corporations or VC firms to the suppliers of capital rather than to research employees, and by highlighting the multi-tier agency relationship in research ventures.

Finally, this paper builds on the literature on the effects of financial imperfections on real economic activity. Following Bernanke and Gertler (1989) and Kiyotaki and Moore (1997), among others, I model capital market imperfections as a *wedge* between the cost of external funds and the opportunity cost of funds generated internally by a firm.[5] In these models, this wedge exists as a result of low borrower net worth, information asymmetries between the suppliers and borrowers of capital, or contractual enforcement problems. Hubbard (1998) provides a useful review of this literature.

2.3 The Model

I consider a multi-level contracting relationship between an investor (the principal) and multiple agents. There are three main types of agents in the economy: managers, research workers (scientists) and ordinary production workers (production engineers). Each worker, in turn, is either "talented" or "untalented". While the principal is assumed to be risk-neutral, all agents are risk-averse.

I divide time into three main periods:

[5]This wedge is sometimes referred to as an "external finance premium".

· A primary contracting stage (date $t = 0$) in which the principal hires managers and makes investments.

· A subcontracting stage (date $t = 1$) in which managers find and hire talented workers.

· A payoff stage (date $t = 2$) in which firms' revenues are realized.

The main focus of my analysis is on informational problems that may arise at date $t = 2$. These problems arise in the model solely because of the assumed inability of the investor to find talented workers on his own -a task delegated to managers. Delegation potentially creates informational asymmetries between the investor and managers, which may be costly. The model highlights the differing degrees and costs of asymmetric information that may be generated by different organizational structures.

2.3.1 Two Organizational Structures

I consider two alternative organizational structures. The first is "integrated structure", in which each organization ("firm") carries out both research and ordinary production activities. The second is "specialized structure", in which some organizations carry out only research activities and others carry out ordinary production activities. A representative firm with integrated structure is depicted in Figure 1.

For simplicity, I assume that each firm carries out only one research activity and one production activity. The model can be easily extended to the case in which many such activities are conducted under the same roof. Moreover, it is assumed that each activity is performed by only one worker.

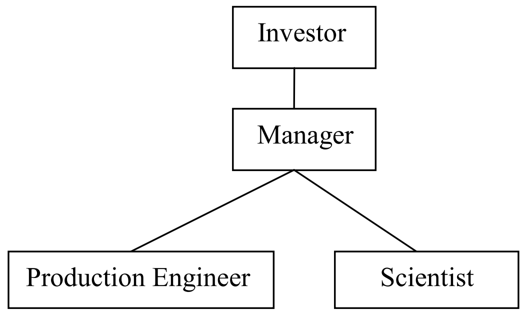

Figure 2.1: A representative integrated firm

In contrast with the integrated structure, there are two types of firms in the specialized structure: research firms and ordinary production firms. In order to keep managerial economies of scope the same across structures, I let each firm carry out two activities of the same type, and that the two activities are independent. A representative firm of each type is depicted in Figure 2.

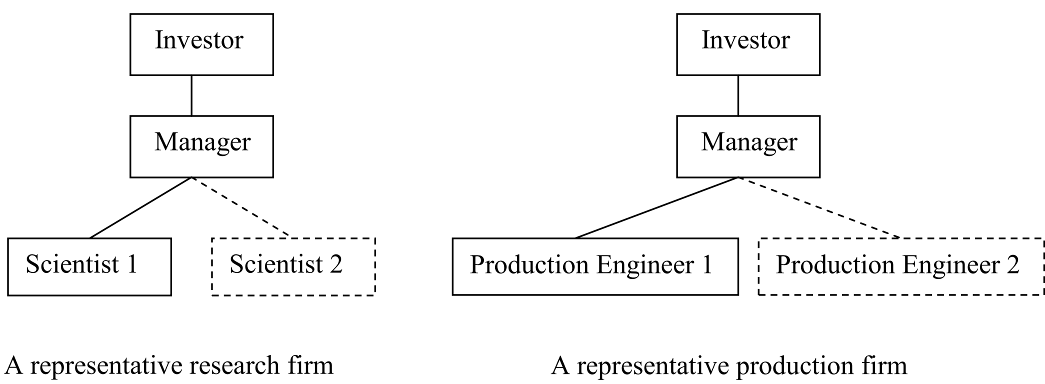

Figure 2.2: Representative specialized firms

Before turning to the description of the contracting problem under each structure, I need to specify the productive activities (the technology) and preferences of agents. The information structure is endogenous and depends on the organizational structure.

2.3.2 Agents and Activities

In what follows, I describe the activities performed by a representative scientist, a production engineer, and a manager, respectively.

Research Activity A research activity requires an investment of $I_R > 0$ at date $t = 0$, and generates a nonnegative cash flow, s^R, at date $t = 2$. The activity is performed by a single scientist, who expends effort to generate ideas or make inventions. This effort may entail the search for an improvement in product design, the investigation of new a method to reduce costs, or the development of a new product. For simplicity, I assume that a scientist can either succeed (i.e. make an invention) or fail (i.e. no invention). The probability of success depends on the "quality" of the scientist. If the scientist is "talented", then the monetary outcome, s^R, of her effort is $\overline{s}^R$ if she succeeds, and 0 if she fails, with $\overline{s}^R > 0$. By contrast, if the scientist is "untalented", then she is never successful and hence $s^R = 0$ with probability 1. I denote the success probability of a talented scientist by r_e, where $r_e \in (0, 1)$, and it depends stochastically on her effort, $e^R \in \{0, 1\}$. If the scientist "works hard" (i.e. $e^R = 1$), then the probability of success is r_1, and if she "shirks" (i.e. $e^R = 0$), then it is r_0, where $0 \leq r_0 < r$. Let $\{\psi_0, \psi_1\}$ denote the disutility to the scientist of shirking and working hard, respectively. Exerting effort is costly for the scientist so that $\psi_1 > \psi_0$, where ψ_0 is normalized to zero. Scientists are strictly risk-averse (i.e. $u' > 0$ and $u'' < 0$) and effort-averse, and each has a utility function of the form $u(t^R) - \psi(e^R)$, where t^R is the monetary compensation and e^R is the effort exerted by her.

Ordinary Production Activity An ordinary production activity requires an investment of $I_P > 0$ at date $t = 0$, and generates a nonnegative cash flow, s^P, at date $t = 2$. The activity is performed by a single production engineer, who supplies one unit of effort to carry out routine tasks such as adaptation and implementation of new blueprints to existing production processes, large-scale manufacturing, and quality control. Differently from scientists, a production engineer can generate three different outcomes: He may also either succeed (e.g. keep defects of products to a minimum) or fail. In addition, however, conditional on success, the engineer may generate ideas independently of the scientist. Again, the probability of success depends on the quality of the engineer. If the engineer is talented, then the monetary outcome, s^P, of the engineer's effort is equal to $s + \overline{s}^P$ if she succeeds and at the same time makes an invention, s if she succeeds but does not make an invention, and 0 if she fails; where $\overline{s}^P > s > 0$. The probabilities of these events are denoted by p, q and d, respectively, with $p + q + d = 1$. By contrast, if the engineer is untalented, then she never succeeds and hence $s^P = 0$ with probability 1. Engineers are strictly risk-averse but effort-neutral (i.e. $\psi_1 = 0$) with utility function $u(t^P)$.

A few remarks are in order. First, I assume that the production engineer's invention is identical to that of the scientist's and so $\overline{s}^P = \overline{s}^R \equiv \overline{s}$. It would probably be more reasonable to assume that inventions are random draws from a quality distribution. As long as the supports of the quality distributions are the same, however, the qualitative results of the paper will not be altered by this simplifying assumption. Second, the probability that a (talented) production engineer generates an invention, p, is assumed to be smaller than the probability that a (talented) scientist generates an invention when she works hard, r_1.

As noted earlier, to ensure that talented workers are hired and that they do a good job, the input of a manager is required.

Management Activity The manager is hired from a continuum of identical strictly risk-averse and effort-averse managers, each with a utility function $u(t^M) - \psi(e^M)$, where t^M is the monetary compensation and e^M is the effort exerted by the manager. The manager performs two functions on behalf of the investor: (i) identifying and hiring talented workers, and (ii) supervising their work. It is assumed that conditional on exerting one unit of effort, a manager can always distinguish a talented worker from an untalented one; otherwise, he always ends up with a untalented worker. Because the manager must identify two talented workers, he must expend an effort $e^M \in \{0, 1\}$ to identify one worker, and another $e^M \in \{0, 1\}$ to identify a second one. Supervision of workers, on the other hand, is assumed, for simplicity, not to cost any disutility for the manager. Accordingly, there are three possible levels of aggregate effort for a given manager: low ($e^M = 0$), medium ($e^M = 1$), and high ($e^M = 2$). Let $\{\psi_0, \psi_1, \psi_2\}$ denote the corresponding disutility of effort for each aggregate effort level. Higher levels of effort are more costly for the manager so that $\psi_2 > \psi_1 > \psi_0$, where $\psi_0 = 0$ as before.[6]

Without loss of generality, all agents are assumed to have the same reservation utility, $\overline{u}$.

2.3.3 Integrated Structure

Consider a representative integrated firm. Since $s^R \in \{\overline{s}, 0\}$, and $s^P \in \{s + \overline{s}, s, 0\}$, there are six possible states of the world at date $t = 2$. Each of these states can be summarized by a triplet, (S, s^R, s^P), where $S = s^R + s^P$ denotes the aggregate revenue. The state space is given by the set $\Omega = \{(s+\overline{s}, \overline{s}, s+\overline{s}), (s+\overline{s}, 0, s+\overline{s}), (s+\overline{s}, \overline{s}, s), (s, 0, s), (\overline{s}, \overline{s}, 0), (0, 0, 0)\}$. Note that in state 1, both the scientist and production engineer generate inventions. Because the inventions are identical, it is no importance which invention is eventually implemented: the aggregate revenues are given by $S = s + \overline{s}$ in both cases.[7] Figure 3 shows the distribution of aggregate revenues induced by high efforts by all agents, that is, by $e^M = 2$, $e^R = 1$, and $e^P = 1$.

[6] The manager's disutility of one unit of effort, ψ_1, is assumed to be the same as that of a scientist. This is without loss of generality.

[7] Although this assumption is a sensible one, it is not necessary for the results.

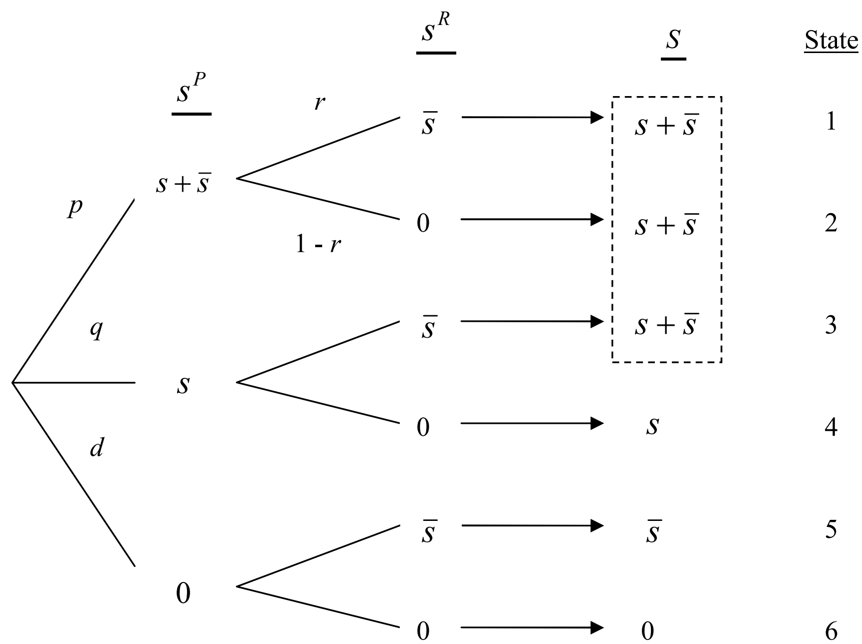

Figure 2.3: Distribution of aggregate cash flows induced by high efforts

Let $\mathrm{E}(S)$ denote the expected aggregate revenue of the enterprise at date $t = 0$, where the expectation is taken with respect to the distribution of aggregate revenues induced by high efforts. Observe that aggregate revenue, S, is the same and equal to $s + \overline{s}$ in states 1, 2 and 3. This equality of aggregate revenues in these three states will be important for the analysis that follows.

Information Structure and the Timing of Moves

There are three incentive problems in the model. First, the scientist's problem, which results from the unobservability of her effort choice. The second and third incentive problems relate to the manager's actions. On the one hand, the manager's decision about whether to work hard in hiring talented workers at date $t = 1$ is not observed by the principal. The manager may not only shirk in one dimension of effort (i.e. $e^M = 1$), but also in both dimensions (i.e. $e^M = 0$). On the other hand, while the aggregate revenue from the enterprise, S, is observed by the principal as well as the manager, the individual components, s^R and s^P, of aggregate revenue are observed only by the manager and the worker who generates that outcome. This creates an informational asymmetry between the principal and the manager when the state of the world is 1, 2 or 3 at date $t = 2$. It is of no importance for the analysis whether the workers can observe the aggregate revenue or not.

I assume that the contracts signed between the manager and the workers at date $t = 1$ are observable by the principal.[8] An immediate implication of this assumption is that the two-tier contracting problem between the principal and the agents can be collapsed down to a "grand" contracting problem that occurs at date $t = 0$. This is a well-known result in the theory of agency and hence the proof is omitted. The intuition is that the principal has the power to "punish" the manager (via the use of a "forcing contract") should the manager be caught having written a contract with workers that is not desired by the principal. I exploit this useful result in the sequel as it simplifies the exposition and solution of the contracting problems.

The timing of moves of different participants is as follows:

- At date $t = 0$, the principal, the manager, and the workers sign a comprehensive contract specifying how the contracting parties will be compensated as a function of the aggregate revenue outcome at date $t = 2$. I assume that the principal makes the ex ante contractual offer to all the agents.

- Once the contract is signed and investments I_R and I_P are made, the manager chooses how much effort to exert (i.e. chooses $e^M \in \{0, 1, 2\}$) in finding talented workers at date $t = 1$.

[8]This is because I do not consider agency problems arising from possibilities for side-contracting between agents, or issues relating to the allocation of contracting capacity -circumstances under which explicit consideration of the two stages would be indispensable. See, for example, Melumad, Mookherjee, and Reichelstein (1995) or Macho-Stadler and Perez-Castrillo (1998) for a model in which second-stage contracts are not observed by the principal.

· Following the manager's choice, the scientist decides whether to work hard (i.e. chooses $e^R \in \{0, 1\}$). She observes the manager's choice before taking that decision. The production engineer supplies one unit of effort (i.e. $e^P = 1$).

· Finally, at date $t = 2$ revenues are realized and the manager decides whether to report the true state of the world.

· Once the manager makes his report, $(S, \tilde{s}^R, \tilde{s}^P)$, all parties are compensated according to the contract signed at date $t = 0$.

I restrict my analysis to parameter values such that the (net) expected profit to the principal is positive when both workers are talented and the scientist chooses $e^R = 1$, but is negative when either the manager or the scientist shirks. I also assume that it is optimal for all agents to exert high effort. The equilibrium concept throughout the paper is subgame perfect equilibrium.

Contracts

Throughout the paper I assume that contracting parties can commit to a long-term contract.

1. **The manager's compensation contract**: The manager's compensation depends on his report, $(S, \tilde{s}^R, \tilde{s}^P)$, about the aggregate as well as individual cash flow realizations. The manager is induced to work hard, that is to choose $e^M = 2$ at date $t = 1$, if he is compensated sufficiently at date $t = 2$ for high cash flow realizations and punished for low cash flow realizations. Moreover, the manager is induced to report the true state of the world at date $t = 2$, if he is compensated sufficiently high in those states in which he has an incentive to misreport.

2. **The scientist's compensation contract**: The scientist's compensation also depends on the manager's report, $(S, \tilde{s}^R, \tilde{s}^P)$, to the principal. The scientist is induced to work hard, that

is to choose $e^R = 1$ at date $t = 1$, if he is compensated sufficiently at date $t = 2$ for high cash flow realizations and punished for low cash flow realizations. Therefore, the scientist's contract specifies a two-piece compensation, one for high cash flow realizations and one for low cash flow realizations.

3. **The production engineer's compensation contract**: The production engineer's compensation at date $t = 2$ also depends on the manager's report. Because the production engineer has no incentive problem, his compensation is a single payment that is independent of outcome.

A *contract*, therefore, is a 3-dimensional vector of contingent payments, $\left(t^M(\tilde{\mathrm{s}}), t^R(\tilde{\mathrm{s}}), t^P(\tilde{\mathrm{s}})\right)$, where $\tilde{\mathrm{s}} = \left(\tilde{S}, \tilde{s}^R, \tilde{s}^P\right)$, and $\tilde{S}$ denotes the manager's *report* to the principal about the *realization* of aggregate cash flows, S, and $\tilde{s}^R$ and $\tilde{s}^P$ denote his report about the *realizations* of the individual components, s^R and s^P, of S.[9] A contract can also be expressed as a vector of contingent utilities induced by contingent payments, $\left(u^M(\tilde{\mathrm{s}}), u^R(\tilde{\mathrm{s}}), u^P(\tilde{\mathrm{s}})\right)$, where $u^j(\tilde{\mathrm{s}}) = u^j(t(\tilde{\mathrm{s}}))$ for $j = M, R, P$. By assumption, there is no uncertainty about aggregate cash flows, and thus $\tilde{S} = S$.

The Contracting Problem

The principal faces a *two-tier* agency problem: He must provide the right incentives for the manager while also providing the right incentives for the scientist and production engineer. The key friction is that the principal cannot observe the individual components, s^R and s^P, of aggregate cash flows, S. To be able to write state-contingent contracts for the workers as well as the manager, the principal must first solicit the realizations from the manager, who may in principle misreport them. The main problem of the principal is, thus, to ensure that the manager truthfully reports the realizations.

[9]Throughout the text, managerial reports are denoted with *tilde* (such as $\tilde{s}$). Both random variables and their realizations are denoted without *tilde* (such as s).

The contract offered to the agents must achieve three objectives. First, it must induce all agents to participate at date $t = 0$. Second, it must provide the incentives for the manager and the scientist to exert the right amount of effort at date $t = 1$. Finally, it must induce the manager to report the true state of the world at date $t = 2$.

The optimization problem of the principal can be set up as a cost minimization problem subject to three participation constraints, two effort-incentive constraints, and one truthful-reporting constraint, and is given by

$$\mathrm{E}^I\big(C\big) \equiv \min_{u^M, u^R, u^P} \mathrm{E}\Big(\sum h(u^j(\tilde{\mathbf{s}}))|e^P = 1, e^R = 1, e^M = 2\Big)$$

$$(P1) \quad \text{s. to} \qquad \mathrm{E}\big(u^M(\tilde{\mathbf{s}})|e^P = 1, e^R = 1, e^M = 2\big) - \psi_2 \geq \overline{u}$$

$$\mathrm{E}\big(u^R(\tilde{\mathbf{s}})|e^P = 1, e^R = 1, e^M = 2\big) - \psi_1 \geq \overline{u}$$

$$\mathrm{E}\big(u^P(\tilde{\mathbf{s}})|e^P = 1, e^R = 1, e^M = 2\big) \geq \overline{u}$$

$$1 = \arg\max_{e \in \{0,1\}} \mathrm{E}\big(u^R(\tilde{\mathbf{s}})|e^P = 1, e, e^M = 2\big) - \psi_e$$

$$2 = \arg\max_{e \in \{0,1,2\}} \mathrm{E}\big(u^M(\tilde{\mathbf{s}})|e^P = 1, e^R = 1, e\big) - \psi_e$$

$$u_1^M(\tilde{\mathbf{s}}) = u_2^M(\tilde{\mathbf{s}}) = u_3^M(\tilde{\mathbf{s}})$$

where $\mathrm{E}^I\big(C\big)$ denotes the principal's (minimum) expected cost of undertaking the venture at date $t = 0$, and where $h = u^{-1}$ denotes the inverse of u.[10] Constraints (1), (2) and (3) are, respectively, the manager's, the scientist's, and the production engineer's participation constraints. These constraints ensure that each agent gets at least his/her reservation utility by accepting the contract offered to him/her. Constraint (4) is the scientist's *ex ante* incentive constraint with respect to effort. It ensures that the scientist finds it in her interest to work hard, i.e. to choose $e^R = 1$ rather than

[10] Note that $h' > 0$ and $h'' > 0$ since all utility functions satisfy $u' > 0$ and $u'' < 0$.

$e^R = 0$ at date $t = 1$.[11] While making that decision, the scientist takes as given the effort level chosen by the manager. Constraint (5) is the manager's *ex ante* incentive constraint with respect to effort. Implicit in this constraint are two types of constraints: The *local incentive constraints* ensure that the manager finds in his interest to exert $e^M = 2$ rather than $e^M = 1$ at date $t = 1$ whereas the *global incentive constraint* ensures that the manager exert $e^M = 2$ rather than $e^M = 0$. Note that when the manager chooses $e^M = 1$, he may expend that effort on finding a talented scientist or on finding a talented production engineer. Therefore, when designing the incentive contract the principal has to consider the possibility that the manager could shirk, not only in one dimension of effort (i.e. $e^M = 1$) but also on both dimensions (i.e. $e^M = 0$).

Constraint (6), on the other hand, is the manager's truthful-reporting constraint and deserves greater discussion. It ensures that the manager does not have an incentive to misrepresent states of the world at date $t = 2$. To see why misrepresentation is a concern for the principal, recall that aggregate cash flows, S, are the same and equal to $s + \overline{s}$ in states 1, 2 and 3. Because the principal cannot observe the individual components of cash flows, however, he cannot tell which of these two states is the true state of the world. Why is this a problem for the principal? There are two important reasons. The first relates to the scientist's incentives: Without the knowledge of who came up with the invention, the principal cannot hope to compensate the scientist appropriately. As an agent with rational behavior, however, this would introduce additional uncertainty into the scientist's expectations that is not connected with her incentives to exert effort. As is well known in the literature on the economics of agency, it is more difficult to provide incentives under such conditions.

The second reason relates to the manager's incentives. In a perfect world where the principal

[11] As in standard principal-agent models, I assume that if an agent is indifferent between two actions, he/she takes the action that is preferred by the principal.

could observe the entire history of events, it would be optimal for the principal to pay the manager more in states 1 and 3 than in state 2. To see this, note that in all of these states the principal is certain that the manager has exerted effort in hiring a talented production engineer. Therefore, the only concern is whether the manager has also exerted effort to find a talented scientist. To induce the manager to also work hard in finding a talented scientist, the principal must offer a higher reward to the manager when he has done so, that is in states 1 and 3. When the principal cannot observe the true state, however, he is forced to pay the manager the same amount in all three states. This introduces a distortion to the optimal contract and reduces the principal's expected profits.

Finally, it should be noted that, by construction, states 1, 2 and 3 are the only situations in which managerial misreporting is possible. In all other states, the principal can determine the true state of the world by simply observing the aggregate cash flows. To see this, suppose for instance that $S = s$ so that we are in state 4. Because $S = s^R + s^P$, this aggregate cash flow can arise only if $s^R = 0$ and $s^P = s$. Similar arguments can be made for the other cases. In these states, the manager's report about individual components of cash flows, $\tilde{s}^R$ and $\tilde{s}^P$, are *uninformative* in the sense of Holmstrom (1979).

Before characterizing the solution to the contracting problem, I describe the economic environment when firms are specialized.

2.3.4 Specialized Structure

In this section, I turn to the case where firms are *specialized* with respect to the type of productive activity they perform. Here, one group of firms of specialize in research activities and the other group of firms specialize in ordinary production activities. I should emphasize that the technological structure, agents' attitudes towards risk, and the timing of moves are identical to that of the previous section. The only difference is the structure of information. The difference arises because each manager is now responsible for a different combination of workers. Specifically, in the integrated structure, a given manager hires and then supervises one scientist and one production engineer, whereas in this organizational arrangement, one group of managers hire and supervise (two) production engineers, and the other group hire and supervise (two) scientists. The principal, therefore, must design a different compensation contract for each "type" of manager in this environment. The next two subsections describe the situation in each case.

Research Firms

Consider a representative research firm. The manager of this firm oversees the research activities for two independent projects. Since the research activities are symmetric, $s^R \in \{\overline{s}, 0\}$ for both activities, and hence there are four possible states of the world at date $t = 2$. Each of these states can be summarized by a triplet, (S^R, s^{R1}, s^{R2}), where $S^R = s^{R1} + s^{R2}$ denotes the realization of aggregate cash flows at date $t = 2$. The state space is given by the set $\Omega^R = \{(2\overline{s}, \overline{s}, \overline{s}), (\overline{s}, \overline{s}, 0), (\overline{s}, 0, \overline{s}), (0, 0, 0)\}$. The distribution of S^R induced by high efforts by the manager and the scientists is displayed in Figure 4.

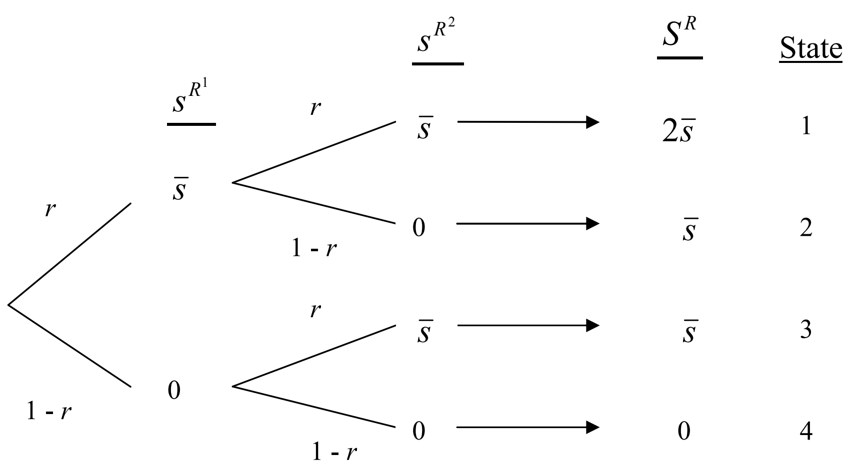

Figure 2.4: Distribution of research cash flows induced by high efforts

Here, the principal's problem is to give the right incentives to the manager while also providing the right incentives for the scientists. As before, the principal's optimization problem can be posed as a cost minimization problem subject to the participation constraints and incentive constraints of the manager and the scientists. Importantly, there is no truthful-reporting constraint for the manager in this case. Before going into discussion of this point, however, it is convenient to state the optimal contracting problem. The optimal "research contract" solves the following program:

$$\mathrm{E}\big(C^R\big) \equiv \min_{u^M, u^{R^1}, u^{R^2}} \mathrm{E}\Big(\sum h(u^j(\tilde{\mathbf{s}}))\big|e^{R^1}=1, e^{R^2}=1, e^M=2\Big)$$

$$(P2) \quad \text{s. to} \quad \mathrm{E}^M\big(u^M(\tilde{\mathbf{s}})|e^{R^1}=1, e^{R^2}=1, e^M=2\big) - \psi_2 \geq \overline{u} \tag{2.3.1}$$

$$\mathrm{E}^R\big(u^{R^j}(\tilde{\mathbf{s}})|e^{R}=1, e^{R^2}=1, e^M=2\big) - \psi_1 \geq \overline{u} \tag{2.3.2}$$

$$1 = \arg\max_{e\in\{0,1\}} \mathrm{E}\big(u^R(\tilde{\mathbf{s}})|e, e^{R^{-j}}=1, e^M=2\big) - \psi_e \tag{2.3.3}$$

$$2 = \arg\max_{e\in\{0,1,2\}} \mathrm{E}\big(u^M(\tilde{\mathbf{s}})|e^{R^1}=1, e^{R^2}=1, e\big) - \psi_e \tag{2.3.4}$$

where $\mathrm{E}\big(C^R\big)$ denotes the principal's (minimum) expected cost of undertaking the research venture at date $t=0$. Conditions (7) and (8) are respectively the manager's and scientist j's participation constraints. Condition (9) is scientist j's and condition (10) is the manager's incentive constraint with respect to effort. Implicit in the above distribution of aggregate revenues is the assumption that if in any state both the research firm and the ordinary production firm are successful in generating inventions, then the research firm always wins the "race". This simplification does not alter the main conclusions of the paper.

Why isn't there a misrepresentation problem in this case? This has an easy and intuitive answer: The research activities are independent and therefore it is not possible for the manager to substitute one scientist's idea for the other's. For example, one research activity may be involved with developing new computer softwares while the other is involved primarily with computer hardware. Clearly, the manager cannot pretend that a new software code has been generated by the scientist working in the hardware activity, or vice versa. As a result, even though the principal may not in fact observe who came up with the invention, he can tell who it was with probability one, and hence the sources of ideas become essentially observable to the principal. This is the key benefit for the principal of having the managers specialize. The next section describes the situation for a representative ordinary production firm.

Ordinary Production Firms

The situation for production is similar to the research case. Consider a representative production firm. Since the production activities are symmetric, $s^P \in \{s+\overline{s}, s, 0\}$ for both activities, and hence there are nine possible states of the world at date $t = 2$. Each of these states can be summarized by a triplet, (S^P, s^{P1}, s^{P2}), where $S^P = s^{P1} + s^{P2}$ denotes the realization of aggregate cash flows at date $t = 2$. The state space is given by the set $\Omega^P = \{(2(s+\overline{s}), s+\overline{s}, s+\overline{s}), (2s+\overline{s}, s+\overline{s}, s), (s+\overline{s}, s+\overline{s}, 0), (2s+\overline{s}, s, s+\overline{s}), (2s, s, s), (s, s, 0), (s+\overline{s}, 0, s+\overline{s}), (s, 0, s), (0, 0, 0)\}$. I skip showing the distribution of S^P induced by high effort by the manager and the production engineers, but it should be straightforward from the previous section.

Here, only the manager has an incentive problem, the production engineers always provide effort as long as they are compensated for their foregone reservation utility. Like in the research case, managerial misrepresentation of states is not an issue. The principal's optimization problem can be posed as a cost minimization problem subject to the participation constraints of all agents and the incentive constraint of the manager. Therefore, the optimal "production contract" is the solution to the following program:

$$\mathrm{E}\big(C^P\big) \equiv \min_{u^M, u^{P1}, u^{P2}} \mathrm{E}\Big(\sum h(u^j(\tilde{\mathbf{s}}))\big|e^{P1}=1, e^{P2}=1, e^M=2\Big)$$

$$(P3) \quad \text{s. to} \quad \mathrm{E}^M\big(u^M(\tilde{\mathbf{s}})|e^{P1}=1, e^{P2}=1, e^M=2\big) - \psi_2 \geq \overline{u} \tag{2.3.5}$$

$$\mathrm{E}^W\big(u^{Pj}(\tilde{\mathbf{s}})|e^{P1}=1, e^{P2}=1, e^M=2\big) \geq \overline{u} \tag{2.3.6}$$

$$2 = \arg \max_{e\in\{0,1,2\}} \mathrm{E}\big(u^M(\tilde{\mathbf{s}})|e^{P1}=1, e^{P2}=1, e\big) - \psi_2 \tag{2.3.7}$$

where $\mathrm{E}\big(C^P\big)$ denotes the principal's (minimum) expected cost of undertaking the production venture at date $t = 0$. Here, condition (11) and (12) are, respectively, the manager's and production engineer j's participation constraints, and condition (13) is the manager's incentive constraint with respect to effort.

2.4 Characterizing the Optimal Contracts

In this section, I characterize the optimal contracts under the integrated and specialized structures, and calculate the associated expected total costs for the principal. At this level of generality, however, characterizing the optimal contracts is difficult. To make the problem tractable, I impose additional structure on the model, and adopt two assumptions. The first pertains to the agents' utility functions.

Assumption 1 $\quad u(t) = \sqrt{t}$.

This simplification was used by Holmstrom (1979) and Ziv (1993), among others. As noted by Ziv (1993), it has the major advantage of using the first two moments in the derivation of the optimal contract.[12]

[12] Alternatively, one can use the exponential utility function and linear contracts as in Holmstrom and Milgrom (1987). Main conclusions of the paper are not likely to be altered by this change.

The next assumption relates to the shape of the cost of effort function of the managers. It requires that this function be at least weakly convex.

Assumption 2 $\psi_2 \geq 2\psi_1$.

In standard models of multitasking, tasks are characterized as substitutes, complements, or simply technologically unrelated. Tasks are said to be substitutes when $\psi_2 > 2\psi_1$, complements when $\psi_2 < 2\psi_1$, and technologically unrelated when $\psi_2 = 2\psi_1$. When tasks are substitutes, it is harder for a manager to accomplish the second task at the margin when the first one has already been performed. The reverse holds when the two tasks are complements. Assumption 2 requires that tasks be either technologically unrelated or substitutes.

The principal solves a convex programming problem under each organizational arrangement. To see this, observe that his objective function in each cost minimization problem is strictly convex in the utility levels as it is the sum of strictly convex functions. Moreover, the constraints are linear in utility levels. As a result, the Kuhn-Tucker first order conditions (FOC) yield necessary and sufficient conditions for optimality. Moreover, the solution to the FOC is unique in each case since the agents' utility functions are strictly concave.[13]

Before characterizing the optimal contracts under the two organizational arrangements, I prove the following useful (and obvious) result. All proofs are in the Appendix.

Lemma 2.1 *Let* $\mathrm{E}^I(S)$ *and* $\mathrm{E}^S(S)$ *denote, respectively, the expected aggregate cash flows under the integrated and specialized structures. Then,* $\mathrm{E}^I(S) = \mathrm{E}^S(S)$.

[13]The assumption that the managers are risk averse is crucial to the model. If the managers are risk-neutral, the principal can implement the informationally efficient outcome, for any information system, by offering properly designed linear contracts. The scientists and production engineers, by contrast, can be made risk-neutral without affecting the qualitative results of the paper.

This lemma states that expected aggregate cash flows are independent of the underlying information structures. An immediate implication of this lemma is that if there is a difference in the expected profits of the principal under the two structures, this must be reflected completely in expected total costs.[14] Furthermore, expected total costs have two components in each organizational structure: (i) total cost of establishing firms, and (ii) total payments to agents. The symmetry between structures implies that the first component of expected total costs is the same across the two organizational arrangements and is given by $2(I_P+I_R)$. As a result, it is enough to compare the total expected payments to agents in order to determine the principal's preferred mode of organization.

2.4.1 Optimal Contracts under Integrated Structure

The following two lemmas characterize, respectively, the agents' optimal compensation contracts and the principal's expected total cost under the integrated structure.

Lemma 2.2 *Suppose that $\psi_2 \geq 2\psi_1$. Then, the solution to problem P1 is such that*

a. *The managers' local incentive constraints and the participation constraints are binding. The global incentive constraints are always slack. Moreover, the optimal contract for the manager of a representative integrated firm is given by*

$$\begin{aligned} u_1^M = u_2^M = u_3^M &= \overline{u} + \psi_2 + \left(\tfrac{d}{1-d} + \tfrac{q(1-r)}{pd+qr}\right)\Delta\psi \\ u_4^M &= \overline{u} + \psi_2 + \left(\tfrac{d}{1-d} - \tfrac{p+qr}{pd+qr}\right)\Delta\psi \\ u_5^M &= \overline{u} + \psi_2 + \left(\tfrac{(p+qr)(1-r)}{(pd+qr)r} - 1\right)\Delta\psi \\ u_6^M &= \overline{u} + \psi_2 - \left(1 + \tfrac{p+qr}{pd+qr}\right)\Delta\psi \end{aligned}$$

[14] See Grossman and Hart (1983) for a more complete discussion of this point.

where $\Delta\psi = \psi_2 - \psi_1$.

b. *The scientists' participation and incentive constraints are binding. Moreover, each scientist's optimal contract is given by*

$$u_1^R = u_3^R = u_5^R = \overline{u} + \frac{\psi_1}{r},$$

$$u_2^R = u_4^R = u_6^R = \overline{u}.$$

c. *The production engineers' participation constraints are binding. Moreover, each production engineer's optimal contract is given by*

$$u_1^P = ... = u_6^P = \overline{u}.$$

Part (a) of Lemma 2 reports that the optimal contracts of the managers are quite variable: Their contracts have five pieces. This variability in the managers' contracts are in large part due the asymmetry of the production and research activities. Part (b) reports that each scientist's optimal contract has two pieces: each scientist receives a high compensation if he is successful, and a low compensation otherwise. Part (c) reports that the production engineers receive a flat compensation. It is important to note that the scientist's contract does not depend on the production engineer's performance or vice versa. This result is not surprising: It is well known that an economic agent should not be made accountable for events over which he/she has no control since it does not help with informational problems and generally worsens incentives.[15]

Given the optimal contracts, the principal's expected total cost under this structure can be easily calculated. The result is summarized in Lemma 3.

[15]The formal version of this point is Holmstrom (1979)'s *sufficient statistic* result according to which an economic agent's optimal compensation is based on a sufficient statistic about the agent's unobserved actions. See Tirole (2006) for a more complete discussion of this point.

Lemma 2.3 *The principal's expected total payments to agents under the integrated structure is given by*

$$
\begin{aligned}
\mathrm{E}^I\big(C\big) &= \mathrm{E}^I\big(C^M\big) + \mathrm{E}^I\big(C^R\big) + \mathrm{E}^I\big(C^P\big) \\
&= (\overline{u} + \psi_2)^2 + \Big(\tfrac{d}{1-d} + \tfrac{(p+qr)(1-r)}{(pd+qr)r}\Big)\Delta^2\psi \\
&\quad + \Big(r(\overline{u} + \tfrac{\psi_1}{r})^2 + (1-r)\overline{u}^2\Big) + \overline{u}^2.
\end{aligned}
$$

Lemma 2 reports that the principal's expected cost has three pieces. The first is the cost of hiring managers, which is the term in the second line in the above expression. The second and third are the costs of hiring scientists and production engineer, and are given by the first and second terms in the third line, respectively.

2.4.2 Optimal Contracts under Specialized Structure

The following two lemmas characterize, respectively, the optimal contracts and the principal's expected total cost under the specialized structure.

Lemma 2.4 *Let $\psi_2 > 2\psi_1$. Then, the solution to problems P2 and P3 are such that*

a. *The managers' local incentive constraints and the participation constraints are binding. The global incentive constraints are always slack. Moreover, the optimal contract for the manager of a representative production firm is given by*

$$
\begin{aligned}
u_H^M &= \overline{u} + \psi_2 + \tfrac{2d}{1-d}\Delta\psi, \\
u_M^M &= \overline{u} + \psi_2 - \tfrac{1-2d}{1-d}\Delta\psi, \\
u_L^M &= \overline{u} + \psi_2 - 2\Delta\psi;
\end{aligned}
$$

and the optimal contract for the manager of a representative research firm is given by

$$u_H^M = \overline{u} + \psi_2 + \tfrac{2(1-r)}{r}\Delta\psi,$$

$$u_M^M = \overline{u} + \psi_2 + \tfrac{1-2r}{r}\Delta\psi,$$

$$u_L^M = \overline{u} + \psi_2 - 2\Delta\psi.$$

b. *The scientists' incentive constraints and participation constraints are binding. Moreover, each scientist's optimal contract is given by*

$$u_H^R = \overline{u} + \tfrac{\psi_1}{r},$$

$$u_L^R = \overline{u}.$$

c. *The production engineers' participation constraints are binding. Moreover, each engineer's optimal contract is given by*

$$u^P = \overline{u}.$$

Lemma 4 reports that both the managers of production firms and research firms receive a three-piece contract. Each receives a high compensation when both of their employees are successful, a medium compensation when only one of their employees is successful, and a low compensation when neither employee is successful. As in under the integrated structure, each scientist receives a high compensation when she is successful, and low otherwise; and the compensation of production engineers is flat.

Given the optimal contracts, the principal's expected total costs under this structure can be easily calculated. The result is summarized in Lemma 5.

Lemma 2.5 *The principal's expected total payments to agents under the specialized structure is given by*

$$\begin{aligned}
\mathrm{E}^S\big(C\big) &= \mathrm{E}^S\big(C^M\big) + \mathrm{E}^S\big(C^R\big) + \mathrm{E}^S\big(C^P\big) \\
&= (\overline{u} + \psi_2)^2 + \Big(\tfrac{d}{1-d} + \tfrac{1-r}{r}\Big)\Delta^2\psi \\
&\quad + \Big(r(\overline{u} + \tfrac{\psi_1}{r})^2 + (1-r)\overline{u}^2\Big) + \overline{u}^2.
\end{aligned}$$

2.5 Comparison of the Organizational Structures

In this section, I compare the principal's expected total profits under the two optimal contracts and characterize his preferred mode of organization. Note that we are in a ”second-best” situation in both of these organizational arrangements as the principal cannot observe the agents' actions in either of the two situations. Let Π^I and Π^S denote, respectively, the expected total profits of the principal under the integrated and specialized structures, respectively. That is, let

$$\Pi^I = \mathrm{E}^I\big(S\big) - \mathrm{E}^I\big(C\big) - 2(I_P + I_R),$$

and

$$\Pi^S = \mathrm{E}^S\big(S\big) - \mathrm{E}^S\big(C\big) - 2(I_P + I_R),$$

where $\mathrm{E}^I\big(S\big)$, $\mathrm{E}^I\big(C\big)$, $\mathrm{E}^S\big(S\big)$, and $\mathrm{E}^S\big(C\big)$ are as defined in section 3.3, 3.4 and lemmas 3 and 4.

Exploiting the result that $\mathrm{E}^I\big(S\big) = \mathrm{E}^S\big(S\big)$ from Lemma 1 and noting that $2(I_P+I_R)$ is common in both expressions, the difference in expected total profits depends only on the difference between expect total payments:

$$\Delta\Pi \equiv \Pi^S - \Pi^I = \mathrm{E}^I\big(C\big) - \mathrm{E}^S\big(C\big).$$

Furthermore, an immediate result that emerges from the comparison of Lemma 1 and Lemma

3 is that the principal's expected total payments to researchers and production workers are identical across the two structures. Consequently, the difference in the principal's expected total profits is simply the difference in the total compensation paid to managers under the two modes. The following proposition summarizes the first main result of the paper.

Proposition 2.1 *Let $\psi_2 \geq 2\psi_1$. Then, $\Pi^S \geq \Pi^I$, and $\Pi^S > \Pi^I$ if and only if $p > 0$. That is, the principal is always weakly better off under the specialized structure, and is strictly better off if and only if the production engineers have a positive probability of making an invention.*

Proposition 6 reports that the principal's preferred mode of organization is determined solely by the extent of agency problems between him and the managers. Specifically, if agency problems are not an issue, then the principal is indifferent between the two modes; and if they are severe, then he prefers specialization.

The key to understanding this result lies in the difference in the structure of information across the two organizational arrangements. Under integration the principal encounters an uncertainty concerning the source of the invention. Specifically, when there is an invention, it may have been developed by the scientist or the production engineer. When the production engineer and the scientist are in separate enterprises, this ambiguity no longer exists, and the principal can always be certain that the managers' reports about the state of the world are truthful. If the production engineers cannot come up with ideas, however, there is no benefit to having the managers specialize -both organizational structures produce the same return to the principal.

This result raises the question: Is the specialized structure always the preferred structure for the principal? The next section shows that the answer to the question is: No, not always.

2.6 Capital Market Imperfections

The analysis so far made the implicit assumption that capital markets were perfect in the sense that specialized research firms could "freely" raise external finance at the market interest rate. In this section, I relax this restrictive assumption in order to study the effects of capital market imperfections on the choice of organizational structure.

Now I reinterpret the static model of the previous section as the reduced form of a multi-period model. Each agent maximizes expected utility given by $\sum \beta^i u(t_i)$ where t_i denotes consumption in period i, and $\beta \in (0,1)$ denotes the common discount factor (inverse of the gross interest rate, R). On the other hand, let x_i^R and x_i^P for $i = 1, 2, ...$ denote the period cash flows generated by a representative research activity and a representative production activity, respectively. Thus, s_i^R and s_i^P of the static model can be thought of representing the present values of the period cash flows, x_i^R and x_i^P. The "evolution" of cash flows from each activity is depicted in Figure 5 and Figure 6.[16]

t	1	2	3	..t..	
x^R	0	$\overline{x}$	$\overline{x}$	......	Innovation
x^R	0	0	0	......	No innovation

Figure 2.5: Period research cash flows induced by high effort

t	1	2	3	..t..	
x^P	x	$x+\overline{x}$	$x+\overline{x}$	......	Innovation + Routine Task
x^P	x	x	x	......	Routine Task
x^P	0	0	0	......	Neither

Figure 2.6: Period production cash flows

[16]The implicit assumption here is that the workers have exerted high effort at the beginning of period 0.

The key assumption is that research activities do not generate any cash flows in the first period. Because the period cash flows are constant for both activities starting from period 2, this model is essentially a two period model with period cash flows as shown in the figures below.

t	1	2	
x^R	0	$\frac{\bar{x}}{R}$	Innovation
x^R	0	0	No innovation

Figure 2.7: Two period research cash flows

t	1	2	
x^P	x	$\frac{x+\bar{x}}{R}$	Innovation + Routine Task
x^P	x	$\frac{x}{R}$	Routine Task
x^P	0	0	Neither

Figure 2.8: Two period production cash flows

It is easy to see that the present discounted value of future cash flows will be the same for both the integrated structure and the specialized structure in this case. Therefore, when specialized research ventures can raise funds at the same rate as ordinary production ventures, the specialized structure is the preferred mode of organization (Proposition 6).

This result does not extend to the case where research ventures cannot raise funds as easily as ordinary production ventures. To see this, let R^B denote the rate at which research ventures can borrow, where $R^B > R$. Consider a representative firm with integrated structure. The expected first period cash flows of this firm are positive since the firm is engaged not only in research but also in ordinary production. This allows the firm to pay the manager and the workers out of ordinary production cash flows, and hence without having to resort to external financing.[17] This implies that future cash flows of a typical firm with integrated structure are discounted at the market interest rate R. Next, consider the specialized structure. While the first period cash flows of a specialized production firm are always positive, they are always zero for the specialized research firm. Clearly, the production firm can pay the manager and the workers using internal funds. The research firm, however, faces non-negativity constraints: it cannot compensate the manager and the workers unless it resorts to external financing. Therefore, while the future production cash flows are discounted at rate R, research cash flows are discounted at the higher rate R^B. This implies that expected future cash flows from the specialized structure are discounted at a rate that is between R and R^B. Consequently, the value to the principal of the specialized firm structure diminishes as the wedge between R^B and R increases, and so the specialized structure may cease to be the preferred mode of organization if R^B is sufficiently large. Figure 9 illustrates these discussions by use of a simple diagram.

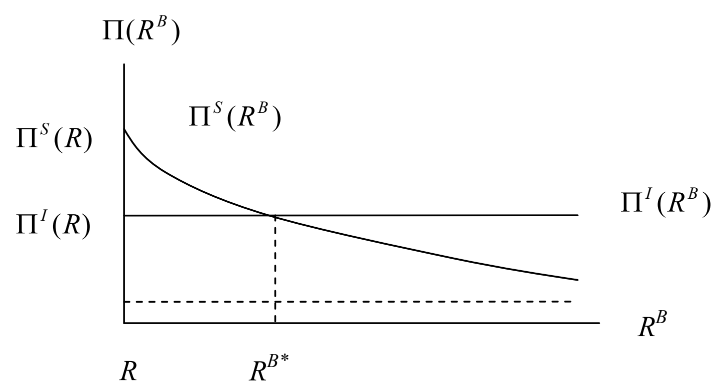

Figure 2.9: Discounted present value of cash flows as a function of the borrowing rate

[17]Therefore, I assume that the expected first period cash flows are sufficiently high. This is a simplifying assumption which does not alter the main conclusion of this section.

The following proposition formalizes the discussion so far.

Proposition 2.2 *There exists a cutoff borrowing rate R^{B^*} such that $\Pi^I > \Pi^S$ if and only if $R^B > R^{B^*}$. That is, the principal's preferred mode of organization is the integrated structure if and only if the borrowing rate is sufficiently high, and the specialized structure otherwise.*

Proposition 7 reports that the principal's preferred mode of organization is the integrated structure if (and only if) the borrowing rate is sufficiently high. In the present model, the wedge between the borrowing rate, R^B, and the market rate, R, is a measure of imperfections in capital markets.[18] That is, capital markets are more imperfect when $R^B - R$ is higher. Therefore, Proposition 7 can be read as: The preferred mode of organization is the integrated structure when capital markets are sufficiently imperfect.

To understand this result, it is useful to understand the difference between integrated firms and specialized firms. A main feature of specialized research enterprises is that they require substantial upfront investments without generating cash flows for a long time. As a result, research entreprises generally depend on external financing, and so their viability depends critically on their ability to raise funds from capital markets. If capital markets are perfect, these entreprises can borrow as much as they want at the market interest rate. By contrast, if there are imperfections in capital markets, research ventures can borrow only at higher rates. This implies that specialized research ventures are less attractive under such conditions. In extreme situations, capital market imperfections may make these ventures totally infeasible.

The situation is different for an integrated firm. Even if the research unit does not generate cash flows for a long period of time, earnings generated by the production unit may be used to subsidize

[18] Bernanke and Gertler (1989) and Kiyotaki and Moore (1997), among others, model capital market imperfections in this way.

the research unit. This implies that an integrated firm (e.g. a large corporation) is less vulnerable to the effects of imperfections in capital markets.

What are the sources of these capital market imperfections? Put differently, why would specialized research firms find it difficult to raise financing from external capital markets? Gompers and Lerner (2006), among others, provide an extensive discussion of this very point. First, specialized research ventures are typically surrounded by substantial uncertainty concerning their potential outcomes. Second, suppliers of capital may be at an informational disadvantage relative to insiders of a firm, who might in principle use their informational advantage to the detriment of the former. Third, most of the assets of a research venture is intangible and hence cannot be used as collateral. All of these issues potentially reduce the willingness of suppliers of capital to provide financing to research enterprises. In extreme situations, these problems may even cause credit-rationing (Stiglitz and Weiss, 1981).[19]

These results shed light on the costs and benefits of specialization in research environments. Specialization is desirable if capital markets are sufficiently perfect, because it reduces multi-level agency problems between the suppliers of capital on one hand and top managers of innovative enterprises and their employees, on the other. If capital markets are sufficiently imperfect, then costs of specialization may outweigh its benefits, however. The reason is that specialized research enterprises rely heavily on external finance, and so the cost of external finance is a crucial determinant of the viability of such enterprises. When capital markets are not sufficiently mature, the cost of ex-

[19] Rajan and Zingales (2003a) discuss some of the recent developments in financial markets that have to some extent reduced the first two problems mentioned in this paragraph. They argue that more data on potential borrowers is now available and is more timely, and that there have been improvements in accounting disclosure which have resulted in greater borrower transparency. Consequently, the ability of financial institutions in assessing and spreading risks has increased resulting in lower costs for potential borrowers.

ternal funds will be higher, making it more difficult to start new innovative ventures. Therefore, an important prediction of the model is that we should observe the dominance of established large corporations in innovation when capital markets are sufficiently imperfect, but this dominance should fade out as capital markets improve.[20] This prediction of the model is in line with the empirical finding of Rajan and Zingales (1998) who show, in a cross-section of countries in the 1980s, that the growth in the number of new establishments is significantly higher in industries dependent on external finance when the economy is financially developed.

2.7 Policy

If specialization is desirable in research environments, then policies aimed at increasing the availability of (early stage) capital to specialized research ventures are of critical importance. Indeed, many of the policy initiatives undertaken in the U.S. (and many other countries around the world) are aimed at this very goal. In the context of venture capital, one key policy initiative stands out: The 1979 amendment to the "prudent man rule" governing pension fund investments.[21] Prior to 1979, the Employee Retirement Income Security Act (ERISA) obstructed pension fund investments in high-risk start-up ventures, as investments in such ventures were deemed to be "imprudent". The Department of Labor's clarification of the rule stated that investments will be judged prudent not by their individual risk but by their contribution to portfolio risk. After the amendment, venture organizations -whose main goal was to provide early stage capital to high-risk, high-potential startup firms- have been able to raise substantial amounts of funds without concern over the perceived risk-

[20] An immediate corollary to this statement is that developments in capital markets pose a threat to large corporations, a point also argued by Rajan and Zingales (2003a,b)

[21] For a detailed discussion of the importance of this policy shift for venture capital see, for example, Gompers and Lerner (2006).

iness for pension funds. Gompers and Lerner (2006) found that in 1978, when $481 million was invested in new venture capital funds, individuals accounted for the largest share (32 percent). Pension funds supplied just 15 percent. Eight years later, when more than $4.8 billion was invested, pension funds accounted for more than half of all contributions.

The effect of this policy shift can be easily understood in the context of the model in this paper. An increase in the supply of funds to specialized research firms (through venture organizations) reduces the cost of external funds to these firms, that is, R^B goes down. As a result, it becomes easier to form specialized research firms and hence more such firms can be started. If specialization in research environments mitigates agency problems, as argued in the present paper, then the shift in policy increases innovative efficiency in the economy.

These discussions have the following implication.

Proposition 2.3 *Policies that reduce informational frictions in capital markets can increase industrial innovative efficiency.*

An immediate corollary to this proposition is that policies that reduce informational frictions in capital markets can enhance economic growth. In models of endogenous growth (e.g. Aghion and Howitt (1992)) innovation is the engine of growth, and as a result any policy that increases innovative efficiency will improve economic growth. The empirical implication is that countries with better developed capital markets will grow faster.

2.8 Conclusion

This paper develops a theoretical model to study the effectiveness of various organizational arrangements in conducting innovative activities. The model highlights the costs and benefits of specialization in research environments with multi-tier agency relationships. It is shown that, if capital markets are perfect, benefits of specialization outweigh its costs, and hence specialization is desirable. This result is reversed if capital markets are sufficiently imperfect, however. This result has an interesting implication: All else equal, the division of innovation between established companies and young, specialized firms will be determined by the extent of imperfections in capital markets. Specifically, the more perfect the capital markets, the greater will be the share of innovation conducted by young firms.

The model is then used to understand the explosion of innovation financed by venture capital sector in the U.S. since the late 1970s. I argue that the specialization implicit in venture capital form of organization helps mitigate multi-tier agency problems between the suppliers of capital on the one hand, and research executives and research scientists on the other, thereby producing more efficient outcomes. This mechanism helps us understand Kortum and Lerner (2000)'s empirical finding that venture capital-backed firms have been more innovative, on average, than their non-venture capital-backed counterparts recently.

The paper finally points to the importance of policy for innovation. I argue that changes in policy that took place in the late 1970s have helped improve capital markets by allowing a greater number of specialized, young research firms to find financing. Increased specialization in innovative activities, in turn, helped alleviate some of the informational problems which otherwise plagued large, diverse corporations. The end result has been a surge in innovative performance of the U.S. economy.

2.9 Appendix: Proofs

Proof of Lemma 1. There is an equal number (or measure) of identical research and production activities under each organizational structure, and the distribution of aggregate cash flows are not affected by changes in organizational structure. It follows immediately that the expected aggregate cash flows are the same across the two structures.

Proof of Lemma 2. Recall that the principal's cost minimization problem under *IF* structure is given by

$$\mathrm{E}^I(C) \equiv \min_{u^M,u^R,u^P} \mathrm{E}\Big(\sum h(u^j(\tilde{\mathbf{s}}))|e^P=1, e^R=1, e^M=2\Big)$$

$$(P1) \quad \text{s. to} \quad \mathrm{E}\big(u^M(\tilde{\mathbf{s}})|e^P=1, e^R=1, e^M=2\big) - \psi_2 \geq \overline{u} \tag{2.9.1}$$

$$\mathrm{E}\big(u^R(\tilde{\mathbf{s}})|e^P=1, e^R=1, e^M=2\big) - \psi_1 \geq \overline{u} \tag{2.9.2}$$

$$\mathrm{E}\big(u^P(\tilde{\mathbf{s}})|e^P=1, e^R=1, e^M=2\big) \geq \overline{u} \tag{2.9.3}$$

$$1 = \arg\max_{e\in\{0,1\}} \mathrm{E}\big(u^R(\tilde{\mathbf{s}})|e^P=1, e, e^M=2\big) - \psi_e \tag{2.9.4}$$

$$2 = \arg\max_{e\in\{0,1,2\}} \mathrm{E}\big(u^M(\tilde{\mathbf{s}})|e^P=1, e^R=1, e\big) - \psi_e \tag{2.9.5}$$

$$u_1^M(\tilde{\mathbf{s}}) = u_2^M(\tilde{\mathbf{s}}) = u_3^M(\tilde{\mathbf{s}}) \tag{2.9.6}$$

where (11), (12), and (13) are the participation constraints of the manager, the scientist, and the production engineer, respectively; (14) and (15) are the incentive constraints with respect to effort for the manager and the scientist, respectively; and (16) is the manager's truthful-reporting constraints. Without loss of generality, the solution of this optimization problem can be broken down into three parts: the characterization of the (a) manager's, (b) scientist's, and (c) production engineer's optimal contracts. I present the solution to each of these problems in turn. To this end, I first write the expectation operators explicitly in terms of the fundamentals of the model. In order to reduce notational clutter, I omit the agent labels such as "*M*" or "*R*" whenever there is no danger of confusion.

a. The manager's compensation contract: The manager's participation constraint, PC, is given by

$$p\big(ru_1 + (1-r)u_2\big) + q\big(ru_3 + (1-r)u_4\big) + d\big(ru_5 + (1-r)u_6\big) - \psi_2 \geq \overline{u}.$$

As discussed in the body of the paper, the manager's incentive constraint (15) involves two local incentive constraints, LIC_1 and LIC_2 and a global incentive constraint, GIC. LIC_1 and LIC_2 are given, respectively, by

$$p\big(ru_1 + (1-r)u_2\big) + q\big(ru_3 + (1-r)u_4\big) + d\big(ru_5 + (1-r)u_6\big) - \psi_2$$
$$\geq p_0\big(ru_1 + (1-r)u_2\big) + q_0\big(ru_3 + (1-r)u_4\big) + d_0\big(ru_5 + (1-r)u_6\big) - \psi_1,$$

and

$$p\big(ru_1 + (1-r)u_2\big) + q\big(ru_3 + (1-r)u_4\big) + d\big(ru_5 + (1-r)u_6\big) - \psi_2$$
$$\geq p\big(r_0u_1 + (1-r_0)u_2\big) + q\big(r_0u_3 + (1-r_0)u_4\big) + d\big(r_0u_5 + (1-r_0)u_6\big) - \psi_1,$$

and GIC is given by

$$p\big(ru_1 + (1-r)u_2\big) + q\big(ru_3 + (1-r)u_4\big) + d\big(ru_5 + (1-r)u_6\big) - \psi_2$$
$$\geq p_0\big(r_0u_1 + (1-r_0)u_2\big) + q_0\big(r_0u_3 + (1-r_0)u_4\big) + d_0\big(r_0u_5 + (1-r_0)u_6\big).$$

The truthful-reporting constraint is the same as before, i.e. $u_1 = u_2 = u_3$. Let's call this constraint TR and denote u_1, u_2 and u_3 by u_1.

The manager's optimal compensation contract is, therefore, the solution to the following cost minimization problem:

$$\min_{u_i}(pq+r)h(u_1)+q(1-r)h(u_4)+drh(u_5)+d(1-r)h(u_6)$$

$$s.to \quad PC, LIC_1, LIC_2 \quad \text{and} \quad GIC.$$

Let $\mu \geq 0$, $\lambda_1 \geq 0$, $\lambda_2 \geq 0$, and $\lambda_g \geq 0$ denote the (negative of) Lagrange multipliers attached to PC, LIC_1, LIC_2, and GIC, respectively.

The solution is by "guess and verify". Assume $\mu > 0$, $\lambda_1 > 0$, $\lambda_2 > 0$, and $\lambda_g = 0$. Then, u_i's must satisfy the following Kuhn-Tucker first-order conditions for $i = 1, .., 6$:

$$(pq+r)h'(u_1) = (pq+r)\mu + (\Delta p + \Delta qr)\lambda_1 + q\Delta r\lambda_2 \tag{2.9.7}$$

$$q(1-r)h'(u_4) = q(1-r)\mu + \Delta q(1-r)\lambda_1 - q\Delta r\lambda_2 \tag{2.9.8}$$

$$drh'(u_5) = dr\mu + \Delta dr\lambda_1 + d\Delta r\lambda_2 \tag{2.9.9}$$

$$d(1-r)h'(u_6) = d(1-r)\mu + \Delta d(1-r)\lambda_1 - d\Delta r\lambda_2 \tag{2.9.10}$$

where $\Delta x = x - x_0$ for $x = p, q, d$. Taking into account that $h'(u) = 2u$ and summing equations (17) to (20) yields

$$2\mathrm{E}(u) = \mu, \tag{2.9.11}$$

where $\mathrm{E}(\cdot)$ denotes the expectation operator with respect to the distribution of aggregate cash flows induced by high efforts, i.e. $e^M = 2$, $e^R = 1$, and $e^P = 1$. Because PC must hold, we have

$$\mathrm{E}(u) \geq \overline{u} + \psi_2 > 0,$$

implying that $\mu > 0$, and hence PC is binding as conjectured. Inserting the value of $\mathrm{E}(u) = \overline{u} + \psi_2$ into (21), we obtain

$$\mu = 2(\overline{u} + \psi_2). \tag{2.9.12}$$

Using (22) and that $h'(u) = 2u$ along with $p_0 = q_0 = 0$ and $r_0 = 0$, we can express (17) through (20) as

$$u_1 = \overline{u} + \psi_2 + \frac{\lambda_1}{2} + \frac{qr}{p+qr}\frac{\lambda_2}{2} \tag{2.9.13}$$

$$u_4 = \overline{u} + \psi_2 + \frac{\lambda_1}{2} - \frac{r}{1-r}\frac{\lambda_2}{2} \tag{2.9.14}$$

$$u_5 = \overline{u} + \psi_2 - \frac{1-d}{d}\frac{\lambda_1}{2} + \frac{\lambda_2}{2} \tag{2.9.15}$$

$$u_6 = \overline{u} + \psi_2 - \frac{1-d}{d}\frac{\lambda_1}{2} - \frac{r}{1-r}\frac{\lambda_2}{2} \tag{2.9.16}$$

Inserting (23) through (26) into LIC_1 and LIC_2 at equality, we obtain a system of two equations involving two unknowns, λ_1 and λ_2. This system of equations admits the following solution:

$$\lambda_1 = \frac{2d\Delta\psi}{1-d} > 0 \tag{2.9.17}$$

$$\lambda_2 = \frac{2(p+qr)(1-r)\Delta\psi}{(pd+qr)r} > 0 \tag{2.9.18}$$

where $\Delta\psi = \psi_2 - \psi_1$. Thus, LIC_1 and LIC_2 must be binding as conjectured at the outset.

Finally, inserting the values of λ_1 and λ_2 from (27) and (28) into (23) to (26), we obtain the manager's optimal compensation contract:

$$u_1^M = u_2^M = u_3^M = \overline{u} + \psi_2 + \Big(\frac{d}{1-d} + \frac{q(1-r)}{pd+qr}\Big)\Delta\psi \tag{2.9.19}$$

$$u_4^M = \overline{u} + \psi_2 + \Big(\frac{d}{1-d} - \frac{p+qr}{pd+qr}\Big)\Delta\psi \tag{2.9.20}$$

$$u_5^M = \overline{u} + \psi_2 + \Big(\frac{(p+qr)(1-r)}{(pd+qr)r} - 1\Big)\Delta\psi \tag{2.9.21}$$

$$u_6^M = \overline{u} + \psi_2 - \Big(1 + \frac{p+qr}{pd+qr}\Big)\Delta\psi \tag{2.9.22}$$

Finally, we need to verify that GIC is not binding, i.e $\lambda_g = 0$. GIC is not binding if and only if

$$u_6 - \overline{u} < 0.$$

Inserting the value of u_6 from (32) and rearranging, this inequality can be expressed (after some computation) as

$$\psi_2 > \Big(1 + \frac{pd+qr}{p+qr}\Big)\psi_1.$$

Note that the coefficient of ψ_1 is a number that is strictly between 1 and 2. Therefore, the results of the lemma also hold for $\psi_2 \geq 2\psi_1$.

b. The scientist's compensation contract: Provided that the manager reports truthfully (which is ensured by (16)), the independence of the production and research activities allows us to consider the scientist's optimal compensation contract separately from the production engineer's contract. The scientist's optimal contract solves:

$$\mathrm{E}(C^R) \equiv \min_{u_1,u_2} rh(u_1) + (1-r)h(u_2)$$

$$\text{s. to} \quad ru_1 + (1-r)u_2 - \psi_1 \geq \overline{u}$$

$$ru_1 + (1-r)u_2 - \psi_1 \geq u_2$$

Letting $\mu \geq 0$ and $\lambda \geq 0$ denote the (negative of the) Lagrange multipliers associated with the participation and incentive constraints of the scientist, respectively, u_i must satisfy the following Kuhn-Tucker first-order condition for $i = 1, 2$:

$$h'(u_1) = \mu + \lambda$$

$$h'(u_2) = \mu - \lambda$$

Claim: Both $\lambda > 0$ and $\mu > 0$.

Proof of claim: First, suppose that $\mu = 0$. Then, $h'(u_2) = -\lambda \leq 0$, which is impossible as $h' > 0$. Second, suppose that $\lambda = 0$. Then, $h'(u_1) = h'(u_2)$, implying that $u_1 = u_2 \equiv u$. But then, the incentive constraint implies that $\psi_1 \leq 0$, contradicting $\psi_1 > 0$.

Therefore, both the participation and incentive constraints are binding. Inserting $h'(u) = 2u$ and solving these two constraints for u_1 and u_2, we obtain:

$$u_1^R = \overline{u} + \frac{\psi_1}{r} \tag{2.9.23}$$

$$u_2^R = \overline{u}. \tag{2.9.24}$$

Note that $u_1^R > u_2^R > 0$.

c. The production engineer's compensation contract: As in the previous case, provided that the manager reports truthfully (which is ensured by (24)), the independence of activities allows us to consider the production engineer's optimal compensation contract separately from the scientist's contract. The production engineer's optimal contract solves:

$$\mathrm{E}(C^P) \equiv \min_{u_1,u_2,u_3} \quad ph(u_1) + qh(u_2) + dh(u_3)$$

$$\text{s. to} \quad pu_1 + qu_2 + du_3 \geq \overline{u}$$

The constraint in this problem always binds at a solution of this problem; otherwise, the principal could lower the worker's compensation while still getting her to accept the contract. Letting μ denote the (negative of the) Lagrange multiplier, at a solution to the above problem, the engineer's contingent utility u_i at any state i must satisfy the first-order condition

$$h'(u_i) = \mu.$$

Thus, the engineer's optimal compensation is constant, with $u_1 = u_2 = u_3 \equiv u$. Plugging u into the (binding) constraint, one obtains

$$u^P = \overline{u}. \tag{2.9.25}$$

Proof of Lemma 3. The principal's expected cost has three components: The manager's, the scientist's, and the production engineer's compensations.

1. The manager's expected compensation is given by

$$\begin{aligned} \mathrm{E}^I\big(C^M\big) &= (p+qr){u_1}^2 + q(1-r){u_4}^2 + dr{u_5}^2 + d(1-r){u_6}^2 \\ &= \mathrm{E}(u^2) \\ &= \big(\mathrm{E}(u)\big)^2 + \mathrm{var}(u), \end{aligned}$$

   where $E(u)$ and $\mathrm{var}(u)$ denote, respectively, the expectation and variance operators with respect to the distribution of cash flows induced by high efforts by all agents. We already know $\mathrm{E}(u) = \overline{u} + \psi_2$. Thus, we only need to calculate $\mathrm{var}(u)$. By definition, we can write

$$\mathrm{var}(u) = (p+qr)\big(u_1 - \mathrm{E}(u)\big)^2 + q(1-r)\big(u_4 - \mathrm{E}(u)\big)^2 + dr\big(u_5 - \mathrm{E}(u)\big)^2 + d(1-r)\big(u_6 - \mathrm{E}(u)\big)^2.$$

   Using (29) through (32) in $\mathrm{var}(u)$, we obtain (after some computation)

$$\mathrm{var}(u) = \Big(\frac{d}{1-d} + \frac{(p+qr)(1-r)}{(pd+qr)r}\Big)\Delta^2\psi,$$

   where $\Delta^2\psi = (\psi_2 - \psi_1)^2$. Inserting this expression back into $\mathrm{E}^I\big(C^M\big)$, we get

$$\mathrm{E}^I\big(C^M\big) = (\overline{u} + \psi_2)^2 + \Big(\frac{d}{1-d} + \frac{(p+qr)(1-r)}{(pd+qr)r}\Big)\Delta^2\psi. \tag{2.9.26}$$

2. The scientist's expected compensation is given by

$$\mathrm{E}^I\big(C^R\big) = r{u_1}^2 + (1-r){u_2}^2.$$

Inserting equations (33) and (34), we obtain

$$\mathrm{E}^I\big(C^R\big) = r\big(\overline{u} + \frac{\psi_1}{r}\big)^2 + (1-r)\overline{u}^2. \tag{2.9.27}$$

3. The engineer's expected compensation is given by

$$\mathrm{E}^I\big(C^P\big) = p{u_1}^2 + q{u_2}^2 + d{u_3}^2.$$

Inserting equation (35), we obtain

$$\mathrm{E}^I\big(C^P\big) = \overline{u}^2. \tag{2.9.28}$$

Finally, summing equations (36), (37), and (38), principal's total expected payments to all the agents involved in a single integrated firm can be computed. Because there are two integrated firms by assumption, the principal's expected cost under integrated structure is given by

$$\mathrm{E}^I\big(C\big) = 2\Big[(\overline{u} + \psi_2)^2 + \Big(\tfrac{d}{1-d} + \tfrac{p+qr}{pd+qr}\tfrac{1-r}{r}\Big)\Delta^2\psi + r(\overline{u} + \tfrac{\psi_1}{r})^2 + (1-r)\overline{u}^2 + \overline{u}^2\Big] \tag{2.9.29}$$

Proof of Lemma 4. Analogous to the proof of Lemma 2.

Proof of Lemma 5. Analogous to the proof of Lemma 3. For subsequent use, the principal's expected cost under the specialized structure for parameter values $\psi_2 > 2\psi_1$ is given by

$$\mathrm{E}^S\big(C\big) = 2\Big[(\overline{u} + \psi_2)^2 + \Big(\tfrac{d}{1-d} + \tfrac{1-r}{r}\Big)\Delta^2\psi + r(\overline{u} + \tfrac{\psi_1}{r})^2 + (1-r)\overline{u}^2 + \overline{u}^2\Big]. \tag{2.9.30}$$

Proof of Proposition 6. Let $\Delta\Pi \equiv \Pi^S - \Pi^I$. Then, by Lemma 1 $\Delta\Pi = \mathrm{E}^I(C) - \mathrm{E}^S(C)$. The fact that $\mathrm{E}^I(C)$ and $\mathrm{E}^S(C)$ are defined over different sets of parameter values implies that we need to consider two cases.

1. $\psi_2 > 2\psi_1$. In this case, $\mathrm{E}^I(C)$ and $\mathrm{E}^S(C)$ are given by equations (39) and (40), respectively. Canceling the common terms, the difference can be written as

$$\begin{aligned}\Delta\Pi &= \left(\tfrac{p+qr}{pd+qr} - 1\right)\tfrac{1-r}{r}\Delta^2\psi \\ &= \tfrac{p(1-d)}{pd+qr}\tfrac{1-r}{r}\Delta^2\psi \\ &> 0\end{aligned}$$

where the last inequality follows since $p \in (0,1)$, $d \in (0,1)$, and $r \in (0,1)$.

2. $\psi_2 = 2\psi_1$. In this case, the principal's cost under the integrated structure is still given by (39), but $\mathrm{E}^S(C)$ must be recalculated as the manager's global incentive constraint is now binding (Lemma 4). Analogous computations to those in Lemma 2 imply that when $\psi_2 = 2\psi_1$ the Lagrange multiplier on the global incentive constraint is equal to zero, i.e. $\lambda_g = 0$. On the other hand, the local incentive constraints are binding for $\psi_2 > \beta\psi_1$, where $\beta \equiv max\{\frac{1+d}{1+d-d(1-d)^2}, 2-r\}$. Note that $\beta < 2$. Therefore, the principal's cost under the specialized structure is exactly equal to $\mathrm{E}^S(C)$ as given by (40). It then follows that $\Delta\Pi > 0$.

Consequently, $\Delta\Pi > 0$ for $\psi_2 \geq 2\psi_1$.

Proof of Proposition 7. By Proposition 6, $\Pi^S > \Pi^I$ when $R^B = R$, for some $R \geq 0$. Moreover, Π^I is strictly positive and independent of R^B while Π^S monotonically declines to zero as R^B increases without bound. The result, then, follows by the Intermediate Value Theorem. See Figure 9 for a diagramatic "proof" of this result.

Chapter 3

Does Deposit Insurance Increase Bank Risk Taking? Evidence from Korean Bank Panel

3.1 Introduction

The effect of deposit insurance on bank risk-taking has been one of the most controversial issues in banking literature. On one hand, there is some literature arguing that the existence of deposit insurance increases moral hazard of market participants and bank failure[1] (Thies and Gerlowski (1989), Wheelock (1992), Demirguc-Kunt and Detragiache (1998)). On the other hand, some economists insist that the effect of deposit insurance on bank risk-taking is insignificant (Wheelock and Wilson (1999), Karels and McClatchey (1999)). Meanwhile, Gropp and Vesala (2001) find that the estab-

[1] The existence of an explicit safety net renders depositors to exert less effort to monitor a bank's investment behavior, which leads to the selection of risky portfolio by the bank and the deterioration of the bank's asset quality.

lishment of explicit deposit insurance significantly reduces the risk-taking of banks using the panel data of EU banks. They note that when there is a comprehensive implicit safety net, the introduction of explicit deposit insurance limits the coverage of bank loss, thus reducing banks' moral hazard incentives.

This paper examines the effect of deposit insurance on bank risk-taking using panel data of 27 Korean commercial banks from 1994 through 2004. Korean banking sector adopted deposit insurance in 1997, but its economic impact has been rarely explored thus far. To the best of our knowledge, this is the first attempt to investigate the existence of risk-taking incentives due to deposit insurance using bank-level data of Korea.[2] In addition, considering that the system has experienced various changes in terms of insurance coverage[3], analyzing their effect will also provide valuable insights. More specifically, in this paper, we test the following two hypotheses: The existence of explicit deposit insurance increases bank risk-taking [H1], and Bank risk-taking increases with insurance coverage [H2].

3.2 Model

To test above hypotheses, we set up the following fixed effects panel regression model[4]

$$R_{it} = \alpha_i + \beta_1 DI_{it} + \beta_2 DR_{it} + \beta_3 EQ_{it} + \beta_4 HHI_t + \beta_5 CMD_t + \beta_6 DCrisis_t + \beta_7 DReg_t + \beta_8 SZ_{it} + \epsilon_{it}$$

[2]Demirguc-Kunt and Detragiache (2002) use Korean macro data. It is difficult to find studies using a country's bank-level data except the U.S. Gueyie and Lai (2001) examine 5 Canadian banks and fail to detect the presence of moral hazard in the Canadian banking industry.

[3]The insurance coverage was 20 million won in 1997 when the deposit insurance was first introduced. The banking authorities implemented an extraordinary full protection scheme between 1998 and 2000 to prevent possible bank runs during the East Asian economic crisis period. Beginning 2001, the insurance coverage was reduced to 50 million won.

[4]The reason behind our use of a fixed effects model is that the sample covers all commercial banks in Korea. Please see, for example, Green (2000) for more details.

where subscripts *i* and *t* represent a bank and a year, respectively, and $\epsilon_{it} \sim N(0, {\sigma_\epsilon}^2)$.

The dependent variable *R* (risk) represents an asset risk calculated by the ratio of bad loans to total loans. *DI* is a dummy variable for deposit insurance, and takes on a value of 0 for the period without deposit insurance (1994-1996), and 1 for the period with deposit insurance (1997-2004) in testing H1. In the second analysis which tests H2, *DI* is a three-way dummy, and takes on a value of 0 for 1997 when the insurance coverage was 20 million won, 1 for 2001-2004 when it was 50 million won, and 2 for 1998-2000 when full protection scheme was implemented. *DR* denotes deposit interest rate and is calculated as the ratio of deposit interest income to average total deposits. It is included to in accordance with a strand of literature on the effect of change in deposit interest rates on bank risk-taking (Hodgman (1961), Benston (1964), Cox (1966), Rolnick (1987), Shughart (1988), Caminal and Matutes (2002)).[5] *EQ* is the ratio of equity capital to total assets, and accounts for the relationship between equity capital and bank risk-taking (Koehn and Santomero (1980), Kim and Santomero (1988), Furlong and Keeley (1989),Hellman, Murdock, and Stiglitz (2000)).

Meanwhile, *HHI* denotes log(Hirfindahl - Hirschman Index), and represents the degree of bank concentration. According to Keeley (1990), a decrease in bank concentration that results from the abolishment of regulatory policies such as entry barriers reduces a bank's charter value, which in turn may increase bank risk-taking. *CMD* is the degree of capital market development, computed as "money values of stocks and bonds traded in the capital market/nominal GDP". It is included to control for the effect of competition from non-bank financial intermediaries on bank risk-taking. In essence, these variables (*HHI*, *CMD*) control for the effect of macroeconomic environment on bank risk-taking.[6]

[5] According to Caminal and Matutes (2002) when deposit interest rates increase, a bank also raises loan interest rates and invests the funds in a risky (high risk, high return) portfolio to maintain its target profit. As a result, the bank's asset quality deteriorates.

[6] Initially, we tried to include GDP in the analysis. However, the correlation between GDP and *DR* was nearly perfect

On the other hand, *DCrisis* is included to control for the influence of the East Asian economic crisis, which equals 1 for 1998 and 0 for others. *DReg* is another dummy variable which controls for the effect of the regulatory policy regarding deposit interest rate (Demirguc-Kunt and Detragiache (1998)). It is equal to 1 for 1994 and 1995, and 0 for other years.[7] Finally, we include *SZ* to determine whether the risk-taking behavior is significantly different across banks of various sizes. Descriptive statistics for the variables used are listed in Table 1.

(Sample Period: 1994-2004)

	No. of Obs.	Mean	Max	Min	Std. Dev.
R	208	5.833	29.9	0.2	5.027
DI	208	0.649	1.0	0.0	0.478
DR	208	6.261	11.6	2.5	1.918
EQ	208	7.859	21.4	0.9	3.496
HHI	208	2.966	3.2	2.9	0.104
CMD	208	0.790	2.2	0.3	0.523
DCrisis	208	0.096	1	0	0.296
DReg	208	0.231	1	0	0.422
SZ	208	5.037	6.3	3.7	0.557

Table 3.1: Descriptive Statistics

3.3 Empirical Results

The sample period is from 1994 to 2004. The sample period begins with 1994 as this is the first year for which data on the dependent variable is available. Most data are from FSS (Financial Supervisory Service) of Korea, and some other data, such as the stock market variables and GDP, are from KSE (Korea Stock Exchange) and the BOK (Bank of Korea).

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and GDP was very insignificant in the regression equations, which led us to exclude it in the final analysis.

[7] There is a consensus that deposit interest rates in Korea were virtually liberalized in November 1995.

According to Baer and Brewer (1986), endogeneity may exist between the dependent variable and *DR*. In order to attract depositors, a bank with a higher bad loan rate, ceteris paribus, needs to increase deposit interest rate more than a bank with a lower bad loan rate. Taking this possibility into account, we employ instrumental variable estimation as well as OLS in estimating equation (1).

As shown in Table 2, the overall results are consistent with the theory that deposit insurance encourages banks to take excessive risk (Matutes and Vives (1995), Freixas and Rochet (1997)). We also find some evidence that bank risk-taking increases with insurance coverage. Models (a) - (d), and (e) - (h) are the results of test 1, and test 2, respectively. Furthermore, this phenomenon turns out to be more severe in larger banks.

DI has a significant positive sign in all models. It is significant at the 1% level in models (a), (b), and 5% level in (c), (d). *DR* has a positive sign in most models, but it is significant only in model (c). *EQ* also has a very strong correlation with the dependent variable in all models, supporting the view that equity capital prevents banks from taking excessive risk.

HHI has a negative sign in all models, indicating that weakened competition decreases the incentive of a bank to take excessive risk. Put differently, stronger competition increases the incentive of a bank to take excessive risks. *CMD* has a strong positive sign in all models, which may suggest that as the capital market develops, banks undertake excessive risks due to the strengthened competition from non-bank financial intermediaries. Both results are consistent with a strand of literature that puts emphasis on the positive relationship between competition and bank risk-taking.

Notably, *SZ* (bank size) has a very strong positive sign in all models. This suggests that larger banks engage in greater risk-taking than smaller banks - a result that is in line with the "too-big-to-fail" hypothesis.

The test results of H2 indicate that risk-taking incentives increase with insurance coverage. The results are essentially the same as those in models (a) - (d), except that *EQ* becomes insignificant.

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Value of DI	**0 for 1994≤ t ≤ 1996, 1 for 1997≤ t ≤2004**				**0 for t=1997, 1 for 2001≤ t ≤2004, 2 for 1998≤ t ≤2000**			
Constant	95.801***	94.576***	54.379*	47.343	86.795***	69.495*	2.230	-24.858
	(0.000)	(0.005)	(0.072)	(0.244)	(0.007)	(0.074)	(0.954)	(0.622)
DI	2.972***	2.970***	2.134**	2.095**	2.271***	2.249***	1.628*	1.533*
	(0.001)	(0.001)	(0.019)	(0.022)	(0.010)	(0.009)	(0.053)	(0.069)
DR	0.395	0.421	1.030*	1.168	0.072	0.442	1.438**	1.968**
	(0.446)	(0.536)	(0.067)	(0.131)	(0.909)	(0.576)	(0.044)	(0.039)
EQ	-0.310***	-0.310***	-0.251**	-0.247**	0.354*	0.349	0.299	0.287
	(0.009)	(0.009)	(0.035)	(0.038)	(0.099)	(0.102)	(0.141)	(0.156)
HHI	-32.441***	-32.076***	-29.363***	-27.612***	-29.419***	-24.264**	-26.114***	-20.510*
	(0.000)	(0.002)	(0.000)	(0.008)	(0.003)	(0.037)	(0.005)	(0.071)
CMD	5.065***	5.052***	4.857***	4.789***	3.300***	3.127***	3.290***	3.113***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.005)	(0.002)	(0.003)
DCrisis	0.123	0.052	-1.629	-2.011	-1.926	-2.918	-4.911**	-6.254**
	(0.942)	(0.980)	(0.358)	(0.384)	(0.409)	(0.273)	(0.039)	(0.029)
Dreg	1.203	1.195	1.794**	1.781**				
	(0.166)	(0.172)	(0.042)	(0.042)				
SZ			5.677***	5.889***			13.063***	14.536***
			(0.007)	(0.008)			(0.000)	(0.000)
R^2	0.580	0.580	0.597	0.597	0.624	0.623	0.667	0.665
No. of obs.	208	208	208	208	135	135	135	135
Sample Period	1994 ~ 2004				1997 ~ 2004			

Source : authors' calculation.
Notes : 1. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.
2. p-values are reported in parentheses.
3. Variables instrumented : DR , Instruments : DI, DR(-1), EQ, HHI, CMD, DCrisis, Dreg, SZ.

Table 3.2: Deposit Insurance and Risk-Taking

3.4 Conclusion

The overall test results using Korean bank-level data provides evidence for the presence of moral hazard effect of deposit insurance. In spite of a strong implicit safety net that existed before the adoption of deposit insurance, the introduction of explicit deposit insurance seems to have significantly increased market participants' incentives to take excessive risk, which is in contrast with the argument of Gropp and Vesala (2001).[8] The adverse incentive effect of deposit insurance increases with insurance coverage and is more severe in larger banks than in smaller banks. It is very interesting that even after the devastating economic crisis, during which 5 out of 27 banks were closed and merged into other relatively sound banks, "too-big-to-fail" seems to still exist in the Korean banking industry.[9] One explanation may be that those banks that failed during the crisis were relatively small compared to the current average Korean bank. We leave the answer to this question for future research.

[8]The Korean banking industry before the East Asian economic crisis can be characterized by strong government regulations and an implicit safety net. In fact, banks in Korea had never failed before the economic crisis mainly due to ex post bail out of troubled banks by the government.

[9]Banks are on average larger than other financial firms.

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