ASYMMETRIC INFORMATION, LEARNING AND PROJECT FINANCE:

THEORY AND EVIDENCE

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ABSTRACT

Asymmetric Information, Learning and Project Finance: Theory and Evidence

Project finance is analysed in three separate papers plus a survey. The survey highlights, *inter alia*, the recent development of multi-stage models with learning and reputation. The following two chapters develop models where projects involve a sequence of investments, while the final chapter is an empirical study. In Chapter Two an entrepreneur makes an initial investment and then faces an optimal stopping problem. It is socially optimal to terminate a high cost project when costs become known sufficiently early. But, due to past investments being sunk costs, there is a cut-off point after which completion of projects is always optimal. With asymmetric learning the entrepreneur may conceal bad state realisations from investors until after the cut-off date. The stopping problem is sometimes resolved by a loan commitment (a single-stage mechanism) and sometimes by convertible and redeemable Preference shares (a two-stage mechanism). In Chapter Three an entrepreneur begins with a project in the form of a call option with two periods to maturity. One period latter another project becomes available. Exercise decisions are observable but non-contractible and contracts to finance the second project cannot be written in advance of its arrival. With symmetric information about state realisations a simple rule for whether the two projects are best incorporated jointly as a single firm or separately as legally distinct firms is given. If joint incorporation is optimal, a contractual covenant to this effect may be required to overcome a time-inconsistency problem. With asymmetric information the exercise decision for the first project becomes a signalling game with a premature-investment pooling equilibrium. The time-inconsistency problem now becomes a useful device for eliminating the pooling equilibrium. The analysis implies that the covenants attached to financial contracts may differ according to whether information is symmetric or asymmetric. Finally, Chapter Four studies a unique sample of high growth entrepreneurial firms financed by 3*i* PLC. We characterise financing arrangements for these firms and discusses their relation with theories of optimal capital structure. Probit analysis is used to study the relation between collateral and risk. Contrary to the significant positive relation found by recent studies, we find no significant relation between collateral and risk.

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PREFACE

This thesis analyses methods of financing investment projects. A primary concern is to understand how financial contracts may overcome inefficiencies in investment due to imperfect, incomplete (asymmetric) information. The general area of optimal financial contracts and security design consists of a very large literature, including principle–agency theory, ex ante and ex post informational problems, incomplete contracts, liquidation versus reorganisation, product and input market interactions, and the market for corporate control. At the outset, therefore, we restrict the scope of our inquiry to those classes of models whose primary emphasis is on investment projects. This accounts for the words *Project Finance* in the title of this thesis. Of course, most of the models in the areas cited can and do have implications for the efficiency of investment. But many of their main results can be obtained without there being any role for investment. An example is the literature on corporate control and capital structure.

The four chapters in this thesis are designed to be read independently of each other. The common thread binding the papers together is the emphasis on multi–stage investment projects with learning. Thus, the main argument is that, unlike adverse selection and signalling, the implications of learning for financial contracts remains largely unexplored. Yet this seems to be an important feature of projects involving inventions and innovations. As a testimony to the importance of these kinds of projects we may note the substantial growth of the U.K. venture capital industry during the 1980s.

The first chapter of the thesis provides an introductory survey on project finance. In addition to highlighting the role of learning, the chapter makes a number of other observations concerning the state of the literature. In terms of generality, the most important observation is that many of the commonly observed financial contracts, such as the standard debt contract, are optimal only within some restricted class of contracts. Two examples of imposed restrictions are monotonicity of the payoff function and limited liability. In particular, the latter restriction is usually a consequence of model design making limited liability synomonous with the resource constraint for non-negative consumption. We argue that this modelling approach is theoretically unsatisfactory because it fails to explain the limited liability feature of most commonly observed financial contracts.

Chapter Two derives the optimal financial contract for a principal-agent model with a form of information revelation which has not hitherto been investigated. Our hypothesis, which we call *temporary asymmetric learning*, assumes there is symmetric information at both the first and final dates, but that the entrepreneur may gain an informational advantage at some intermediate date. This assumption extends a traditional private information model to an intertemporal framework. Alternatively, it can be thought of as a variation on symmetric learning problems. The temporary asymmetric learning hypothesis leads to an interesting problem because at the time of the informational asymmetry the entrepreneur must make crucial decisions about the future of the project. However, with symmetric information at the initial and final dates we are able to apply the theory of mechanism design to show that the optimal contract resembles either debt with a loan commitment option attached or a financial structure with convertible and redeemable preference shares. Some evidence is cited showing that these types of shares are commonly found in venture captial contracts. Another interesting feature of the model is that the extent of limited liability associated with project terminations is derived endogenously.

Chapter Three addresses the question of whether and how asymmetric information may affect decisions to incorporate two projects jointly as a single firm or separately as legally distinct entities. This question has received very little attention in the literature as most models implicitly assume that technological factors prevent separation of new investments from existing assets. By contrast, the projects in our model can be operated independently. Amoung models which allow for separable projects, the model in this chapter is the first which does not rely on exogeneous factors, such as the taxation benefits of debt, to motivate joint incorporation of projects. Instead, the optimal mode of incorporation derives from the fact that a new project is essentially a call option with two periods to maturity: following the initial investment in a project the entrepreneur chooses to implement the second stage investment at one of two dates. The model posits an ex post informational asymmetry in the form of costly-state verification so that debt is optimal. However, debt finance leads to the Myers [1977] Under-Investment problem and, with symmetric information, it is the minimisation of these distortions which determines whether joint or separate incorporation is optimal ex ante.

Two interesting features arise in this framework. First, a *time-inconsistency problem* may arise where in some circumstances the entrepreneur will try to renege on an ex ante optimal promise to incorporate projects jointly. This problem, which has not previously been modelled formally, provides a justification for covenants to financial contracts and/or corporate charters which bind the company to joint incorporation of projects. The second feature of the model is the existence of a *premature-investment problem* where by all investment options are exercised at the first available date in order to avoid sending a bad signal to investors. This problem can occur when there is asymmetric information and projects are incorporated jointly. In addition to the analysis of optimal "incorporation covenants", the premature-investment problem represents a novel and significant contribution to the current literature on project finance with asymmetric information.

The final chapter studies balance sheet data from a sample of high growth entrepreneurial firms. The study is in two parts. The first characterises, by sample average, the financing arrangements for these firms both in terms of the type of financial instrument and in terms of the distribution of claims among entrepreneur and venture capitalist. The latter consideration is a unique feature of the study. Also, we compare our statistics with those of U.K. publicly listed companies to highlight the special features of finance for high growth firms. The second part of the chapter undertakes a probit analysis of the relation between collateral and risk. For this purpose, our data exhibit two unique features. First, we can make the important theoretical distinction between inside and outside collateral. Second, our ex post measures of risk are computed on the basis of company-by-company, rather than bank-by-bank, data. In contrast to the significant positive relation found by recent studies, we can find no significant relation between collateral and risk. Some suggestions are offered concerning these negative results.

CHAPTER ONE

AN INTRODUCTION TO PROJECT FINANCE

How can entrepreneurs and firms best finance their investment projects? This question is one component of a much broader inquiry into optimal corporate policy and financial contracts that began with Modigliani and Miller's [1958] famous irrelevance propositions. These state that for perfect and complete markets (without taxation): (1) the market value of any firm is independent of its capital structure, and; (2) the cut-off point for investment in the firm is completely unaffected by the type of security used to finance the investment. Since Modigliani and Miller [1958] a voluminous literature has developed examining how the irrelevance propositions are affected by various market imperfections. In this paper our aim is to survey those theoretical issues which are most relevant for the financing of investment projects. Thus, we are primarily concerned with the second, rather than the first, of the irrelevance propositions.

Restricting attention to investment projects means that we do not survey models of taxation benefits and bankruptcy costs of debt, issues of liquidation versus reorganisation, strategic interactions with product or input markets, or theories of capital structure based on corporate control contests (i.e. takeovers). We provide two justifications for omitting this fairly substantial literature. First, our restricted scope accords well with the project-oriented focus of the other papers in this thesis. Second, the issues not covered can be found in excellent surveys by, for example, Allen [1990], Harris and Raviv [1991], Masulis [1988] and Miller [1988].

Our basic approach in this survey is to try to explain the underlying rationale for why each set of assumptions produces particular results.[1] We also highlight the sensitivity of some results to the particular assumptions upon which they are based. However, taking the above approach has lead to a correspondingly low emphasis on comparing and contrasting the empirical implications of each theory. Nevertheless, this seems a favourable trade-off in view of the empirical content of Harris and Raviv [1991].

The main conclusions of this survey are two-fold. First, although some financial contracts, such as debt, correspond well with casual observation, they are in fact optimal only within some restricted class of contracts. Two examples of imposed restrictions are limited liability and monotonicity of payoff functions. Second, further development of the recent costly-state falsification model would likely be fruitful. The costly-state falsification model is interesting because contracts resemble equity, although without full limited liability. In contrast, most other information-based models predict that debt is the optimal contract. Also, costly-state falsification appears to be a natural framework in which to assess the reasonableness of the monotonicity constraint mentioned above.

In addition to these conclusions, the survey identifies a number of recent developments in the literature. The most prominent is the distinction between private information and symmetric by non-verifiable information. Models of learning and reputation-building have also been a subject of recent interest. A less prominent development is the interaction between financial structure and the optimal incorporation mode for new investment projects. The question here is whether a new project should or should not be incorporated jointly with existing assets.

The survey is organised into four main sections followed by a summary and conclusions. The first three sections correspond to models of agency/moral hazard, ex post informational asymmetries, and ex ante informational asymmetries. The fourth section discusses models that combine agency costs and ex ante informational asymmetries. Section 5 provides a brief summary and discussion of the previous four sections and is followed by conclusions in Section 6.

1. Agency Costs/Moral Hazard

An entrepreneur who owns a profitable investment opportunity may be unable to self-finance all investment requirements associated with his or her project. Undertaking the project requires that the entrepreneur raise finance by writing a contract with outside investors. Once the necessary funds have been obtained the entrepreneur/manager implements an investment project by taking various actions. In general these actions will be imperfectly observable and, therefore, cannot be specified in the financial contract. The agency cost or moral hazard theory of project finance refers to the conflicts of interest that can arise between the contracting parties due to the non-contractibility of actions. The two main areas of conflict identified in this literature are[2]: (i) conflicts between outside shareholders and entrepreneur/managers; and (ii) conflict between shareholders and debt holders. Our discussion below of these conflicts is cast in terms of whether the agency problem or moral hazard occurs before or after state realisations. In the terminology of Arrow [1985], the former is classified as *moral hazard with hidden action* and the latter as *moral hazard with hidden information*. This distinction is convenient because the nature of conflicts and their potential resolution differ significantly.

1.1. Moral Hazard with Hidden Actions

Jensen and Meckling [1976] consider an entrepreneurial firm which is initially 100 per cent equity financed (i.e. owned solely by the entrepreneur/manager). In order to finance an investment the entrepreneur must raise funds by issuing debt and/or equity shares, both of which have agency costs. Other types of financial instrument and the potential role of managerial remuneration functions are not considered. Issuing equity to outside investors, who have no ability to control the day-to-day actions of the incumbent manager, leads to the standard principal-agent problem: the entrepreneur, as manager, bears a non-pecuniary cost of effort or human capital investment but receives less than 100 per cent of the returns at the margin. Hence, there is a conflict of interest between managers and shareholders, which we refer to as the problem of *managerial incentives*. In addition, if risky debt is issued then the entrepreneur's payoff function becomes convex in project returns and this creates an incentive to substitute in favour of risky projects. The expected return to debt holders falls because their payoff function is concave in project returns and this leads to a conflict of interest between shareholders and debt holders. We refer to this as the problem of the *risk-shifting incentive*, although in other papers it is sometimes referred to as the asset-substitution effect.[3]

The managerial and risk-shifting incentive problems suggest that insiders (the entrepreneur or manager) can impose costs on one or more groups of outside investors. However, rational investors will anticipate these agency costs and price their financial claims appropriately. Thus, agency costs are ultimately borne by the original owners of the project. In general, we would expect these owners to offer financial and/or managerial contracts which maximise their expected utility. In the following we discuss the possible solutions, looking first at optimal financial contracts and then at optimal managerial contracts.

Optimal Contracts

Haugen and Senbet [1981, 1987] claim that both the managerial and risk-shifting incentive problems can be eliminated by the appropriate mix of convertible debt, callable debt and managerial stock options. The idea behind their analysis is that the correct mix of these put and call options can be found such that the entrepreneur/manager's wealth function passes through the first-best solution and has a slope that mimics the optimal marginal trade-off. Hence, the entrepreneur bears the full cost of increased perquisite consumption or lower effort. However, the results of Haugen and Senbet depend on their specification of the entrepreneur's utility function and also suffer from an inappropriate application of the Option Pricing Model.[4]

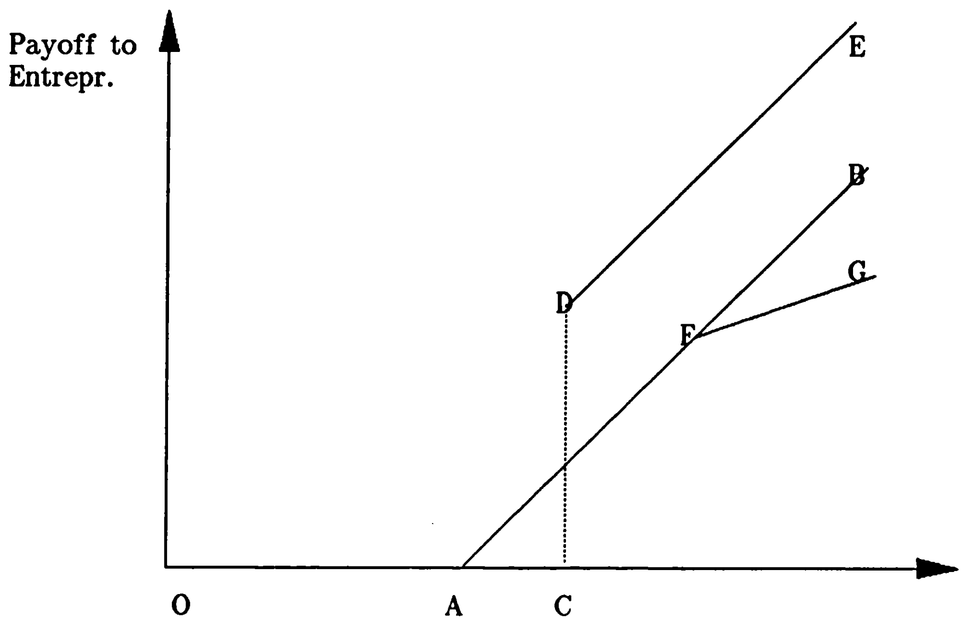
For the case of risk-shifting incentives Green [1984] shows how convertible debt or warrants may be used to resolve these conflicts between bondholders and shareholders.[5] Green derives his result in a model where the entrepreneur maximises his or her expected payoff. Convertible debt or warrants can resolve the incentive problem because the entrepreneur's residual payoff in non-bankruptcy states becomes concave in returns. In terms of Figure 1 we can see that the risk-loving behaviour is induced by the convex structure OAB. All points to the right of A are non-bankruptcy states. With debt that is convertible into equity shares the payoff function over these states can look like AFG, which is concave. With appropriate conversion parameters the risk-aversion induced by the concave section can exactly offset the risk-loving behaviour induced by straight debt.[6]

For the case of managerial incentives Innes [1990] shows that the form of the optimal financial contract depends on whether outsiders and/or insiders to the firm can manipulate earnings. If earnings can be manipulated then the class of truth-telling contracts is restricted to the set of contracts with monotonically non-decreasing payoff functions and the optimal contract for a risk neutral entrepreneur is the standard debt contract. In this case actions are second best when debt is risky. If, however, earnings cannot be manipulated, then the optimal contract is a "live-or-die" contract. This contract states that there is a critical profit realisation below which all profits are paid to investors and above which <u>no</u> profits are paid to investors. Figure 1 illustrates the entrepreneur's residual payoff with both debt (OAB) and live-or-die (OCDE) contracts. A live-or-die contract provides the greatest incentive for high effort but does not necessarily attain first-best.

An Application to Venture Capital Contracts

Chan, Siegel and Thakor [1990] apply the managerial incentives problem to a two-period model of venture capital contracts. In their model both the entrepreneur and venture capitalist have ability to operate the project. In a given period either the entrepreneur or venture capitalist is in control of the

Figure 1: Contract Payoffs



Debt = OAB
Live-or-Die = OCDE
Debt + Warrant = OAFG

project and takes an action which affects the project's probability of success. A key additional feature is that the entrepreneur's skill at operating the project is initially unknown by either party (i.e. there is symmetric information). In the first period, therefore, the entrepreneur operates the project so that his or her skill level can be determined from cash flows. The optimal financial contract is shown to exhibit many of the features common to venture capital contracts, including a prohibition on external funding at the intermediate date, a buy-out arrangement if the entrepreneur's skills are demonstrated to be deficient, and an sharing arrangement where by the entrepreneur's share of second period returns is a function of the observed level of skill.

1.2. Moral Hazard with Hidden Information

The previous section has been concerned with the case where actions occur after contracting but before resolution of uncertainty. This means that rational investors, given that they know the structure of the problem, can correctly compute the entrepreneur's actions in equilibrium. In contrast, the moral hazard problems of this section have the property that the entrepreneur privately observes a state realisation before taking an action. This changes the nature of the problem because investors cannot know whether a particular observed outcome is due to the state realisation or the agent's action. We begin the section by re–analysing the problem of perquisite consumption. Following this we discuss two agency problems known as *Jensen's free cash flow theory* and *Myers' under – investment problem*, and also introduce two recent developments referred to as *stopping failures* and *non–verifiable information.*

Perquisite Consumption

The managerial incentive problem discussed in this section is best interpreted as perquisite consumption. The managerial effort and human capital investment interpretations are better suited to ex ante, rather than ex post, moral hazard. As in the previous section, it can also be shown that convertible debt and managerial stock options are unable to eliminate excessive perquisite consumption (see Farmer and Winter [1986], Narayanan [1987], and Williams [1987][7]). Williams [1987] is a particularly interesting model which combines ex ante moral hazard in the form of risk–shifting incentives with ex post perquisite consumption. The main result is that debt does not necessarily induce entrepreneurs to increase risk. The structure of Williams' model is as follows. The entrepreneur/manager chooses project risk and then observes the state realisation in the form of project cash flow. Debt holders (and other prior claimants) are paid and then the entrepreneur consumes perquisites. Further payments may then be made to external investors after which any excess cash belongs to the entrepreneur. It is assumed that failure to pay the debt holders leads to the immediate removal of the entrepreneur so that no perquisites can be consumed. Investors are risk neutral while the entrepreneur's utility is linear in wealth, strictly concave in consumption of perquisites and additively separable in wealth and perquisite consumption. With these assumptions, Williams shows that an increase in the face value of debt may lead entrepreneur's to choose *less* risky projects. This result, which contrasts with the analysis of Jensen and Meckling, is due to interactions between risk and perquisite consumption. To see this note that the entrepreneur's ability to consume perquisites following the state realisation is like a contingent claim. For low state realisations the maximum feasible consumption is low and so the marginal utility of perquisite consumption is high. Consequently, for relatively low state realisations an increase in debt (or prior claims) reduces feasible consumption and increases marginal utility, which in turn induces the entrepreneur to place greater weight on low realisations by initially choosing projects with lower risk. In addition to this result, Williams shows that even when risk is increasing in debt the potential adverse effects on bondholders are more than offset by decreases in the consumption of perquisites. Thus, the idea that debt leads to a conflict of interest between shareholders and bondholders is not a general property.[8]

Jensen's Free Cash Flow Theory

In the finance literature the problem of perquisite consumption is often recast in terms of managerial discretion over investment expenditure. The basic story, due to Jensen [1986], is that managers have incentives to cause their firms to grow beyond the optimal size because this increases the amount of resources under their control and, hence, their power (and possibly managerial remuneration). Thus, a sequence of good state realisations generating high cash flows can lead to conflicts between manager and shareholder as managers begin to invest in projects with negative NPV, rather than increase dividend distributions. This is known as *Jensen's free cash flow theory.* (In this context "free cash flow" is defined as cash flow in excess of that required to fund all projects with positive NPV).

Jensen argues, therefore, that a key advantage of debt over equity is that it can prevent over-investment by forcing management to pay out cash. A more formal model of optimal capital structure is developed in Stulz [1990]. In this model free cash flow can be either positive or negative and lead to over- and under-investment, respectively. A crucial feature of Stulz's model is that the manager's marginal utility of wealth is approaching zero so that it is impossible to align conflicting interests with an appropriate managerial incentive scheme. Stulz assumes the realised level of free cash flow is private information of managers and that they always claim it to be negative in an attempt to persuade existing shareholders to vote for additional external funding. Realising this, shareholders determine external funding by trading off the potential losses from over-investment with those of under-investment.

Myers Under-Investment Problem

The previously noted risk-shifting incentives of debt occur because an increase in project risk effects a wealth transfer from debt holders to shareholders. As a result of this transfer, shareholders may over-invest by undertaking projects with negative NPV. Similarly, we would expect under-investment to occur if undertaking a positive NPV project were to lead to a reverse transfer of wealth from shareholders to bondholders. Myers [1977] illustrates this possibility in a one-period model of growth options. At date 0 the firm owns a technology which will produce an investment opportunity at date 1. The gross value of this investment is V(s), where V(s) is increasing in state s and the value of s becomes known to the firm at date 1. For simplicity, we assume that V(s) is known with certainty conditional on s. To exercise the opportunity (i.e. invest in the project) costs an amount I. If we let s^a be such that $V(s^a) = I$, then the investment is socially optimal for all $s > s^a$. Now suppose, for whatever reason, that the firm has debt outstanding with face value B. Clearly, if B has senior claim on the cash flow from the prospective investment then it will only be financed if $s > s^b$, where $V(s^b) = I + B$. Thus, if the state realisation falls into the interval (s^a, s^b) the firm fails to exercise a socially profitable investment. This is referred to as the *Myers under-investment problem.*

Implicitly, the above analysis makes several important assumptions. First, that the project cannot be incorporated as a separate legal entity. Separate incorporation would prevent the existing debt holders from gaining any value from the new project. In practice, however, separation of new from existing projects may be costly either for technological reasons or because it is prevented by covenants attached to existing debt contracts. A second important assumption is that existing claims cannot be renegotiated. In the example above, the debt holders have an incentive to forgive a portion of the debt because the value of their claims fall to zero unless the investment option is exercised. Myers [1977] and Hart and Moore [1990] argue, however, that when debt claims are widely dispersed, renegotiation may not be feasible due to hold-out and free-rider problems.

In an optimal contracting framework the Myers under-investment problem can be overcome with convertible debt (Chiesa [1988]) or loan commitments (Berkovitch and Greenbaum [1991]). The choice between convertible debt and loan commitments depends on the source of uncertainty at the contracting date. Convertible debt is optimal when investments are fixed and there is uncertainty about the distribution of returns. On the other hand, when the investment requirement is the main source of uncertainty the loan commitment contract is optimal. A loan commitment contract specifies a maximum borrowing limit, say $\hat{L}$, and a usage fee, u, which varies according to investment requirements. This is a slight variation of Myers [1977] as we now assume V is constant and $I = I(s)$, a function of s. In this case, better state realisations translate into lower I(s) and, hence, higher surplus, V−I(s)−B. Thus, without violating incentives for truthful reporting, it is possible to make the usage fee an increasing function of $\hat{C}$ − I(s), so that entrepreneurs with good realisations pay more. The additional expected revenue from the usage fee can then be offset by a lower face value of debt, B, such that investors make zero expected profits and all projects with positive NPV are undertaken.

One potential problem with the "optimal contracting" approach above is that these models may fail to include important complicating features. For example, suppose debt has an important taxation advantage over equity and various hybrid contracts. Then, in general, we would expect only limited use of hybrid contracts such that the marginal cost due to distortions equals the marginal benefit of debt. It is therefore useful to consider how the incidence of under-investment can be minimised by the covenants attached to debt contracts. Such covenants may include seniority provisions, collateral provisions and restrictions on dividend payments (see Berkovitch and Kim [1990] and Stulz and Johnson [1985]). Another approach to this problem is to introduce adverse selection into the moral hazard model and assess the extent to which under-investment can be mitigated by signalling and reputational considerations. These factors are discussed in Sections 4.1 and 4.2.

Stopping Failures

The under-investment problem discussed above can be characterised as an optimal exercise problem. The problem there is that outstanding debt makes the entrepreneur reluctant to exercise some worthwhile investment options. A natural extension of this research is the possibility that entrepreneurs, rather than being reluctant, may be too willing to exercise an investment option, i.e. there may be a *stopping failure* in the sense that once an investment process has begun it may be difficult to induce entrepreneurs to terminate unprofitable projects.

In contrast to the Myers under-investment problem, which requires that renegotiation is prohibitively costly, a stopping failure can occur precisely because investors are unable to precommit against renegotiating initial contracts in the face of inefficiencies ex post. Models of this type include Dewatripont and Maskin [1989] and Chapter Two of this thesis (Hansen [1991a]).

The structure of my own model is as follows. An entrepreneur has a project requiring a sequence of sunk cost investments and an effort decision. The project is either low cost (positive NPV) or high cost (negative NPV). In the former case total cost is c_0+c_1 while in the latter case total cost is $c_0+c_1+c_2$, where the subscripts are the dates at which the investments are made. At date 0 nature chooses whether the project is high or low cost and this is initially unobserved by either party. If the project is high cost then the entrepreneur has an exogenous probability of learning this at either date 1 or date 2. The crucial distinction is that at date 1 the total future investment requirement is c_1+c_2 while at date 2 it is only c_2. Thus, the parameters of the model are set so that it is socially optimal to terminate a high cost project if this becomes known at date 1, but to otherwise complete the project if this becomes known only at date 2. A self-financing entrepreneur will follow the socially optimal stopping policy. An entrepreneur with no initial wealth will need to raise finance from investors who learns about total cost at date 2, i.e. after the critical "point-of-no-return" date. Thus, knowing that investors cannot credibly commit to refuse finance for the final stage, entrepreneurs may conceal their private information until after date 1. The paper shows that for some parameter values the stopping failure is resolved most efficiently by a one-stage mechanism which corresponds to debt with a loan commitment option attached. For some other parameter values efficient stopping requires a two-stage mechanism which can be interpreted as combinations of convertible and redeemable preference shares. These types of arrangements are observed in venture capital contracts.

Non-Verifiable Information

The previous models of this sub-section have the common property that state realisations are privately observed by the entrepreneur. A closely related class of models develops moral hazard problems when state realisations are commonly observed but are non-verifiable by third parties, e.g. law courts (Aghion and Bolton [1988] and Hart and Moore [1989, 1990]). Non-verifiability of states is motivated by the costs of writing contracts and/or the difficulty of accurately defining and describing relevant state realisations.

The main advantage of assuming symmetric but non-verifiable information is a simplification of the renegotiation game that arises in the event of ex post inefficiencies. Apart from this, the results of most models are similar to the case of moral hazard with hidden information. An example is Aghion and Bolton [1988], which analyses the role of debt in effecting transfers of control between entrepreneur and investor. In their model the investor is a more efficient controller of the project in low state realisations because the entrepreneur is reluctant to incur the non-pecuniary costs associated with liquidation. Debt increases the probability that the transfer of control takes place in low states while enabling the entrepreneur to make high-value contributions in high states.

In another model, Hart and Moore [1990] develop a variation on Jensen's free cash flow theory where the manager is very wealthy and has an insatiable appetite for investment (i.e. as in Stulz [1990] the manager's marginal utility of wealth approaches zero). In their model all cash flows accrue at the end-date so that free cash flow at intermediate dates is non-positive and hence any investment must be funded by issuing new securities. Hart and Moore point out that the ability to raise funds for any new investment will depend on the seniority rules specified by existing claims. For example, if there is debt outstanding then financing with equity shares may be difficult because the debt holders have first claim to any cash flows generated by the investment. This idea is developed to allow for a general structure of claims and seniority rankings. Thus, the primary role of debt in Hart and Moore is to control the manager's ability to bring cash into the firm whereas in Stulz [1990] the role of debt is to get cash out.

2. Ex Post Information Asymmetries

In this section we begin by discussing the costly-state verification literature and follow on with a recent model of costly-state falsification. A key distinction between the two is that the former assumes there are costs of verifying or monitoring the state realisation while the latter assumes it is costly to falsify or hide the true state realisation. The costly-state falsification approach is an exciting new development because optimal contracts can look very much like equity shares. This, of course, is in sharp contrast with the debt contracts commonly associated with costly-state verification.

2.1. Costly-State Verification

The term *costly-state verification* refers to a situation where only one of two parties to a contract can costlessly observe the state realisation. However, the uninformed party can become informed by taking some appropriate costly action. This class of models was first analysed by Townsend [1979] and, in the specific context of investment projects, has been extended by Diamond [1984][9], Gale and Hellwig [1985], Williamson [1987], Chang [1990] and Bester [1990]. Here, as before, there is a risk neutral entrepreneur with an investment project but with insufficient wealth to be self-financing. The entrepreneur therefore seeks external finance by offering a contract with promised repayments, possibly as a function of the project's return. However, since the external investor does not initially observe project returns, he or she will not know whether the entrepreneur reports the true outcome. Indeed, whenever the repayment function is increasing in project returns the entrepreneur will have an incentive to under-report income. One possible solution is for the investor to act so as to verify the entrepreneur's report irrespective of how good the report is. But this cannot be optimal since verification, here interpreted as bankruptcy, is a costly process. In general, minimisation of expected verification costs subject to honest reporting by the entrepreneur requires that the verification decision be random (see Townsend [1988]). However, if we restrict attention to the class of contracts with deterministic verification functions then, with some further assumptions, the optimal contract is shown to be the ***standard debt contract***, i.e. there is some critical level, say $\hat{r}$, such that: (1) for reports above $\hat{r}$ verification does not occur and repayments are constant; and (2) for reports below $\hat{r}$ verification (bankruptcy) occurs and all returns in excess of the verification cost are paid to the investor.[10]

Gale and Hellwig [1985] and Williamson [1987] consider the efficiency consequences of debt when investments are divisible and indivisible, respectively. They show that investment may be less than the first-best level. For the case of divisible investments, an example is where the pecuniary cost of verification in each state is increasing in the level of investment. Thus, compared with the first-best level, the loss from a small reduction in investment may be more than offset by the gain from lower expected verification cost.

An important qualification of the Townsend, Gale and Hellwig and Williamson results is that they are derived within a one-period framework. Chang [1990] shows that in a multi-period framework a simple condition is sufficient for the optimal contract to be debt with commonly observed features such as coupon and/or sinking fund payments.[11] In the context of a two-period model the condition is that verification costs for each date be increasing in the value of the firm's assets at that date. The interim coupon and sinking fund payments then result from minimisation of total verification costs.

Several other features of the standard costly-state verification model should be noted. First, since the model assumes entrepreneurs have no illiquid wealth (e.g. human wealth from present value of prospective labour earnings), the limited liability constraints arise trivially from the resource constraints requiring non-negative consumption for the entrepreneur. Second, the debt contract of the standard model is not renegotiation-proof. Since costly verification/bankruptcy is inefficient ex post it is sequentially rational for the original contract to be renegotiated. In particular, if creditors are less efficient operators of projects we might expect a new contract to be written under which the entrepreneur maintains ownership of the project at a reduced level of debt.

These issues are studied in Bester [1990], who finds an interesting interaction between renegotiation and limited liability. In his model the entrepreneur can put up some personal wealth as collateral, but the maximum amount is limited so that debt remains risky. It is also assumed that both the project and the collateral are less valuable when owned and controlled by the investor. On this basis, we might expect that posting collateral increases the ex post inefficiencies and would be suboptimal. However, Bester shows that this is not necessarily true. For any given probability that the creditor will force bankruptcy (rather than renegotiate), an increase in collateral reduces the probability that the entrepreneur under-reports his return. It turns out that if the inefficiencies associated with changing project ownership are sufficiently high relative to those associated with collateral, then an increase in external collateral will reduce expected total bankruptcy costs. In contrast to the screening models discussed below, Bester shows that use of collateral is more likely to increase efficiency if the project is high risk.

2.2. Costly-State Falsification

In the previous sub-section the assumption of costly-state verification implied that outsiders could not observe project return unless some deadweight loss was incurred. The term *costly-state falsification* represents the reverse side of the coin because now outsiders can perfectly observe returns unless the agent actively hides (i.e. falsifies) some portion of it.[12] Falsification is assumed to be a costly activity. A general model of costly falsification is developed by Lacker and Weinberg [1989], but in terms of project finance we can imagine a legal structure where all registered companies must publish audited accounts annually. Since these accounts must balance on both sides and reconcile with bank statements and so on, deceiving auditors is not a trivial exercise.

Two key differences between costly verification and costly falsification suggest that their optimal contracts may be quite different. First, the decision as to whether deadweight costs are to be incurred shifts from the uninformed agent (investor) to the informed agent (entrepreneur). Second, in the earlier model the cost of verification is increasing (or at least non-decreasing) in the magnitude of the returns to be verified, while in the present model the costs of falsification depend on the extent to which returns are falsified. i.e. if we let x be the actual realised return and y the return displayed to outsiders, then $z=x-y$ is the amount of output being hidden. Verification costs are increasing in x while falsification costs are increasing in z (they may also be a function of x).

In contrast to the standard debt contract in the verification model, Lacker and Weinberg show that the optimal non-falsification contract is generally non-contingent on some left-hand interval of returns and increasing with a slope strictly less than one on the right-hand interval. Under some conditions the repayment function is linear on the right-hand interval. This latter property makes the contract resemble equity, but without full limited liability for the entrepreneur, i.e. it is akin to venture capital finance with collateral requirements. However, Lacker and Weinberg show that optimal non-falsification contracts are not always globally optimal. Their sufficient condition for non-falsification to be globally optimal requires that the entrepreneur not be too risk averse and/or that the cost function not be too convex. For example, non-falsification is optimal if falsification costs are proportional to the amount hidden, z.

3. Ex Ante Information Asymmetries

The models considered in this section have the common feature that information is asymmetric at the time of contracting. The key assumption is that the entrepreneur, as an informed insider, knows much more about his or her future prospects than do investors (outsiders). Two types of model are considered in this section. First, we review the literature for models where the informational asymmetry is uni-dimensional. The typical model is of a number of entrepreneurs, each with a single project characterised by an investment requirement and a distribution function for returns which accrue one period later. These models, beginning with Stiglitz and Weiss [1981], are discussed in Sub-sections 3.1 and 3.2 on adverse selection and screening. The second type of model allows for informational asymmetries along two dimensions. The proto-type is the Myers and Majluf [1984] model where outsiders are uninformed about the true values of both existing assets and an investment option. Our discussion of this area, which begins in Sub-section 3.3 on signalling[13], highlights the sensitivity of optimal financing strategies to the assumptions of the model.

3.1. Adverse Selection

Stiglitz and Weiss [1981] show that a debt contract leads to under-investment (via credit rationing) when projects are ranked by mean-preserving spread (MPS)[14]. The rationale for their result was the standard *lemons problem* (Akerlof [1970]) where by bad (high risk) projects drive-out good projects. In the context of credit markets, adverse selection can occur because with debt contracts the entrepreneur's expected returns increase with a mean-preserving increase in risk. However, de Meza and Webb [1987] show that Stiglitz's and Weiss's MPS assumption is inconsistent with debt being the optimal equilibrium contract. Instead, the optimal contract is an equity contract. Moreover, with equity contracts the aggregate level of investment attains first-best levels.

For the case of first-order stochastic dominance (FOSD)[15] and where each project has only two feasible state realisations, de Meza and Webb [1987, 1990] show that debt finance is optimal and that even in the presence of risk aversion aggregate investment will never be lower than the first-best level, and will often exceed it.[16] That debt is the unique Nash equilibrium can be seen as follows. First, the assumption of only two-state realisations limits the set of feasible contracts to debt and equity. Second, compared with equity, debt gives the entrepreneur a higher payoff in high profit states and a lower payoff in low profit states. This implies that equity cannot be a Nash equilibrium since if all other financiers offer zero-profit equity contracts, each financier can make positive profit by offering a debt contract. Doing so would attract the higher quality entrepreneurs since they have greater probability weight concentrated on high-profit states. On the other hand, debt is a Nash equilibrium because any financier which attempts to attract higher quality entrepreneurs by offering an equity contract will also attract the lower quality entrepreneurs. Given that other financiers are offering zero-profit debt contracts, any equity contract which is attractive to higher quality entrepreneurs will imply negative profits for the deviating financier.

The above analysis is conducted in an economy where each project has two possible realisations: success or failure. We have noted that this characterisation limits the set of feasible contracts to debt and equity. In general, with more than two feasible state-realisations FOSD is not sufficient for debt to be optimal. Innes [1991] shows that the relevant conditions are that higher quality be defined by the monotone likelihood ratio property and a monotonicity condition which requires investor payoffs to be non-decreasing in profits.[17] In the absence of the monotonicity condition the optimal contract will generally take the form of the "live-or-die" contract in Section 1.1.

3.2. Screening

The financial contracts and associated market equilibria identified above are all characterised by some degree of pooling of entrepreneurs. Some of the lower quality entrepreneurs may drop out of the market but the remainder all receive the same credit terms. There are several possible responses to this situation. One is for high quality entrepreneurs to take observable actions which distinguish themselves from lower quality types. This is the subject of the next section on signalling. Another response is for investors (or lenders or banks) to offer a menu of contracts and thereby sort or *screen* entrepreneur types through self-selection. Potential screening mechanisms include collateral requirements, investment size, and long-term contracts.

The role of collateral as a potential screening device was first analysed in Stiglitz and Weiss [1981]. However, they did not allow lenders to vary simultaneously both interest rates and collateral requirements. Once this is allowed for most models of competitive banking with projects ranked by either MPS or FOSD obtain separating equilibria with market clearing, provided entrepreneurs have arbitrarily large amounts of collateral available (Bester [1985] and Besanko and Thakor [1987a, 1987b]). The reason is that good borrowers, being less risky, will offer more collateral in return for lower interest rates than will bad borrowers. Thus, we obtain the *single-crossing property* that is necessary for separating equilibria to exist. A similar analysis also applies to models with divisible investments, though the equilibrium can be characterised by either under- or over-investment (Milde and Riley [1988]). If, however, collateral is limited then one-period contracts can lead to rationing in the sense that some borrowers have positive probability of being denied credit (see Besanko and Thakor [1987a] and Calomiris and Hubbard [1990]).

Additional possibilities for sorting borrowers are available when the one-period model is extended to a multi-period framework. Two approaches have been studied. The first, in Webb [1991a], assumes there are two entrepreneur types -- high and low quality -- and that each will undertake a succession of two identical one-period projects. Webb shows that an investor can sort the entrepreneurs by offering two types of contract. The first type is a succession of standard one-period debt contracts and the second is a long-term contract. In the latter contract, the financing terms for the second project are made contingent on the outcome of the first project. A good outcome leads to a low second period interest rate while a bad outcome leads to a high second period interest rate. In addition to the higher interest rate, a defaulter is further penalised because the amount of internal equity available for the second project is reduced. Consequently, a low quality entrepreneur who has only low probability of success in the first project will choose the standard debt contract while high quality entrepreneurs will choose the long-term contract.[18]

The above resolution of adverse selection involved extending the contract for one or more periods into the future. This requires that entrepreneurs have a succession of projects or returns. However, if entrepreneurs have only one project then an alternative possibility is to shift the contracting process back one period prior to the start of the project. Thakor [1989] shows that it is sometimes possible to sort entrepreneurs by designing a menu of loan option agreements. The idea can be illustrated with a two-period model in which the project begins at date 1 and ends at date 2. It is possible to write a *spot contract* when the project begins (date 1) or to write a *loan commitment* one period prior to the beginning of the project (date 0). As an example, suppose there are two entrepreneur types, good and bad, who have profitable investments provided interest rates fall in intervals $[0,r_g]$ and $[0,r_b]$, respectively, where $r_g > r_b$. Also, there are two possible macro-economic state realisations which translate into low and high interest rates, r_ℓ and r_h. The prior probability distribution over states and the subsequent state realisations (at date 1) are commonly observed. Assume $r_\ell < r_b < r_h < r_g$ so that r_ℓ is the low interest rate (economy wide) in which the projects of both entrepreneur types are profitable while r_h is the high interest rate in which only the good entrepreneur's project is profitable. Hence, there is a problem of adverse selection in state r_ℓ but not in state r_h. Consequently, spot contracting at date 1 does not perform well in state r_ℓ. On the other hand, contracts written prior to date 1 can use the possibility that state r_h may occur to sort entrepreneurs. Specifically, consider a contract which gives the holder an option to borrow at an interest rate r_o where $r_b \leq r_o < r_h$. Clearly, the option is worthless to a bad entrepreneur since r_o exceeds the upper bound r_b for which the bad type's project is profitable. However, the option is valuable to the good entrepreneur because of the interest rate subsidy $r_h - r_o$ it confers in state *h*. Thus, a contract which incorporates the loan commitment option will sort entrepreneurs because only the good entrepreneur will be prepared to pay an up-front fee at date 0 to obtain the option. The bad entrepreneur will obtain finance through an actuarily fair spot contract at date 1.

3.3. Signalling

A large portion of the literature on optimal corporate financial policy consists of signalling models. The four main types are: (1) signalling by managers due to interactions between debt levels and managerial incentives (Ross [1977]); (2) signalling by risk averse entrepreneurs with the proportion of equity holdings retained (Leland and Pyle [1977]); (3) signalling with dividend payouts (Bhattacharya [1979]); and, (4) signalling firm value by not investing in projects with low but positive NPV (Myers and Majluf [1984]). Each of these models may have implications for optimal investment. However, in the case of the first three models the role of investment is not of primary concern. In contrast, the primary focus of Myers and Majluf is whether firms forego positive NPV projects. Thus, in keeping with our focus in this survey on investment projects, we discuss only Myers and Majluf [1984] and associated papers.[19]

The idea underlying Myers and Majluf [1984] can be illustrated by the following simple example. Suppose firms can be either type H or type L with existing assets of value V_H and V_L, respectively, where $V_H > V_L$. These values are known to managers, who act in the interests of existing shareholders, but are not known by the market in general. However, the market knows that the type H firms accounts for a proportion p of all firms. In the absence of separating equilibria, therefore, the market value of each firm's existing assets is $V_P = pV_H + (1-p)V_L$. Hence, $V_L < V_P < V_H$, and so the market overvalues low quality firms and undervalues high quality firms. If the managers of high quality firms attempt to finance an investment by issuing equity shares they must accept that the issue is under-priced. Quite simply, therefore, the managers will forego an investment whenever the loss from underpricing exceeds the original shareholders share of the value of the new project[20].

The Myers/Majluf model is clearly very stylised and employs a number of restrictive assumptions. In particular, since firm types are ranked by FOSD we would expect (from de Meza and Webb [1987]) that debt will dominate equity. These and other aspects are considered in extensions to the basic model by Brennan and Kraus [1987], Constantinides and Grundy [1989] and Noe [1988], who show that there often exist *non-dissipative* signalling equilibria (i.e. all firm types invest in all projects with positive NPV). However, as our discussion of these models proceeds it will become clear that the implications for the equilibrium method of finance is very sensitive to the assumptions of the particular model.

We begin the discussion with Noe [1988], who extends the Myers/Majluf analysis to an arbitrary number of firm types, allows managers to issue either debt or equity or to forego the project altogether, and also introduces residual uncertainty into manager's information sets. The introduction of residual uncertainty has an asymmetric effect on market valuation of debt and equity. Without residual uncertainty for insiders, debt would either be riskless or prohibitively expensive, i.e. if R_t is the certain return on (firm) type t's project then debt F is riskless if $F \leq V_t + R_t$ and prohibitively expensive if F >

$V_t + R_t$. With residual uncertainty, debt becomes risky and its value can be expressed as a fixed payment plus an option to default. This option value is higher for low quality types and may lead them to mimic any debt issue by high quality types. On the other hand, the proportional nature of equity claims means that valuation of equity is unaffected by the introduction of uncertainty. In an example with three firm types, Noe shows that all firm types accept the positive NPV project but the low and high types issue debt while the medium type issues equity. This equilibrium arises because the gain to low types from issuing over-priced equity (i.e. imitating medium types) is more than offset by the gain in option value on debt from imitating high types.

The signalling equilibrium proposed by Noe implements the efficient investment policy since any project with positive NPV is undertaken. However, the equilibrium is only partially revealing since the high and low quality types pool with debt while the medium quality types pool with equity. The next two papers have the property that their equilibria are fully revealing. Brennan and Kraus [1987] show how financing strategies involving the initial capital structure can increase the cost of masquerading by low quality types and thereby achieve separating equilibria. In the case of FOSD, separation can be achieved by the simultaneous issue of new equity and repurchase of outstanding debt. This financing operation is relatively more expensive for low quality types since repurchasing debt kills the option to default on that debt. From the above discussion we know that the default option is more valuable for low quality types. For the case of mean-preserving spreads the revealing equilibrium involves the issue of convertible bonds, junior bonds, or packages of bonds and warrants.

In general, the procedure employed by Brennan and Kraus is to invoke a "lemons property" for each financing method: that is, for any proposed financing method, z, investors assume that it is issued by the worst type of firm in the sense that the value of z to investors is lowest when issued by a firm of this type. Investors value z accordingly. Thus, for each financing z, all firms apart from the corresponding worst type would be undervalued if they announce z. They are better-off to announce some financing method for which they obtain actuarily fair terms. This can only be done by choosing a financing method which other types will not mimic, i.e. choose that financing method for which you are the worst type. This confirms to investors that their beliefs are rational.

The existence of Brennan and Kraus' proposed equilibria is dependent on an appropriate initial capital structure. Repurchasing debt is only possible if there is debt outstanding. Another important aspect of both Brennan/Kraus and Noe is that managers are assumed to act in the best interests of existing shareholders. These features are avoided by Constantinides and Grundy [1989], who consider a model where the firm is initially entirely financed by equity and partially owned by risk neutral managers. In this case the non-existence of debt in the initial capital structure renders the debt repurchase solution infeasible. However, with the explicit managerial maximisation, a fully revealing signalling equilibrium can be achieved by driving a wedge between managers and existing shareholders. Essentially, this is done by a financing which comprises the issue of convertible debt and a commitment to use excess proceeds to repurchase stock (cf. repurchasing debt in Brennan and Kraus). The wedge between managers and shareholders is created by a precommitment preventing the management from tendering its own stock holdings. The repurchase of stock from existing shareholders creates a countervailing incentive to managers against over-valuation of the firm since market prices of stocks are more sensitive to firm value than is debt, i.e. the additional cash brought into the firm from over-valuation of (convertible) debt is more than offset by the cash paid out on the repurchase of over-valued stock. Thus, over-stating the value of the firm will reduce the manager's equity value.[21,22]

4. Mixed Agency-Information Models

In each of the previous three sections we have grouped and discussed models according to the type of information problem being modelled -- whether it be an agency problem or ex ante or ex post information asymmetry. There are, however, a number of papers which, because they combine agency with asymmetric information, do not fit well into any of the previous sections. A number of these mixed models are discussed in this section.

Two lines of motivation for mixed agency-informational models is provided in John [1987]:

(i) consider the problem of moral hazard with hidden actions as in Section 1.1. In this case the agency problem occurs because the agent's action is either unobservable by investors or non-verifiable by third parties (e.g. law courts). Nevertheless, the investors are assumed to understand the structure of the problem in terms of the entrepreneur's preferences and the available set of investment technologies. With this knowledge the investors are able to completely determine the effects of each contract on the entrepreneur's actions. Investors can, therefore, offer the best contract. Hence, a feature of the standard agency model is that outsiders know as much about the parameters as do insiders. A natural generalisation is therefore to introduce (ex ante) asymmetric information about either the entrepreneur's preferences or the investment technology;

(ii) information asymmetries at the date of contracting can result in pooling equilibria or separating equilibria via screening or signalling (Section 3). However, if there is a time lag between the issuing of claims and the implementation of investment decisions then new information can arrive which may affect the agent's optimal investment action. This case corresponds closely with the standard model of moral hazard with hidden information (Section 1.2) except that the initial symmetry of information is generalised to allow for private information.

Besides the above motivations, mixed agency-information models are interesting because the agency and informational aspects interact to produce new results. One finding is that introducing ex ante private information into an agency framework can sometimes, but not always, help to ameliorate the moral hazard problem.

In the following we begin with agency-adverse selection models and then consider agency-signalling models.

4.1. Agency and Adverse Selection

The most common method of introducing adverse selection problems into agency models is via information about the set of socially profitable investment opportunities available to the entrepreneur. This approach is followed in the Myers under-investment model of Webb [1987] and in the risk-shifting model of Diamond [1989a]. Each of these models assumes that some positive amount of debt is optimal due either to taxation advantages of debt or to costly-state verification. Webb [1987] constructs an economy with an arbitrary horizon where there are two types of entrepreneur, α and β. These entrepreneurs are ex ante observationally equivalent: type α always take value-maximising decisions while type β behave strategically and may under- (or over-) invest according to how its actions affect investors beliefs (i.e. its reputation). The state of the world at each date is independently distributed across time and realisations are common knowledge. In this model a high reputation corresponds to investors putting a high probability on the firm being type α. A reputation is valuable because it reduces the cost of funding investments. Webb shows that provided the horizon is initially sufficiently long there will be a period where type β entrepreneurs mimic type α entrepreneurs by taking value-maximising decisions. However, as the horizon draws closer there comes a date where, for some state realisations, value maximising investments are no longer consistent with maximisation of equity value. Thus, with positive probability the type β entrepreneur will eventually under-invest and will be correctly identified as type β.

Diamond [1989a] combines adverse selection with ex ante moral hazard where some types of entrepreneur can choose the level of risk for their project. Altogether there are three types of (ex ante) observationally equivalent entrepreneur: type G have safe, positive NPV projects, type B have risky, negative NPV projects, and type BG have both safe and risky projects. As in Stiglitz and Weiss [1981], the parameters are such that in a one-period model the type BG would choose the risky project if interest rates are high but would choose the safe project if interest rates are sufficiently low. The multi-period model is a simple repetition of the one-period model with the degree of adverse selection, and hence interest rates, falling over time as those entrepreneurs who previously took risky projects and failed drop out of the pool. Thus, the model has the property that if the adverse selection is initially sufficiently strong then the type BG entrepreneurs will begin by choosing the risky project (i.e. over-invest) but, if they survive, will later switch to the safe project when interest rates are sufficiently low.[23] In the final period a type BG who previously choose safe projects will continue to do so. This contrasts with Webb [1987] where the value of a reputation falls over time so that a type β is subject to the under-investment problem in the final periods.

The previous two papers show that introducing adverse selection into an agency framework can sometimes fully resolve the agency problem. In contrast, the final paper for this section, Webb [1991b], illustrates how adverse selection can *induce* an agency problem that would otherwise not arise. The model assumes a continuum of entrepreneurs ranked by FOSD. Each entrepreneur has access to two project types: project A is standard in that it involves a single investment followed by a return, while project B, on the other hand, requires a sequence of two investments and produces a sequence of two returns. A key assumption is that the first period return for project B becomes common knowledge before the issuing of debt to finance the second period investment. In the absence of adverse selection all entrepreneurs would choose the project with highest NPV. Suppose this is project A. With adverse selection, however, the equilibrium may be characterised by high quality types choosing B (i.e. low NPV projects) and low quality types choosing A. The reason is that the early cash flows of project B reveal information about entrepreneurial quality and so leads to financing terms at the second date which are closer to actuarially fair terms. Also, in equilibrium the implicit subsidy from high to low quality types is smaller with project B because all the lowest quality entrepreneurs choose project A. These two effects may more than outweigh the loss due to project B's lower NPV.

4.2. Agency and Signalling

Necessary conditions for the existence of signalling equilibria are that the signal be a costly action and that the marginal cost of signalling be decreasing in firm quality. The models in this section illustrate the point that agency costs can exhibit these conditions. John [1987] uses the probability of risk-shifting behaviour as the underlying basis for separation, while John and Nachman [1985] rely on a two-period Myers' under-investment problem. In the latter model, state realisations each period are independently distributed and privately observed by the entrepreneur. An intertemporal linkage is provided by making the second period expected return on investment a positive function of the first period state realisation, s_1. To see how this works, let s_1 be distributed on $[0,\bar{s}]$. Compared with the standard model without intertemporal linkage, entrepreneurs are more willing to invest because failure to do so is a signal about poor future opportunities. Failure to invest signals to investors that the true value of s_1 is in some interval $[0,\hat{s})$, while investing signals that the true value is in the interval $[\hat{s},\bar{s}]$. The intertemporal linkage means that these signals affect the price of finance obtained for second period investments.

In the above paper the introduction of private information helps to alleviate inefficiencies in a Myers under-investment framework. As before, however, this need not always be the case. Chapter Three of this thesis (Hansen [1991b]) illustrates this point with a model of investment-timing decisions when projects overlap. The paper is concerned with the impact of asymmetric information on whether projects should be incorporated jointly as a single firm or whether they should be legally distinct entities.[24] The structure of the model is such that it is sometimes socially efficient for projects to be jointly incorporated because this creates diversification effects which reduce the incidence of the Myers' under-investment problem. However, with asymmetric information distortions in the entrepreneur's investment policies may arise which can make separate incorporation of projects more efficient ex ante. The idea is that firms who are in the process of raising finance for new projects may try to mislead the market about the performance of their existing projects. One way that they might do this is by prematurely exercising a low value investment option under the pretence that it is in a high state. This creates an adverse selection problem because entrepreneurs whose projects are actually in the high state would optimally exercise their project. Failure to do so would risk the project falling into the low state.

5. Summary and Discussion

In the previous sections we have discussed in detail a wide range of models grouped according to their key informational assumptions. In the following paragraphs we provide a brief overview by re-grouping models by type of financial contract. We consider ordinary equity shares, standard debt contracts, convertible debt, loan commitments and long-term contracts, and, in addition, the role of collateral. The section ends with some general comments regarding the optimal contracting literature.

Ordinary equity shares have been shown to be globally optimal in models of adverse selection where projects are ranked by MPS (de Meza and Webb [1987]). In addition, some tentative support for the use of equity is provided by the recently developed model of costly-state falsification, though this model does not produce the limited liability feature usually associated with ordinary equity (Lacker and Weinberg [1989]).

The standard debt contract is optimal within the class of monotonic contracts when there are problems of managerial incentives or adverse selection with MLRP (de Meza and Webb [1987], Innes [1990]). As discussed in Section 1.1 the reasonableness of a monotonicity constraint depends on whether managers and/or investors can artificially boost or sabotage the firm's earnings. If these possibilities are not significant then the optimal contract is a "live-or-die" contract. Standard debt contracts are also optimal in models of costly-state verification provided the entrepreneur is risk neutral and stochastic auditing or monitoring is ruled out (Townsend [1979, 1988]).

Convertible debt, or debt with warrants, arises as an optimal response to risk-shifting incentives (Green [1984]), Myers type under-investment in growth options (Chiesa [1988]), and stopping failures (Hansen [1991a]). Issuing convertible debt can also help to solve the Myers/Majluf adverse selection problem if managers act on behalf of initial shareholders and firms are ranked by MPS (Brennan and Kraus [1987]). However, the optimal financing strategy can change dramatically if managers act in their own interest (Constantinides and Grundy [1989]).

Under certain conditions both long-term debt contracts and loan commitment options can resolve extended versions of the standard adverse selection problem (Webb [1991a], Thakor [1989]). In addition, loan commitments can solve the Myers under-investment problem when the required level of investment is the main source of uncertainty (Berkovitch and Greenbaum [1991]). For long-term contracts to be a fully effective sorting device the number of projects available (in sequence) must exceed the number of entrepreneur types. In the case of loan commitments we require that entrepreneurs have sufficient initial wealth to pay the up-front fees.

In addition to the contractual forms discussed above, the literature reveals several potential roles for collateral. An important distinction is made between internal collateral, which is based on the assets of the firm, and external collateral provided by the entrepreneur's personal assets. In the case of internal collateral the Myers under-investment problem can be minimised if debt contracts allow future investment projects to be financed by new debt secured on internal collateral (Stulz and Johnson [1985]). For external collateral, two possibilities have been analysed. The first is the role of collateral, coupled with interest rates, as a sorting device (Bester [1985]). The second is collateral as a device to aid pareto-improving renegotiations in the costly-state verification model (Bester [1990]). The screening theory implies that lower quality borrowers put up less collateral (but pay higher interest rates) while the verification model implies the reverse.

The above discussion has highlighted a number of restrictions required for optimal financial contracts to conform with common observation. This is particularly true in the case of standard debt contracts. Several additional remarks can be made about the generality of the optimal contracting literature. The first concerns the role of limited liability. Most models, especially the one-period variety, assume that the life of the entrepreneur or firm ends when the project ends. This effectively imposes on the problem a resource constraint in the form of non-negative consumption. The resource constraint is then interpreted as limited liability for the entrepreneur. Given that limited liability is an important feature of most financial contracts, including debt, equity and hybrid contracts, a more satisfactory approach would be to derive limited liability endogenously within the model. The availability of external collateral is one approach found in the literature. Another approach is the role of outside employment in multi-period models (Hansen [1991a] obtains partially limited liability).

As a final comment we refer to Hart's and Holmstrom's [1987] suggestion that financial contracts are inappropriate incentive devices. They argue that direct managerial incentive schemes are likely to be cheaper than capital structure arrangements. Although this claim appears reasonable in the context of large public firms, it has considerably less appeal in the context of the entrepreneurial models studied in this paper. In these models, the optimal financial contract is synomonous with the optimal managerial incentive scheme (Green [1984], Innes [1990])

6. Conclusions

The objective of this paper has been to provide a comprehensive introduction to optimal financing for investment projects. In the introduction to the paper we noted the omission of a number of interesting topics with implications for the relationship between finance and investment, but for which investment is not their primary concern. Nevertheless, the foregoing discussion covers a wide range of models with numerous implications for optimal project finance.

The initial approach of the project financing literature was to assume straight debt and ordinary equity shares were the only securities available. More recently, the method of inquiry has involved explicit derivations of optimal financial contracts in the context of both individual firm optimisation and overall market efficiency. Many, but not all, of these contracts may totally eliminate the proposed inefficiency; examples include risk-shifting incentives, Myers under-investment problem, stopping failures, and some types of adverse selection. We have noted, however, that although some financial contracts, such as debt, correspond well with casual observation, they are in fact optimal only within some restricted class of contracts.

A number of other recent developments can be identified. The most prominent is the distinction between private information and symmetric but non-verifiable information. This distinction is particularly important for models focusing on the extent to which renegotiation may avoid ex post inefficiencies. Models of symmetric or asymmetric learning and reputation-building have also been a subject of recent interest. A less prominent development is the interaction between financial structure and the optimal incorporation mode for new investment projects. The question of whether a new project should or should not be incorporated jointly with existing assets has received relatively little attention in view of the prominence of the Myers/Majluf signalling literature.

At a more fundamental and theoretical level, we can identify two other areas worthy of further research. First, as previously noted in Section 5, the limited liability feature common to most financial contracts has been imposed via resource constraints rather than derived endogenously within the model. Progress on this issue requires further development of multi-period models. Another research topic would be to further develop the costly-state falsification model (Section 2.2) in the context of investment projects. This is an interesting topic because the existing models imply a contract resembling equity but without full limited liability. Also, costly-state falsification appears to be a natural framework in which to assess the reasonableness of the monotonicity constraint that is often imposed on contracting problems.

1 We do not attempt to trace these features back to the more general pure theory of, for example, principal-agents or signalling. The interested reader can find relevant references in articles cited.

2 A third area of conflict can arise between shareholders and the firms customers and employees. This forms part of the literature on Product Market Interactions and is discussed in Harris and Raviv [1991].

3 The risk-shifting incentive is avoided if each investor holds all securities issued by the firm in proportion to their values.

4 First, the entrepreneur's utility function is ill-defined: they assume utility, U(V,F), is a function of *current* market value of wealth, V, and the *present value* of perquisite consumption, F. This formulation is inconsistent with their claim that F is chosen prior to the resolution of uncertainty (Haugen and Senbet [1987,p.1091]). i.e. the appropriate function is expected utility over consumption and end-of-period wealth. Second, the option pricing model they apply takes as given the characteristics of the underlying asset (i.e. of the firm). This is not entirely appropriate as the model is being used to determine the entrepreneur's action choice for the firm.

5 Extension of the one-period problem to a framework where entrepreneurs undertake a succession of projects can lead the contracting parties to minimise risk-shifting distortions by building incentive effects into long-term contracts. In particular, Stiglitz and Weiss [1983] show that contract terminations and exclusion from the credit market may be used as an incentive device against risk-shifting behaviour. A credible threat to terminate a relationship in the event that the first project is unsuccessful will lead entrepreneurs to choose safer projects. The threat itself is seouentially rational because the alternative of charging higher penal interest rates to defaulters exacerbates the second period moral hazard problem to such an extent that termination is a better policy. The role of contract termination has also been studied by Bolton and Scharfstein [1990] in the context of costly-state verification.

6 As noted by Green, his analysis is crucially dependent on the model being in discrete time. In a continuous time model the put-option effect disappears due to the put-call parity relation. Also, the results were proved for an investment allocation problem over two projects (not mutually exclusive) and it is not clear whether or not they can be extended for three or more projects.

7 Grossman and Hart [1982] analyse the role of debt as a bonding device to prevent excessive perquisite consumption. The idea that debt claims have priority over managerial consumption is similar to Williams [1987].

8 Moreover, stepping back a stage to consider the form of the optimal financial contract, Williams finds that it is necessarily discontinuous, i.e. the optimal contract cannot be replicated by a combination of bonds, stocks and options.

9 Diamond develops the implications of costly-state verification for the role of financial intermediaries.

10 Hart and Moore [1989] also obtain debt as the optimal contract in a model where verification costs differ across assets. Specifically, they assume verification costs are infinite for cash flows but zero for physical assets. This means that it is impossible for the investor to use verification procedures to force the entrepreneur to pay out cash flows. But since physical assets are costlessly verifiable the investor can obtain some leverage over the entrepreneur by writing a contract which gives him the right to seize these assets in the event of non-payment. Bolton and Scharfstein [1990] also assume verification costs are infinite for cash flows. However, instead of seizing assets, the financier induces repayment by using the threat to terminate future funding.

11 Coupon payments are interest payments made on a regular basis. A sinking fund provision requires the firm to repurchase or retire a portion of the bond issue each year starting from a number of years to maturity. A failure to meet the coupon or sinking fund payments results in default.

12 The problem of costly-state falsification is also closely related to that of ex post perquisite consumption, as discussed in Section 1.2. However, a distinguishing feature is that the model of perquisite consumption assumes that the entrepreneur's utility function is of the form U(C,W), where C and W are perquisite consumption and wealth, respectively. A conflict of interest between shareholders and managers arises because shareholders only value W. In the model of costly falsification both parties to the contract value only W. In addition, there is a deadweight loss from falsification.

13 Strictly, the Myers and Majluf model belongs in the sub-section on adverse selection. However, we defer this model to our discussion of signalling because most subsequent developments of the model are to do with signalling.

14 Roughly speaking, ranking by MPS means that all projects with the same mean expected return are ordered according to the variance of their returns.

15 A project first-order stochastically dominates another project if it has higher expected return.

16 The over-investment result requires that the supply of loanable funds not be backward-bending as a function of interest rates.

17 The latter "monotonic contract" condition can be motivated by a requirement that investors never have an incentive to sabotage the firm or by an ability of entrepreneurs to falsify their profit report (e.g. with hidden borrowing). The costly-state falsification model of Lacker and Weinberg [1989] suggests that this constraint might be restrictive in some circumstances.

18 In contrast to Stiglitz and Weiss [1983] the possibility of optimal termination does not arise because the moral hazard problem is absent.

19 For an introduction to the class of models of Ross [1977] and Leland and Pyle [1977] see the survey in Harris and Raviv [1991]. For a recent analysis of dividend signalling see Williams [1988].

20 Lucas and McDonald [1990] apply a variation of the Myers and Majluf model to an infinite horizon stock market model where the informational advantage of insiders is temporary. They obtain a number of empirical predictions which are consistent with observed stock price (and volume) dynamics.

21 The above analysis assumes investments are indivisible. When investments are divisible the convertibility feature is not required for equilibria to be fully revealing. Instead, the face value of debt and investment level (and stock repurchase commitment) serve as signals.

22 A further logical extension of the Constantinides and Grundy approach of explicit managerial maximisation is to derive an optimal managerial contract. Dybvig and Zender [1988] take this approach in a model where the manager's remuneration contract is determined prior to the arrival of private information. They show that the optimal managerial contract always costlessly resolves the under-investment problem. However, the ability to contract prior to information arrival significantly alters the Myers/Majluf model because it opens up the possibility that the firm can also raise finance at this prior contracting date. Basically, the under-investment problem cannot arise if investments can be financed with retained earnings.

23 Diamond [1989b] develops the implications of this profile of risk-shifting behaviour for the role of monitoring activities.

24 Shah and Thakor [1987] also analyse optimal incorporation modes. They employ a tax advantage for debt which, with symmetric information, would imply that the project be 100 per cent debt financed. They then introduce asymmetric information about project risk and show there exists a dissipative (Riley) reactive equilibrium in which the degree of inefficiency is decreasing in risk. Whether projects are incorporated jointly or separately then depends on risk of the project relative to existing assets. The implications of monitoring costs are also derived.

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CHAPTER TWO

VENTURE CAPITAL FINANCE WITH TEMPORARY ASYMMETRIC LEARNING

Consider the tunnel currently being built under the English channel. Between 1987 and mid–1990 the estimated construction cost of the tunnel increased from £2.71 billion to around £4.25 billion (The Times [p.26,1 June 1990]). However, although the channel tunnel may now be a loss–making venture, past investments are sunk and so it is economic to complete it. This example illustrates two key features of new projects, whether they be large publicly–owned projects or smaller, privately funded entrepreneurial projects. The first key feature is that past investments are effectively sunk costs because an incomplete project has little or zero market value. This means that there exists a critical stage beyond which the project's financiers are unable to pre–commit against re–financing in the event of "unexpected" cost increases. The second key feature is that information about the profitability of the project is revealed during the investment phase. Moreover, due to intimate involvement in the project we would expect that it is the entrepreneur (rather than financier) who first receives this information. A self–financing entrepreneur who learns the project is bad prior to the critical, "point–of–no–return" stage will terminate the project. But with external finance an entrepreneur may have an incentive to conceal bad news from the financier until after the "no–return" stage. The key problem for financiers, therefore, is to design a financial contract which induces truthful reporting by the entrepreneur.

The above problem, which we call the *stopping problem*, is largely neglected in the extant literature on financial contracting with imperfect information. Instead, a large part of the literature during the late 1970s and 1980s focuses on various adverse selection problems arising from asymmetric information prior to contracting.[1] These models typically posit a project consisting of an initial one–off investment followed by some payoff at the end of the period. More recently, there has been greater recognition of the importance of learning and reputation building for understanding the trade–off between debt, equity and various hybrid financial claims (see Chiesa [1988], Diamond [1989], Green [1984] and the surveys in Allen [1990] and Harris and Raviv [1991]). However, in these models the revelation of information occurs after completion of the investment process and, hence, abandonment decisions do not arise.

An exception to the above literature is Dewatripont and Maskin [1989]. Their model resembles the stopping problem in this paper in the sense that refinancing is also sequentially optimal. Dewatripont and Maskin assume an adverse selection problem whereby entrepreneurs know whether they are high or low cost prior to contracting. They argue that investors can sort loan applicants by deliberately remaining of a small size relative to the projects they are financing. By being small, investors can credibly pre-commit not to refinance high cost projects and so these types do not apply for loans. The implication is that a decentralised financial system with many small financial institutions will be more efficient than a centralised system as in Soviet style planned economies. In contrast, we do not allow any ex ante informational asymmetry. Our model assumes symmetric information at the initial contracting date but allows an asymmetry to develop during the investment process as entrepreneurs learn the project's true cost. Eventually, the financier/investor will learn whether the project is good or bad (in the sense of an ex ante NPV) but this information arrives after the "point-of-no-return".

An important additional feature of our model is that the stopping problem is set in the context of a principal-agent model with a risk neutral entrepreneur. Here, the expected gross return is determined by the level of entrepreneurial effort. The principal-agent framework serves several purposes: first, in the absence of the stopping problem, it ensures that debt is optimal within the class of monotonic contracts; second, in the presence of the stopping problem it leads to an efficiency trade-off between the face value of debt and level of redundancy payment as methods for inducing termination of high cost projects. Without the effort problem the optimal levels of debt and redundancy payment would be indeterminate.

We show that when cost-states are publicly observable the efficient solution can be implemented by a contract in which the face value of debt is contingent on the state realisation. When cost-states are not publicly observable state-contingent contracts become inadmissible. In this case our solution method is to obtain a fully-revealing equilibrium by applying the theory of "Implementation by Stage Mechanisms" (see Moore and Repullo [1988]). For some parameter values the contract will specify a single-stage mechanism (a loan commitment option) to be played once information is revealed to the investor. For some other parameter values, the single-stage mechanism fails to implement the efficient solution and it is necessary to resort to a two-stage mechanism. We interpret this latter mechanism as a financial structure with convertible and redeemable Preference shares, as are observed in venture capital contracts.

The structure of the paper is as follows: Section 1 describes the model and the first-best solution. Then, to provide intuition for the main results, two intermediate versions of the model are solved in Section 2. Section 3 presents the main results on contractual form. A discussion of our results in the context of the existing literature and our observations of venture capital contracts follows in Section 4. Finally, Section 5 concludes the paper.

1. The Model

In this section we describe in detail our assumptions concerning the types of agents in the economy, project technology, information, learning and verifiability, and our solution method. The section ends with a brief description of first-best investment actions and also a table summarising notation.

1.1. Agents

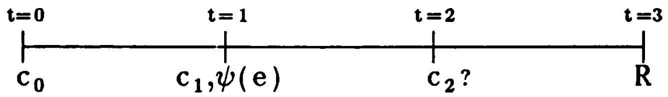
There is a single entrepreneur and many investors. The entrepreneur has identified a potentially profitable investment opportunity requiring the input of financial resources and effort. However, the entrepreneur's wealth endowment is zero.[2] Each investor, on the other hand, is endowed with arbitrarily large wealth but no project. Both the entrepreneur and investors are risk neutral and each seeks to maximise their own expected terminal wealth. The entrepreneur's wealth is computed net of the non-pecuniary cost of effort, which we assume can be measured in monetary terms. For the entrepreneur the alternative to undertaking the project is to be employed at a wage, which we normalise to zero.[3]

For investors the alternative to investing in the project is to earn a riskless return of r per cent from a storage technology. For simplicity we also set $r = 0$. The investors are assumed to be profit maximizing Bertrand competitors in the financial "prices" they offer the entrepreneur (this is made precise in Subsection 1.4 below). Thus, in equilibrium the optimal contract will maximise the entrepreneur's expected wealth subject to zero excess profits for the investor and other constraints to be specified below.

1.2. Project Technology

We consider a single project lasting for three periods, dated $t = 0, 1, 2, 3$. To realise returns from this project requires a sequence of indivisible investments, c_t, with $t \in \{0,1,2\}$. In addition, effort is required only at date 1 and is perfectly divisible on $[0,1]$. The entrepreneur's non-pecuniary cost of effort, $\psi(e)$, passes through the origin and is convex in e: i.e. $\psi(0) = 0$, and $\psi'(e)$, $\psi''(e) \geq 0$. Returns, R, accrue at date 3. Figure 1 shows the time line representing these actions and events. We may think of the sequences $\{c_t\}$ and R as research and development costs and net operating income, respectively. Throughout the paper we assume the c_t are specific to the entrepreneur in order

Figure 1: Time Line



to prevent the entrepreneur from selling outright the patent to an investor.[4]

All projects require *at least two* successive periods of investment. In this model projects are differentiated according to whether they require the third-stage investment, c_2. Any project requiring an investment at date 2 has total cost of $c_0+c_1+c_2$ and is called a high cost (h) project. These projects have negative net present value (NPV). A low cost (ℓ) project has total cost of c_0+c_1 and has positive NPV. We denote the state of the project by s, where $s \in \{h, \ell\}$. In the next subsection projects are further classified according to whether the entrepreneur learns the project's state at date 1 or date 2.

All projects have the same distribution of gross returns irrespective of their development cost (state s). R has support $[0,\infty)$ and distribution function F(R,e), which is twice continuously differentiable with respect to R and e. The conditional expected return is:

$$R(e) \equiv \int_0^\infty Rf(R,e)dR,$$

where f(R,e) is the density function.

Higher levels of effort give rise to "better" revenue return distributions in the sense that expected returns increase, i.e. $R'(e)>0$. For technical reasons we formalise this property by assuming the Monotone Likelihood Ratio Property (MLRP) and Convexity of the Distribution Function Condition (CDFC). MLRP requires:

$$\frac{\partial}{\partial R} \frac{f_e(R,e)}{f(R,e)} > 0, \tag{1}$$

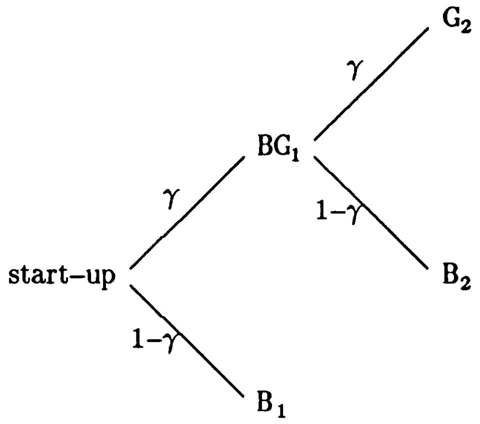
where the subscript e indicates partial derivative with respect to e. For any utility function increasing in wealth, including the risk neutral players in this model, MLRP implies first order stochastic dominance (FOSD);[5] i.e. $F_e(R,e) \leq 0$. CDFC requires that F(R,e) be convex in effort at each level of R. This condition and MLRP are sufficient (but not necessary) to invoke the First-Order Condition Approach in the effort problem.[6]

1.3. Information and Contracting

Prior to start-up $(t=0)$ information is symmetric. Implicitly, we assume that any initial payoff-relevant information available to the entrepreneur is obtained by the investor (venture capitalist) through its intensive screening procedures. However, some information can only ever become known to the entrepreneur and investor by undertaking the project and going forward in time. In the following we state and discuss our specific assumptions on the learning process, verifiability, and effort.

(a) temporary asymmetric learning: We postulate a particularly simple passive learning process, which we call *temporary asymmetric learning.* Prior to start-up nature is assumed to choose between three project types which differ according to their development cost, $s \in \{h, \ell\}$, and according to the date at which the entrepreneur observes s. The three types are denoted by τ, $\tau \in \{B_1, B_2, G_2\}$, where B is for high cost or "bad" projects, G is for low cost or "good" projects, and the subscript denotes the date of learning. The interpretation is as follows: If nature chooses B_1 the entrepreneur receives a signal at date 1 (before investing c_1 and exerting effort) that the project is high cost. If nature chooses B_2 or G_2 the entrepreneur observes it's true type at date 2 (before investing c_2). As a matter of notation, we cater for the fact that B_2 and G_2 cannot be distinguished at date 1 by forming a purely notional type called BG_1, which indicates that the project is either type B_2 or type G_2. We assume the probability of a good observation each period is γ and that γ is known to both the entrepreneur and investor. These features of the entrepreneur's learning process are illustrated

Figure 2: The Entrepreneur's Learning Process



in Figure 2.

In contrast to the entrepreneur, the investor cannot distinguish between B_1 and BG_1 at date 1. Thus, irrespective of project type the investor only learns at date 2 whether the project is high or low cost; i.e. at date 2 the investor can distinguish B_1 and B_2 from G_2 but cannot distinguish between B_1 and B_2. This is the essence of the stopping problem.

The above learning process is independent of any actions or other resource expenditure by either party. Underlying this set–up is the idea that the entrepreneur's intimate involvement with the project may provide him or her with an informational advantage over the investor -- at least during the initial R&D and marketing phases -- but that this advantage is at most temporary. The investor will always eventually learn the true cost of the project, though in our model this information arrives after the "point–of–no–return".

(b) verifiability: We assume that gross costs and returns are non–verifiable but that net returns are verifiable[7] In particular, this means that contracts cannot be made contingent on realisations of s and R. However, contracts can be made contingent on retained earnings at date 3, denoted R_T. This assumption allows the use of equity contracts (cf. Townsend [1979] and Gale and Hellwig [1985]).

(c) the effort problem: We assume the entrepreneur's level of effort is not observable by the investor at any time during or after exertion. The level of effort by the entrepreneur is therefore not directly contractible. Instead, the financial contract between entrepreneur and investor must be formulated to induce the appropriate level of effort.

1.4. Solution Method

To solve the problem described above we need to be explicit about the form of the game being modelled. In the following it is helpful to distinguish between the initial contracting game and the possibility that the contract itself will define a game to be played as development of the project progresses. Let $\{\mathcal{G}_0,\mathcal{G}_1\}$ denote the sequence of games, where $\mathcal{G}_0$ is the date 0 contracting game between the entrepreneur and many investors and $\mathcal{G}_1$ is the game played if the outcome of $\mathcal{G}_0$ is for the project to be undertaken. In this section we describe $\mathcal{G}_0$ in detail and give an overview of $\mathcal{G}_1$. We wish to avoid specifying $\mathcal{G}_1$ in detail here as the intuition for our main results can best be appreciated by considering a series of intermediate information structures.

In Sub-section 1.1 we stated that the "prices" of the financial contract are determined as in a Bertrand competitive equilibrium. We can now explain this more fully by describing $\mathcal{G}_0$. We begin with two definitions: (i) ϕ_t, $t \in \{0,1,2\}$, is a transfer from investor to entrepreneur at date t, and; (ii) $\theta(R_T;\tau)$ defines a type τ entrepreneur's repayment obligations at date 3 as a function of retained earnings. In the following sections both ϕ_t and $\theta(R_T;\tau)$ may be contingent on verifiable states and/or messages transmitted between the contracting parties. These variations will be introduced later as required. In addition, the contract may also specify a mechanism, $\mathcal{M}$, which allocates certain option rights between various parties to the contract (this is further explained below). A contract is denoted by $\mathcal{C}$ and defined by:

$$\mathcal{C} \equiv \left\{\phi_0,\ \phi_1,\ \phi_2,\ \theta(\mathrm{R}_T;\tau),\ \mathcal{M}\right\}.$$

We assume $\mathcal{G}_0$ is a three-stage game:

(1) the entrepreneur announces $\mathcal{C}$;

(2) investors simultaneously make bids over the "prices" listed in $\mathcal{C}$;

(3) the entrepreneur either accepts a single bid or rejects all bids. Acceptance invokes $\mathcal{G}_1$ while rejection ends the entire game.

An example of $\mathcal{G}_0$ would be where $\theta(\mathrm{R}_T;\tau)$ takes the form of a debt contract. This, along with transfers ϕ_t, is announced by the entrepreneur in stage 1. Then in stage 2 investors post bids on the face value of debt. Finally, the entrepreneur will either accept one bid or reject all bids.

We impose two requirements on our equilibrium contracts. The first is that they be renegotiation-proof. This rules out contracts specifying transfers which the parties to the contract know they will later find mutually advantageous to renegotiate. In particular, with symmetric information with respect to states at date 2, neither party can pre-commit against renegotiation to avoid inefficiencies ex post.[8] The second requirement for contracts is that the repayment function $\theta(\mathrm{R}_T;\tau)$ be monotonically increasing in R_T. Innes [1990] argues that the monotonicity constraint is reasonable on the basis that either the entrepreneur or investor would otherwise have an incentive to manipulate profits.[9] However, the restrictions implied by the monotonicity constraint are not crucial for this paper as it is the conversion and redemption rights held by various parties, rather than the exact form of the underlying repayment function, which provide the main results in Section 3.

1.5. First-Best

As a bench-mark case we state here the optimal actions of an entrepreneur with sufficient wealth to be completely self-financing.[10] Such an entrepreneur can unilaterally decide at each date whether to continue or terminate the project. We assume the parameters of the model are such that an entrepreneur's expected wealth is maximised by adhering to the following policy:

(FB1) Start-up the project by investing c_0;

$$\gamma[R(e) - \psi(e) - (c_1+(1-\gamma)c_2)] > c_0$$

(FB2) Terminate the project at date 1 if it is B_1, i.e. continuation value (LHS) is less than termination value (RHS):

$$R(e_{fb}) - \psi(e_{fb}) - (c_1+c_2) < 0,$$

where e_{fb} is first best level of effort, as explained below.

Otherwise continue the project by investing c_1, i.e. there exists a range of effort levels for which

$$R(e) - \psi(e) - (c_1+(1-\gamma)c_2) > 0$$

This inequality holds by virtue of the condition for (FB1).

(FB3) If the project survives to date 2 then continue it to completion irrespective of it's type. (If type is either B_1 or B_2 completion will require a further investment amounting to c_2). i.e. there exist a range of effort levels for which

$$R(e) - c_2 > 0$$

Finally, we need to determine the optimal level of effort, e_{fb}, chosen at date 1. This is extremely simple since, as previously noted, the value of effort is independent of state s. The only relevant factors are the expected operating return and the non-pecuniary cost of effort. Hence, the first-best level of effort maximises $R(e)-\psi(e)$. The first order condition (FOC) is:

$$R'(e_{fb})-\psi'(e_{fb})=0. \tag{2}$$

To summarise, the self-financing entrepreneur will start-up the project by investing c_0. If at date 1 the project turns out to be bad (B_1) it is immediately terminated and the entrepreneur's earnings are zero. Otherwise the entrepreneur continues by investing c_1 and exerting effort e_{fb}. If at date 2 the project is found to be good (G_2) then no further action or investment is required. But if it is found to be bad (B_2) the entrepreneur completes the project by investing a further c_2. Finally, the notation developed in this section is summarised in Table 1.

Table 1: Summary of Notation

c_t	investment at date t, $t \in \{0,1,2\}$.
e	effort level at date 1. Cost is $\psi(e)$.
R(e)	expected return as function of effort.
R	realised return at date 3.
R_T	retained earnings at date 3.
s	cost–state of project, $s \in \{h,\ell\}$.
τ	project type, $\tau \in \{B_1,B_2,G_2\}$.
BG_1	B_2 and G_2 from date 1 perspective.
γ	probability of $s=\ell$ per period.
ϕ_t	transfer to entrepreneur at date t, $t \in \{0,1,2\}$.
$\theta(R_T;\tau)$	entrepreneur's repayment function at date 3.

2. Contingent Contracts

We return to the case where the entrepreneur's initial wealth is zero. The information structure of the full model, as described in Section 1, is quite complex. It comprises a dual structure where unobservable effort determines expected return and also a hidden information problem with respect to the project's cost. However, analytical simplicity is maintained by the additive separability of costs and returns. Nevertheless, before considering the full model, it is worthwhile analysing the structure of optimal contracts for two simpler problems. First, we begin with the simplest possible structure where only the effort problem is present, i.e. project type (τ) is verifiable and, hence, contractible. The optimal contract is shown to be a debt contract with the following two properties: (*i*) the face value of debt is invariant across cost-states (*invariance property*); and (*ii*) entrepreneurs who terminate their project receive zero return (*zero-redundancy property*).

The second contracting problem introduces the temporary asymmetric learning hypothesis by assuming only state s -- rather than project type τ -- is verifiable at date 2. We show that neither the invariance or zero-redundancy properties continue to hold. These results then provide a basis for the following section where state s is observable but non-verifiable. Our analysis shows that there is a range of parameter values for which it is possible to implement the state-contingent outcome by designing either a one- or two-stage mechanism.

2.1. Contracting on Project Type (τ): the effort problem

Assume that contracts contingent on τ are enforceable at zero-cost. The entrepreneur and investor are then able to write the following τ-contingent contract:

$$\mathcal{C} \equiv \Big\{ \phi_0 = c_0;\ \phi_1(B_1) = 0,\ \phi_1(BG_1) = c_1;\ \phi_2(B_2) = c_2,\ \phi_2(\tau) = 0 \text{ for } \tau \in \{B_1, G_2\};\ \theta = \theta(R_T;\tau) \text{ for } \tau \in \{B_1, B_2, G_2\} \Big\}$$

This contract has the following interpretation:

(a) The investor pays c_0 to the entrepreneur for initial project development;

(b) If $\tau = B_1$ the second stage payment is zero and the entrepreneur is forced to terminate the project at date 1. Otherwise the investor pays a further c_1 and the entrepreneur exerts his own privately optimal level of effort;

(c) At date 2 the investor pays a further c_2 if, and only if, $\tau = B_2$.

(d) A type τ entrepreneur pays $\theta = \theta(R_T;\tau)$ to the investor at date 3.

Clauses (a) and (b) are clearly necessary for any state-contingent contract to be an equilibrium contract. In particular, (b) follows directly from condition (FB2) that any project known at date 1 to be bad should be terminated. Thus, to fully characterise the optimal contract we need only determine the form of the repayment function $\theta(R_T;\tau)$.

Define $E_t(\theta(R_T;\tau),e,z)$ and $P_t(\theta(R_T;\tau),e,z)$ to be the date t conditional expected return to the entrepreneur and investor, respectively, where z is the information vector. For example, for the pure effort problem $z=\tau$ at date 2 while $z=\emptyset$ (null) at date 0. The entrepreneur's problem is to choose effort e and a function $\theta(R_T;\tau)$ to obtain the required finance at the lowest price. More formally,

$$\underset{e,\theta(\,.\,)}{\textit{Maximise}}\; E_0(\theta(R_T;\tau),e,\emptyset) \tag{3}$$

subject to

$$P_0(\theta(R_T;\tau),e,\emptyset) \geq C \tag{4}$$

$$e \in \underset{\hat{e}\in[0,1]}{\textit{Argmax}}\; E_1(\theta(R_T;\tau),\hat{e},BG_1) \tag{5}$$

$$E_1(\theta(R_T;\tau),e,BG_1) \geq 0, \tag{6a}$$

$$E_2(\theta(R_T;\tau),e,\tau) \geq 0, \quad \tau \in \{B_2,G_2\} \tag{6b}$$

$$\theta(R_T;B_1) \leq 0, \quad \text{all } R_T \tag{7a}$$

$$\theta(R_T;\tau) \leq R_T, \quad \tau \in \{B_2,G_2\} \text{ and all } R_T \tag{7b}$$

$$\partial\theta(R_T;\tau)/\partial R_T \geq 0 \quad \text{for all } R_T \tag{7c}$$

where $C=c_0+\gamma c_1+\gamma(1-\gamma)c_2$ is the unconditional expected development cost.

The above formulation states that the entrepreneur's problem is to choose effort e and repayment functions $\theta(R_T;\tau)$ to maximise expected terminal wealth (3) subject to the investor's participation constraint (4), the incentive constraint for effort (5), the entrepreneur's participation constraints for dates 1 and 2 (6a,b), two ex post resource constraints (7a,b), and the monotonicity constraint (7c).

The solution to the problem (3)–(7) is best proved by breaking it into two parts. The first part is essentially the effort problem that would occur in a one–period model while the second part allows for the possiblity of project terminations and the participation constraints for intermediate dates. The effort problem is defined by the investor's participation constraint (4), the incentive constraint for effort (5), the resource constraint[11] (7b), and the monotonicity constraint (7c). Innes [1990] shows that debt is the optimal contract for this effort problem when all entrepreneurs are identical.[12] Applying this result to our model we have $\theta(R_T;\tau) = \rho(R_T,D^*_\tau)$ where

$$\rho(R_T,D^*_\tau) = \begin{cases} D^*_\tau, & \text{if } R_T \geq D^* \\ R_T, & \text{otherwise} \end{cases} \qquad \tau \in \{B_2, G_2\}, \tag{8}$$

and D^*_τ is the minimum face value of debt consistent with investor participation. Debt is optimal because any other monotonic contract would induce lower effort by giving the entrepreneur a higher pay–off in some low profit states and lower pay–off in some high profit states. In addition to debt being optimal for each type τ entrepreneur, we claim that the face value of debt is ***invariant*** across types, i.e. $D^*_{B_2} = D^*_{G_2} = D^*$. This follows because the good and bad states only refer to the project's development cost. Hence, as shown by the first–best solution (2), the state s does not affect the marginal value of effort. Minimising distortions to BG_1's effort choice therefore requires all projects to bear the same debt level.

The second part of the solution is to re–introduce the entrepreneur's participation constraints (6a,b) and the resource constraint on termination payments (7a). We show: (*i*) the optimality of debt is unaffected; and (*ii*) that type B_1 receive zero redundancy payment (i.e. $\theta(R_T;B_1) = 0$). These results are explained as follows. First, the participation constraints (6a,b) say that any optimal date 0 contract must ensure that entrepreneurs have an incentive to continue socially profitable projects. However, neither of (6a) or (6b) binds provided the face value of debt is finite and the upper support for R is unbounded.

We next turn to the question of redundancy payments for type B_1 entrepreneurs (who terminate their project). With $\phi_1(B_1) = 0$ the level of redundancy payment is defined using constraint (7a), $\theta(R_T,B_1) \leq 0$. Without loss of generality, we write $\theta(R_T;B_1) = -b$, where $b>0$ implies positive redundancy payment by the investor. An optimal τ-contingent contract specifies *zero-redundancy* $(b=0)$ for type B_1 entrepreneurs. Any $b>0$ would fail to be optimal because the investor's participation constraint (4) would require higher D^*. Higher debt would create additional distortions due to the impact of risky debt on effort levels. On the other hand, setting $b=0$ involves no additional costs ex ante as entrepreneurs are risk neutral. Thus, for τ-contingent contracts zero-redundancy is optimal because it minimises the face value of debt.

The discussion above is summarised in the following proposition:

Proposition 1: (*Second-Best*)

If project type τ is verifiable then the optimal equilibrium contract is a debt contract with the following properties:

(*i*) *invariance: the face value of debt is identical for all completed projects.*

(*ii*) *zero redund a ncy*: $b=0$.

Proof: See the Appendix.

The above results are crucially dependent on the ability of the investor to observe and distinguish between types B_1 and BG_1. This allows contract C to specify $\phi_1(B_1)=0$ so that a type B_1 is forced to terminate. In the next two contracting problems we solve for the optimal contract when types B_1 and BG_1 are not observable by the investor. We find that neither the invariance nor zero-redundancy properties continue to hold.

2.2. Contracting on Cost State (s): temporary asymmetric learning

Assume the entrepreneur gains a temporary informational advantage over the investor at date 1 but that state s, $s \in \{h, \ell\}$, is publicly observed at date 2 and, hence, contractible. The impact on the transfer and repayment functions in $\mathcal{C}$ are two-fold. First, since s is verifiable at date 2 all subsequent transfers and repayments (i.e. ϕ_2 and $\theta(R_T;\tau)$) can be made contingent on s. Accordingly, define D_s as the face value of debt conditional on state s, $s \in \{h, \ell\}$. Second, the transfer ϕ_1 can no longer be a direct function of τ. The contract must now provide incentives for a type B_1 entrepreneur to terminate at date 1. Thus, we re-define ϕ_1 as a function of the messages that the entrepreneur may send to the investor. These messages will be a function of τ and are denoted by $m = m(\tau)$, where m, $\tau \in \{B_1, BG_1\}$. Thus, the date 1 payment is given by $\phi_1(m(\tau))$. In the following we employ Myerson's [1979] Revelation Principle to enable our search for the optimal equilibrium contract to be restricted to those contracts which induce truth-telling, i.e. we require $m(\tau) = \tau$ for $\tau \in \{B_1, BG_1\}$. Hence, for $\tau = B_1$ we require the termination value from truthfully reporting $m = B_1$ to exceed the continuation value from reporting $m = BG_1$ (and eventually being allocated D_h).

$$b \geq E_1(D_h, e_B, B_1) \tag{9}$$

where e_B is determined by

$$e_B \in \underset{\hat{e} \in [0,1]}{Argmax}\, E_1(D_h, \hat{e}, B_1) \tag{10}$$

Similarly, for $\tau = BG_1$ truth-telling requires that the continuation value exceeds the termination value. Since BG_1 will be high cost with probability γ and low cost with probability $1-\gamma$, the entrepreneur's continuation value is a function of both D_h and D_ℓ. We require:

$$E_1(D_\ell, D_h, e_{BG}, BG_1) \geq b \tag{11}$$

where e_{BG} is determined by (5).

In formal terms we augment the original problem, as defined by (3)-(7), with the additional constraints (9)-(11). Accordingly, consider a new contract:

$$C' \equiv \Big\{\phi_0 = c_0;\ \phi_1(B_1) = 0,\ \phi_1(BG_1) = c_1;\ \phi_2(h) = c_2,$$
$$\phi_2(\ell) = 0,\ \theta(R_T;B_1) = -b,\ \theta(R_T;s) = \rho(R_T,D_s)\Big\},$$

where $s \in \{h,\ell\}$. C' has the following interpretation:

(a) The investor pays c_0 ...[as in C];

(b) At date 1 the entrepreneur reports his type. If he reports $m = BG_1$ then the investor pays c_1. Alternatively, if $m = B_1$ then the project is terminated and at date 3 the entrepreneur receives b from the investor;

(c) If at date 2 the project is observed to be high cost $(s = h)$ the investor pays c_2 to the entrepreneur and the face value of debt is D_h. Otherwise, if development costs are low $(s = \ell)$ the face value of debt is D_ℓ.

We have:

Proposition 2. (*Temporary Asymmetric Learning*)

If project type at date 1 is private information of the entrepreneur but states are publicly observable at date 2 then an optimal equilibrium contract is C' with the following properties:

(*i*) *state-contingent debt with* $D_h > D_\ell$;

(*ii*) *positive redundancy payment* $(b > 0)$.

Proof: See the Appendix.

Properties (*i*) and (*ii*) differ from those of Proposition 1. Beginning with property (*ii*), the change to strictly positive redundancy can be understood by inspecting (9). Zero-redundancy is now not feasible because it violates the truth-telling constraint by setting the LHS of (9) to zero. With $b = 0$ and any finite D_h, a type B_1 entrepreneur would fail to terminate the project.

Property (*i*), that debt becomes state-contingent, can be understood by recalling that the optimal contract will maximise entrepreneurial effort (which is always below first-best level). Suppose we were to set $D_h = D_\ell = \hat{D}$, with $\hat{D}$ chosen to give zero expected profits for investors. Then the effort choices and continuation values of types B_1 and BG_1 will be equal, i.e. $e_B = e_{BG}$ and $E_1(D_h, e_B, B_1) = E_1(D_\ell, D_h, e_{BG}, BG_1)$. Thus, the truth-telling constraints (9) and (11) must both hold with equality. Suppose now we allow a small increase in D_h and a decrease in D_ℓ such that the investor's participation constraint continues to bind. Unambiguously, both e_B and $E_1(D_h, e_B, B_1)$ fall since a type B_1 who chooses to continue will later be identified as high cost $(s = h)$ and will be allocated D_h. Thus, B_1's truth-telling constraint (9) is satisfied. It is also true that the decrease in D_ℓ will be sufficient to cause type BG_1's effort to increase. Since the investor's expected profit is zero, it is the entrepreneur who gains from the increased effort.

Finally for this contracting problem, Proposition 2 states that *C'* is an optimal contract. It is not uniquely optimal. In *C'* we specified that only high cost projects receive the date 2 instalment, c_2. An alternative contract, which will be useful in next section, is to transfer c_2 to all entrepreneurs and compensate with an increase in D_ℓ:

$$\hat{C}' \equiv \left\{ \text{...as in } C' \text{ except } \phi_2(BG_1) = c_2,\ \theta(R_T;\tau) = \rho(R_T, D_s^*),\ s \in \{\ell, h\} \right\},$$

where $D_h^* = D_h$ and $D_\ell^* = D_\ell + c_2$, and D_h and D_ℓ are the solution to Proposition 2. We have:

Lemma 1: *C' and $\hat{C}'$ are equivalent in the sense that the entrepreneur's expected return is identical.*

Proof: See the Appendix.

Sub-sections 2.1 and 2.2 have developed two key propositions. The first is that the efficiency of effort is enhanced when the level of debt is invariant across states. The second is that this second-best solution is unobtainable when the entrepreneur gains private information at date 1. The contract must be structured to induce entrepreneurs with type B_1 projects to terminate at date 1. In Sub-section 2.2 this was achieved by making the face value of debt conditional on state s. In the next section we take the analysis one step further by assuming s is non-verifiable by third parties.

3. Non-Verifiable States:

In the previous section the form of the optimal financial contract was analysed under fairly strong informational assumptions. Essentially, we assumed that either one or the other of the two parties to the contract could produce incontrovertible evidence about project cost to some third party (e.g. to the law courts). We now relax this assumption by assuming state s is observable to both entrepreneur and investor but non-verifiable by third parties. The aim is to characterise the type of mechanisms necessary to implement the state-contingent debt solution as found Proposition 2. We show that the form of the mechanism depends on the magnitude of $D_h - D_\ell$: (*i*) If $D_h - D_\ell > c_2$ but not too large, then a single-stage mechanism with the option belonging to the entrepreneur will implement the correct allocation; (*ii*) If $c_2 > D_h - D_\ell$ then a two-stage mechanism with both entrepreneur and investor owning options will implement the correct allocation; and, (*iii*) if $D_h - D_\ell$ is too large the correct allocation can not be implemented.

The general form of the contract considered in this section is as follows:

$$\mathcal{C}'' \equiv \left\{\phi_0 = c_0;\ \phi_1(B_1) = 0,\ \theta(R_T;B_1) = -b;\ \phi_1(BG_1) = c_1,\ \text{play } \mathcal{M} \text{ at date } 2\right\},$$

which is interpreted as follows:

(a) The investor pays c_0 ... [as in $\mathcal{C}$];

(b) If the entrepreneur's date 1 report is $m = B_1$ then the project is terminated and at date 3 the investor pays b. If $m = BG_1$ then the investor pays c_1

immediately and payoffs are finally determined by the outcome of the mechanism $\mathcal{M}$, which is played at date 2.

Figure 3 illustrates this interpretation of C''. In the following sub-sections we consider a number of mechanisms. In terms of this paper a mechanism $\mathcal{M}$ assigns to one or more of the contracting parties the right to choose between two pre-specified payment functions or sets of payment functions. Since our mechanisms are played at date 2 each set of payment functions can include only ϕ_2 and $\rho(R_T,D)$. Accordingly, a set of payment functions is denoted by $\sigma = \{\phi_2,\rho(R_T,D)\}$. For example, from Proposition 2 we know that efficiency requires that high and low cost entrepreneurs be allocated schedules $\sigma_h = \{c_2,\rho(R_T,D_h)\}$ and $\sigma_\ell = \{0,\rho(R_T,D_\ell)\}$, respectively. Equivalently, using Lemma 1 the two entrepreneur types could be allocated $\sigma_h^* = \{c_2,\rho(R_T,D_h^*)\}$ and $\sigma_\ell^* = \{c_2,\rho(R_T,D_\ell^*)\}$. Both types will be used in the following sub-sections.

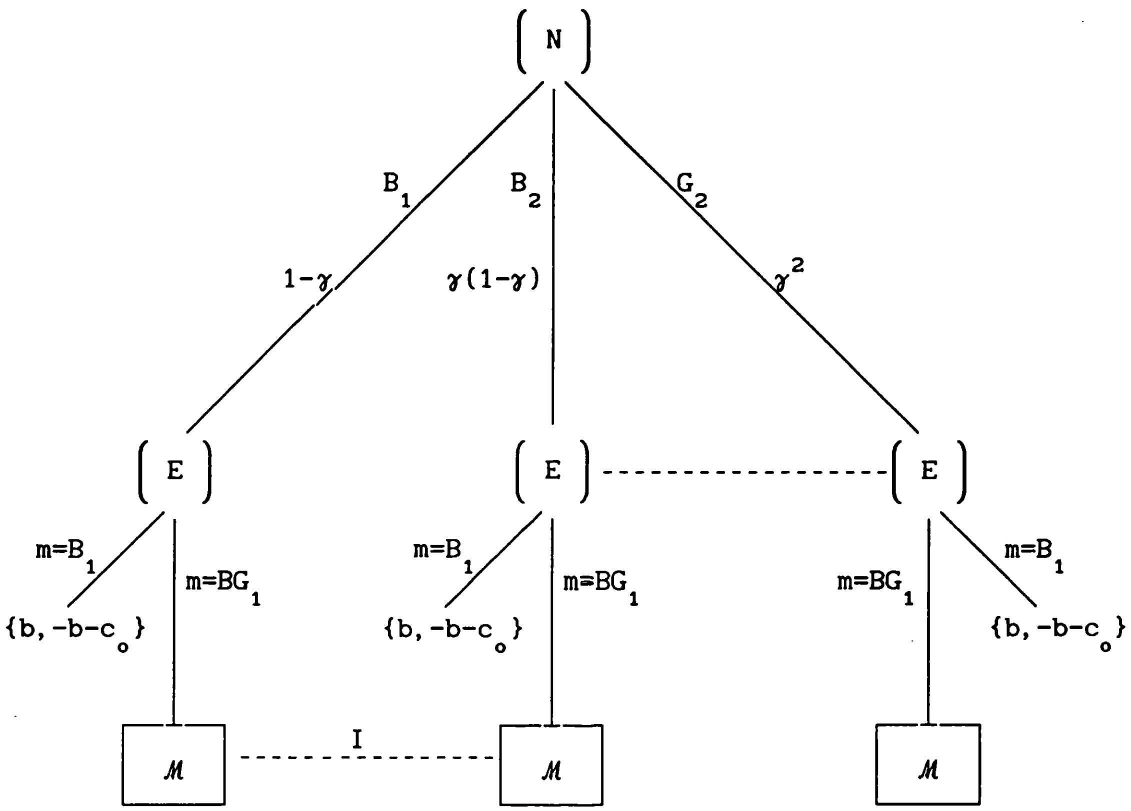
3.1. Single-Stage Mechanisms

To analyse the potential role and limitations of single-stage mechanisms we begin by briefly considering the outcome with *recontracting* at date 2. With recontracting, the entrepreneur and investor agree at date 0 to an initial face value of debt of D_ℓ, and agree to recontract at date 2 in the event that c_2 is required for project completion. We assume the recontracting process allows the entrepreneur to raise finance from the competitive financial market.[13] Assuming further that the initial debt, D_ℓ, has seniority the market will offer to finance c_2 with debt of δ such that:

$$\int_{D_\ell}^{D_\ell+\delta} (R-D_\ell)f(R,e)dR + \delta[1-F(D_\ell+\delta,e)] = c_2 \tag{12}$$

Thus, the high cost entrepreneur has total debt of $D_\ell+\delta$, while the low cost entrepreneur's debt is D_ℓ. Clearly, to implement the results of Proposition 2 we require $\delta = D_h - D_\ell$. Hence, recontracting is not a generic solution and we

Figure 3: Form of C''



KEY: N ≡ nature

E ≡ entrepreneur

I ≡ investor

$\boxed{\mathcal{M}}$ ≡ play mechanism $\mathcal{M}$

m ≡ entrepreneur's report

--- ≡ information set

payoff order: {E, I}

therefore proceed to consider single–stage mechanisms.

A single–stage mechanism gives one of the two parties to the contract the right to choose between two pre–specified σ schedules. From Proposition 2 we know that the low cost entrepreneur should be allocated $\sigma_\ell = \{0,\rho(R_T,D_\ell)\}$ (or σ_ℓ^*) and the high cost entrepreneur should be allocated $\sigma_h = \{c_2,\rho(R_T,D_h)\}$ (or σ_h^*). Any other allocation would lead to an additional efficiency loss. For mechanisms with a single option the number of alternative mechanisms is limited to the number of contracting parties. In our context, this implies that the relevant two single–stage mechanisms are:

Mechanism $\mathcal{M}1$(a)

At date 2 the entrepreneur has an option to choose between σ_ℓ and σ_h.

Mechanism $\mathcal{M}1$(b)

As in $\mathcal{M}1(a)$ except that the option belongs to the investor.

In C'' with $\mathcal{M}1$(a) all moves, apart from the initial move by nature, are by the entrepreneur. Once the investor has signed the contract she has no choice but to abide by the decisions of the entrepreneur. With $\mathcal{M}1$(a), therefore, the game $\mathcal{G}_1$ degenerates so that the actions of the entrepreneur can be determined by backward induction. In contrast, for C'' with $\mathcal{M}1$(b) the entrepreneur reports $m = B_1$ or $m = BG_1$ at date 1 and then at date 2 the investor observes s and chooses either to accept σ_ℓ or exercise her option over σ_h. The following proposition characterises the potential role of these single–stage mechanisms:

Proposition 3. (*Single–Stage Mechanisms*)

Contract C'' with $\mathcal{M}1$(a) implements the results of Proposition 2 provided $\bar{D}_\ell + \delta > D_h \geq D_\ell + c_2$. *Contract C'' with $\mathcal{M}1$(b) can never implement Proposition 2.*

Proof: We consider the two mechanisms separately. Mechanism $\mathcal{M}1$(a): In this case a low cost entrepreneur can freely choose between $\sigma_\ell = \{0,\rho(R_T,D_\ell)\}$ and $\sigma_h =$

$\{c_2,\rho(R_T,D_h)\}$ without recourse to the credit market. Since a type ℓ entrepreneur requires no further funds, the effective (risky) debt burden associated with some $\sigma = \{\phi_2,\rho(R_T,D)\}$ is $D - \phi_2$. Accordingly, the low cost entrepreneur will choose σ_ℓ if and only if

$$D_h - c_2 > D_\ell. \tag{13}$$

The high cost entrepreneur, on the other hand, requires c_2 for investment and can only choose $\{0,\rho(.,D_\ell)\}$ by simultaneously raising additional funds of c_2. This can be done by selling debt amounting to δ, as determined in (12). Therefore, a high cost entrepreneur will choose σ_h if and only if

$$D_\ell + \delta > D_h. \tag{14}$$

Taken together, the conditions (13) and (14) show that $\mathcal{M}1$(a) will implement the correct allocation if and only if $D_\ell + \delta > D_h \geq D_\ell + c_2$.

Mechanism $\mathcal{M}1$(b): The right to choose between σ_h and σ_ℓ now belongs to the investor. Since we have a zero-sum game at date 2, the investor will implement the correct allocation provided the inequalities in (13) and (14) are reversed. However, since $\delta > c_2$ this implies $D_h \geq D_\ell + \delta > D_\ell + c_2 > D_h$, which is a contradiction. Thus, $\mathcal{M}1$(b) cannot implement the correct allocation.

Q.E.D.

Proposition 3 shows that a one-stage mechanism with the option owned by the entrepreneur can successfully allocate D_h and D_ℓ provided $D_\ell + \delta > D_h \geq D_\ell + c_2$. For a low cost entrepreneur the benefit from choosing σ_ℓ is the lower face value of debt, while the benefit from choosing σ_h is an increase in retained earnings from $R_T = R$ to $R_T = R + c_2$ (for any realisation of R). However, if $D_h - D_\ell \geq c_2$ then the additional retained earnings from σ_h accrue back to the investor and a low cost entrepreneur will prefer σ_ℓ to σ_h. For a high cost entrepreneur the choice is between funding c_2 from σ_h or from the market. The entrepreneur will thus choose the option with the lowest total face value of debt.

Two aspects of the above analysis are worth discussing here. The first relates to the assumption that c_2 can be funded from the market. In one respect this is an important assumption because without recourse to the market the high cost entrepreneur would be forced to choose σ_h irrespective of whether $D_h < D_\ell + \delta$. In this case successful implementation by $\mathcal{M}1(a)$ would only require $D_h > D_\ell + c_2$. However, it is the possibility that $D_\ell + c_2 > D_h > D_\ell$ which leads to a role for two-stage mechanisms. The second, and more important, feature of our analysis is the absence of intermediate returns. For example, suppose the entrepreneur receives a return, R_2, at date 2[14], with $R_2 \geq c_2$. Then a high cost entrepreneur can self-finance c_2 without recourse to the market and, as in the case of a low cost entrepreneur, will choose σ_h if and only if $D_h - c_2 < D_\ell$. Thus, $\mathcal{M}1(a)$ would no longer implement the correct allocation because all entrepreneurial types would choose the same σ. This problem does not arise in the two-stage mechanism developed below because it is based on schedules σ_h^* and σ_ℓ^*. Each of these specify $\phi_2 = c_2$ so that, irrespective of project type, any schedule can be chosen without recourse to the financial market.

3.2. Two-Stage Mechanisms

Our two-stage mechanism has the property that the option available to the second player at the second stage is contingent on the exercise decision of the first player at the first stage. This sequential structure effectively reduces the degrees of freedom available to the first player because he or she must take into account the action of the second player. Applying the theory of "Implementation by Stage-Mechanisms" (see Moore and Repullo [1988]) we show that a two-stage mechanism can implement the solution to Proposition 2 as the outcome of a fully-revealing perfect Bayesian equilibrium whenever $D_h + c_2 > D_h > D_\ell$.

Implementation is achievable because, conditional on effort e, the expected net return on high and low cost entrepreneurs differ by c_2. This provides a wedge between high and low cost entrepreneurs and enables the design of a mechanism which creates a type of "single-crossing property" (see Figure 5). Since the final allocation will be either $\sigma_h^* = \{c_2, \rho(R_T, D_h^*)\}$ or $\sigma_\ell^* = \{c_2, \rho(R_T, D_\ell^*)\}$, where $D_h^* = D_h$ and $D_\ell^* = D_\ell + c_2$ as in contract $\hat{C}'$, the single-crossing property is obtained using some non-debt schedule, such as equity. Accordingly, we define the schedule $\sigma_\alpha^* = \{c_2, \rho(R_T, \alpha, D)\}$, where the combined debt-equity repayment function $\rho(R_T, \alpha, D)$ is defined by:

$$\rho(R_T,\alpha,D) = \begin{cases} D + \alpha(R_T - D), & \text{if } R_T \geq D \\ R_T, & \text{otherwise} \end{cases}, \tag{8'}$$

where α is the equity share of the investor.

We define[15]:

Mechanism $\mathcal{M}2$

(*i*) *At date 2 the initial schedule is σ_h^*. The investor has an option to either accept σ_h^* or reject it in favour of σ_α^*.*

(*ii*) *If the option in (i) is exercised then the entrepreneur has an option to either accept σ_α^* or reject it in favour of σ_ℓ^*.*

The structure of $\mathcal{M}2$ is illustrated in Figure 4. Contract C'' with $\mathcal{M}2$ defines $\mathcal{G}_1$ as a four-stage game:

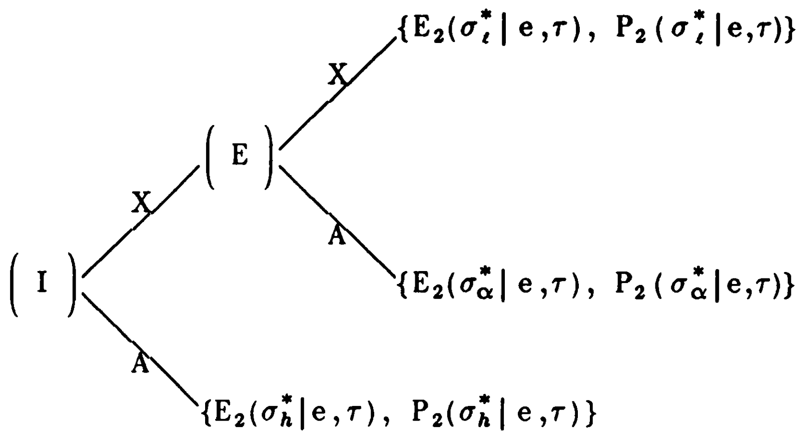
(*i*) Nature chooses project type τ, $\tau \in \{B_1, B_2, G_2\}$.

(*ii*) The entrepreneur observes his type as either B_1 or BG_1 and sends a message m, $m \in \{B_1, BG_1\}$;

(*iii*) The investor observes the state s, $s \in \{h, \ell\}$, and chooses A (accept σ_h^*) or X (exercise option in favour of σ_α^*);

(*iv*) The entrepreneur fully learns his type τ, $\tau \in \{B_1, B_2, G_2\}$, and chooses A (accept σ_α^*) or X (exercise in favour of σ_ℓ^*).

Figure 4: Extensive Form For Mechanism $\mathcal{M}2$



Key: X ≡ exercise option; A ≡ accept existing contract; $\tau = \{B_1, B_2, G_2\}$

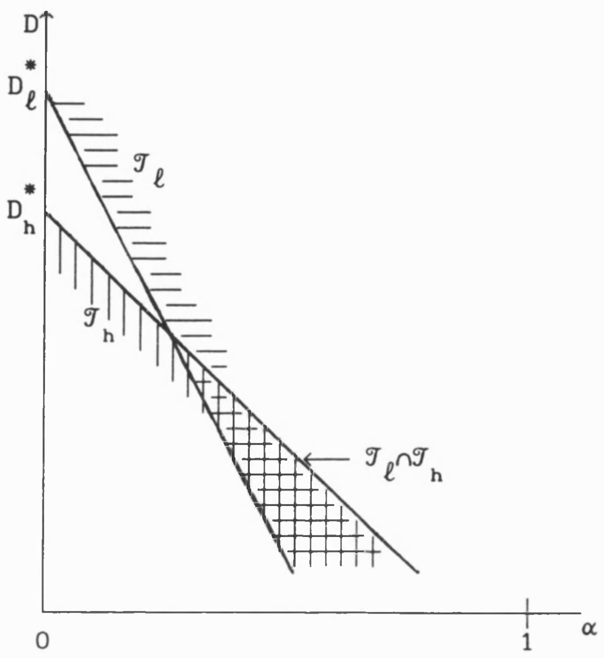
$\sigma_h^* \equiv \{c_2, \rho(R_T, D_h^*)\}$

$\sigma_\alpha^* \equiv \{c_2, \rho(R_T, \alpha, D)\}$

$\sigma_\ell^* \equiv \{c_2, \rho(R_T, D_\ell^*)\}$

The extensive form for $\mathcal{G}_1$ is represented by appending Figure 4 onto Figure 3. We are interested in perfect Bayesian equilibria in pure strategies, where the strategy spaces for entrepreneur[16] and investor are $\mathcal{S}_E = \{B_1, BG_1\} \times \{X, A\}$ and $\mathcal{S}_I = \{X, A\}$, respectively. Since the investor's exercise decision is made after observing s, $s \in \{h, \ell\}$, she will be unable to distinguish types B_1 and B_2. We represent the investor's beliefs over types by $\mu(\tau \mid s, m)$, $\tau \in \{B_1, B_2, G_2\}$, which is a function of the entrepreneur's message, m and state s. Trivially, $\mu(G_2 \mid \ell, m) = 1$ since only type G_2 can enter state ℓ. Also, $\mu(B_1 \mid h, m) + \mu(B_2 \mid h, m) = 1$ for $m \in \{B_1, BG_1\}$. In the usual manner, we define a perfect Bayesian equilibrium as a set of strategies such that each strategy is a best response to the other, given beliefs. In particular, consider the following pair of strategies which implement truth–telling by the entrepreneur at date 1 and the appropriate allocation of high and low debt (where E, I and N denote entrepreneur, investor and nature, respectively):

Figure 5: The Admissible Region for (α,D)



– Entrepreneur's strategy:

$$\sigma_E = \begin{pmatrix} \text{if N chooses } B_1 \text{ report } m=B_1, \text{ otherwise report } m=BG_1 \\ \text{if I chooses X choose X if } \tau=G_2, \text{ otherwise choose A} \end{pmatrix}$$

– Investor's strategy:

$$\sigma_I = \begin{pmatrix} \text{if } s=\ell \text{ choose X, otherwise choose A} \end{pmatrix}$$

We note that the truth–telling property of σ_E implies that all paths are equilibrium paths. Thus, Bayes' rule implies $\mu(B_2 | h, BG_1) = 1$.

The next proposition states the conditions required for $\{\sigma_E, \sigma_I\}$ to be an equilibrium to the game defined by C" with $\mathcal{M}2$. In the process we define $\mathcal{T}_\ell$ as the set of (α,D) where a type G_2 entrepreneur is better–off with σ^*_ℓ rather than σ^*_α. $\mathcal{T}_h$, in contrast, is the set for which type B_2 prefers σ^*_α to σ^*_h. These sets are illustrated in Figure 5 for the case $D^*_h < D^*_\ell$, i.e.

$$\mathcal{T}_\ell \equiv \{(\alpha,D): E_2(\sigma^*_\alpha | e,G_2) \le E_2(\sigma^*_\ell | e,G_2),\ 0 \le \alpha \le 1,\ D \ge 0\}$$

$$\mathcal{T}_h \equiv \{(\alpha,D): E_2(\sigma^*_\alpha | e,B_2) \ge E_2(\sigma^*_h | e,B_2),\ 0 \le \alpha \le 1,\ D \ge 0\}$$

We have:

Proposition 4. (*Two-Stage Mechanisms*)

Let C" with M2 specify values (b, D^*_h, D^*_ℓ) *as prescribed by the state-contingent contract* $\hat{C}$'. *If*:

(*i*) $D^*_h \le D^*_\ell$, *and*;

(*ii*) $\mathcal{T}_\ell \cap \mathcal{T}_h \neq \emptyset$,

then there exists a schedule (α, D) *such that the strategy pair* $\{s_E, s_I\}$ *are perfect Bayesian equilibria whose outcome implements truth-telling.*

Proof: The solution to $\hat{C}$' has been shown to induce type B_1 to report truthfully. Thus, if $\{s_E, s_I\}$ are equilibrium strategies for *C"* with *M2* then B_1 will continue to report $m = B_1$ and, hence, from Bayes' rule $\mu(B_2 | h, BG_1) = 1$. The task, therefore, is to show that (*i*) and (*ii*) imply s_E and s_I are best responses to each other given rational beliefs. First, consider the case where $\tau = G_2$. Inspection of Figure 3 shows that the mechanism beginning at this node constitutes a proper subgame. Applying subgame perfectness to Figure 4 the following set of inequalities ensure that s_E and s_I are best responses to each other for type G_2 projects:

$$E_2(\sigma^*_\alpha | e,G_2) \le E_2(\sigma^*_\ell | e,G_2) \quad (15)$$

$$P_2(\sigma^*_h | e,G_2) \le P_2(\sigma^*_\ell | e,G_2) \quad (16)$$

Since $D^*_h \le D^*_\ell$ by condition (*i*), equation (16) is always satisfied. $\mathcal{T}_\ell$ is defined to ensure that (15) is satisfied.

Secondly, consider the case of $\tau = B_2$. Figure 3 shows that B_1 and B_2 are members of the same information set for the investor at date 2. However, as noted above, given the entrepreneur's strategy of truthfully reporting B_1 the investor rationally believes that any high cost project observed at date 2 is type B_2. i.e. $\mu(B_2|h,BG_1)=1$. For a type B_2 the entrepreneur and investor each choose A provided:

$$E_2(\sigma^*_\alpha|e,B_2) \geq E_2(\sigma^*_\ell|e,B_2) \tag{17}$$

$$P_2(\sigma^*_h|e,B_2) \geq P_2(\sigma^*_\alpha|e,B_2) \tag{18}$$

Since the entrepreneur's return equals project return minus payments to the investor, (18) is equivalent to:

$$E_2(\sigma^*_\alpha|e,B_2) \geq E_2(\sigma^*_h|e,B_2) \tag{18'}$$

Also, since $E_2(\sigma^*_h|e,B_2) \geq E_2(\sigma^*_\ell|e,B_2)$ whenever $D^*_h \leq D^*_\ell$ it follows that (18') implies (17). $\mathcal{T}_h$ satisfies (18').

Thus, provided $\mathcal{T}_\ell \cap \mathcal{T}_h \neq \emptyset$ there exists some (α,D) such that the correct assignment of debt levels occurs.

Q.E.D.

A natural question arising from Proposition 4 is whether the conditions (*i*) and (*ii*) are restrictive. In particular, from Proposition 2 we know that $D_h > D_\ell$ is optimal while Proposition 4 requres $D^*_h \leq D^*_\ell$, where $D_h = D^*_h$ and $D_\ell = D^*_\ell - c_2$. Hence, to replicate the optimal state-contingent contract with $\mathcal{M}2$ we require the parameters to be such that $D_\ell < D_h \leq D_\ell + c_2$. From (A6) in the Proof of Proposition 2 the magnitude of $D_h - D_\ell$ depends on the parameter values and functional forms of the effort and distribution functions. Consequently, in the general framework of this paper it is not possible to determine the conditions on the underlying parameters for which $D_\ell < D_h \leq D_\ell + c_2$ and $\mathcal{T}_\ell \cap \mathcal{T}_h \neq \emptyset$ are satisfied.[17] We argue, though, that this is not a significant drawback as comparative static exercises have little relevance here.

3.3. Interpretation of Mechanisms $\mathcal{M}1$(a) and $\mathcal{M}2$

Mechanisms $\mathcal{M}1$(a) and $\mathcal{M}2$ have both been shown to implement the solution described in Proposition 2. Mechanism $\mathcal{M}1$(a) gives the entrepreneur the right to choose between an initial face value of debt, D_ℓ, and a higher face value, D_h. By choosing D_h the entrepreneur receives funds of c_2. The additional face value of debt, $D_h - D_\ell$, exceeds c_2 but is less than δ, the face value offered by the market. Thus, the contract C" with $\mathcal{M}1$(a) can be interpreted as a debt contract with a loan commitment option attached. Options of this type have also been shown to resolve certain types of adverse selection and under-investment problems (see Thakor [1989] and Berkovitch and Greenbaum [1991]).

Mechanism $\mathcal{M}2$ is a two-stage mechanism which gives option rights to both entrepreneur and investor. A similar mechanism is analysed by Chiesa [1988] as a method of reducing under-investment in growth options. The two models are similar in that both posit an effort problem. In Chiesa [1988] the option rights expire before the entrepreneur's effort decision, whereas in this paper effort is predetermined at the time the options become available. However, the analysis is similar because rational agents correctly anticipate the outcome of the "mechanism game". A more important distinction is that Chiesa assumes symmetric information and focuses on the Myers' under-investment problem, while we assume temporary asymmetric learning and analyse a stopping problem.

Chiesa interprets her two-stage mechanism as a debt-warrant contract with a call provision. In our context a better interpretation of $\mathcal{M}2$ may be as a convertible and redeemable Preference share with fixed dividends. This interpretation is particularly relevant for this paper because the project is assumed to be specific to the entrepreneur. Thus, failure to meet scheduled repayments would not lead to bankruptcy in the sense that the entrepreneur loses control and ownership of the project. Rather, the payments would be either rolled-over or written-off by the investor. Hence, the function $\rho(R_T,D)$, which we have called debt, can also be interpreted as fixed-dividend Preference shares. Our result that financial structures may include convertible and redeemable Preference shares is consistent with case studies of venture capital deals (see Lorenz [1985] and Sahlman [1990]).

4. Further Discussion:

Throughout this paper we have maintained the assumption that entrepreneurs have zero initial wealth and that the project and other outside opportunities are mutually exclusive. This reflects our aim of modeling the provision of venture capital finance to business start-ups, rather than the financing of larger, established businesses. One problem encountered with any attempt to model venture capital finance is the lack of a comprehensive and rigorous empirical analysis of their characteristics. However, some assessment of our results above can be made from the less formal information from case studies. Lorenz [1985], who is a U.K. venture capital practitioner, describes the nature of project financing and the types of financial contracts employed. In the proto-typical examples provided by Lorenz the financing deal almost always included Ordinary shares, Preferred ordinary shares, convertible Preference shares and redeemable Preference shares. Some support is also provided by Chapter Four of this thesis which shows that 3*i*, the largest U.K. venture capital company, holds some form of hybrid share in around 40 per cent of their portfolio companies (although it was not possible to identify whether these shares were convertible or redeemable). Another source of support for the importance of convertible shares is provided by Sahlman [1990, Table 3]. His case studies of multiple financing rounds by U.S. venture capital funds all involve convertible Preferred shares.

On the theoretical side, the nature of venture capital contracts is also analysed by Chan, Siegel and Thakor [1990]. They derive the opitmal financial contract in a dynamic principal–agent model with symmetric learning about entrepreneurial skill[18]. Their contract has three key features:

(*i*) there is a performance requirement where the entrepreneur is relieved of productive control after the first period if certain minimum skill levels are not obtained;

(*ii*) if the entrepreneur retains control then the sharing rule corresponds to equity;

(*iii*) an entrepreneur who is relieved of control is paid a fixed amount independent of his demonstrated skill and subsequent cash flows of the firm (called the "buy–out" option for the investor).

Parts (*i*) and (*ii*) contrast with the results of this paper. In part, this is because we assume the entrepreneur to be essential for project development and completion; the venture capitalist has no managerial or productive ability and is only concerned with efficient implementation of optimal stopping. Thus, in our model the entrepreneur always retains control of the project. Another difference between the models is that Chan *et. al.* assume the entrepreneur is risk averse whereas we assume risk neutrality. This difference explains the use of equity shares in (*ii*) compared for our debt or Preference share contracts. Finally, the buy–out provision in (*iii*) is similar to our redundancy payment. However, the former arises from risk aversion while the latter is due to the need to induce optimal stopping with minimal distortion to effort incentives.

Some support for both models is provided in Gorman and Sahlman [1988], who found in their survey of venture capitalists that both skill deficiencies and delayed product development were important and frequent causes of failure[19]. At the theoretical level, consideration of monitoring costs suggests the two models are complementary. If day–to–day monitoring costs are large we would expect to see the Chan *et. al.* model applying to only the most profitable projects where a high level of skill is very important. For most projects, however, such intensive monitoring would not be profitable. Instead, the asymmetric learning model of this paper would be more appropriate, especially if the entrepreneur's skill improves from "learning by doing".[20]

5. Conclusions

This paper highlights the difficulties that arise when arrival of information during the development phase of projects is private to the entrepreneur. In particular, when the entrepreneur has no wealth or collateral, previous tranches of finance must be treated by the investor as sunk costs. As a result, standard debt contracts are no longer viable. Instead, if cost–states are contractible the optimal monotonic contract will specify the face value of debt as being contingent on the state and will also provide redundancy payments for entrepreneurs who terminate their project. If cost–states are non–verifiable, and hence non–contractible, then a loan commitment option or convertible and redeemable Preference shares may implement the correct allocation of debt among entrepreneur types.

The use of equity in the two–stage mechanism occurs despite the risk neutral principal–agent setting. This is because the equity component of our financial contracts acts purely as a fulcrum between high and low debt outcomes, rather than as a means of sharing risk. The model predicts that in equilibrium investors would never need to convert their Preference shares into Ordinary shares because the entrepreneur will agree to redeem the appropriate portion of the Preference shares.

Issues for future research arise on two levels. The first is to allow the possibility of an entrepreneur contracting simultaneously with more than one investor. From an empirical point of view this would be interesting because many projects are financed by syndicates of venture capitalists, particularly in the U.S. On a theoretical level we have the basic theoretical result that implementation by stage-mechanisms requires weaker assumptions when there are three or more players. It would be interesting to analyse whether and how this basic result carries over to the mechanisms of Section 3. A second line of research could focus on integrating the learning models of venture capital finance with the asymmetric information models of finance for larger, established business enterprises. Such models would be useful for analysing how financial and investment policies change over the "life-cycle" of firms.

Endnotes:

1 This has become a very large literature. The main pioneering papers are Leland and Pyle [1977], Myers and Majluf [1984], Stiglitz and Weiss [1981] and Ross [1977]. See also de Meza and Webb [1987] for an example of the importance of deriving the form of the optimal contract.

2 In contrast to signalling models, all the results in this paper go through if entrepreneur has small positive wealth.

3 This normalisation does not affect the substance of any of our results. However, if wages were strictly positive the redundancy payment described in Proposition 2 could then be re-interpreted in terms of the degree of limited liability.

4 All the results of the paper would hold if we were to weaken our assumption by assuming that any buyer of the patent could develop the same project but at a cost which is some multiple of the c_t's. Provided this multiple is sufficiently large it would always be better for the originator of the project idea to seek finance for his project, rather than sell it.

5 However, except in the case of two-point distributions, FOSD does not imply MLRP. Nevertheless the MLRP condition characterises a large class of distribution functions (see Milgrom [1981]).

6 CDFC is a restrictive assumption since most of the distribution functions commonly used in economic analysis, such as the exponential distribution, fail to satisfy this condition. Jewitt [1988] has provided some alternative sufficient conditions which also validates the First-Order Approach for the traditional principal-agent problem with a risk neutral principal and risk averse agent. However, our assumption that both the entrepreneur and investor are risk neutral rules-out a direct application of Jewitt's conditions.

7 A state is verifiable when objective evidence can be presented to independent third parties (e.g. law courts). This makes verifiability a stronger assumption than symmetric information.

8 If the investor could pre-commit the problem of this paper becomes trivial.

9 There are two arguments. The first relies on the fact that any repayment function with a decreasing segment will provide the entrepreneur with an incentive to enter the decreasing segment by borrowing from third parties after observing the realisation of returns. The second is that investors will also have an incentive to avoid the decreasing segment. Possibly, investors may be in a position to sabotage the firm, essentially burning profits sufficient to take the firm out of the decreasing segment.

10 The symmetric information case that follows in Section 2 is not the same as self-finance because effort is not observable.

11 Sappington [1983] also studies a principal-agent problem with ex post limitations on payments by an agent. However, his model assumes that the observed state affects the productivity of effort. Our model, on the other hand, maintains an independence between states and productivity of effort by relating the former to the project's development costs and the latter to expected future net operating income. Without this separation the simple debt schedule derived in this section would be suboptimal.

12 With out the monotonicity constraint the optimal contract is a "live-or-die" contract where the entrepreneur receives either all or none of the project's return.

13 The alternative is to assume the contract restricts the entrepreneur's access to the financial market. In this case it would be necessary to explicitly model the recontracting process as a bargaining game. A particularly simple bargaining structure is to give one of the parties the right to make a Take-It-Or-Leave-It (TIOLI) offer. On the one hand, allowing the entrepreneur to make a TIOLI offer is equivalent to assuming a competitive financial market. On the other hand, if the original investor can make a TIOLI offer she will appropriate the surplus, $R(e_{BG}) - c_2$, by setting the face value of debt to infinity. In this case, the adverse consequence for the entrepreneur's effort choice suggests that a contract restricting access to the financial market will be dominated ex ante by a contract with no restrictions.

14 Formally including intermediate returns would alter our interpretation of the mechanisms as the standard debt contract would no longer be an optimal contract for the effort problem (see Proposition 1).

15 Mechanism $\mathcal{M}2$ gives the investor the first move. An analysis similar to that of this sub-section would apply were the order of moves reversed.

16 Strictly, the date 1 report (m) by the entrepreneur should include his report about effort, e. Then we would have $\mathcal{S}_E = [0,1] \times \{B_1, BG_1\} \times \{X, A\}$. However, for simplicity, we avoid this additional notational complication.

17 A minimal requirement for the derivation of an explicit solution would be to specify the functional form of F(R,e) and $\psi(e)$. In the principal–agent literature it has become almost traditional to follow the Mirrlees–Rogerson approach, which assumes F(R,e) to be convex in e at each level of output (CDFC). This CDFC assumption, combined with MLRP, validates the so called "first-order approach" as the solution to the principal–agent problem. However, a major problem with the CDFC assumption is that almost all of the distributional forms commonly used in economics fail this test. In response to this problem Jewitt [1988] has recently developed alternative conditions for the first-order approach and has shown that these are satisfied by the Gamma, Poisson and Chi-squared distributions. However, his results do not carry-over directly to the model of this paper since our model does not conform to the proto-typical principal–agent problem. In particular, Jewitt's proofs require at least some positive risk aversion by the agent, which contrasts with our assumption of risk neutrality. One possibility is that our limited liability constraint may negate this problem. But any such analysis is far beyond the scope of this paper. Given the limited guidance of the theoretical literature on the appropriate functional form for F(R,e) we believe that a numerical example is the best approach.

18 Other papers on venture capital finance include Chan [1983] and Cooper and Carleton [1979] but their analyses don't involve either learning or the stopping problem.

19 Gorman and Sahlman's results show that venture capitalists identified entrepreneurial deficiencies much more highly than any other category. However, they argue that this could partly be due to the fact that the entrepreneur is usually the point of contact for the venture capitalist and so have been unfairly blamed.

20 This conclusion has also been reinforced by my discussions with Ms. C. Biggs and Mr. D. Clarke of 3*i* PLC. In circumstances where the managerial team has serious deficiencies 3*i* rely on moral suasion to introduce a new member to management. They also report that some leverage is possible through the investor's control over future tranches of finance. However, even where there are problems the entrepreneur retains his original ownership claims.

Appendix: Proofs

Proof of Lemma 1: Equivalence of *C' and* $\hat{C}$'.

Comparing *C'* and $\hat{C}$' we see there are two differences: a type G_2 receives an additional c_2 from ϕ_2 and the face value of debt for this type increases by c_2. By substitution into the entrepreneur's payoff function conditional on e, we see that these effects cancel so that G_2's payoff with $\hat{C}$' is the same as with *C'*:

$$\begin{aligned} E_2(D_\ell^*,e,G_2) &= \int_{D_\ell^*-c_2}^{\infty}(c_2+R-D_\ell^*)f(R,e)dR \\ &= \int_{D_\ell}^{\infty}(R-D_\ell)f(R,e)dR \\ &= E_2(D_\ell,e,G_2) \end{aligned}$$

Q.E.D.

Proof for Proposition 1: The invariance property.

Proof of the zero-redundancy property is trivial. We prove here the invariance property for the effort problem defined by (3), (4), (5), (7b) and (7c). The problem can be simplified in two ways. First, following Innes [1990] we know that debt is optimal and thus we can eliminate constraints (7b) and (7c). Second, for the purposes of choosing D_h and D_ℓ, the maximand (3) and the incentive constraint (5) are complementary since:

$$E_0(b,D_h,D_\ell,e_{BG}) = \gamma E_1(D_h,D_\ell,e_{BG}) + (1-\gamma)b.$$

Thus, subject to zero expected profits for investors, maximising the value of e_{BG} on $[0,e_{fb}]$ is equivalent to maximising $E_0(b,D_h,D_\ell,e_{BG})$. Also, for given b, the investor's participation constraint $P_0(b,D_h,D_\ell,e) \geq C$ can be rewritten as $P_1(D_h,D_\ell,e) \geq C_1$, where $C_1 = \gamma^{-1}\{C + (1-\gamma)b\}$. Thus, the problem essentially boils down to choosing debt levels D_h and D_ℓ to:

$$\text{maximise} \quad e_{BG}(D_h,D_\ell) \tag{A1}$$

$$\text{subject to } P_1(D_h,D_\ell,e) \geq C_1, \tag{A2}$$

where the function $e_{BG}(D_h,D_\ell)$ is determined by the FOC for effort, $\partial E_1(D_h,D_\ell,e)/\partial e = 0$. The FOC's for (A1)-(A2) are:

$$\frac{\partial e_{BG}}{\partial D_s} + \lambda\frac{\partial P_1}{\partial D_s} = 0, \; s\in\{\ell,h\}, \tag{A3}$$

where λ is the Lagrange multiplier.

The first term in (A3) can be evaluated by taking total differential of the FOC for effort, $\partial E_1(D_h,D_\ell,e)/\partial e = 0$. In the process, we use the fact that expected returns for the entrepreneur and investor must sum up to expected project returns (i.e. $E_1(D_h,D_\ell,e) + P_1(D_h,D_\ell,e) = R(e) - \psi(e)$), and thus re-write

(A3) as:

$$\frac{\partial^2 P_1}{\partial e \partial D_s} + \lambda \frac{\partial P_1}{\partial D_s} = 0, \ s \in \{\ell, h\}.$$

Finally, noting that

$$P_1(D_h, D_\ell, e) = \gamma P_2(D_\ell, e, G_2) + (1-\gamma) P_2(D_h, e, B_2)$$

and

$$P_2(D, e, \tau) = \int_0^D Rf(R,e)dR + D[1-F(D,e)],$$

the conditions (A3) can be shown to require (upon elimination of λ):

$$\frac{-F_e(D_h, e)}{1 - F(D_h, e)} = \frac{-F_e(D_\ell, e)}{1 - F(D_\ell, e)}. \qquad \text{(A4)}$$

Clearly, $D_h = D_\ell$ is sufficient for (A4). Invariance is also necessary since MLRP implies $F_e(D,e) \leq 0$ for all D, so that $-F_e(D,e)/[1 - F(D,e)]$ is increasing D.

Q.E.D.

Proof for Proposition 2: $D_h > D_\ell$ is optimal with temporary asymmetric learning.

The proof is similar to Proof 1 except for the addition of constraint (9) (which is re-written here as (A5)); i.e. we have:

$$\text{maximise } e_{BG}(D_h, D_\ell) \qquad \text{(A1)}$$

$$\text{subject to } \gamma P_1(D_h, D_\ell, e) - (1-\gamma)b \geq C, \qquad \text{(A2')}$$

$$b \geq E_1(D_h, e_B, B_1) \qquad \text{(A5)}$$

Solving for b, D_h and D_ℓ (in the same manner as for Proof 1) we obtain:

$$\frac{-F_e(D_h, e_{BG})}{\gamma[1 - F(D_h, e_{BG})] + 1 - F(D_h, e_B)} = \frac{-F_e(D_\ell, e_{BG})}{\gamma[1 - F(D_\ell, e_{BG})]} \qquad \text{(A6)}$$

In comparison with (A4), the above condition has the additional term $1 - F(D_h, e_B) > 0$ in the denominator of the LHS. Thus, for $D_h = D_\ell$, which satisfies (A4), the LHS of (A6) would be less than the RHS. Since $-F_e(D,e)/(1-F(D,e))$ is increasing in D it follows that $D_h > D_\ell$ is necessary for (A6) to hold.

Q.E.D.

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CHAPTER THREE

CONTRACTUAL COVENANTS AND PREMATURE INVESTMENT

This paper is concerned with the role of asymmetric information in determining whether projects should be incorporated jointly as a single firm or separated as legally distinct entities. Our approach to this question is based on the possibility that, prior to raising finance for new projects, entrepreneurs or firms may try to mislead the market about the performance of their existing projects. If an existing project can be characterised as an investment option, then one way that they might do this is by prematurely exercising a low value investment under the pretence that it is in a high state. An adverse selection problem is created because entrepreneurs whose projects actually are in the high state would optimally exercise their project; failure to do so would risk the project falling into the low state in future periods. This type of adverse selection problem, which we call *premature investment*, has not been studied in the literature. Moreover, to the best of our knowledge, our explanation of whether projects will be jointly or separately incorporated is the first which does not rely on exogeneous factors, such as corporate taxation rules (cf. Shah and Thakor [1987]).

Until recently the literature on asymmetric information and optimal financial structure has focused on models where projects are characterised as a single, instantaneous investment followed by a flow of returns. In particular, two of the most important results are that debt outstanding may lead to under-investment in growth options (see Myers [1977] and discussion below) or to over-investment due to risk-shifting behaviour (Jensen and Meckling [1976]). Under-investment may also occur when the existing assets of a firm are under-valued (Myers and Majluf [1984]). In these contexts over-investment occurs when the firm invests in projects with negative net present value (NPV) and under-investment occurs when the firm passes up projects with positive NPV. An important characteristic of the above class of models is that the instantaneous nature of investment precludes any role for information arrival during the investment process. While this may be appropriate when the project represents an extension or replacement of existing assets, it is less so for new projects involving innovations. Implementation of the latter will usually require several stages of investment before returns are appropriated.

Allowing for a sequence of investments opens additional avenues through which information may affect a firm's investment decisions. For example, in Dewatripont and Maskin [1989] and Hansen [1991] (which is Chapter Two of this thesis) there are low cost and high cost projects and there is a critical stage beyond which it is socially optimal for any project to be completed. This means that financiers generally cannot precommit to not refinance high cost projects once they are past the critical "no return" stage. The two papers differ in their assumptions about private information at the time of the first investment. In Hansen there is initially symmetric information but the entrepreneur receives private information about costs prior to the "no return" stage. The paper shows that truth–telling with minimum efficiency loss may be achieved with loan commitment options or convertible and redeemable Preference shares. In contrast, Dewatripont and Maskin assume an ex ante informational asymmetry and show that financiers may deliberately remain of small size in order to credibly commit to not refinance high cost projects. In another paper, Webb [1991] considers project choice in an optimal stopping model where the entrepreneur also has private information about his or her ability. He shows that high quality entrepreneurs may prefer low value projects with intermediate cash flows over higher value projects with long gestation periods. The reason is that early cash flows reveal information about entrepreneurial quality and so lead to subsequent financing terms which are closer to actuarially fair terms. Thus, contrary to received wisdom, project choice based on the timing of cash flows may be better than simply choosing projects according to NPV.

Each of the above papers limit the entrepreneur's action at each date to either continue the project by investing or stopping the project by not investing. In the latter case the project is lost as the entrepreneur does not have an opportunity to start it up again. In contrast, this paper analyses an investment *timing* problem where a project has positive expected NPV provided it is implemented on one of several dates. The problem for the firm is to choose the best date at which to implement the project, i.e. the firm essentially owns a call option. In this context, suboptimal investment does not refer to over- or under-investment as conventionally defined, but rather whether the firm implements the project before or after it reaches maximal NPV. We focus on the former case, referred to as premature investment.

A natural starting point for our analysis is Myers' [1977] model of growth options. This is a one-period model where the firm begins with some level of debt outstanding[1] and an investment option which can be exercised only at the end of the period. Prior to the exercise decision the firm observes the state of nature which determines NPV with certainty. The key insight of Myers' model is that the entrepreneur will *under-invest* by failing to exercise the option whenever the amount of outstanding debt exceeds NPV. The reason is that all proceeds from the project accrue to debtholders (and, implicitly, the entrepreneur has an arbitrarily small non-pecuniary cost of investment).[2] The model in our paper introduces a timing problem into the Myers' analysis by supposing that investment options have two periods to maturity and can be exercised at either date. We assume the entrepreneur operates two projects, labelled 1 and 2, which are identical apart from the fact that Project 2 becomes available one period after Project 1. In addition, the space of feasible contracts is restricted by two assumptions: first, exercise decisions are observable but, due to costs of writing contracts, are non-contractible (see discussion below); the contract to finance Project 2 is written only when this project first becomes available. This latter assumption is realistic as it rules out the possibility of writing all–encompassing "life–time" contracts at the birth of the firm (see also the discussion below).

Since there are two projects there arises the question of whether they should be incorporated jointly or separately. Joint incorporation of projects creates a single distinct legal entity upon which financial claims can be issued. Hence, a claim written before Project 2 becomes available will give the holders of this claim some recourse to cash flows generated by Project 2. The same is not necessarily the case when projects are incorporated separately. We assume that the covenants attached to contracts can specify whether or not joint incorporation is compulsory.

Beginning with symmetric information, we show there is a range of parameter values for which joint incorporation of projects creates a diversification effect and so minimises Myers' type distortions. However, ex post incentives may not be aligned with ex ante optimality and so for some parameter values equilibrium contracts would specify covenants binding the firm to joint incorporation. In contrast, when state realisations are private information of the entrepreneur, the above results no longer hold. With asymmetric information there arises a signalling game where the exercise decision for Project 1 affects the terms of the financial contract for Project 2.[3] A disadvantage of joint incorporation is that there may now exist a premature–investment pooling equilibrium in the sense of excessive early exercise of Project 1. On the other hand, ability to separate projects may allow the pooling equilibrium to be broken. For this to happen the benefits to entrepreneurs in bad states, which arise from the elimination of premature investment and also a transfer in market value from debt holders, must outweigh the costs. These costs arise from higher probability of future under–investment. Hence, in contrast to the case of symmetric information, private information means that covenants of equilibrium contracts will not necessarily require joint incorporation of projects.

The paper is organised as follows. The next section describes the model in formal terms. Section 2 analyses some properties of the model under the assumption of symmetric information, including the diversification benefits from joint incorporation of projects. Section 3 begins by specifying a reduced-form signalling game and shows how asymmetric information can result in premature investment. Section 3 also analyses how contractual covenants allowing separate incorporation of projects may overcome the early exercise problem. Finally, conclusions are presented.

1. The Model

In this section we provide a formal description of the model, including types of agents and market structure, project technology, information and verifiability assumptions, and a description of the contracting game. The model is kept as simple as possible and is intended to be illustrative only.

1.1. Agents

The economy comprises both entrepreneurs and investors, both of which are risk neutral. Each representative entrepreneur (or firm) is endowed with two projects, labelled 1 and 2, and lives for three periods, dated $t=1,2,3,4$. However, the entrepreneur has zero wealth[4] and so requires outside finance to undertake the necessary investments. Investors have wealth available to invest but are not endowed with projects. They value consumption at each date and have a constant rate of time preference between consumption at any two adjacent dates, which for simplicity is set equal to zero. The financial markets through which entrepreneurs and investors meet are characterised by Bertrand competition. Thus, given the above assumptions, the optimal equilibrium financial contract will maximise the entrepreneur's terminal wealth subject to the investor's participation constraint and other resource– and information–based constraints (as specified below).

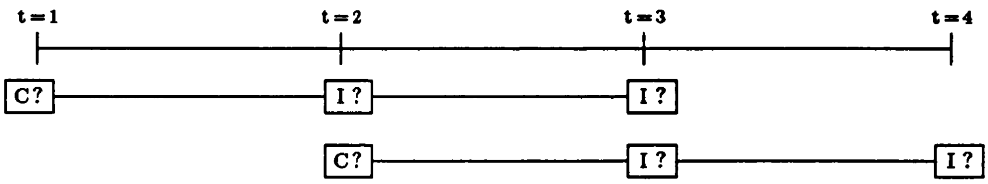
We assume the technology is specific to each entrepreneur so that it is not possible for any investor with a large wealth endowment to buy–out the entrepreneur. In the absence of this specificity assumption the inefficiencies derived below could be avoided by a transfer of ownership and managerial decision–making to a wealthy individual.

1.2. Project Technologies

The entrepreneur's two projects are identical technologies except that Project 1 becomes available at $t=1$ while Project 2 becomes available at $t=2$. The lagged arrival of project opportunities is exogenous to the model. For simplicity we assume their state realisations are independently distributed. A project requires a sequence of two investments of fixed amounts before any return from that project can be produced. The first investment is C. However, once C has been invested the firm has some discretion over the timing of the second investment, I. Specifically, we assume that I can be invested either one or two periods after C. Failure to invest I at either of these dates results in the opportunity lapsing in the sense that the return falls to zero. Thus, to use a financial contracting analogy, each project is an American Call Option (in discrete time) with two periods to maturity and an exercise price of I. The purchase price of the option is C.

The structure described above is illustrated in Figure 1, which shows how lagged arrival of projects leads to an overlapping at t=2 and possibly also at t=3. Let s_{it} be the state of project i at date t and $s_t=(s_{1t},s_{2t})$ the corresponding state vector. For simplicity, we assume s_{it} is either high (h) or low (ℓ) and that, for given t, s_{it} are independently distributed across i. For a project which starts at date $t=\tau$ the probability distribution of $s_{i\tau+1}$ is $s_{i\tau+1}=h$

Figure 1: Project Arrival and Exercise Decisions



and $s_{i\tau+1} = \ell$ with probability p and 1–p, respectively. Then, if $s_{i\tau+1} = s$ the transition probability for remaining in state s is q_s and the probability of transferring to the other state is $1-q_s$. Hence, the transition probabilities are state–dependent and the transition probabilities are state–dependent and Markov. We do not place restrictions on the relative sizes of q_h and q_ℓ at this stage, though the analysis below will generally require a low q_h and a high q_ℓ. The evolution of states is illustrated in Figure 2.

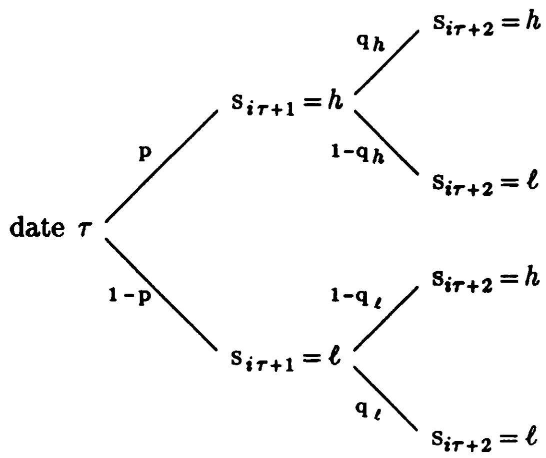
For $s_{it} = s$ the non–random gross return of project i is G^s. The return net of exercise costs is $R^s \equiv G^s - I$, and we assume

$$R^h > C > R^\ell \geq 0 \tag{1}$$

In (1) the first inequality allows positive net returns in the high state while the second inequality guarantees the project is risky. The last inequality ensures that the lowest return exceeds the exercise price so that it is never socially optimal to let an investment option die unexercised.[5]

Since R^s is non–random for given s we can, without loss of generality, set $I = 0$ for the remainder of the paper.[6] Thus, each project is formally analysed as though it requires only investment C. However, the problem retains the essential feature that the entrepreneur faces a sequence of exercise decisions. For a given project and date the entrepreneur either exercises (denoted X) or waits (denoted W). Letting d_{it} be the exercise decision for project i at date t, we can write $d_{it} \in \{X,W\}$, for $i \in \{1,2\}$ and $t \in \{\tau+1, \tau+2\}$, and $\mathbf{d}_t = (d_{1t}, d_{2t})$.

Figure 2: Evolution of States for Project Beginning at Date τ



Clearly, given (1), independence of state realisations across projects and the assumption that C is a sunk cost, the first-best policy for each project is to exercise the option at $t=\tau+1$ if, and only if, $s_{i\tau+1}=h$ and to always exercise any option which is unexercised at $t=\tau+2$. The latter follows since (1) implies $0>R^\ell-C\geq -C$, so that the losses in the low state are minimised by exercising the investment option. Hence, first-best can be described as:

$$d^{fb}_{i\tau+1}=\begin{cases} X, \text{ if } s_{i\tau+1}=h \\ W, \text{ if } s_{i\tau+1}=\ell \end{cases} \qquad d^{fb}_{i\tau+2}=X \text{ for all } s_{i\tau+2}\in\{h,\ell\}. \tag{2}$$

Given the policy as described in (2) and the probability distribution over states, the ex ante expected net present value of each project is

$$V_{fb}=(1-\gamma_u)R^h + \gamma_u R^\ell - C, \tag{3}$$

where γ_u = prob($s_{i\tau+1}=s_{i\tau+2}=\ell$) = $q_\ell(1-p)$ is the probability that the project is unsuccessful (i.e. enters and remains in state ℓ). We assume V_{fb} is positive.

1.3. Information and Contracting

We assume information is symmetric at date 1 so that prior to the first investment neither the entrepreneur nor investors know the future states, s_t. However, they all know the probability distributions described above, i.e. there is no adverse selection at date 1.

Following Townsend [1979] and Gale and Hellwig [1985] we assume costly state verification for investors. Hence, although the state realisation s_t is revealed costlessly to the entrepreneur, investors must pay a fixed cost to observe it. This assumption implies that the optimal repayment function can be characterised as debt with bankruptcy where bankruptcy occurs whenever the entrepreneur fails to repay the face value of debt.[7] Furthermore, we assume that the process of bankruptcy destroys the investment option so that renegotiation to avoid the under-investment problem is not possible. Thus, if the level of debt is too high it will not be possible to implement the first-best investment policy described by (2).

Though s_t is costly for investors to observe, we assume they can costlessly observe the entrepreneur's investment actions. However, it is important for the results below that these actions be non-contractible.[8] Following Grossman and Hart [1986] and Hart and Moore [1988] we justify non-contractibility of actions by pointing to the costs of writing contracts with detailed descriptions of future states and actions.[9] An important implication of the assumption that exercise actions are observable is that investors can condition their beliefs about the state of the firm on these actions. It is this conditioning of the uninformed party's beliefs which gives rise a signalling problem and leads to premature investment.

In addition to the above assumptions, we add a further important restriction on the contracting problem: *we preclude contracting prior to project arrival.* By this we are assuming that it is not possible to write a single contract at the birth of the firm (t=1) which determines financial arrangements for the whole life of the firm (i.e. until t=4). Instead, we assume that financing arrangements for each project can only be written as a formal contract when the project first becomes available. In terms of our two-project firm described above, this means that the contract for Project 2 is determined at t=2, while the contract for

Project 1 is determined at t=1. At both dates the terms of the contract are therefore determined by competition in financial markets. Hence, we are ruling out financial contracts with a single investor.[10] If "prior contracting" were permitted then the parties would be able to avoid the signalling problem and associated premature investment developed below. Nevertheless, allowing for the possibility that a firm may need to finance a new project while also taking observable actions on an existing project appears to be a realistic formulation.

In the following we denote the contract for project i, $i \in \{1,2\}$, by $C_i \equiv \{\rho, U_i\}$, where ρ is the repayment function and U_i is a vector of covenants attached to the contract. We have already noted that the repayment function ρ will be a debt function. However, before specifying the exact form of ρ we need to discuss the nature of the covenants U_i. Two covenants of particular interest are the seniority rule applying to repayments specified by C_1 and C_2 and any restrictions for projects to be jointly or separately incorporated. Let $U_i = (u_1, u_2)$, where u_1 is the maximum amount of senior claims that can be issued by any contract subsequent to C_i and $u_2 \in \{CJI, CSI, \emptyset\}$ specifies either compulsory joint incorporation (CJI), compulsory separate incorporation (CSI) or a null covenant ($\emptyset$) with no restrictions on incorporation of projects. We follow the convention that covenants U_i must not contradict covenants from earlier contracts. Hence, if $U_1 = (u_1, CJI)$ then u_2 in C_2 can specify either CJI or $\emptyset$ but not CSI. A third covenant that may be attached to C_i concerns restrictions on interim dividend and managerial remuneration. However, in contrast to Berkovitch and Kim [1990], it will become clear below that setting interim payments to zero can never be suboptimal in this model since the corresponding reduction in external financing requirements reduces the potential for under-investment. Thus, for simplicity, we assume zero dividend and other payments without adding this as an explicit covenant in our contracts.

We can now be explicit about the repayment function, ρ. Let $\rho = \rho(b)$ specify that the face value of debt is b. Then $C_1 = \{\rho(b),(u_1,u_2)\}$ specifies that the investor who signs this contract will receive

$$\rho(b) \equiv min\{b,max\{0,R_T - u_1\}\}, \tag{4}$$

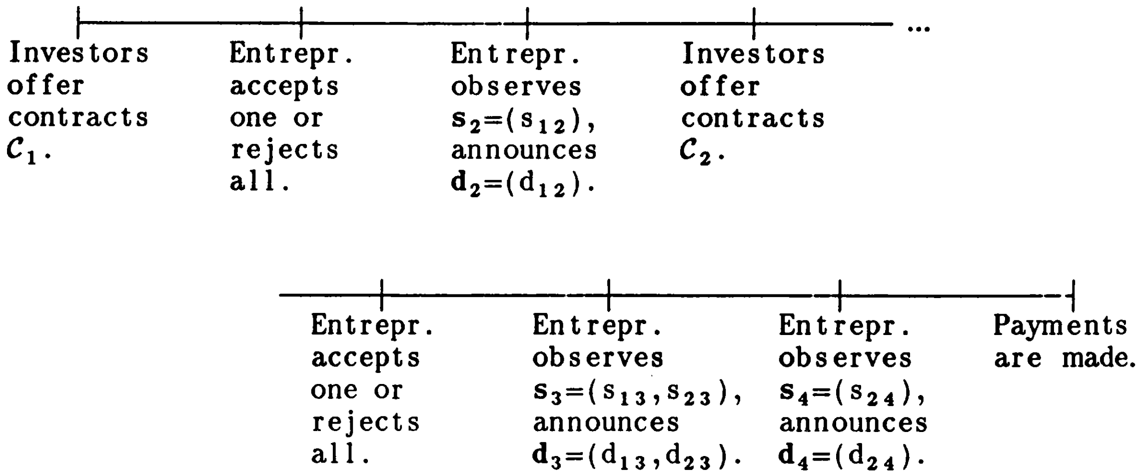
where R_T is total returns accruing at $t=4$. Equation (4) says that the return net of payments on senior claims is $max\{0,R_T - u_1\}$ and that the investor who signs C_1 receives the lessor of this amount and b. If we let $u_1 = B$ then we would say that b and B are junior and senior debt, respectively.

1.4. The General Contracting Game

The general contracting game has the following form, as illustrated in Figure 3. First, investors offer contracts C_1 to finance investment C for Project 1. Second, the entrepreneur either accepts one of these contracts or rejects all offers and ends the game with zero pay-offs. Third, the entrepreneur observes the first state realisation for Project 1 and then announces/precommits to either exercise (X) Project 1 or wait (W). Fourth, investors offer contracts C_2 to finance Project 2. Fifth, the entrepreneur either accepts one of these contracts or rejects all. Sixth and seventh, the entrepreneur observes two state realisations and announces an exercise decisions after each observation. Eight, payments are made according to the rules specified in C_1 and C_2.

The game is analysed for pure strategies using the concept of perfect Bayesian equilibrium. This requires that equilibria satisfy the following conditions: (1) at each of $t=3,4$ the entrepreneur chooses exercise action $\mathbf{d}_t$ optimally as a function of contracts C_1 and C_2, the sequence of state realisations $\{s_j\}_{j=1}^{j=t}$ and past decisions $\{\mathbf{d}_j\}_{j=1}^{j=t-1}$; (2) once the investors have made their contract offers, the entrepreneur's acceptance decision is made optimally to maximise his or her own expected terminal wealth; (3) given C_1 and the entrepreneur's announced action $\mathbf{d}_2$, each investor's contract offer C_2 is made given the optimal response of the entrepreneur in terms of both acceptance and

Figure 4: The Contracting Game



future exercise decisions, beliefs about the entrepreneur's current state (type) and given contract offers by other investors; (4) when offering C_2 the beliefs of each investor must be consistent with the equilibrium strategies of the entrepreneur and other investors; (5) given C_1 and the current state $\mathbf{s}_2$, the entrepreneur chooses exercise action $\mathbf{d}_2$ optimally, knowing that this action may affect the beliefs of the investors and hence their contract offers C_2; (6) each investor's contract offer C_1 is made given the optimal response of the entrepreneur in terms of both acceptance and future exercise decisions, beliefs about contract offers by other investors and the equilibrium contract C_2.

A feature of the above description is that, given C_1 and C_2, actions $\mathbf{d}_3$ and $\mathbf{d}_4$ can be determined by backward induction. For the case of asymmetric information (Section 3), this fact will allow us to model the contracting process for C_2 as a standard *signalling game* where the payoffs are given by expected terminal wealth as at date 2. We will analyse equilibria of the signalling game for the two cases where $u_2 = \text{CJI}$ (compulsory joint incorporation) and $u_2 = \emptyset$ (no restrictions). It will become clear that the third case, $u_2 = \text{CSI}$, can never be preferred to both CJI and $\emptyset$.

As a precursor to the signalling model, we next analyse the form of equilibrium contracts for the case of symmetric information.

2. Symmetric Information

In this section we assume symmetric information so that outside investors can observe state realisations. Our main purpose is to provide a benchmark to aid understanding of the asymmetric information case that follows. We show here how the face value of debt affects the level of inefficiency due to under-investment and also characterise the nature of covenants. In the later the focus is on the role of covenants in preventing separate incorporation of projects ("project financing") and the role of seniority rules. In addition, we show that premature investment cannot occur when information is symmetric. This therefore makes clear that it is the signalling induced by the informational asymmetry that leads to premature investment.

Our assumption that state realisations are commonly observed raises the possibility that investment inefficiencies could be avoided by ex post renegotiation. This is because in the event of a low state realisation (at the terminal date) it is in the interests of the debtholder to ensure the entrepreneur exercises the project by setting the face value of debt sufficiently low. However, in view of our aim of providing a benchmark for the case of asymmetric information, we rule out these possibilities.

2.1. Under-Investment

For future reference it is useful to characterise here the under-investment problem for both CSI and CJI. In each case, the face value of debt, F, is assumed to give zero-expected profits for the investor. For the case of CSI we can consider a single representative project, each with face value of debt equal to

F. To begin with we note that F must satisfy $R^h > F \geq R^\ell$. To see this, note first that if $F \geq R^h$ the entrepreneur will never exercise the project and the initial investment C would never be made. Also, from (1) $F < R^\ell$ is also not feasible since $R^\ell < C$ implies $F < C$, which in turn implies negative expected profit for investors. With $R^h > F \geq R^\ell$ the optimal exercise policies for each date are:

$$d_{it} = \begin{cases} X, & \text{if } s_{it}=h \\ W, & \text{if } s_{it}=\ell \end{cases}, \quad i\in\{1,2\} \text{ and } t\in\{\tau+1,\tau+2\} \tag{5}$$

Comparing with the first-best policy described by (2) we see that $d_{i\tau+1}$ is first-best but $d_{i\tau+2}$ is not since $R^\ell \geq 0$ implies that exercise is always socially optimal for projects reaching their terminal date. For each project, the inefficiency occurs when $s_{i\tau+1} = s_{i\tau+2} = \ell$, which has probability γ_u (see Figure 2). Given $R^h > F \geq R^\ell$, therefore, zero expected profits for the investor requires that the debt F satisfy $(1-\gamma_u)F = C$. Hence, a credit market will exist for individual projects provided the entrepreneur's expected return on each project is positive, i.e. provided $(1-\gamma_u)R^h - C > 0$. Equivalently, using (3) we can rewrite the entrepreneur's expected return per project as:

$$\bar{E}_1 = V_{fb} - \gamma_u R^\ell \tag{6}$$

Hence, with CSI total expected return over two projects is $2\bar{E}_1$ and the total expected cost of distortions is $2\gamma_u R^\ell$.

The case for CJI is similar to the forgoing analysis. There are two feasible cases of interest: namely, $2R^\ell \leq F < R^\ell+R^h$ and $R^\ell+R^h \leq F < 2R^h$, where F is now the total face value of debt issued to raise funds of 2C. The relevant results for these two cases are stated in the following two lemmas.

Lemma 1:

If $2R^\ell \leq F < R^\ell+R^h$ *then the entrepreneur's optimal exercise policies are:*

$$d_{12} = \begin{cases} X, & \text{if } s_{12}=h \\ W, & \text{if } s_{12}=\ell \end{cases} \qquad d_{13} = X \quad \text{for all } s_{13}\in\{h,\ell\}$$

$$d_{23} = \begin{cases} X, & \text{if } s_{23}=h \\ W, & \text{if } s_{23}=\ell \end{cases} \qquad d_{24} = \begin{cases} X, & \text{if } s_{12}, s_{13}, s_{23} \text{ or } s_{24} = h \\ W, & \text{if } s_{12}=s_{13}=s_{23}=s_{24}=\ell \end{cases}$$

Proof: When $F < R^{\ell}+R^{h}$ the entrepreneur will receive a positive return provided just one of the two projects enters state h. At $t=3$ Project 1 is at its terminal date (if not previously exercised). It will be exercised irrespective of the state of either project because Project 2 has positive probability of being in the high state at $t=4$, i.e. the entrepreneur has positive probability of profit of at least $R^{\ell}+R^{h} - F > 0$. Also, if Project 1 is exercised in state h then the effective level of debt outstanding is $F_o = \max\{F-R^{h},0\}$. Since $F_o < R^{\ell}$ the entrepreneur would excerise Project 2 at its terminal date $(t=4)$ irrespective of its own state. However, if Project 1 is exercised in state ℓ then debt outstanding is $F_o=F-R^{\ell}$, where $R^{\ell} < F_o < R^{h}$. In this case, Project 2 is exercised only if $s_{24}=h$.

Q.E.D.

In Lemma 1 the exercise decisions d_{12} and d_3 are first–best, but d_{24} is not since exercise of Project 2 is socially optimal for all realisations of s_{24}. The inefficiency occurs if, and only if, $s_{12}=\ell$, $s_3=(\ell,\ell)$ and $s_{24}=\ell$, which has probability γ_u^2. Thus, when $F < R^{\ell}+R^{h}$ joint incorporation of projects leads to a diversification effect which reduces expected total distortionary costs to $\gamma_u^2 R^{\ell}$ (cf. cost of $2\gamma_u R^{\ell}$ for CSI). The entrepreneur's expected return is:

$$E_1(F<R^{\ell}+R^{h},\text{CJI}) = 2V_{fb} - \gamma_u^2 R^{\ell} \tag{7}$$
$$> 2\bar{E}_1$$

where V_{fb} is defined by (3).

Lemma 2:

If $R^\ell + R^h \leq F < 2R^h$ *then the entrepreneur's optimal exercise policies are:*

$$d_{1t} = \begin{cases} X, \text{ if } s_{1t}=h \\ W, \text{ if } s_{1t}=\ell \end{cases} \quad \text{for } t=2,3$$

$$d_{2t} = \begin{cases} X, \text{ if } s_{2t}=h \text{ and } s_{12} \text{ or } s_{13} = h \\ W, \text{ if } s_{2t}=\ell \text{ or } s_{12}=s_{13}=\ell \end{cases} \quad \text{for } t=3,4$$

Proof: When $F \geq R^\ell + R^h$ the entrepreneur's realised return is positive if and only if both projects are exercised in high states. Thus, if Project 1 enters and stays in the low state (i.e. $s_{12}=s_{13}=\ell$), the total return will never be sufficient to repay F. In this case, neither project will be exercised. If, however, Project 1 enters state h at either date 2 or 3 then it will be exercised (irrespecitive of Project 2's current state) because at both dates there is positive probability that Project 2 will also enter state h and be exercised.

Q.E.D.

Lemma 2 shows that joint incorporation with $F \geq R^\ell + R^h$ leads to a contagion effect. The inefficiencies associated with individual projects are compounded because a failure of the first project results in a debt over-hang which exceeds the maximum feasible return on the second project. As a result, the entrepreneur obtains a positive return if and only if both projects enter state h. Since state realisations are independent across projects this has probability $(1-\gamma_u)^2$. The entrepreneur's expected return is:

$$\begin{aligned} E_1(F \geq R^\ell + R^h, CJI) &= 2(1-\gamma_u)^2 R^h - 2C \\ &= 2V_{fb} - 2\gamma_u\{R^\ell + (1-\gamma_u)R^h\}, \qquad (8) \\ &< 2\bar{E}_1 \end{aligned}$$

where the second equality uses (3). Of the two terms in curly brackets, the first represents the inefficiencies associated with separated projects while the second is the additional inefficiency due to the contagion effect.

To summarise, the appropriate incorporation mode for minimising the costs of under-investment distortions depends on whether the total face value of debt is greater or less than $R^{\ell}+R^{h}$. Joint incorporation has a beneficial diversification effect when $F \leq R^{\ell}+R^{h}$ and an adverse contagion effect when $F \geq R^{\ell}+R^{h}$.

2.2. Contractual Covenants

In the above we have characterised the entrepreneur's optimal exercise policies as a function of a given face value of debt. In this subsection we analyse the nature of seniority covenants (u_1) and incorporation covenants (u_2) recognising that the face value of debt is a function of equilibrium exercise policies. In order to derive results which will be comparable with the case of asymmetric information in Section 3, we exogenously rule out contract renegotiation once states are realised. Similarly, we continue to consider only debt contracts.

As discussed in Section 1.3, we assume that it is not possible at the birth of the firm (t=1) to write financing contracts for projects arriving later during the life of the firm. In terms of our two-project model, this implies there are two contracts, $\mathcal{C}_1$ and $\mathcal{C}_2$, which are written at t=1 and t=2, respectively. Due to this lag in project arrival, the state s_{12} for Project 1 will be observed by all parties prior to their agreement on $\mathcal{C}_2$. In general, therefore, the face value of debt specified in $\mathcal{C}_2$ will be conditional on s_{12}.

An issue that arises naturally in this context is the seniority provisions in $\mathcal{C}_1$. Clearly, if the covenants of $\mathcal{C}_1$ don't forbid it, issuing debt which is senior to that of $\mathcal{C}_1$ will always be optimal for the entrepreneur at t=2. Ex post of $\mathcal{C}_1$ this minimises the total face value of debt outstanding. Ex ante, however, the seniority covenant of C_1 will be indeterminate unless there are implications for the efficiency of the entrepreneur's exercise decisions. Proposition 1 below shows that there are parameter values for which C_1 can reduce inefficiencies by allowing future debt issues to be senior to any debt outstanding at that time. In the following we represent junior and senior debt by b and B, respectively (with the addition, where necessary, of date subscripts and state superscripts).

Proposition 1: (*Seniority*)

Consider two alternative contracts $C_1=\{\rho(b_1),B_2^s,CJI\}$ *and* $\hat{C}_1=\{B_1,0,CJI\}$. C_1 *specifies that debt* b_1 *is raised to finance project* 1 *and that this debt is junior to debt* B_2^s *issued for project* 2 *when* $s_{12}=s$. $\hat{C}_1$ *specifies the reverse seniority rule. Assume both contracts imply zero expected profits for the investor. Then with symmetric information the risk neutral entrepreneur always weakly prefers* C_1 *to* $\hat{C}_1$ *and there exist parameter values for which* C_1 *is strictly preferred to* $\hat{C}_1$.

Proof: See Appendix.

Junior debt is optimal for Project 1 because this reduces the variation across states in the face value of Project 2's debt. Compared for the issue of senior debt at t=1, the total debt will be higher in state h but lower in state ℓ, i.e. $b_1+B_2^h > B_1+b_2^h$ and $b_1+B_2^\ell < B_1+b_2^\ell$. But only state ℓ is relevant for efficiency because there are no distortions in good states.

It may be noted that the role of seniority covenants in this model is analogous to Stulz and Johnson [1985] and Berkovitch and Kim [1990]. There is also some similarity to Hart and Moore [1990] except that we wish to encourage, rather than discourage, investment. In the remainder of the paper we will use the result of Proposition 1 and assume date 2 debt is senior to date 1 debt whenever projects are incorporated jointly.

We now turn to an analysis of the optimality of covenants on incorporation. Since $B_2^h < B_2^\ell$ we know from Lemma 1 that $b_1 + B_2^\ell < R^\ell + R^h$ is sufficient for joint incorporation to be optimal ex ante. Proposition 2 below shows that $b_1 + B_2^\ell < R^\ell + R^h$ is also a necessary condition. In addition, the proposition shows that for some parameter values there is a time-inconsistency problem where *ex post* (t=2) incentives differ with ex ante optimality (t=1). Hence, in these cases any announcement by the entrepreneur that the projects will be incorporated jointly is credible only if C_1 includes a CJI covenant.

Proposition 2: (*Time-Inconsistency*)

Let b_1 and B_2^s, $s = s_{12} \in \{h, \ell\}$, be the face values of junior and senior debt with CJI such that expected profits of investors are zero. Provided there exists a credit market for individual projects, joint incorporation of projects is optimal ex ante if, and only if, $b_1 + B_2^\ell < R^h + R^\ell$. When, in addition, p is close to 1 a CJI covenant will be a binding constraint on the entrepreneur at $t = 2$ if R^h is sufficiently high and Project 1 is the low state (i.e. $s_{12} = \ell$).

Proof: See Appendix.

When $s_{12} = \ell$ the CJI covenant may become binding ex post because separation of projects increases the probability of default on outstanding debt (i.e. on b_1). Hence, separation of projects leads to a fall in the market value of b_1 which represents a transfer to the entrepreneur. If p is high, so that Project 2 has a high probability of immediate success, then the value of the transfer will outweigh the expected costs of additional distortions due to separation of projects.

Although the time-inconsistency problem is undesirable when information is symmetric, it is not necessarily so with asymmetric information. This is because the time-inconsistency problem can eliminate the premature investment problem by causing projects to be separated whenever $s_{12}=\ell$. Thus, in the next section we will find that for some parameter values, a null covenant may be preferred to a CJI covenant even though total debt is less than $R^{\ell}+R^{h}$.

Finally for this section, we note another important implication of this section: exercise and investment decisions at date 2 are always first-best. This is due to two factors. First, at $t=2$ neither of the projects have reached their terminal date so there remains some positive probability that the high state will be attained. Hence, there is potential for under-investment only when one or more of the investment options have reached their terminal date. Second, information is symmetric. The public observability of project states means that the entrepreneur's actions for Project 1 have no external effects on financing terms for Project 2. The face value of debt negotiated at t=2 is conditioned directly on observations of the state s_{12}. In the next section we introduce asymmetric information so that state realisations are private information of the entrepreneur. In this case the actions of the entrepreneur are potential signals of the current state of the firm, and this leads to premature investment at t=2.

3. Asymmetric Information

The purpose of this section is to show that asymmetric information can reverse some properties of the model with symmetric information. The first stage of the analysis focuses on the contracting game played at t=2. Given that the entrepreneur has observed a state realisation for Project 1, we can formulate a reduced-form signalling game to analyse the possibility of sub-optimal exercise and investment decisions at t=2. In Subsection 3.1, we show that when C_1 has a CJI covenant there exists a pooling equilibrium where Project 1 is exercised at date 2 irrespective of its state, i.e. $d_{12}=X$, for all $s_{12}\in\{h,\ell\}$. This contrasts with the first-best policy which is to exercise Project 1 at date 2 if, and only if, $s_{12}=h$. In Subsection 3.2 we show there are parameter values for which the pooling equilibrium is robust to the Intuitive Criterion. In Subsection 3.3 we replace CJI with a null covenant and show that the time-inconsistency identified in Proposition 2 can break the pooling equilibrium. Finally, in light of our pooling and separating equilibria Subsection 3.4 discusses whether the equilibrium C_1 will include a CJI or null covenant. We argue that this depends on whether premature investment or under-investment represents the greater inefficiency. Our results for the case of asymmetric information contrast with those of symmetric information as the same parameters would imply CJI covenants are unambiguously optimal.

3.1. The t=2 Signalling Game with CJI

In this section the general contracting game described in Section 1.4 is reduced to a standard signalling game where the payoffs are defined as the expected terminal wealth as at t=2. This is feasible because the entrepreneur's exercise decisions $\mathbf{d}_3$ and d_{24} have been shown to be unique functions of state realisations and the total debt outstanding (see Lemmas 1 and 2). An advantage of the reduced-form formulation is that selection among equilibria can be based on standard tests for signalling games, as discussed below.

In the following it is convenient to omit the subscripts on most variables, so that, for example, b_1, B_2, d_{12} and s_{12} become b, B, d and s. Also we define S $\equiv \{h,\ell\}$. With $C_1 = \{\rho(b),B,CJI\}$ the t=2 game is formulated as follows: The entrepreneur observes the state s and then either exercises (X) Project 1 or waits (W). This action is publicly observable and, in the context of the signalling game, may be thought of as a message to investors. The message of an entrepreneur in state s is denoted d(s), where $d(s) \in \{X,W\}$. Each investor's response to message d, denoted B(d), is to offer a face value of debt $B \in [C,\infty)$.

In general, the entrepreneur's announcement of d will cause each investor to revise beliefs about the current state of Project 1. As before we assume prior beliefs are identical across all investors. In addition, we now assume posterior distributions conditional on message d are identical across investors, and are denoted by $\mu(s|d)$.

Given state s, message d and response B, the reduced-form payoffs (net of existing debt claims, b) to the entrepreneur and chosen investor are denoted E(s,d,B) and $\rho(s,d,B)$. These payoffs can be given precise formulations using Lemmas 1 and 2. However, since investors do not observe s, their expected gross return is:

$$P(d,B,\mu) = \sum_{s \in S} \rho(s,d,B)\mu(s|d) \qquad (9)$$

A perfect Bayesian equilibrium (PBE) in pure strategies for our reduced-form game is defined as a set of entrepreneur strategies, $d^*(s)$, investor offer functions, $B^*(d)$, and posterior probability measures, $\mu(.|d)$, satisfying the following conditions:

(*i*) Given state s and the response strategy of investors, $B^*(d)$, the entrepreneur selects d to maximise expected terminal wealth, i.e. for all $s \in S$,

$$d^*(s) \in \mathop{arg\ max}_{d \in \{X,W\}} E(s,d,B^*(d))$$

(*ii*) Given the entrepreneur's message strategy $d^*(s)$, the offer strategy of other investors and posterior beliefs, $\mu(.|d)$, each investor selects response B as a Bertrand competitor,[11] i.e.

$$P(d^*(s),B,\mu(.|d)) = C.$$

(*iii*) Whenever m is an equilibrium (pure) strategy for some type s then $\mu(.|d)$ is given by Bayes' rule, i.e. if $d^*(s)=d$ and p(.) is the distribution of prior probabilities, then:

$$\mu(s|d) = \frac{p(s)}{\sum_{\{j:d^*(j)=d\}} p(j)}$$

Since the CJI covenant restricts d to a binary message there can exist only one pooling equilibrium and one separating equilibrium. The pooling equilibrium is characterised by premature investment and is based on the following reasoning. When in the low state the benefit to the entrepreneur of a strategy to announce $d=X$ is that the credit market, being unable to distinguish types, will over-value the debt offered by the low quality type. Since competition ensures zero expected profits for investors, the over-valuation burden falls on firms in state h. Nevertheless, firms in state h will not deviate because of the potential loss of value if Project 1 were to transfer into the low state. The intuition is made precise as follows:

Proposition 3: (*Premature Investment Pooling Equilibrium*)

If states are private information of entrepreneurs and $C_1 = \{\rho(b), B_P, CJI\}$ *then for* q_ℓ *sufficiently high the unique equilibrium is a pooling equilibrium where all entrepreneur's exercise project* 1 *at the first available date,* $t=2$. *This equilibrium is represented as:*

$$\begin{cases} d^*(s) = X \text{ for all } s \in S \\ B^*(X) = B_P \\ prob(h \mid d=W) = \pi \end{cases}$$

where B_P *satisfies* $P(d^*, B_P, p) = C$ *and* π *is investors' beliefs for off-the-equilibrium paths.*

Proof: See Appendix.

Proposition 3 shows that a premature investment problem may exist in an extended version of the Myers' under-investment model. The intuition is easily understood by considering the limiting case where $q_\ell \to 1$. In this case, since the project will remain in state ℓ with high probability, the extent of the inefficiency from early exercise becomes arbitrarily small. With zero costs from early exercise, the signalling content disappears and the problem essentially reduces to one of pure adverse selection. This intuition can be made more precise by the following formulation of benefits and costs of early exercise. Let $\phi(p,q_\ell)$ be the benefit to type ℓ from the reduction of $B_W(\pi) - B_P$ in the face value of debt. The extent of this debt reduction is determined by the difference in default probabilities, say $\gamma_W(\pi)$ and γ_P. From the Appendix (see (A9) and (A10)) we can show

$$\phi(p,q_\ell) \propto q_\ell(1-p)\{(1-\pi)(p+q_\ell-1) + \pi(p+q_h)\}.$$

Thus, the benefit remains strictly positive as $q_\ell \rightarrow 1$ provided we choose beliefs such that $\pi q_h < p$. On the other hand, the cost of premature investment is the loss of option value plus any additional distortions to future investment. The sum of these costs is given by:

$$\psi(p,q_\ell) = (1-q_\ell)[(R^h-R^\ell) + \gamma_u R^\ell].$$

The first term within the square brackets represents the loss from killing the option (expected value of the option to exercise next period, $(1-q_\ell)R^h + q_\ell R^\ell$, minus the value obtainable by exercising now, R^ℓ). The second term represents the additional distortions to future exercise decisions for Project 2. With $2R^\ell \leq b + B_P < R^h + R^\ell$, the inefficiency due to premature exercise occurs because the effective level of debt outstanding becomes $b+B_P-R^\ell$, which is greater than R^ℓ. Hence, Project 2 will expire unexercised with probability γ_u. However, if premature exercise were avoided then Project 1 has probability $1-q_\ell$ of entering state h and so avoiding any inefficiency with Project 2. Hence, in addition to the direct loss of option value, premature exercise leads to an indirect cost of $(1-q_\ell)\gamma_u R^\ell$. Clearly, for $0<p<1$, $\lim_{q_\ell \rightarrow 1} \phi(p,q_\ell) - \psi(p,q_\ell) > 0$. It follows, then, that the pooling equilibrium will exist for all q_ℓ in some interval $(\bar{q}_\ell,1]$ and that this equilibrium is a premature investment equilibrium for $q_\ell \in (\bar{q}_\ell,1)$.

The benefit and cost functions, $\phi(p,q_\ell)$ and $\psi(p,q_\ell)$, are also useful for indicating conditions for which pooling equilibria cannot exist. In particular, $\lim_{p \rightarrow 1} \phi(p,q_\ell) - \psi(p,q_\ell) < 0$ indicates that pooling equilibria cannot exist for p sufficiently high (provided $q_\ell<1$). This makes sense because as $p\to 1$ the investment in each project becomes riskless and so the face value of debt (for each project) falls to C. In this case there exists a separating equilibrium as the entrepreneur benefits from the improved efficiency.

3.2. A Refinement of the Equilibrium

A well known problem with the perfect Bayesian equilibrium (PBE) concept is that it generally admits a large number of equilibria. The source of this problem is that although beliefs of the uninformed are determined by Bayes' rule when equilibrium strategies are played, there are no restrictions on beliefs for off-equilibrium strategies. In terms of our pooling equilibrium where all entrepreneurs exercise Project 1 at t=2, the uninformed investors should never observe a failure to exercise Project 1, which is an out-of-equilibrium action. But if such a deviation does occur then how should it be interpreted by investors? i.e. what value is taken by π. With the PBE concept the modeller is free to assign to π any value on [0,1]. Moreover, the value of π, which is assumed to be common knowledge of both entrepreneur and investor, may be critical for the equilibrium to exist. A small change in π may destroy the proposed equilibrium. It is useful, therefore, to test the robustness of proposed equilibria with refinements which are more restrictive than PBE. In this section we employ the *Intuitive Criterion*, as developed in Cho and Kreps [1987]. Our view is that this is a minimal test which any reasonable equilibria in signalling games should pass.[12]

A formal definition of the Intuitive Criterion is provided at the beginning of the Appendix. The intuition for the test can be stated as follows: Recall that the state space for Project 1 at t=2 is $S\equiv\{h,\ell\}$. Since the intrinsic value of the firm varies across these states, the set S can be reinterpreted as the set of entrepreneur *types* at t=2. Now suppose we pick some PBE, denoted by (d^*,B^*,μ), and consider some off–the–equilibrium–path strategy, d_o. Define $T(d_o)$ as the set of entrepreneur types which, irrespective of investor response (from the set of best responses), are strictly worse off with d_o than with the supposed equilibrium (d^*, B^*, μ). Now we ask the following question: if the investors observe d_o, is it reasonable for them to attach even some small positive probability that the entrepreneur is of type $T(d_o)$? If we require investors to be sequentially rational, the answer is no because the investors know that each member of $T(d_o)$ strictly prefers the equilibrium. On this basis a sequentially rational investor will surmise that d_o could only be sent by some type in $S \setminus T(d_o)$ and so we must concentrate the investor's beliefs to have support on $S \setminus T(d_o)$. In general, however, the reduced support may alter the set of best responses for investors, which in turn could affect the ranking of d_o relative to d^* for some type in $S \setminus T(d_o)$. Indeed, if concentrated beliefs imply there is just one type who is strictly better off with d_o, then the original equilibrium is said to fail the Intuitive Criterion. Otherwise, the equilibrium passes the test. We now apply this test to show:

Proposition 4:

If q_ℓ *and* R^h *are sufficiently high and* $q_\ell > 1 - p > 1 - q_h$ *the pooling equilibrium of Proposition* 3 *passes the Intuitive Criterion.*

Proof: See Appendix.

Once again the intuition is simplest for the case of pure adverse selection (i.e. $q_\ell = 1$). The essential feature of the Intuitive Criterion applied to this paper is that concentrating the beliefs of investors requires that we set $\pi = 0$, i.e. if an investor observes a deviation they assume the deviation is by a type ℓ entrepreneur. But if type ℓ entrepreneurs are more likely than type h to be in the low state next period (i.e. $q_\ell > 1 - q_h$) then the reduction in π to zero increases investors' estimates of default probability, which in turn increases the face value of debt. Indeed, with $\pi = 0$ the debt for deviants will exceed the debt for non-deviants and so a deviant is worse-off (since with $q_\ell = 1$ there are no efficiency gains to be obtained by deviating)[13].

3.3. Equilibria with a Null Covenant in $\mathcal{C}_1$

The above equilibria were derived with the signalling space restricted by a CJI covenant in $\mathcal{C}_1$. The purpose of that analysis was to show that with asymmetric information CJI can lead to distortions which are not present with symmetric information. We now consider the case where $\mathcal{C}_1$ includes the null covenant. Specifically, we are able to give a simple condition for which the premature investment pooling equilibrium cannot exist and we identify a separating equilibrium which does exist. In this equilibrium a type h entrepreneur incorporates projects jointly and exercises Project 1, while a type ℓ entrepreneur incorporates projects separately and defers Project 1.

Compared for CJI, a null covenant alters slightly the form of the signalling game. We expand the entrepreneur's decision space from {X,W} to {X,W}×{J,S}, where J and S are announcements that projects are incorporated jointly or separately. For example, under this specification of the game the pooling equilibrium of Proposition 3 would specify $d^* = (X,J)$ for all $s \in \{h,\ell\}$. We have:

Proposition 5: (*No Premature Investment*)
Suppose the credit market for an individual project exists. Then if $p > \frac{R^\ell}{C}$ *the pooling equilbrium of Proposition 3 can not exist.*
Proof: See Appendix.

The above proposition says that it is possible to break the premature investment equilibrium even when $q_\ell = 1$. This contrasts with the CJI covenant because in that case a pooling equilibrium always exists when $q_\ell=1$. The extra power afforded by the null covenant derives from the time-inconsistency identified in Proposition 2. Compared for the message (W,J), the additional gain to the entrepreneur from announcing (W,S) is due to the loss of market value for existing holders of b when projects are separated. Unlike the benefit $\phi(p,q_\ell)$ associated with an announcment of (X,J), the value of the transfer associated with an announcement of (W,S) is increasing in q_ℓ. In fact, for $q_\ell=1$ an announcement of (W,S) causes the market value of b to fall to zero since Project 1 will never be exercised.

The next proposition shows that with a null covenant the unique equilibrium is a separating equilibrium where a type ℓ entrepreneurs separate the projects while type h entrepreneurs incorporate projects jointly. The result is essentially the asymmetric information analogue of the time-inconsistency analysed with symmetric information in Proposition 2.

Proposition 6: (*A Separating Equilibrium with* $\emptyset$)

If states are private information of entrepreneurs and $C_1=\{\rho(b),B,\emptyset\}$ *then for* p, q_ℓ *and* R^h *sufficiently high and* $q_\ell+q_h>1$ *the unique equilibrium is a separating equilibrium where*:

(*i*) *type* h *entrepreneur exercise project* 1 *and incorporate project* 2 *within the same firm, and*;

(*ii*) *type* ℓ *entrepreneurs do not exercise project* 1 *and incorporate project* 2 *independently of project* 1;

and this equilibrium is robust to the Intuitive Criterion. The equilibrium is represented as:

$$\begin{cases} d^*(h) = (X,J),\ m^*(\ell) = (W,S) \\ B^*(X,J) = B_{XJ},\ B^*(W,S) = \bar{B} \\ \text{prob}(h \mid d\in\{(X,S),(W,J)\}) = \pi \end{cases}$$

where B_{XJ} *and* $\bar{B}$ *ensure zero expected profit for investors and* π *is investors' beliefs for off-the-equilibrium paths.*

Proof: See Appendix.

3.4. Ex Ante Efficient Covenants

Given the above analysis for the two cases of CJI and $\emptyset$ covenants, we now seek to determine which of the two covenants is ex ante efficient. Clearly, the potential for risk-shifting behaviour by entrepreneurs entering state ℓ will be anticipated at t=1 and the face value of debt, b, appropriately adjusted. Therefore, whether the list of covenants will or will not include joint incorporation depends only on the relative inefficiencies associated with each of the pooling and separating equilibria analysed above. We recall that the inefficiencies from premature investment are given by:

$$\psi(p,q_\ell) = (1-q_\ell)(R^h - R^\ell) + \gamma_u(1-q_\ell)R^\ell.$$

Inefficiencies due to the separating equilibrium of Proposition 6 are (see Lemma A1 in the Appendix):

$$\lambda(p,q_\ell) = q_\ell R^\ell + \gamma_u(1-q_\ell)R^\ell.$$

The first term in $\lambda(p,q_\ell)$ is the inefficiency that results if Project 1 remains in state ℓ and expires unexercised. The second term is the inefficiency in the exercise policy for Project 2 that would be avoided with the message (W,J). It is the same inefficiency for Project 2 that occurs with premature investment (i.e. message (X,J)).

The null covenant is optimal for C_1 whenever $\lambda(p,q_\ell) < \psi(p,q_\ell)$. This requires:

$$R^\ell < (1-q_\ell)R^h$$

Hence, it is possible for asymmetric information to lead to separate incorporation of projects for the same parameter values for which CJI would be optimal for symmetric information.

4. Conclusions

This paper has analysed the role of asymmetric information in generating premature investment in the sense that projects are exercised before they reach their maximal NPV. We believe this is the first paper to consider such timing issues as previous papers define suboptimal investment more narrowly in terms of whether negative NPV projects are undertaken or positive NPV projects are foregone.

The model assumes the entrepreneur operates two projects which are identical apart from independent state realisations and the fact that the second project becomes available one period after the first project. In addition, a number of critical assumptions were made concerning the observability and contractibility of certain variables, including a restriction that contracts to finance a given project cannot be written in advance of it's arrival. We showed that with symmetric information, joint incorporation of projects is optimal whenever this minimises distortions due to the under-investment problem. However, when state realisations are private information of the entrepreneur, covenants requiring joint incorporation of projects may lead to premature investment pooling equilibrium. On the other hand, ability to separate projects may allow the pooling equilibrium to be broken. This fact then leads to a revision of the conditions for which equilibrium contracts will include joint incorporation covenants. In essence, the equilibrium is determined by trading off the cost of premature investment against the efficiency cost of separate incorporation.

Clearly, the model in this paper has a number of special characteristics. The most important feature is the binary nature of the exercise decision which acts as a potential signal of quality. It is well known that pooling equilibria are generally not robust to extensions to continuous action space. However, the binary specification does seem natural in the context of an investment model. For example, when projects take time to build, it is not difficult to imagine that "precommitments" to large projects can be reversed once the contract for the second project is signed.

Future research could extend the model in a number of directions. For example, a more general formulation would allow projects to differ in terms of return and risk characteristics. The state space might also usefully be extended to a continuum as this would eliminate discontinuities and enable easier derivation of comparative statics. Another logical extension would be to allow endogenous project selection.

Endnotes:

1 In Myers [1977] the level of debt is exogeneous to the model. One interpretation is that it arises from past failures of earlier investment projects. On this basis it is unclear why the new project is not incorporated independently of the existing firm. In contrast, in this paper the level of debt and incorporation mode are determined endogeneously from the sequence of investments required for each project.

2 A number of potential resolutions of the Myers problem have been proposed in the literature, including renegotiation and financing with convertible bonds (Chiesa [1988]). Nevertheless, the main features of our model remain as the timing of investments still creates a signalling problem.

3 This linkage between investment decisions for Project 1 and financing terms for Project 2 is similar to John and Nachman [1985]. However, a crucial difference is that John and Nachman require the expected return on the second investment to depend on the state realisation of the first investment whereas we don't require this. The linkage in our paper operates through the under-investment problem due to outstanding debt.

4 This assumption of zero wealth is made for simplicity and is not crucial. Some small but positive level of wealth would not change any of the results below.

5 We could allow $R'<0$ if the state space were enlarged to three or more states, but this should not detract from the main results.

6 Setting $I=0$ affords considerable simplification when defining the contracting game. If $I>0$ then our assumption below that investment requirements cannot be contracted for prior to their investment date would lead to a dynamic model with a contracting game being played at each potential investment date. The entrepreneur's exercise policy for each date would then need to be characterised as the equilibrium of the corresponding contracting game. Setting $I=0$ reduces the number of contracting games to one per project so that the exercise policy is characterised by the entrepreneur's optimal policy given the initial contract.

7 Strictly, debt is optimal within the class of contracts with deterministic auditing.

8 If we allowed actions to be contractible then for R^h and p sufficiently high and q_h sufficiently low it would be possible to attain first-best. This follows since when $s_{12}=h$ the opportunity cost of not exercising Project 1 is increasing in R^h and p and decreasing in q_h. The higher the opportunity cost the higher can be repayments to the investor in this state without violating the incentive to exercise the project.

9 Since exercise decisions are binary decisions it may appear extreme to suppose that it is costly to write contracts contingent on these decisions. One possible approach is to suppose that the entrepreneur also manages other specific assets (i.e. assets with no collateral value) which have positive probability of breakdowns and so requiring (unforeseen) costly repairs. It may then be difficult to specify in advance how to distinguish between investments in repairs and investments resulting from the exercise of Project 1. However, it is beyond the scope of this paper to formally model this possibility.

10 It is clear that this is unrestrictive with respect to contracts giving the entrepreneur a credit facility (option). This is because the entrepreneur would only exercise the option if the face value of debt is less than in the market. Thus the investor would lose money. On the other hand, a contractual structure which gave an investor exclusive financing rights would likely have problems due to strong bargaining power of the investor at $t=2$ (A low initial debt being traded for the right to extract all benefits from Project 2). Clearly, this would be inefficient if the entrepreneur has specific investments which affect either the arrival probability or return distribution of Project 2. However, we do not attempt to model these effects.

11 That these conditions arise from the Nash equilibrium of a Bertrand competition game between the two investors can be reasoned in the following manner. First, it is not optimal for investors to refuse to offer if there exists an offer which would generate strictly positive expected profits. For, if all investors refuse to make an offer, then there is an incentive for each investor to deviate from the equilibrium and make an offer at positive profit. Second, condition (*ii*) follows from the fact that the entrepreneur chooses the offer with lowest face value of debt, as implied by (*i*). While if all offers are identical then each investor has some probability strictly less than one of being chosen by the entrepreneur. Thus, any collusive strategy to hold the face value of debt above B^* cannot be an equilibrium since each investor has an incentive to deviate from the equilibrium by offering a slightly lower face value of debt.

[12] Other refinements belonging to the class of equilibrium domination tests are also available, such as *Divinity* and *Universal Divinity* of Banks and Sobel [1987], but they are not explored in this paper. In general, the Intuitive Criterion is weaker than these other refinements. However, the reader should be aware that the forward induction arguments employed in these tests are not with out controversy. See, for example, Cho and Kreps [1987,p.203].

[13] A key feature which helps the pooling equilibrium to pass the Intuitive Criterion is the restricted signalling space due to the fact that exercise decisions are binary. If the exercise decision was accompanied by an observable decision on the size of investment (I) then the pooling equilibrium will fail the Intuitive Criterion.

Appendix: Proofs

A Formal Definition of the Intuitive Criterion.

The formal definition of the Intuitive Criterion requires that we first define the best response set of investors. In the following $\pi(s)$ is some probability distribution over the states (types) s and $BR(\pi,d_o)$ is the best response by investors to off-equilibrium message d_o, given beliefs π about the type of entrepreneur proposing the alternative. From condition (*ii*) of the PBE the best response is defined as:

$$BR(\pi,d_o) \equiv \{B\in[C,\infty): P(d_o,B,\pi) - C = 0\}, \tag{A1}$$

Given some set S', the set of best responses is defined as the union of best responses over all probability distributions on S'. i.e.

$$BR(S',d) \equiv \bigcup_{\{\pi:\pi(S')=1\}} BR(\pi,d) \tag{A2}$$

Finally, if (d^*,B^*,μ) is some PBE then we can write the equilibrium payoff for the entrepreneur of type s as $E^*(s) \equiv E(s,d^*(s),B^*(d^*(s)))$.

Definition: (*The Intuitive Criterion*)

For each out-of-equilibrium message d_o *form the set* $T(d_o)$ *consisting of all states (types) s such that*

$$E^*(s) > \max_{B\in BR(S,d_o)} E(s,d_o,B). \tag{A3}$$

If for any one message d_o *there is some type* $s'\in S$ *(necessarily not in* $T(d_o)$*) such that*

$$E^*(s') < \min_{B\in BR(S\setminus T(d_o),d_o)} E(s',d_o,B) \tag{A4}$$

then the equilibrium outcome is said to fail the Intuitive Criterion.

Proof for Proposition 1: (*Seniority*)

The initial contracts, $C_1=\{\rho(b_1),B_2,CJI\}$ and $\hat{C}_1=\{\rho(B_1),0,CJI\}$, can each be associated with some corresponding date 2 contract offered by the Bertrand competitive investors after observing $s=s_{12}\in\{h,\ell\}$. These are $\mathcal{C}_2=\{B_2^s,0,\emptyset\}$ and $\hat{\mathcal{C}}_2=\{b_2^s,0,\emptyset\}$. Since both sets $\{\mathcal{C}_1,\mathcal{C}_2\}$ and $\{\hat{\mathcal{C}}_1,\hat{\mathcal{C}}_2\}$ imply zero expected profits for investors the ranking of $\mathcal{C}_1$ relative to $\hat{\mathcal{C}}_1$ will be strict if, and only if, $\{\hat{\mathcal{C}}_1,\hat{\mathcal{C}}_2\}$ leads to greater distortions in the entrepreneur's exercise policy than $\{\mathcal{C}_1,\mathcal{C}_2\}$. By Lemmas 1 and 2 this will be true if there exist parameters such that $b_1+B_2^\ell < R^h+R^\ell \leq B_1+b_2^\ell$. (The value of t=2 debt for $s_{12}=h$ is irrelevant since $B_2^h < B_2^\ell$ and $b_2^h < b_2^\ell$). Such an inequality ranking is feasible if $b_1+B_2^\ell < B_1+b_2^\ell$ for all parameter values. This later inequality can be proved for all p and q_ℓ as follows. Assume $\max\{b_1+B_2^\ell,\ B_1+b_2^\ell\} < R^h+R^\ell$ so that both sets of contracts induce the same distortion. By Lemma 1 all debt is fully repaid unless $s_{12}=s_{13}=s_{23}=s_{24}=\ell$. When this worst outcome occurs the senior debt pays R^ℓ while the junior debt pays zero. But at t=1 the market values of b_1 and B_1 must be equal to each other, so that:

$$(1-\alpha)b_1 + \alpha.0 = C = (1-\alpha)B_1 + \alpha R^\ell, \tag{A5}$$

where $\alpha = \text{prob}(s_{12}=s_{13}=s_{23}=s_{24}=\ell) = \gamma_u^2$ is the unconditional probability of the worst outcome. Similarly, at t=2 the market values of b_2^ℓ and B_2^ℓ are equal:

$$(1-\beta)b_2^\ell + \beta.0 = C = (1-\beta)B_2^\ell + \beta R^\ell, \tag{A6}$$

where $\beta = \text{prob}(s_{13}=s_{23}=s_{24}=\ell\,|\,s_{12}=\ell) = q_\ell\gamma_u$ is the probability of the worst outcome conditional on being in the low state at t=2. Rearranging (A5) and (A6) and using the fact that $\alpha<\beta$ we have $b_1+B_2^\ell < B_1+b_2^\ell$, as desired.

Q.E.D.

Proof for Proposition 2: (*Time – Inconsistency*)

The ex ante optimal covenant on incorporation, u_2, will minimise distortion to the entrepreneur's investment policy. The total NPV with CSI is $2\bar{E}_1$ where $\bar{E}_1$ is given by (6). The sufficiency of $b_1+B_2^\ell<R^h+R^\ell$ for CJI is obvious by comparing this with the values given in Lemmas 1 and 2 (since $B_2^h < B_2^\ell$ implies total debt is highest in state ℓ). That optimality of CJI also implies $b_1+B_2^\ell < R^h+R^\ell$ can be shown by contradiction. Suppose $b_1+B_2^\ell \geq R^h+R^\ell$, so that the entrepreneur's expected return is $E(b_1+B_2^\ell \geq R^h+R^\ell,CJI)$, as defined by (8). Joint incorporation is optimal provided $E(b_1+B_2^\ell \geq R^h+R^\ell,CJI) > 2\bar{E}_1$. After some manipulation, this inequality reduces to $R^\ell > (1-\gamma_u)R^h$, which contradicts the assumption that projects are individually profitable. i.e. $(1-\gamma_u)R^h > C$ and $C > R^\ell$ by (1). Hence, with symmetric information, $b_1+B_2^\ell < R^h+R^\ell$ is necessary and sufficient for $u_2 = CJI$ to be ex ante optimal.

It remains to determine whether a CJI covenant in $\mathcal{C}_1$ binds ex post. In state $s_{12} = h$ the firm would not separate projects because the immediate exercise of Project 1 yields revenue of $R^h > B_1^h$ which reduces the effective debt burden on Project 2 to $F_2 = b_1+B_2^h-R^h$. Thus, $F_2 < R^\ell$ since $b_1+B_2^h < b_1+B_2^\ell < R^h+R^\ell$. Hence, with CJI and $s_{12}=h$ the exercise decisions d_{23} and d_{24} will be first-best. In state $s_{12} = \ell$ there may be incentives to separate due to the transfer in value from debt holders to equity holders (the entrepreneur). Let $P_2(b_1,S,s_{12}=\ell)$ and $P_2(b_1,J,s_{12}=\ell)$ be the date 2 market values of b_1 conditional on separation (S) and non-separation (J) and $s_{12}=\ell$. Also let $V_2(S,s_{12}=\ell)$ and $V_2(J,s_{12}=\ell)$ be the corresponding intrinsic values of the firm. $P_2(b_1,S,s_{12}=\ell) = (1-q_\ell)b_1$ since with separation the entrepreneur defaults on b_1 unless Project 1 transfers into state h at t=3. Similarly, $P_2(b_1,J,s_{12}=\ell) = (1-q_\ell\gamma_u)b_1$ for non-separation. The combined intrinsic value of the two separated projects is $V_2(S,s_{12}=\ell) = (1-q_\ell)R^h + \bar{E}_1$, where $\bar{E}_1$ is the value of Project 2, as in (6). Using the exercise policies from Lemma 1 it is straight forward to verify

$$V_2(J,s_{12}=\ell) = q_\ell(1-\gamma_u)(R^h+R^\ell) + (1-q_\ell)\{(1-\gamma_u)2R^h + \gamma_u(R^h+R^\ell)\} - C$$

The benefit to the entrepreneur from separation is $P_2(b_1,J,s_{12}=\ell) - P_2(b_1,S,s_{12}=\ell) > 0$ (the fall in the market value of debt) and the cost is $V_2(J,s_{12}=\ell) - V_2(S,s_{12}=\ell) > 0$. Taking limits as $p \to 1$ we find *lim* $P_2(b_1,J,s_{12}=\ell) - P_2(b_1,S,s_{12}=\ell) = q_\ell b_1$ and *lim* $V_2(J,s_{12}=\ell) - V_2(S,s_{12}=\ell) = q_\ell R^\ell$. Since $b_1 \geq C > R^\ell$ we have proved that there exists a $\bar{p} \in (0,1)$ such that for all $p > \bar{p}$ the entrepreneur has an incentive ex post to separate projects. All this has assumed $b_1+B_2^{\ell} < R^h+R^{\ell}$, but given that the above limits don't involve R^h we can always choose R^h sufficiently high to ensure the inequality holds.

Q.E.D.

Proof for Proposition 3: (*Premature Investment Pooling Equilibrium*)

Existence of pooling equilibria $d^*=X$, $B^*(X)=B_P$ for some π requires that the following incentive compatibility (IC) and non-separation (NS) constraints be satisfied:

$$E(s,X,B_P) \geq E(s,W,B_W(\pi)) \quad \text{for all } s\in\{h,\ell\} \tag{IC}$$

$$E(h,X,B_P) \geq E(h,X,B_X) \tag{NS1}$$

$$E(\ell,X,B_P) \geq E(\ell,W,B_W) \tag{NS2}$$

where B_P and $B_W(\pi)$ each imply zero expected profits for investors and the pair (B_X,B_W) proposed by a deviating investor imply non-negative profits for that investor. It is straight forward to show that any pair (B_X,B_W) violating either (NS1) or (NS2) also implies negative profits. Given $d^*=X$ for all entrepreneur types, the deviating investor makes zero profit on B_W and can only make non-negative profit if $B_X \geq B_P$. However, violation of (NS1) would require $B_X < B_P$! The final part of the existence proof requires that there exist some π such that (IC) holds. This is effectively proved in the proof for Proposition 4 on the Intuitive Criterion.

Uniqueness of the equilibrium for some parameter values requires that we show non-existence of a separating equilibrium where $d^*(h)=X$ and $d^*(\ell)=W$. The proof is by contradiction. A necessary condition for the separating equilibrium to exist is the truth-telling constraint for type ℓ:

$$E(\ell,W,B^*(W)) \geq E(\ell,X,B^*(X)). \tag{A7}$$

Suppose $B^*(W)=B^*(X)=\hat{B}$. Then the LHS and RHS of (A7) would differ only to the extent that early exercise in state ℓ is inefficient. This inefficiency becomes arbitrarily small as $q_\ell \to 1$ i.e. $\lim_{q_\ell \to 1} E(\ell,W,\hat{B})-E(\ell,X,\hat{B})=0$. But since the proposed separating equilibrium is fully revealing we know from Section 2.2 that $B^*(X)=C$

(i.e. when $s_{12}=h$ debt is riskless) and $B^*(W)=B_2^\ell > C$ for all $q_\ell \in (0,1]$. Hence $\lim_{q_\ell \to 1} E(\ell,W,B_2^\ell) - E(\ell,X,C) < 0$, so that there exists a $\bar{q}$ such that (A7) fails to hold for all $q_\ell > \bar{q}$.

Q.E.D.

Proof for Proposition 4:

This proof makes use of the Intuitive Criterion as described at the beginning of the appendix. The equilibrium strategy is $d^*=X$ and so the off-equilibrium strategy is $d_o=W$. The proof begins with a conjecture that d_o is equilibrium dominated by d^* when $s=h$ but not with $s=\ell$. i.e. in terms of our earlier definitions for the Intuitive Criterion we have $T(d_o)=\{h\}$ and $S\setminus T(d_o)=\{\ell\}$. We then derive the implications of conditions (A3) and (A4) of the Intuitive Criterion and verify the existence of parameter values for which the proposed equilibrium passes the Intuitive Criterion.

Since the entrepreneur's future exercise decisions are a function of total debt outstanding, the investors' expected gross return is *not everywhere* continuously differentiable with respect to B (investors' response). In particular, from Lemmas 1 and 2 there is a discontinuity in $P(d,B,\pi)$ at $B=R^h+R^\ell-b$. Nevertheless, we avoid this problem by showing existence for $B<R^h+R^\ell-b$. For this case, $P(d,B,\pi)$ is strictly increasing in B and so from (A1) the best response, $BR(\pi,d_o)$, is a unique function of π. Since $d_o=W$, we denote the best response function as $B_W(\pi)$, where π is the investor's belief that type h sent message $d_o=W$. Also, since debt issued on Project 2 is senior to debt b, the face value $B_W(\pi)$ can easily be computed using the following fact: For senior debt with face value B the market value is:

$$P(d,B,\pi) = (1-\gamma)B + \gamma R^\ell, \qquad (A8)$$

where γ is the belief of investors about the probability of default. For the off-equilibrium deviation we write $\gamma=\gamma_W(\pi)$, where

$$\gamma_W(\pi) = \text{prob}(s_{23}{=}s_{24}{=}\ell)[\pi\text{prob}(s_{13}{=}\ell\,|\,s_{12}{=}h) + (1-\pi)\text{prob}(s_{13}{=}\ell\,|\,s_{12}{=}\ell)]$$
$$= \gamma_u[\pi(1-q_h) + (1-\pi)q_\ell]. \qquad \text{(A9)}$$

For the proposed equilibrium we write $\gamma = \gamma_P$, where

$$\gamma_P = \text{prob}(s_{23}{=}s_{24}{=}\ell)\text{prob}(s_{12}{=}\ell)$$
$$= \gamma_u(1-p). \qquad \text{(A10)}$$

Using (A8) with $P(W,B_W(\pi),\pi) = C$ we find $dB_W(\pi)/d\pi < 0$ provided $q_\ell+q_h>1$.

We are now in a position to consider condition (A3) of the Intuitive Criterion. Since $E(s,W,B_W(\pi))$ is decreasing in $B_W(\pi)$ and $dB_W(\pi)/d\pi < 0$, it follows that $\max_{\pi\in[0,1]} E(s,W,B_W(\pi)) = E(s,W,B_W(1))$. In summary, when $q_\ell+q_h > 1$ and $b+B_W(1) < R^h+R^\ell$, our conjecture that d_o=W is equilibrium dominated only if $s = h$ requires:

$$E^*(h) > E(h,W,B_W(1)) \qquad \text{(A11)}$$

and

$$E^*(\ell) < E(\ell,W,B_W(1)) \qquad \text{(A12)}$$

Finally, to obtain the full set of constraints we must consider (A4). Concentrating beliefs on $S\setminus T(W)=\{\ell\}$ implies that we set $\pi=0$. Thus, from (A4) a further necessary condition for the equilibrium outcome to pass the Intuitive Criterion test is:

$$E^*(\ell) \geq E(\ell,W,B_W(0)) \qquad \text{(A13)}$$

We now wish to show that there exist parameters for which $\max\{B_P,B_W(1)\} < R^h+R^\ell-b$ and (A11)–(A13) are satisfied. From (A9) and (A10) we see that the $q_\ell > 1-p > 1-q_h$ implies $\gamma_W(1) < \gamma_P < \gamma_W(0)$. Using (A8) with $P(d,B,\pi) = C$ this in turn implies

$$B_W(1) < B_P \leq B_W(0). \qquad \text{(A15)}$$

i.e. high default probability implies high face value of debt. Clearly, $B_W(1) < B_P$ is a sufficient condition for (A12) since in this case the deviation $d_o^- = W$ by type ℓ implies both an efficiency gain and lower debt. By using the exercise rules of Lemma 1 the remaining two inequalities, (A11) and (A13), can be evaluated as:

$$(1-\gamma_W(0))B_W(0) - (1-\gamma_u)B_P \geq (1-q_\ell)\delta(R^h) \qquad \text{(A11')}$$

and

$$B_P - (1-\gamma_W(1))B_W(1) < (1-q_h)\delta(R^h), \qquad \text{(A13')}$$

where $\delta(R^h) = \gamma_u(R^h+R^\ell-b) + (1-\gamma_u)(R^h-R^\ell)$.

(A9) and (A15) imply that the LHS of (A13') is positive. Using (A8) and (A9) it is also straight forward to that there exists a $\bar{q}<1$ such that the LHS of (A11') is positive for $q_\ell>\bar{q}$. Also, the LHS of (A11') and (A13') are both independent of R^h. Therefore, it is possible to satisfy both (A11') and (A13') by choosing q_ℓ and R^h sufficiently high. Thus, there exist parameter values for which the pooling equilibrium passes the test of the Intuitive Criterion.

Q.E.D.

Proof for Proposition 5: (*No Premature Investment*)

The proof is by contradiction. Suppose there did exist a pooling equilibrium with $d^*(s) = (X,J)$ for $s\in\{h,\ell\}$. The set of possible deviations is $D \equiv \{(W,J),(X,S),(W,S)\}$. The following incentive constraint is a necessary condition for the proposed pooling equilibrium to exist:

$$E(s,(X,J),B_P) \geq max_{d\in D}\, E(s,d,B^*(d,\pi)) \quad \text{for all } s\in\{h,\ell\} \qquad \text{(A16)}$$

As before, when $d=(W,J)$ an important determinant of investors' offers are their beliefs, π. However, investors' beliefs are irrelevant for messages (X,S) and (W,S) since separate incorporation of Project 2 implies that the face value of debt to be issued is independent of Project 1's state. For these two cases let $\bar{B}$ be the face value of debt to finance Project 2 with zero expected profits for investors. Clearly, $E(\ell,(W,S),\bar{B}) > E(\ell,(X,S),\bar{B})$, since waiting is more efficient for type ℓ.

We wish to show that $p > R^\ell/C$ implies $E(\ell,(W,S),\bar{B}) > E(\ell,(X,J),B_P)$, so that the necessary condition (A16) is violated. This can be proved by using the following equations:

$$E(\ell,(W,S),\bar{B}) = (1-q_\ell)(R^h-b) + \bar{E}_1,$$

$$E(\ell,(X,J),B_P) = (1-\gamma_u)(R^h+R^\ell-B_P-b), \quad \text{and}$$

$$b = \frac{C}{1-\gamma_u(1-p)},$$

where $\bar{E}_1$ is defined by (6) and B_P is as previously defined (using (A8) and (A10)). Also, the value of the failure probability in b, $\gamma_u(1-p)$, assumes the pooling equilibrium exists. After some manipulation we find that $E(\ell,(W,S),\bar{B}) > E(\ell,(X,J),B_P)$ is equivalent to:

$$q_\ell p(R^\ell - pC) < (1-q)[(1-\gamma_u(1-p))R^h - R^\ell] \qquad \text{(A17)}$$

The RHS of (A17) is positive since $(1-\gamma_u(1-p))R^h > (1-\gamma_u)R^h > C > R^\ell$, where the middle inequality follows from the existence of a credit market for individual projects. In contrast, the LHS of (A17) is negative if $p > R^\ell/C$. Thus, $p > R^\ell/C$ is a sufficient (but not necessary condition) for the pooling equilibrium to not exist.

Q.E.D.

Proof for Proposition 6: (*A Separating Equilibrium with* $\emptyset$)

Existence. The proposed equilibrium strategies for the entrepreneur are $d^*(h) = (X,J)$ and $d^*(\ell) = (W,S)$, which leaves $\{(W,J),(X,S)\}$ as the set of off-equilibrium strategies. Denoting $E^*(s) = E(s,d^*(s),B^*(d^*))$ the proposed separating equilibrium requires the following self-selection and non-pooling constraints be satisfied:

(self-selection) $\quad E^*(s) \geq max_{d\in D}\, E(s,d,B^*(d,\pi))$ for all $s\in\{h,\ell\}$

(non-pooling) $\quad E^*(s) > max_{d\in D}\, E(s,d,B_p(d))$ for some $s\in\{h,\ell\}$

where $B_p(d)$ is investors best response if entrepreneurs were pooling at d.

We begin with the self-selection constraints. Suppose type ℓ receive actuarily fair terms, so that $B^*(W,S) = \bar{B}$ where $\rho(\ell,(W,S),\bar{B}) = C$. Then the type ℓ entrepreneur's total expected return is the sum of return on Project 1, $(1-q_\ell)(R^h-b)$, and return on Project 2, $\bar{E}_1$. i.e. $E^*(\ell) = (1-q_\ell)(R^h-b) + \bar{E}_1$. Also, letting B_{XJ} be the investors response to message (X,J), we can compute $E(\ell,(X,J),B_{XJ}) = (1-\gamma_u)(R^h+R^\ell-B_{XJ}-b)$. The self-selection constraint for type ℓ

requires $E^*(\ell) > E(\ell,(X,J),B_{XJ})$. Some manipulation shows that the constraint is satisfied provided

$$B_{XJ} \geq \frac{C - (1-q_\ell)(R^h-R^\ell) - q_\ell p(b-R^\ell)}{1 - q_\ell(1-p)}.$$

However, Bertrand competition implies actuarily fair terms for type h entrepreneurs. i.e. $\rho(h,(X,J),B_{XJ}) = C$. Hence, $B_{XJ}=C$ since we assume $b+B_{XJ} < R^h+R^\ell$. Thus, if we define

$$B_{XJ} = max\{C, \frac{C - (1-q_\ell)(R^h-R^\ell) - q_\ell p(b-R^\ell)}{1 - q_\ell(1-p)}\},$$

then there exists some $\bar{p}$ such that $B_{XJ}=C$ and for all $p>\bar{p}$ the Bertrand equilibrium exists. Note also that for $p>\bar{p}$ the definition of B_{XJ} ensures type h will self-select (X,J) rather than (W,S).

Now consider the off-equilibrium strategies {(W,J),(X,S)}. For d_o = (X,S) the separation of projects implies that investors' best response is $\bar{B}$, which is independent of their beliefs, π. Thus, using efficiency arguments we can readily establish $E^*(s) > E(s,(X,S),\bar{B})$ for all s. For d_o = (W,J) we can show the proposed equilibrium passes the Intuitive Criterion for p sufficiently high. First, for p sufficiently high we have $B_{XJ} = C$ and, since waiting is inefficient for type h and feasibility requires $B(W,J,\pi) \geq C$, we also have $E^*(h) > \max_{\pi\in[0,1]} E(h,(W,J),B(W,J,\pi))$. Therefore, concentrating beliefs leads to $\pi = 0$. As in the proof to Proposition 4 the assumption $q_\ell+q_h>1$ implies $B(W,J,\pi)$ is decreasing in π (Note that $B(W,J,\pi)$ is identical to $B_W(\pi)$ of Proof 4) . Hence we need only show $E^*(\ell) > E(\ell,(W,J),B(W,J,0))$. Using the equation for $E(\ell,(W,J),B_W(0))$ from Proof 4 we find that the previous inequality requires $(1-\gamma_u)b > (1+(1-q_\ell)(1-p))R^\ell$. This is true in the limit as $p \to 1$ since the LHS becomes b, the RHS becomes R^ℓ, and $b \geq C > R^\ell$.

Finally, we need to check the non-pooling constraints. These require that we show for each of the four possible pooling equilibria there is at least one entrepreneur type which prefers the proposed separating equilibrium. This is trivial to prove since for p sufficiently large we have B_{XJ} = C and so a type h

entrepreneur receives the maximum feasible return. No pooling equilibrium could ever have debt less than C.

Uniqueness. We have shown that the pooling equilibrium will not exist for p and q_ℓ sufficiently high. It remains therefore to show that the separating equilibrium $d^*(h) = (X,J)$ and $d^*(\ell) = (W,J)$ does not exist. The proof is by contradiction. A necessary condition for the CJI separating equilibrium to exist is $E(\ell,(W,J),B^*(W,J)) > E(\ell,(W,S),\bar{B})$. But since the proposed equilibrium is fully revealing, we have $B^*(W,J) = B_2^\ell$ as defined in Section 2.2. But this is precisely the combination of debt levels that were used in Proposition 2 to prove the time-inconsistency problem. Hence, the proposed alternative separating equilibrium does not exist.

Q.E.D.

Lemma A1:

Let E_1^{PE} and E_1^{SE} be the entrepreneur's $t=1$ expected return conditional on the $t=2$ equilibria being pooling and separating, respectively. Using the analysis from earlier proofs we compute:

$$E_1^{PE} = (1+p - \gamma_u)R^h + (1-p)(1+pq_\ell)R^\ell - 2C$$

$$= E_1(F<R^h+R^\ell,CJI) - (1-p)\psi(p,q_\ell)$$

$$E_1^{SE} = 2(1 - \gamma_u)R^h + p\gamma_u R^\ell - 2C$$

$$= E_1(F<R^h+R^\ell,CJI) - (1-p)\lambda(p,q_\ell)$$

where $E_1(F<R^h+R^\ell,CJI)$ is defined in (8).

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CHAPTER FOUR:

FINANCIAL STRUCTURE AND THE ROLE OF COLLATERAL:

EVIDENCE FROM THE 3I SAMPLE

This paper has two main objectives. The first is to characterise the capital structure of high growth entrepreneurial companies. The second objective relates to the literature on collateral and risk. Some theoretical models predict a positive relation between collateral and risk, while others predict a negative relation. We undertake a range of econometric tests on this issue and find, contrary to other recent studies, that there is no significant association between collateral and risk.

The data analysed in this paper are from a group of companies who have been financed by a leading U.K. venture capital company, 3*i* PLC. Our balance sheet data are unique since previous studies of venture capital and project finance have relied on survey methods (e.g. Dixon [1989], Gorman and Sahlman [1988] and MacMillan *et. al.* [1989]). Also, these studies have focused on the venture capital process: investment appraisal, project selection, the extent of ex post involvement by venture capitalists, and portfolio performance. In contrast, our analysis focuses on the financial policies of companies. The main findings for the descriptive part of the paper can be summarised as follows:

(1) Both the initial capital structure at start-up and subsequent financing is dominated by debt claims, rather than equity.

(2) The venture capitalist holds a significant proportion of equity claims, though rarely obtains majority voting rights. The most important equity instrument for the venture capitalist is cumulative and participating Preferrred Ordinary shares. The venture capitalist also provides significant amounts of unsecured debt at start-up, but is a much less important source thereafter.

(3) On the basis that the entrepreneur and associated company are separate and distinct legal entities, we find that a significant proportion of the average company's debt claims are held by the entrepreneur. Typically, the entrepreneur's debt holdings are similar in magnitude to that of the venture capitalist. If it is true that the underlying source of these loans are bank loans secured on personal assets, then this implies that

collateral has an important role in project finance.

The paper is organised into 7 sections. The next section briefly discusses the nature of venture capitalism and highlights the differences between young entrepreneurial companies and more mature publicly listed companies. Section 2 describes the nature of our data. Section 3 analyses the capital and ownership structure of companies at start-up, while Section 4 takes an incremental approach to gross sources of finance and provides comparisons with UK publicly listed companies. Both Sections 3 and 4 find an important role for collateral in project finance, providing the basis for an analysis of the collateral-risk relation in Section 5. Finally, conclusions are presented in Section 7.

1. The Nature of Venture Capitalism

The practitioner oriented literature describes venture capitalism as the process by which investors seek capital gain by providing both equity capital and business expertise to young, unquoted firms. According to the British Venture Capital Association's (BVCA) *Report on Investment Activity* [1989b,App.2] this description includes: finance for seed capital and business start-ups requiring product development; initial marketing and commercial manufacturing and sales expenses; finance for growth and expansion of companies beginning to trade profitably; finance for the restructuring of poor performers; and finance for management buy-outs and buy-ins. In this section, however, the term venture capital refers to start-up and other early stage financing. We do not specifically discuss expansion financing, restructuring, or management buy-outs and buy-ins because we wish to bring into sharp focus the essential nature of venture capitalism.[1] The purpose of this section is to discuss a number of key characteristics of venture capitalism in general. In particular, we argue that intensive pre-contract screening overcomes any ex ante asymmetric information, so that a key characteristic of venture capital and project finance is *learning* as the project develops.

A key feature of all new investments is that their profitability is inherently uncertain. Sources of uncertainty include incomplete information about the price elasticity of demand for a new product, the development and production cost of the product, and the overall level of skill of the entrepreneur or management team. For the venture capitalist (VC), financing early-stage investments is more risky than other investments because these firms typically have very little collaterisable assets relative to the size of the proposed investment. Also, because their proposed investment project dominates the existing business, past performance may provide little guidance to future performance. More mature firms will have assets in place generating a positive cash flow which may be used to partially finance the start-up phase of new projects. Thus, the VC's return on an individual entrepreneur depends almost entirely on the success or failure of the new project. This is true irrespective of whether the financial contract is a debt or equity contract.

Given the level and types of risk encountered, the VC is likely to develop specialised methods of investment appraisal and some form of continuing involvement after the initial investment. Typically, the VC operates an intensive screening procedure involving industrial "sector experts" and financial experts. For R&D type projects the VC may also commission reports from scientists in the academic community (Lorenz [1985,p.70]). In addition to the project itself, the past experience and record of the entrepreneur or management team is also assessed. The high intensity of the screening process is illustrated by survey results reported that on average in the U.K. only 3.4 per cent of proposals to VC's obtained funds (Dixon [1989,p.13]). It would appear, therefore, that the VC will know almost as much, if not more, than the entrepreneur about prospects for success. On this basis, it seems reasonable to rule out any role for adverse selection generally, and signalling in particular, in the analysis of capital structure at start-up.

Screening, however, does not eliminate the underlying risk. Some uncertainties can only ever be resolved by undertaking and developing the project. Thus, it is in the nature of early–stage investments that much information about the viability of a project becomes available during the development and initial marketing phases. The degree of involvement of the VC is likely to reflect the most important sources of risk. At one end of the scale there is the 'hands–on' fund, which forms a regular working partnership with the entrepreneur and has representation on the board. At the other extreme is the 'hands–off' fund which is entirely passive following the initial investment. In between these extremes are 'reactive' and 'eyes–on' funds. These funds require financial statements at more regular intervals than do 'hands–off' funds. In addition, the 'reactive' VC may have board representation and will have the right to be consulted on key decisions, such as major capital expenditure, acquisitions and board appointments (Lorenz [1985,p.71–2]).

As described at the beginning of this section, there is a popular perception that, in addition to finance, VC's often contribute valuable business experience through a hands–on approach. However, a survey of the U.S. venture capital industry by Gorman and Sahlman [1988] finds that even for early–stage investments the average VC spends only around two hours per week in direct contact by phone or visiting the entrepreneur. Gorman and Sahlman conclude that this finding does not support the view that VC's are deeply involved on a day–to–day basis in their portfolio companies. Rather, a VC might be better described as a conglomerate company which undertakes a primarily monitoring role. It thus appears that the VC's business experience, though probably important for the initial screening and subsequent monitoring of projects, is not an important ingredient in the day–to–day operations of their portfolio companies.

The key feature of venture capitalism, therefore, is the flow of information generated during the early stages of development. Clearly, there are many forms this information can take, but a useful generic distinction can be made between information on the quality of management and information on product development and performance. In general, we would expect contracts between VC's and their portfolio companies to differ according to which of the two cases is most important for the learning process. If the possibility of ineffective senior management is thought to be more important, we would predict that the VC will wish to acquire specific control rights, such as the right to fire senior management. This is supported by the survey evidence[2] of Gorman and Sahlman and Tyebjee and Bruno [1984], and has been modelled theoretically by Chan, Siegel and Thakor [1990]. Chan *et. al.* develop a two-period model of moral hazard where both parties learn about the entrepreneur's level of management skill. Implicitly, the VC is closely involved in the project so that information is distributed symmetrically throughout the development phase. In this passive learning model the optimal equilibrium contract is for the VC to have a risky share of the firm. The contract also allows for the VC to buy-out the entrepreneur if the revealed level of entrepreneurial skill is below some critical value.

The case of delayed or unsuccessful product development is studied in chapter two of this thesis (Hansen [1991]). In this model the VC monitors the project but is not intimately involved with it. Consequently, the initial situation of symmetric information may become one of asymmetric information as the entrepreneur gains an informational advantage during development. The task for the VC is to limit investment losses by designing contracts which induce the entrepreneur to truthfully reveal bad news at the earliest possible date. Hansen [1991a] shows that the potential for truthful revelation can be enhanced by including convertible and redeemable preference shares in the capital structure. The use of these types of instruments is supported by survey evidence (Tyebjee and Bruno [1984]) and also by the evidence presented below.[3]

In conclusion, therefore, survey evidence of venture capital contracts generally support theoretical models where learning is important. Implicitly, these models assume the screening process is highly successful so that information is initially distributed symmetrically. In the following analysis we assume start-up projects are characterised by symmetric information.

2. The *3i* Sample

The results reported in this paper are based on a sample of firms receiving finance from *3i* PLC during 1979 to 1989. *3i*, formerly Investors in Industry, is an independent unquoted company owned by the Bank of England and the Clearing Banks. When originally incorporated, the primary role of Investors in Industry was to remedy a perceived market failure by providing long-term debt to finance investment capital for small firms.[4] Since 1979 *3i* has also provided equity capital and is now the largest member of the British Venture Capital Association (BVCA) with around £4 billion invested in 5000 companies (BVCA [1989a,p.62]). In 1989 *3i* invested £406 million,[5] accounting for 29 per cent by value of all investments reported by BVCA members (BVCA [1989b,p.13]).

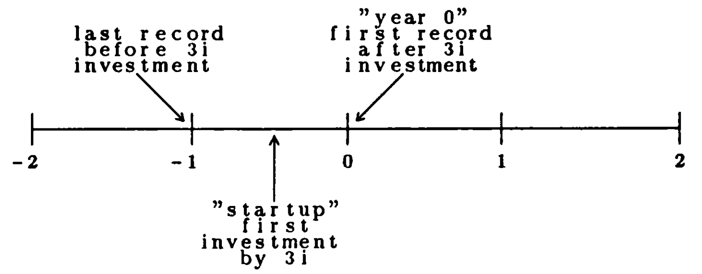
In terms of its degree of post-investment involvement *3i* can be classified as either a 'hands-off' or 'eyes-on' fund. In part, this continuation of the passive approach associated with *3i*'s earlier role of providing longt-term debt finance. But it also reflects the diversification of idiosyncratic risk obtained from *3i*'s large investment portfolio. This contrasts with many other venture capitalists, whose smaller portfolios make more attractive a strategy of close involvement in order to reduce non-systematic portfolio risk. In addition, the lower costs associated with their passive approach enables *3i* to apply slightly less restrictive screening criteria, in terms of both minimum investment size and upside potential, than would be the case for many venture capitalists. For example, in 1989 the average value per investment by *3i* was approximately £500 000, which is one third less than the £750 000 average for all BVCA members (BVCA [1989b,p.13]).

The original sample obtained from *3i* included investments ranging from start-up capital through to management buy-outs and buy-ins in all sectors of the economy and in many countries (particularly the U.K., E.E.C., and U.S.A.). However, for the purposes of this paper we deleted all companies whose accounts were reported in currencies other than the pound sterling. Management buy-outs and buy-ins (approximately 800 companies) were also eliminated from the data set. But it was not possible to further classify between seed, start-up and expansion financing. Also eliminated were companies that changed their balance date, or had subsidiaries which could not be separately identified. Finally, due to the late 1970s shift in operating policy towards venture capital activity, the sample includes only those companies who received their first tranche of funds during 1979–1989. As a result of the above adjustments we obtained an unbalanced panel of 9244 records on 1476 companies.

The data are annual balance sheet records plus some additional information such as industry code and the date of the first investment by *3i*. Figure 2.1 illustrates the convention we have followed. In general, the date of initial investment by *3i*, referred to as the 'start-up' date, does not correspond to the first balance date. For this reason the first observation following start-up, being less than 12 months for most companies, is referred to as the end of year 0. It is used as a proxy for the position of the company at start-up (after *3i* investment). For about one half of the companies year 0 is also the first record in the data. However, for some companies the data also includes one or more balance dates prior to the first *3i* investment. These dates are referred to as years –1, –2, and so on.

Background summary statistics are reported in Tables 2.1–2.4. Tables 2.1 and 2.2 report the number of start-ups for each year during 1979–89 and industry classifications, respectively. Table 2.3 reports the number of observations

Figure 2.1



available on companies by length of relationship (in years). Because of on-going investments at the end of the sample it is not possible to compute the average years to maturity of the investments. However, Table 2.3 does show that 25 per cent of investments were terminated by the end of the second full year and that only 50 per cent of the investments were on-going at the end of year 5. The data do not provide information on the reason for a company's exit. But given a reported investment horizon of around 7 years for the U.K. venture capital industry (Dixon [1989,p.14]) it is reasonable to suppose that most terminations during the first 2-3 years represent investment failures. Finally, Table 2.4 reports that the sample of start-ups has an average turnover of 7.7 million pounds (1985 prices) and an average book-value of fixed assets of 3.2 million pounds. However, the size distribution for turnover is weighted to the low end with nearly 80 per cent of start-ups having turnover of 4 million pounds or less. The annual average growth rate and standard deviation in real sales is 11.8 per cent and 46.6 per cent, respectively.

As a matter of notation, it is important to distinguish the entrepreneur from his or her company, which is a separate legal entity. For example, we will later refer to the entrepreneur's loans to the company in the same manner in which we refer to *3i*'s debt claims on the company. In addition, many start-ups are undertaken by a team of two, three or four entrepreneurs and so references to "the entrepreneur" should also be read as referring to "the entrepreneurial team".

3. Capital and Ownership Structure at Start-up

In this section we characterise capital structure features of companies based on their book values at start-up (i.e. year 0). The analysis begins with a broad overview in terms of debt and equity and then proceeds with a more in-depth analysis of debt claims and of hybrid equity instruments. This is then followed by a summary of the main features and a discussion of capital structure theories.

3.1. Debt versus Equity: An Overview

Table 3.1 presents a breakdown of financial structure in terms of equity and fixed commitments. Fixed commitments are defined as short- and long-term debt and fixed-dividend shares. Equity includes all other instruments (see below), but excludes retained earnings. The table shows that on average equity accounts for about 18 per cent of total claims. However, the standard deviation of 23 per cent implies substantial variation across companies. In terms of ownership, *3i* held an equity stake in one-half of all firms in the sample. For this half the *3i* holding amounts to an average of 21 per cent of total issued equity, though in 14 per cent of companies *3i* held majority voting rights. Profits participation rights for *3i* were included in nearly all deals involving equity participation by *3i*. In addition to equity claims, *3i* held fixed-commitment claims in nearly 9 out of every 10 companies, accounting for a conditional average of 30 per cent of such claims outstanding.

The broad picture, therefore, is that in book value terms most companies are operating with gearing (debt/total claims ratio) of between 60–100 per cent. *3i* holds a significant proportion of both debt and equity claims, though rarely more than 50 per cent. The above analysis also finds that *3i* held equity claims in approximately one half of the sample. To assess the extent of difference between companies with and without *3i* equity claims, Table 3.2 provides a number of summary statistics, including average fixed assets and sales at start-up and the rate of growth of sales. The table shows that on average companies receiving equity finance were smaller at start-up, particularly in terms of fixed assets, but experienced higher rates of growth. Figure 3.1 shows that the higher growth in real sales for companies receiving equity participation by *3i* is concentrated in the first one or two years. Thereafter, the average rate of growth more or less converges, with both groups experiencing a marked fall off in growth rates during years 4 to 6.

Assessing differences in riskiness across the two groups of companies is complicated by the disappearance of companies from the data set. A complete analysis would require specification of distribution functions with mass points representing companies which have disappeared from the sample. We neglect these issues, however, and instead compute just two crude measures of risk. The first measure involves a comparison of the rate at which companies disappear from the sample. Table 3.2 shows that the proportion of the sample accounted for by the *3i* equity group falls only slightly from 49.1 per cent at start–up to 47.9 per cent in year 5. Thus, risk of a total investment failure leading to liquidation of the company appears similar across both groups. The second measure of risk is the standard deviation of real sales growth, which is reported in Figure 3.2. by age of investment. Apart from year 1, standard deviations for the two groups have similar profiles, with the group receiving 3i equity contributions having slightly lower standard deviation in most years. In summary, therefore, the data does not suggest that companies receiving equity finance are riskier than those receiving only debt finance. More significant distinguishing characteristics are the lower stock of fixed assets at start–up and the higher rates of sales growth during years 1 and 2.

In the next two subsections we go beyond the above generic analysis to consider in more detail the types of securities on issue. We begin with debt in Section 3.2, followed by hybrid equity instruments in Section 3.3. The key characteristics we identify are then related to theories of capital structure in Section 3.4.

3.2. Debt

Table 3.3 provides a disaggregated view of financial structure at start–up. The table shows that debt accounts for 80 per cent of total claims and that, as with the broader class of fixed commitments, *3i* is a major provider of debt finance. Conversations with *3i* reveal that these loans are typically unsecured and have maturities of several years (though these characteristics cannot be identified from the data).

In addition to *3i*'s contribution, we are able to identify the entrepreneur's claims on the company. Table 3.3 reveals that in 9 out of every ten cases the entrepreneur holds debt claims against his or her own company. Moreover, on average these loans by the entrepreneur (40% of debt) are typically larger than loans by *3i* (30% of debt). Discussions with *3i* suggest that much of the entrepreneur's contribution of debt is obtained by mortgaging personal property. Apart from issues of debt claims to the entrepreneur and *3i*, other sources for loans are available through hire purchase and mortgage over the company's assets. Table 3.3 shows that only around half of firms obtained funds in this manner and that even in these cases such claims amounted to only around 15 per cent of total debt claims. Thus, as described in Section 1, a feature of project finance for entrepreneurial firms is the relatively low stock of company assets available as collateral. In Section 5 we analyse further the role of both 'inside' and 'outside' collateral and its relation to investment risk.

An important aspect of the above discussion is that it is based on a sample comprising a very wide range of industry groups. It is of interest, therefore, to assess robustness across industry groups. Table 3.4 reports three statistics for each of the nineteen industry groups. The first column of the table shows that the proportion of total claims accounted for by debt is virtually constant across industry groups. This confirms the dominance of debt found in the more aggregated sample. It is an interesting result because it means that very little of the 22 per cent standard deviation recorded in the whole sample (see Table 3.3) is due to industry characteristics, such as capital intensity and market structure. The second comparison across industries measures the degree of asset backing for total debt outstanding. Since the book value of fixed assets is likely to be an upper bound on the market value of assets, the debt/asset ratio of Table 3.4 is intended to serve as a lower bound on the degree of asset backing. Two debt/asset ratios are reported. The first is the ratio of total debt to assets (column 2). This shows that for half of the industry groups the face value of debt is more than twice the book value of fixed assets. However, a problem with this ratio is that it does not take account of asset-backing provided by the entrepreneur's personal assets. Also, if we are interested in the exposure of debt holders without controlling interest then a more accurate picture of asset-backing is provided in column 3, which is the ratio of net debt to assets (where net debt is total debt minus loans from the entrepreneur). Nevertheless, even with this adjusted measure, the degree of asset-backing for loans varies from industry to industry, with around one half of the industries having ratios in excess of 100 per cent.

3.3. Hybrid Equity Claims

In Table 3.1 we found that equity claims accounted for a conditional average of around 20 per cent of total claims. Included in this class are fixed-dividend Preference and Preferred shares, Preference shares, cumulative and participating Preferred Ordinary shares, Ordinary shares and deferred Ordinary shares.[6] Table 3.3 provides a break down of the relative importance of these instruments. Of the 20 per cent of total claims accounted for by non-debt claims, three quarters are Ordinary shares. The next most important equity claim is the fixed-dividend share, which was previously included in the term 'Fixed Commitments' due to the close similarity of fixed-dividend requirements with interest payments on debt.

Turning to ownership of claims, the claim most frequently held by *3i* is the cumulative and participating Preferred Ordinary (CPPO) share, which forms part of the *3i*'s portfolio in 40 per cent of companies. Holdings of CPPO shares account for more of *3i*'s claims than the combined holdings of fixed-dividend, Preference, Ordinary, and deferred Ordinary shares. Although Ordinary shares account on average for 14 per cent of claims by book value, in only 10 per cent of cases are any of these shares held by the *3i*; most Ordinary shares are owned by the entrepreneur.

Finally, as in the previous subsection, we note that the above statistics are based on a sample comprising a wide range of industries. To assess the robustness of the above statistics we present Table 3.5, which is a reconstruction of the capital structure break down as in Table 3.3 but with the sample restricted to the manufacturing sector (industry groups 2–12 in Table 2.2). By comparing Tables 3.3 and 3.5 it is clear that there are no significant differences between the full and restricted samples. The previously noted importance of Ordinary shares in total claims and 3*i*'s holdings of CPPO claims are reaffirmed.

3.3. Discussion

The above analysis has revealed a number of interesting statistics about project finance which may be interpreted in terms of theories of optimal capital structure. However, before beginning the discussion, it is important to recall the usual limitation that applies to any analysis of stocks. This is that due to costs of adjustment the capital structure observed at any point in time will to some extent reflect disequilibrium dynamics, rather than the desired equilibrium structure.[7] Clearly, the significance of disequilibrium dynamics depends on the magnitude of adjustment costs. On the basis of the previously noted close relationship between 3*i* and their portfolio companies, it is likely that adjustment costs are relatively low compared for companies which raise finance on public securities markets. We therefore proceed with our discussion on the basis that observed capital structure at start-up is a close approximation to equilibrium capital structure.

In terms of book value, we have seen that 3*i* companies are often highly geared, though on average around 40 per cent of debt claims are held by the entrepreneur. The fact that a large proportion of the entrepreneur's claims are held in the form of debt claims, rather than all as Ordinary shares, is partially consistent with the taxation theories of capital structure (see Miller [1977] and De Angelo and Masulis [1980]). These theories determine the firm's optimal debt/equity ratio by trading-off the value of interest tax deductibles against expected bankruptcy costs of debt. In the case of the entrepreneur's own holdings of debt claims, marginal expected bankruptcy costs are zero since the entrepreneur can always forgive debt repayments if the company under performs relative to expectations. Thus, to maximise company value from interest tax deductibles the entrepreneur's claims should be virtually all debt. Clearly, the data does not quite support this extreme conclusion. To explain the nature of the entrepreneur's claims, therefore, it is necessary to complement the taxation-bankruptcy theory with some other theory. One possibility is that at the margin a larger entrepreneurial holding of debt claims reduces the entrepreneur's share of equity (assuming *3i* holds an equity claim). Agency costs arising from dilution of the entrepreneur's equity share, in the form of excessive perquisite consumption and suboptimal effort on the part of the entrepreneur-manager, would reduce firm value (Jensen and Meckling [1976]). These factors would, therefore, tend to reduce the optimal debt-equity ratio.

In addition to the entrepreneur's personal debt/equity ratio, we have found a high overall level of debt relative to asset backing. In part, some of the arguments above can also be applied here. For example, since debt claims are not widely dispersed the costs of renegotiation if a firm under performs are relatively low. Hence, in comparison to firms with widely dispersed debt holdings, expected bankruptcy costs are lower and the equilibrium debt/equity ratio will be higher. Furthermore, to the extent that *3i* holds a share of the equity there will be additional incentives for debt renegotiation, which further reinforces the argument for high debt/equity ratios. However, there are two cost associated with debt claims held by outside investors which did not apply in the case of the entrepreneur's holdings of debt.[8] First, there is an agency cost associated with debt due to risk-shifting incentives (Jensen and Meckling [1976]). These incentives arise because the debt repayment function is a concave function of profits, which results in the entrepreneur's payoff being a convex function of profits. As a consequence, the entrepreneur has an incentive to undertake a high risk R&D and marketing strategy.

A second incentive problem with debt, which is particularly appropriate to the high growth, entrepreneurial companies of the *3i* sample, is identified in Myers [1977]. This is the problem of a firm with debt outstanding when an option to invest reaches its exercise date. Since the debt holders have prior claim over the proceeds from the investment option, it may be privately optimal for the entrepreneur to allow the investment to pass unexercised. Myers [1977] claims that this may account for the observed regularity of debt being limited to the book value of assets. However, in Section 3.2 we found that average debt to assets ratios (excluding the entrepreneur) exceeded 150 per cent for many industries. Moreover, an implication of Myers' analysis is that short maturity debt is better than long maturity debt because the repayment of debt then occurs before the exercise/investment decision is made.[9] In contrast, for the *3i* sample the majority of debt is known to be long term (i.e. 3, 4 or 5 years to maturity). Clearly, if profits in the first years of operation following start-up are expected to be low or negative then the major portion of debt cannot feasibly be repaid during the early years. Hence, most short-term debt would be short-term in name only. Another crucial assumption in the Myers model is that debt contracts cannot be renegotiated in the event of a low state realisation. This assumption is clearly not very appropriate for the *3i* sample.

Finally, another feature of the above characterisation of capital structure is that the claims of the main outside investor, *3i*, rarely involve Ordinary shares. Instead, fixed-dividend shares and CPPO shares are most important. Two key characteristics of these shares are the combination of debt-like fixed coupon payments and the equity-like inability to force a transfer of control in the event of non-payment. Thus, in contrast to Aghion and Bolton [1988] and Chan, Siegel and Thakor [1990], a transfer of control will not be socially beneficial if project value is specific to the entrepreneur. If *3i*, being a passive venture capitalist, does not possess the high level of managerial skill required to operate projects and if the market value of an incompletely successful project is very low, then allowing the entrepreneur to continue the project in the event of non-payment will be optimal.[10]

4. Incremental Sources of Finance

A major shortcoming of the previous section is the reliance on book values for measures of debt and equity claims. In most economic contexts it is the market value and underlying cash flows which are important. The aim of this section, therefore, is to attempt a partial remedy by analysing companies' principle sources of investment finance during the years subsequent to start–up. Another feature of the present section is that we are able to compare the incremental financing characteristics of our sample with similar statistics for U.K. publicly listed companies.

Although the incremental approach of this section eliminates many problems associated with interpreting book values, there do arise other problems. These are discussed in the next subsection. Then, following the format of Section 3, we proceed to describe a range of statistics in Subsections 4.2 – 4.4, and end the section with a discussion in Subsection 4.5.

4.1. Data Limitations and Methodology

It is important to note that the following analysis suffers from a number of data limitations. First, the analysis below should ideally be conducted on a 'flow of funds' basis. However, such data are not available for the *3i* sample, so flow of funds are proxied by changes in balance sheet totals. In the case of debt, the potential bias will be limited to the extent that the face value of debt reflects the loan principal, as in conventional bank loans. This will be the case if the risk premium is computed into interim interest payments rather than into the face value of debt.

In the case of new equity issues the total cash injection has been estimated on the basis of *3i*'s purchase cost. This is necessary because balance sheet records show only the par value of total shares on issue. However, we do have information on both the cash cost and par value of shares purchased by *3i*. The total cash injection from new share issues is estimated on the assumption that all purchasers pay the same price per share. Thus, letting C_{3i} and P_{3i} be the cash cost and par value of shares issued to *3i* in a given year, the estimated total cash raised, C_T, from issuing an amount P_T in that year is:

$$C_T = (\frac{C_{3i}}{P_{3i}})P_T.$$

Two types of bias may arise from this procedure. First, there are observations where *3i* do not participate in the share issue. In these cases we attempted to limit the extent of bias by eliminating all observations for that firm (approximately 10 per cent of sample). Nevertheless, there is likely to be some downward bias in the share of equity issues as a source of finance. A second, but positive, bias may result from differential prices paid for shares. In particular, entrepreneur's with particular abilities or knowledge at the time of start–up are likely to have been allocated shares at a large discount relative to other purchasers. Our estimates do not account for this possibility.

Finally, it should be noted that the sources of finance reported here are based on gross magnitudes. No account has been taken of changes in corresponding financial assets such as bank current and deposit accounts. Conceptually, since the objective is to measure how investment is being financed, the net approach is the appropriate measure. However, with the net approach there arises the problem of how to treat items such as changes in minority interests, short–term and other provisions, and the change in intangibles, which neither relate to financial flows nor to real investments. One approach is to adjust retentions for these variables, as in Mayer and Alexander [1990]. However, while adjusting retentions may be adequate for a set of large, established companies, it would be much less so for the *3i* sample. For example, the inclusion of intangibles in retentions may lead to a much greater downward bias in retentions due to large R&D programmes during the first few years of operations. For all these reasons our financing ratios are computed on a gross basis.

4.2. Internal versus External Funds

We begin our description of incremental financing with a comparison of investment ratios and internal and external sources of funds between the *3i* sample and U.K. quoted companies. The ***investment ratio*** reported in Table 4.1 is defined as the ratio of physical investment (including stocks of raw materials and work-in-progress) to zero-distribution profits, where the latter is defined in Appendix C. Table 4.1 also reports the average dividend, distribution and external financing ratios. The ***dividend pay-out ratio*** is defined as the gross (cash) dividend as a percentage of zero-distribution profits. However, due to the dividend imputation system of taxation in the U.K. (see Appendix C) the retentions foregone by a dividend may be less than the gross payment. Adjusting for these factors, the ***distribution ratio*** is a measure of retentions forgone as a percentage of zero-distribution profits. Given dividend behaviour, the ***external financing ratio*** measures the amount of external finance required, again as a percentage of zero-distribution profits. This ratio is computed as the sum of the investment and distribution ratios minus one.

The investment ratio shows that on average the increment to physical capital by *3i*-backed companies is more than two and a half times current profit. This compares with an average for the U.K. quoted sector reported by Mayer and Alexander [1990] of around eight tenths of current profit. As would be expected, therefore, *3i* companies are high growth firms relative to the average and, consequently, require high levels of external financing. In contrast, the external financing ratio for the quoted sector indicates that the average publicly listed firm finances both investment and dividend distributions from profit retentions.

The distribution ratio in Table 4.1 shows that retentions foregone by *3i*-backed companies amount to around 20 per cent of profits. This ratio is similar to that of the quoted sector, despite the very large disparity in their investment requirements. Moreover, column (3) of Table 4.1 reports a similar distribution ratio for the case where the *3i* sample is restricted to years 0 and

1 after start-up.[11] A similar picture also holds for quoted/*3i* comparisons of small electrical engineering companies.[12]

Overall, therefore, we find that even high growth companies have dividend pay-outs which are on average significantly different from zero. The resulting contribution of retentions as a proportion of total gross sources of finance is reported in Table 4.2. For the full *3i* sample, retentions account for one third of total gross finance, while for years 0 and 1 the average contribution is -10 per cent.

4.3. External Finance: Debt versus Equity

Table 4.2 also reports the relative importance of new equity issues and new debt as sources of finance. In contrast to quoted companies, where new equity issues dominate all other sources of external finance, debt issues are dominant for *3i*-backed companies. On a gross basis, debt accounts for 42 per cent of all sources for *3i* companies, compared for 9 per cent for quoted companies.[13] A similar comparison can be made for the electrical engineering sector, which forms part B of Table 4.2. The dominance of debt (78 per cent) is further illustrated by column (3), which reports financing proportions for *3i* companies during the first two years when profits are generally low or negative. In these first years debt accounts for 78 per cent of gross sources while trade credit accounts for a further 25 per cent. Finally, Figure 4.1 shows how the proportions financed by retentions and debt vary with age (number of years after start-up).

4.4. Ownership of Debt Issues

The previous subsection has demonstrated the dominance of debt as a source of external finance during the rapid growth phase of *3i* companies. In this brief section, therefore, we report the ownership claims on new debt issues. Four classifications have been constructed from the data: loans by the entrepreneur; loans by *3i*; other loans secured; and, other loans unspecified. Secured loans include mortgages and hire purchase loans. Figure 4.2 reports, by age of *3i* relationship, the first three classifications as proportions of total new debt. The figure reaffirms the conclusions of Section 3 that the entrepreneur is a major provider of debt finance. It also illustrates that the entrepreneur is the dominant source of debt finance over the longer term. After the initial start-up phase, *3i* becomes less important as a source of finance, providing around 10–15 per cent of total new debt. The average contribution of the entrepreneur, on the other hand, falls to around 10 per cent during years 1–3 but then increases to in excess of 30 per cent. The data do not provide any indication of how entrepreneurs are able to play such a major role in the provision of expansion finance for their companies. It is likely, however, that part of the explanation derives from rapidly increasing asset prices during the 1980s, such as house prices, which has allowed increased borrowing on personal wealth. Hence, collateral appears to play an important role in project finance. In Section 7 we explore further the role of collateral in terms of its interaction with project risk.

4.5. Discussion

The above analysis has revealed several interesting statistics. One of the most interesting is that the distribution ratios of *3i*–backed companies are clearly significantly greater than zero, despite high investment ratios. In competitive capital and credit markets the role of internal versus external sources of finance is indeterminate provided there are no taxes (Modigliani and Miller [1958, 1961]). However, this indeterminateness breaks down in the presence of taxes. With taxes debt and new equity issues are each preferred to retentions if:

$$1-m > (1-t)(1-z) \qquad \text{(debt)}$$

and

$$1-m > (1-z)(1-c), \qquad \text{(equity)}$$

where m is the marginal personal tax rate on interest income, z is the tax rate on capital gains, t is the corporate tax rate and c is the rate of imputation for

Advance Corporation Tax (King [1977]). In the case of individual investors, such as the entrepreneur, the above two inequalities may or may not be satisfied. Following Keen and Schiantarelli [1988] we can identify three factors which favour retentions over new issues to entrepreneurs. First, small companies may qualify for a lower corporate tax rate (t). Second, the effective rate of imputation (c) is reduced if profits are likely to remain negative for some years so that imputations cannot be offset against mainstream corporation tax. Third, there is a high allowance for capital gains which results in $z=0$ for investors earning less than about 6000 pounds annually. These factors suggest that entrepreneurs should prefer to re-invest profits rather than issue new claims to themselves.

On the other hand, the above inequalities will always be satisfied for institutional investors, such as *3i*, since $m = z = 0$. Thus, on the basis of taxation advantages, issuing new debt or new equity to *3i* and banks would be preferred to retentions. We observe, however, that most new claims are issued to the entrepreneur.

5. Collateral and Risk

The nature of venture capitalism was described in Section 1 as involving the financing of entrepreneurs with low collateral value relative to their proposed risky investment. However, the analysis of Sections 3 and 4 show that significant amounts of collateral are often supplied by entrepreneurs. More generally, there are a number of interesting issues concerning the role of collateral. In particular, many, but not all, theoretical models predict that safer borrowers are more likely to pledge collateral. On the other hand, recent empirical evidence supports conventional banking wisdom that high-risk borrowers tend to pledge more collateral (Berger and Udell [1990] and Leeth and Scott [1989]). It seems appropriate, therefore, that this paper provide an introductory empirical analysis of the relation between collateral and risk.

There are two key features of the tests in this paper which other papers (see below) have omitted. The first is the distinction between inside and outside collateral. The second is the use of company-by-company data for ex post measures of risk. In the next subsection we briefly review the main theories for the role of collateral. This is followed by a description of regression variables and a discussion of the results. Our principle finding for this section is that neither inside nor outside collateral provide significant explanatory power for risk.

5.1. Distinguishing between Inside and Outside Collateral

The empirical predictions of the theoretical literature differ according to whether collateral is 'inside' or 'outside' and on the information structure. 'Outside collateral' refers to the case where the entrepreneur pledges personal assets not owned by the firm, while the pledging of 'inside collateral' occurs when company-owned assets are used as security for a lender. The largest part of the literature analyses the optimality of outside collateral when the borrower has private information about risk. In Bester [1985] and Chan and Kanatas [1985] collateral acts as an incentive or sorting device because the expected loss from posting outside collateral is higher for high-risk projects. Similarly, Besanko and Thakor [1987] show that collateral may mitigate credit-rationing problems in an equilibrium where low-risk borrowers pledge more collateral than high-risk borrowers. However, the negative association between outside collateral and risk predicted by these screening models can be reversed when borrower wealth, in addition to risk, is private information of the borrower (Stiglitz and Weiss [1986]).

Other types of information structures also predict a positive relation between collateral and risk. In Boot, Thakor and Udell [1988] the quality of the project is observable by all parties but lenders cannot observe the borrower's actions. This moral hazard problem leads, under certain conditions, to a positive association between outside collateral and risk. Another form of informational asymmetry leading to a positive association is that of costly state verification.

In Bester [1990] outside collateral acts as a bonding device to ensure truthful reporting of the state outcome by the entrepreneur: failure to meet a debt repayment allows the lender to invoke bankruptcy and appropriate the collateral. However, when asset liquidation is costly, the lender may prefer to renegotiate the loan rather than force bankruptcy. Thus, in the absence of precommitment to bankruptcy by the lender, the borrower will have an incentive to under report the true state. Posting outside collateral weakens this under-reporting incentive while simultaneously increasing the probability of debt forgiveness (a Pareto-improvement). Bester shows that offering collateral is especially advantageous for high risk firms.

Issues relating to inside collateral have been considered by Smith and Warner [1979], Stulz and Johnson [1985] and Swary and Udell [1988]. Although, Smith and Warner and Stulz and Johnson are able to show that inside collateral can weaken adverse incentive problems, such as asset-substitution and under-investment, they do not demonstrate a clear relation between collateral and risk. Swary and Udell, on the other hand, do demonstrate a positive collateral-risk relationship. They develop a model where secured debt enforces optimal firm closure and where the closure problem is positively related with firm risk.

5.2. Previous Empirical Studies

Analysing the relation between collateral and risk requires knowledge of collateral arrangements and some consistent measure of either the ex ante risk of each loan or the realised outcome (e.g. bankruptcy). Due to the limited number of data sets containing such information there have been only a few empirical studies in this area. In earlier years in particular, empirical studies relied upon official bank examination reports or book accounting ratios as proxies for risk (Orgler [1970] and Hester [1979]). Similarly, in a recent study of survey data, Leeth and Scott [1989] found a positive collateral-risk relation by using the number of years the firm has been in business as a proxy for risk of default.

This approach relies on studies of small business failure which show that survival probability and age are positively correlated.

Finally, Berger and Udell [1990] undertake both ex ante and ex post tests using a very large, high quality data set. Their ex ante test is to regress loan risk premia on collateral and various control variables. For their ex post test they replace loan risk premia with an examination of realised loan performance in terms of net charge-offs (bad loans), overdue repayments and renegotiation status. These latter dependent variables are computed as ratios to total loans on a bank-by-bank basis, rather than on a company-by-company basis. In both the ex ante and ex post tests, Berger and Udell are able to report a statistically significant (at 1 per cent level) positive relation for most equations. However, in view of the theoretical distinction between inside and outside collateral, an important limitation of the Berger and Udell tests is that they do not identify the source of the collateral in terms of being 'inside' or 'outside'. In addition, their ex post test may have low power due to the pooling of data. In contrast, the ex post tests below do distinguish between inside and outside collateral and, moreover, are carried out directly on company data.

5.3. Construction of Regression Variables

In this section we describe the construction of endogenous and exogenous regression variables. The exogenous variables are constructed from observed variables for year 0 -- the year of start-up. The endogenous variable, 'investment failure', is measured ex post by an indicator variable for company survival. Thus, for each of the regressions there is one observation per company. Details of variable construction are as follows:

(a) Investment Failure: For our purposes, risk of investment failure is measured on an ex post basis by whether the company liquidates within a certain number of years from start-up. However, although we can observe the number of years after which a company is absent from the data set, we do not know the reason for its absence. Nevertheless, we proxy for failure by constructing two indicator variables for whether the firm disappears from the database after two or after three years,[14] denoted FAIL2 and FAIL3 respectively (see Table 5.1). These indicator variables are likely to be good proxies for investment failure since, as noted in Section 1, most venture capital investments are intended to last between 5–7 years. Thus, a disappearance from the data set within the first few years of start–up is very likely to be due to failure of the company.

(b) Outside Collateral: Outside collateral refers to the extent to which finance provided to the company is secured on the entrepreneur's personal wealth. We use the entrepreneur's debt claims as proxies for outside collateral on the basis that the entrepreneur raised this finance with loans secured against personal property, such as a house mortgage. This variable, which is listed in Table 5.1 as OC, is the entrepreneur's loan capital as a per cent of total debt plus leasehold costs.

(c) Inside Collateral: The key feature of collateral is that in the event of failure the collaterised assets become the property of the lender. It is clear, therefore, that although the literature on inside collateral focuses on secured debt as the classical form of asset–backed financial contract, the results carry over to other financial contracts with similar ownership provisions. For this reason, our proxies for inside collateral include not only mortgages (denoted IC_MORT) but also hire purchase (IC_HP) and leasing (IC_LH). Each is computed as a per cent of total debt plus leasehold costs.

(d) 3i Equity Claims: A universal assumption in the theoretical literature on collateral is that debt holders have no other interests in the company. Clearly, this assumption is violated for many of the companies in the *3i* sample. And although it is beyond the scope of this paper to model theoretically the interactions between collateral and equity claims of various types, it is clear that the probability of failure in terms of observations on FAIL2 and FAIL3 should be negatively related to the extent of *3i*'s equity claims. This is due to the convex pay–off structure of equity claims, which would encourage *3i* to roll–over debt rather than force bankruptcy. Hence, included in the regression are variables 3i_PREF, 3i_CPPO, 3i_ORD and 3i_DEF, which measure the proportion of total equity claims accounted for by *3i*'s holdings of Preference shares, CPPO shares, Ordinary shares and deferred Ordinary shares.

(e) Dummy variables: Three dummy variables were constructed. First, since the collateral value of an asset depends on it's resale value, the availability of collateral is likely to be at least partially dependent on the state of the economy. To account for this effect we include a dummy variable for all but one year of the relevant sample (usually YR79, ...,YR85). The second set of dummy variables refer to the company's trading history prior to *3i* investment. ENTRY1, ENTRY2 and ENTRY3, which are indicator variables taking the value one if there are 1, 2, or 3 or more years of data prior to *3i* investment, are intended as proxy variables for underlying risk in terms of early- and late-stage investment. Finally, we control for the fact that some industries employ mainly tangible assets while others comprise mainly intangible assets with industry dummy variables, IND1, ..., IND19.

The sample statistics for each of the regression variables described above are reported in Table 5.1.

5.4. The Results

Three sets of regressions for FAIL2 and FAIL3 were computed. The first set uses the full sample of 1191 observations. The second set of regressions, totalling 694 observations, excludes all companies where *3i* holds equity claims. Apart from the elimination of potential confounding effects due to equity claims, the "debt-only" sample provides a more direct comparison with Berger and Udell's [1990] results for bank loans. Finally, there is the possibility that industry group effects are not well captured by including industry dummies IND1, ..., IND19 in linear form in regressions. For example, interaction terms between industry dummies and collateral and/or year dummies may be appropriate. However, given the large number of industry groups, the testing of all possible interactions would lead to a very large set of exogenous variables. Instead, therefore, we account for industry effects by computing separate regressions for the four largest groups, each of which have in excess of 100 observations.

In the following discussion a negative sign on a coefficient indicates a positive impact on default probability. Beginning with the full sample regressions for FAIL2, Table 5.2 reports negative coefficients for all collateral measures except hire purchase. However, the t–ratios, which are uniformly less than or equal to one, are particularly low for hire purchase (ranging between 0.03 to 0.17). Comparing these results with regressions for FAIL3 (Table 5.3), we find that the sign of the coefficient for outside collateral (OC) changes from negative to positive, though this change coincides with a marked fall in the t–ratio to 0.07. In contrast, measures of inside collateral maintain their sign and generally have improved t–ratios. This is especially true for leaseholds (IC_LH) which have negative coefficients and t–ratios above 2.

The overall low level of t–ratios is reflected in low overall performance of both FAIL2 and FAIL3 regressions. The likelihood ratio for joint significance of the four collateral variables is 1.4 and 7.4 for FAIL2 and FAIL3 regressions, respectively. With a Chi–square statistic of 7.8 the collateral variables are not jointly significant at the 10 per cent level. This result is supported by the 'within sample' prediction statistics, which show that the FAIL2 and FAIL3 equations make correct predictions in 79 per cent and 70 per cent of cases, respectively. These are extremely poor results since the sample means for FAIL2 and FAIL3 (see Table 5.1) indicate that a passive policy of predicting success for every firm would obtain the same percentage of correct predictions.

Results for the "debt–only" sample are reported in Table 5.4, where, again, the t–ratios are generally very low. Nevertheless, both outside collateral and hire purchase have positive signs for both FAIL2 and FAIL3, which provides some very weak evidence of collateral being associated with lower risks. This contrasts with the relatively strong positive association between collateral and risk reported by Berger and Udell [1990].

Finally, we consider regressions for the four industry groups with the largest number of observations. These are: Mechanical Engineering (group 5); Electrical and Instrument Engineering (group 6); Distribution, Hotels and Catering (group 14); and Business Services and Rentals (group 18). Sample statistics for these groups are reported in Table 5.5. Due to the smaller number of observations for each subsample some of the exogenous variables have been omitted from the industry regressions. This applies particularly to mortgages (IC_MORT) and leaseholds (IC_LH), but also some variables for *3i* equity claims and the year dummies.

The results of the industry regressions are similar to those for the more aggregated samples. For outside collateral the coefficient is negative for 6 of the eight regressions (see Tables 5.6 and 5.7), with t–ratios ranging from –0.16 to –1.45. On the other hand, the coefficient for hire purchase is again positive in the majority of regressions for which it is reported, with the highest t–ratio being 2.12. Thus, there is perhaps some very weak evidence of an overall positive association between collateral and risk. However, given the generally low t–ratios and low predictive power of the probit model, strong conclusions are obviously inappropriate.

There are a number of potential measurement errors which may be contributing to the poor performance of the regressions. First, the theory of collateral with asymmetric information (where collateral acts as a screening device) assumes that entrepreneur's own sufficient assets to meet collateral requirements. But if the amount of collateral offered by entrepreneur's is constrained by their limited holdings of assets, then the predictions break down. This may well be an important factor in this data set since a characteristic of venture capitalism is that new investments are large relative to existing operations. Alternatively, a measurement error in outside collateral may arise from tax considerations. For the purposes of the above regressions we have assumed that the entrepreneur's total debt claims represent bank loans secured on personal property. However, given the tax advantage of debt over equity (see Section 3.3), it may be the case that a significant proportion of the entrepreneur's debt is unrelated to personal assets. The claims may be debt claims, rather than equity, simply because of interest deductibility advantages of debt.

Not with standing the above comments, an important avenue for future research with this data set would be to collect information on an some ex ante measure of risk. In contrast, in the above we have studied the relation between collateral and default probability measured on an ex post basis. Thus, it would be very desirable to obtain data on the interest rate charged on each loan so as to enable the tests to be repeated with risk premia as the dependent variable.

6. Conclusions

This paper has sought to characterise the nature of project finance for unquoted companies using balance sheet data. In contrast, previous studies have been based on survey data and, consequently, they were not able to study issues such as capital and ownership structure. The main findings of the paper are as follows:

(1) The initial capital structure at start-up and subsequent financing of investments is dominated by debt claims, rather than equity.

(2) *3i* holds a significant proportion of equity claims, though does not often obtain majority voting rights. The most important equity instrument for the venture capitalist are cumulative and participating Preferred Ordinary shares. *3i* also provide significant amounts of unsecured debt at start-up, but is a much less important source thereafter.

(3) The entrepreneur typically lends to the company on a scale similar to that of *3i*. On the basis that the source of these loans are bank loans secured on personal assets, the role of outside collateral appears important for entrepreneurial project finance.

(4) The relation between collateral and default risk was found to be ambiguous. Our measures of collateral did not provide significant

explanatory power for defaults. This contrasts with studies of bank loans which find a significant positive association between collateral and riks.

The above conclusions should clearly be treated with caution as they are based on simple correlations and other sample statistics, rather than properly specified econometric equations. However, due to the inherent difficulties of testing theories based on private information, they should not be completely discarded.

Several areas for future research can be identified. First, as discussed in Section 5.4, the econometric analysis of the relation between collateral and risk could be greatly improved with further collection of data. In addition to the ex post tests in this paper, some ex ante tests could be undertaken if the interest rate on loans could be added to the data set. There are also questions about the relation between collateral and hybrid securities, both of which have been suggested in the literature as remedies for under investment problems. Again this would require further data collection to enable correct identification of the convertible and redeemable rights attached to various securities.

Endnotes:

1 We do not discuss the process by which venture capitalists choose between potential projects. These aspects are discussed in Dixon [1989] and Tyebjee and Bruno [1984].

2 This evidence refers only to the United States. In correspondence with 3i PLC it has become clear that giving the VC the option to remove the entrepreneur is less frequent in the U.K.

3 One of the original aims for this paper was to test the empirical implications of Hansen [1991]. However, it has since become apparent that this is not possible due to data limitations.

4 There exists a literature on the financial environment faced by small firms in general. This literature traces the historical development of the availability of both public and private sources of finance, including venture capitalism. They discuss the findings of the Bolton and Wilson Committees and assess their relevance in the current financial environment. See, for example, Hutchinson and Ray [1983] and Woodcock [1986].

5 This figure includes only those investments for which *3i* obtained an equity stake. As shown in Table 3.1 these investments account for approximately 49 per cent of investments by *3i*.

6 A brief description of each hybrid is provided in Appendix B.

7 In principle, it is possible to specify econometric equations for debt/equity ratios which allow for disequilibrium dynamics (see Bradley, Jarrell and Kim [1984], Long and Malitz [1985] and Titman and Wessels [1985]). Unfortunately, we have not been able to undertake similar analyses due to the small number of observations per company and the absence from our data of important explanatory variables such as expenditure on research and development and advertising.

8 From our description of venture capitalism in Section 1 -- in particular, the intensive screening procedures -- it would seem reasonable to assume symmetric information at start-up. Thus, for the purposes of Section 3, we can discard signalling theories of capital structure.

9 Another implication of Myers' under-investment problem is that convertible debt with warrants attached would be optimal (Chiesa [1988]). Unfortunately, it is not possible to identify convertible instruments in the *3i* sample.

10 Unfortunately, it is not possible to identify the extent to which debt and other fixed-coupon claims are convertible into Ordinary shares. This would be interesting to discover as the risk-shifting and under-investment incentives associated with fixed-coupon claims suggests that conversion will be optimal for under-performing companies. See Chiesa [1990], Green [1984] and Hansen [1991a].

11 Note, however, that the ratios may be distorted by the exclusion of observations for which profits are negative. Table 4.2 shows that average retentions are negative during years 0 and 1, indicating that the incidence of negative profits may be important for pay-out ratios during years 0 and 1.

12 The electrical engineering industry was chosen for comparison because the U.K. figures were available from Mayer and Alexander [1990]. A company is defined as small if it had sales of less than 25 million pounds in 1982.

13 In the case of the U.K. quoted sector, Mayer and Alexander show that the positive 14 per cent contribution of new equity issues becomes negative once the financing of corporate takeovers are netted out. They also report that netting out financial assets reduces the average contribution of short-term debt from 1 per cent to around -25 per cent. However, given the clear dominance of short-term debt in *3i*-backed companies it is unlikely that similar netting-out transformations would reverse the order of importance of debt and equity.

14 An indicator variable for whether the company disappears from the database after the first year was also constructed but was dropped from the subsequent regressions due to convergence problems.

Appendix A: Figures and Tables

Table 2.1: Number of Startups

Year	Number of Firms	Year	Number of Firms
1979	66	1985	167
1980	147	1986	124
1981	231	1987	108
1982	155	1988	103
1983	139	1989	75
1984	161	Total	1476

Table 2.2: Industry Groups

Grp.	Industry	SIC Clas	Number of Firms
0.	Agriculture, Forestry and Fishing	0-3	87
1.	Energy and Water Supply	11-17	5
2.	Metals and metal goods	21,22,31	79
3.	Other minerals and mineral products	23,24	19
4.	Chemicals and man made fibres	25,26	27
5.	Mechanical engineering	32,33	176
6.	Electrical and instrument engineering	34,37	122
7.	Motor Vehicles and transport equipment	35,36	24
8.	Food, drink and tobacco	41,42	38
9.	Textiles, clothing, leather and footwear	43,44,45	72
10.	Timber and wooden furniture	46	25
11.	Paper products and printing & publishing	47	80
12.	Rubber, plastics and other manufacturing	48,49	61
13.	Construction	50	49
14.	Distribution, hotels and catering	61,63-66	290
15.	Scrap and waste materials and repairs	62,67	19
16.	Transport and communications	71-79	38
17.	Banking/finance, insurance and real estate	81,82,85	27
18.	Business services and rentals	83,84	167
19.	Other services and R&D	92-99	71

Table 2.3: Number of Observations

Length of Relationship (years)	Number of Firms	Survival Rate (%)
0	1476	100
1	1196	85
2	972	75
3	768	64
4	601	56
5	437	49
6	314	43
7	218	36
8	111	25
9	42	20
10	4	6

Notes:
The survival rate for year x is computed as the percentage of companies whose first investment was x or more years before the end year of the sample.

Table 2.4: Start-Up Size and Growth Rates
(con ant prices, 1985)

	Turnover (£m)	Fixed Assets (£m)
Ave. size at startup (£m)	7.7	3.2
Ave. ann. growth rate (%)	11.8	-
Std. Devn. of growth	46.6	-
Size Distribution (£m)	(%)	(%)
0	3.7	0.4
0-2	64.2	87.2
2-4	11.2	5.4
4-6	4.7	1.8
6-8	3.7	1.4
8-10	1.6	1.1
10-12	1.8	0.3
12-14	1.4	0.2
≥ 14	7.8	2.1
Total	100.1	99.9

Table 3.1: Capital Structure at Start-Up

	Frequency	Condnl. Average (%)	Condnl. Std. Devn.
Fixed commitments	0.99	84.5	20.1
Equity claims	0.91	18.2	22.5
3i – % of fixed commitments	0.86	30.0	14.6
– % of issued equity	0.49	21.2	10.8
– majority voting	0.14		
– participation rights	0.96		

Notes:
The conditional average for claim type x is the average for all records with x > 0. Similarly for conditional standard deviation. Fixed commitments are debt plus fixed-dividend shares. Equity includes Preference shares, cumulative and participating Preferred Ordinary (CPPO) shares, Ordinary and deferred Ordinary shares, but excludes retained earnings. Total claims are the the sum of fixed commitments and equity claims.

Table 3.2: Characteristics of Firms With and Without 3i Ownership of Equity Claims (averages)

	3i equity	No 3i equity
Fixed assets at startup (£m)	1.6	4.6
Sales at startup (£m)	6.3	8.9
Sales growth (ann. %)	14.7	9.2
% of sample in yr. 0	49.1	50.9
% of sample in yr. 5	47.9	52.1

Table 3.3: Capital Structure at Start-Up

	Uncondnl. Average	Frequency	Condnl. Average (%)	Condnl. Std. Devn.
Total Debt				
– as % of total claims	79.7	0.99	80.9	22.3
– entrepr.– % of debt		0.90	40.2	17.9
– 3i – % of debt		0.78	29.8	12.3
– (other) secured debt		0.52	15.0	19.6
Fixed-Dividend Shares				
– as % of total claims	3.7	0.20	17.9	20.2
– 3i – % of fix. divs.		0.12	82.2	28.5
Preference Shares				
– as % of total claims	0.3	0.04	8.7	1.9
– 3i – % of pref. shares		0.03	88.0	25.2
Cumul. Partic. Preferred				
– as % of total claims	1.9	0.37	5.2	7.3
– 3i – % of CPPO shares		0.36	95.3	6.4
Ordinary Shares				
– as % of total claims	14.0	0.91	15.4	19.7
– 3i – % of ord. shares		0.09	13.2	15.9
Deferred Ordinary Shares				
– as % of total claims	0.4	0.05	9.3	14.7
– 3i – % of deff. shares		0.01	63.2	42.9
	100.0			

Notes:
Secured debt (other) is mortgages and hire purchase agreements. See also the notes for Table 3.1.

Table 3.4: Debt Claims by Industry Group

Industry Group	Total Debt / Total Claims (%)	Total Debt / Fixed Assets (%)	Net Debt / Fixed Assets (%)
0.	75.4	123.2	85.5
1.	58.6	77.1	46.6
2.	77.4	155.4	95.7
3.	78.8	134.7	78.2
4.	72.5	155.5	98.1
5.	79.5	218.2	142.8
6.	81.1	256.6	153.1
7.	79.5	220.3	139.7
8.	79.4	113.7	58.2
9.	74.8	177.1	112.7
10.	81.9	151.6	85.8
11.	84.9	406.6	210.0
12.	81.2	129.5	73.6
13.	80.9	254.8	170.2
14.	80.2	248.4	158.4
15.	89.2	146.1	90.8
16.	78.9	151.9	99.5
17.	72.0	1921.1	676.4
18.	82.9	2145.4	530.4
19.	78.4	300.0	114.2

Notes:
Net debt is total debt minus loans from the entrepreneur.

Table 3.5: Capital Structure for Manufacturing

	Uncondnl. Average	Frequency	Condnl. Average (%)	Condnl. Std. Devn.
Total Debt				
– as % of total claims	79.6	1.00	80.2	22.3
– entrepr.– % of debt		0.91	40.1	17.9
– 3*i* – % of debt		0.79	29.3	12.3
Fixed–Dividend Shares				
– as % of total claims	4.1	0.22	19.0	20.5
– 3*i* – % of fix. divs.		0.13	83.9	9.0
Preference Shares				
– as % of total claims	0.2	0.03	5.8	8.4
– 3*i* – % of pref. shares		0.02	80.1	31.0
Cummul. Partic. Preferred				
– as % of total claims	1.7	0.36	4.8	6.4
– 3*i* – % of CPPO shares		0.35	95.5	16.6
Ordinary Shares				
– as % of total claims	13.8	0.97	14.3	18.0
– 3*i* – % of ord. shares		0.09	13.2	15.9
Deferred Ordinary Shares				
– as % of total claims	0.6	0.06	10.3	17.1
– 3*i* – % of deff. shares		0.01	49.8	42.3
	100.0			

Notes:
Manufacturing includes industry groups 2-12. See also the notes to Table 3.3.

Table 4.1: Investment and Pay-Out Ratios

	UK Quoted (1)	*3i* Full Sample (2)	*3i* Years 0–1 (3)
A: All Industry Groups			
Investment ratio	78.0	268.8	324.3
Dividend payout ratio	30.9	22.7	19.2
Distribution ratio	21.9	20.1	17.2
External financing ratio	0.1	188.9	241.5
B: Electrical Engineering (small)			
Investment ratio	127.8	223.3	–
Dividend payout ratio	41.4	27.6	–
Distribution ratio	29.4	25.4	–
External financing ratio	57.2	148.7	–

Notes:
Each ratio is an unweighted average for all observations for which profits are positive. The investment ratio is net physical investment plus change in stock of raw materials and work-in-progress divided by zero distribution profits (as defined in Appendix C). The dividend pay-out ratio is gross dividends as a percentage of zero-distribution profits. The distribution ratio is retentions forgone as a percentage of zero distribution profits. The external financing ratio is the sum of investment and distribution ratios minus one. Statistics for the U.K. 'All Industry Groups' and 'Electrical Engineering (small)' are from tables 4 and 6 in Mayer and Alexander [1990]. For the purposes of part B of the table, a small company is defined as having sales of less than 25 million pounds in 1982. All but three of the electrical engineering companies in the 3i data satisfied this definition of small. Mayer and Alexander [1990] report that their sample of quoted companies includes 13 electrical engineering companies satisfying our definition of small.

Table 4.2: Gross Sources of Finance by Claims

	UK Quoted (1)	3*i* Full Sample (2)	3*i* Years 0–1 (3)
A: All Industry Groups			
Retentions	58.2	33.1	–9.5
New Equity	14.3	1.6	6.5
New debt	9.0	41.6	77.7
Trade Credit	18.5	23.7	25.3
B: Electrical Engineering (small)			
Retentions	32.2	16.4	–
New Equity	35.1	2.0	–
New debt	10.0	27.3	–
Trade Credit	22.7	54.2	–

Notes:
The proportions are computed as the percentage of total gross sources accounted for by each source. New equity includes fixed dividend, Preference, Preferred Ordinary, Ordinary, and deferred Ordinary shares. Figures for the UK 'All Industry Groups' and 'Electrical Engineering (small)' are from Tables 2 and 6 in Mayer and Alexander [1990]. See also the notes for Table 4.1.

Table 5.1: Summary Statistics for Regression Variables

Dependent variable		Means (%)	Std. Dev.
FAIL2	= 1 if company absent from data set after 2 years.	21.2	–
FAIL3	= 1 if company absent from data set after 3 years.	35.5	–
Exogeneous variables (as at year 0)			
OC	Entr.'s loan capital as per cent of debt plus leasing	35.9	19.7
IC_MORT	Mortgages as per cent of debt plus leasing	0.3	3.7
IC_HP	Hire purchases as per cent of debt plus leasing	6.4	13.7
IC_LH	Cost of leaseholds as per cent of debt plus leasing	0.9	5.2
3*i*_PREF	3*i*'s preference shares as per cent of total equity claims	2.9	16.4
3*i*_CPPO	3*i*'s CPPO shares as per cent of total equity claims	30.9	45.7
3*i*_ORD	3*i*'s ordinary shares as per cent of total equity claims	1.1	6.0
3*i*_DEF	3*i*'s deferred ordinary shares as per cent of total equity claims	0.6	7.5
ENTRY1	= 1 if record shows one balance date previous to initial 3*i* investment.	45.5	–
ENTRY2	= 1 if record shows two balance dates previous to initial 3*i* investment.	4.3	–
ENTRY3	= 1 if record shows 3 or more bal.dates previous to initial 3*i* investment.	1.3	–

Notes:
Total number of observations equals 1191. Relative frequencies for dummy variables YR79, ..., YR85 and IND1, ..., IND19 can be ascertained from Tables 2.1 and 2.2.

Table 5.2: Probit Regressions for FAIL2 with Full Sample

	(1)	(2)	(3)	(4)
Constant	-0.60	-0.57	-0.51	-0.56
	(-2.87)	(-2.92)	(-2.71)	(-3.41)
OC	-0.13	-0.14	-0.13	
	(-0.54)	(-0.57)	(-0.55)	
IC_MORT	-0.42	-0.47	-0.44	
	(-0.32)	(-0.34)	(-0.32)	
IC_HP	0.96E-02	0.18E-01	0.57E-01	
	(0.03)	(0.06)	(0.17)	
IC_LH	-1.01	-1.00	-0.94	
	(-1.08)	(-1.08)	(-1.01)	
3*i*_PREF	-0.11E-02	-0.12E-02		
	(-0.41)	(-0.42)		
3*i*_CPPO	0.11E-02	0.11E-02		
	(1.16)	(1.15)		
3*i*_ORD	0.42E-02	0.44E-02		
	(0.58)	(0.61)		
3*i*_DEFF	0.65E-02	0.63E-02		
	(1.31)	(1.27)		
LOG OF LIKELIHOOD	-573.7	-574.2	-575.9	-576.6
% CORRECT PREDNS.	78.9	78.8	78.9	78.7

Note:
Industry group 15 (scrap and waste materials and repairs) is omitted due to the absence of observations. Equations (2)-(4) exclude the dummy variables ENTRY1- ENTRY3.

Table 5.3: Probit Regressions for FAIL3 with Full Sample

	(1)	(2)	(3)	(4)
Constant	0.59	0.67	0.67	0.68
	(0.92)	(3.51)	(3.66)	(4.14)
OC	0.15E-01	0.70E-02	0.47	
	(0.07)	(0.03)	(0.21)	
IC_MORT	-1.63	-1.70	-1.66	
	(-1.05)	(-1.07)	(-1.05)	
IC_HP	0.20	0.22	0.26	
	(0.65)	(0.72)	(0.86)	
IC_LH	-2.14	-2.29	-2.08	
	(-2.07)	(-2.09)	(-2.02)	
*3i*_PREF	-0.43E-02	-0.43E-02		
	(-1.49)	(-1.51)		
*3i*_CPPO	0.79E-03	0.60E-03		
	(0.87)	(0.67)		
*3i*_ORD	0.14E-02	0.16E-02		
	(0.19)	(0.22)		
*3i*_DEFF	0.68E-02	0.66E-02		
	(1.29)	(1.26)		
LOG OF LIKELIHOOD	-680.2	-682.3	-684.7	-688.4
% CORRECT PREDNS.	71.0	70.5	70.7	70.6

Note:
Industry group 15 (scrap and waste materials and repairs) is omitted due to the absence of observations. Equations (2)-(4) exclude the dummy variables ENTRY1- ENTRY3.

Table 5.4: Probit Regressions with Debt-Only Sample

	FAIL2		FAIL3	
Constant	-0.57 (-1.97)	-0.69 (-3.08)	0.81 (2.85)	0.85 (3.41)
OC	0.28E-01 (0.07)		0.20 (0.55)	
IC_MORT	0.43 (0.18)		-1.62 (-0.73)	
IC_HP	0.55 (0.93)		0.65 (1.23)	
IC_LH	-1.53 (-0.61)		-3.67 (-1.46)	
LOG OF LIKELIHOOD	-306.4	-309.1	-382.6[a]	-385.4
% CORRECT PREDNS.	79.2	79.1	70.6	69.9

a. convergence not achieved after 20 iterations.

Table 5.5: Sample Frequency and Means for Four Industry Groups

	Group 5	Group 6	Group 14	Group 18
FAIL2	0.22	0.15	0.32	0.25
FAIL3	0.31	0.35	0.42	0.46
OC	35.91	36.84	40.91	37.54
IC_HP	5.39	7.31	3.65	8.09
IC_LH	0.00	0.46	1.74	2.14
3*i*_PREF	0.07	0.00	0.01	0.01
3*i*_CPPO	0.02	0.09	0.07	0.09
ENTRY1	0.49	0.49	0.35	0.39
No. of Observatns.	137	105	119	122

Table 5.6: Probit Regressions for FAIL2 by Industry Group

	Group 5	Group 6	Group 14	Group 18
Constant	-0.17	-0.99	0.35	-0.68
	(-0.33)	(-1.76)	(0.49)	(-1.54)
OC	-0.11E-01	0.77E-03	-0.18E-02	-0.25E-02
	(-1.45)	(0.08)	(-0.23)	(-0.35)
IC_HP	-0.92E-02			0.88E-02
	(-0.55)			(0.93)
3i_PREF	0.80			
	(0.75)			
3i_CPPO		2.58	-1.33	0.18
		(2.02)	(-1.05)	(0.16)

Notes:
Ommission of a variable indicates insufficient number of positive observations.

Table 5.7: Probit Regressions for FAIL3 by Industry Group

	Group 5	Group 6	Group 14	Group 18
Constant	-0.18	0.41E-01	0.43	-0.16
	(-0.36)	(0.09)	(0.79)	(-0.34)
OC	-0.25E-02	-0.99E-02	-0.12E-02	0.55E-02
	(-0.35)	(-1.24)	(-0.16)	(0.81)
IC_HP	0.23E-01			0.24E-01
	(1.56)			(2.12)
3i_PREF	0.53			
	(0.52)			
3i_CPPO		1.60	-2.02	-0.56
		(1.47)	(-1.66)	(-0.51)

Notes:
Ommission of a variable indicates insufficient number of positive observa

Figure 3.1: Growth in Real Sales by Age of Relationship

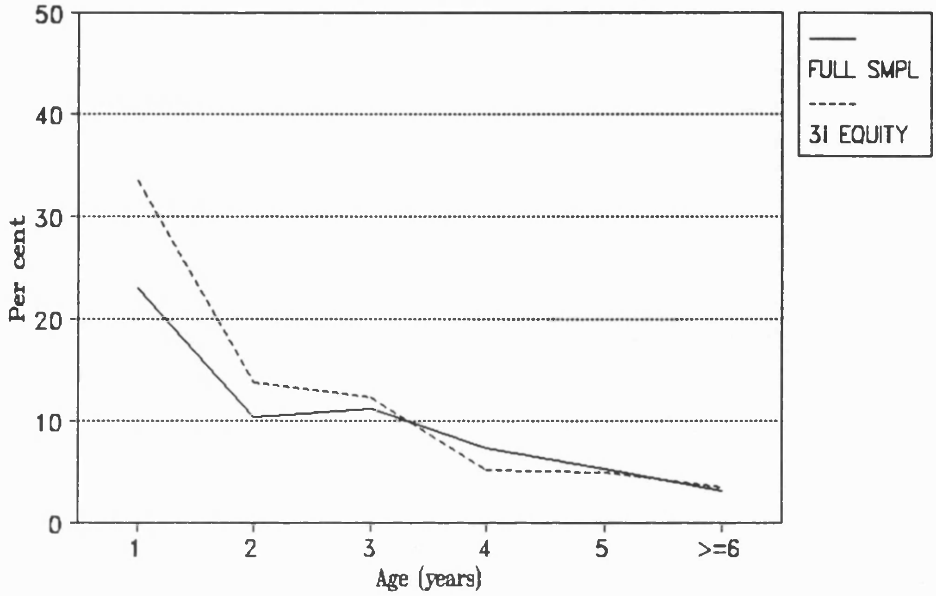


Figure 3.2: Std. Devn. in Real Sales Growth by Age of Relationship

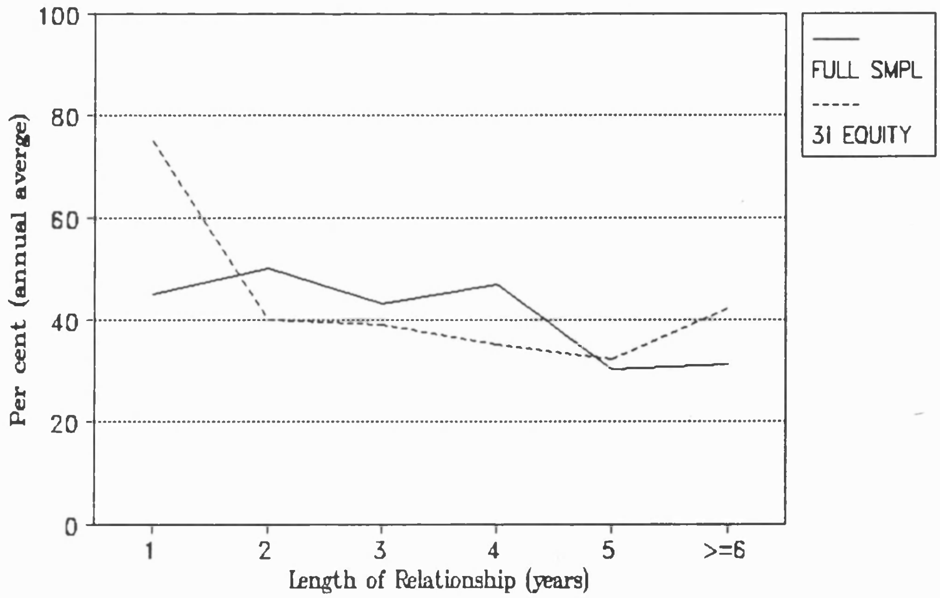


Figure 4.1: Sources of Finance by Age of 3i Relationship

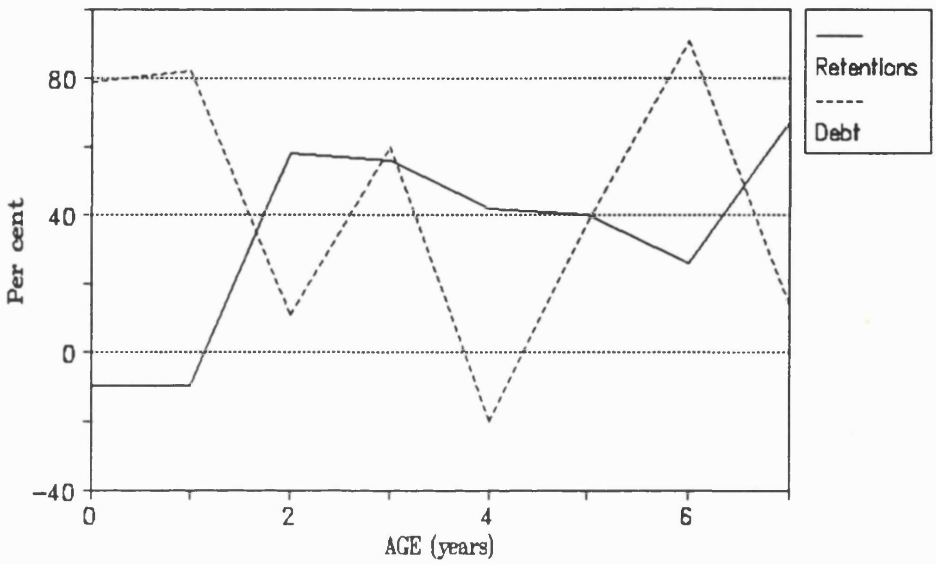
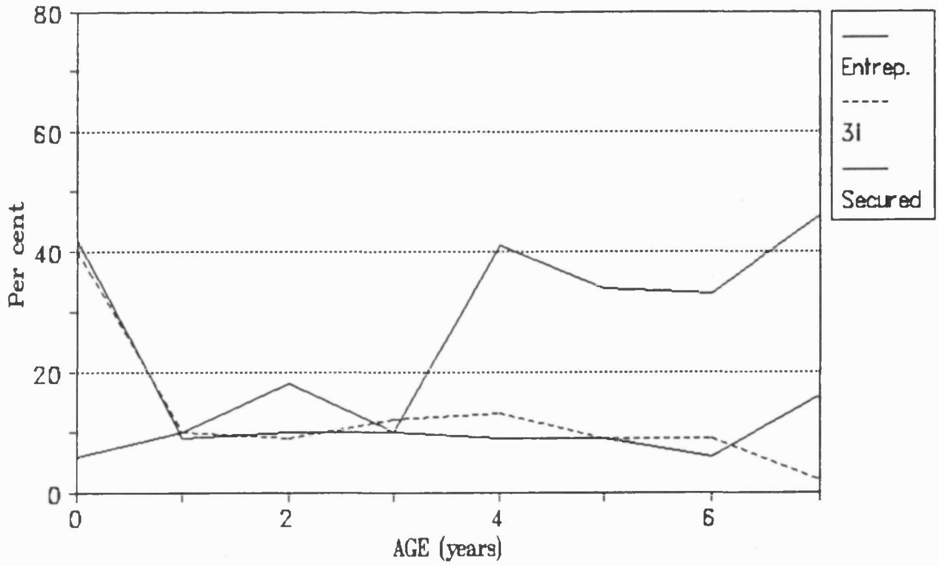


Figure 4.2: Ownership of New Debt Claims by Age of 3i Relationship



Appendix B: Description of Financing Instruments

The following is a brief description of the types of equity claims referred to in the text. The descriptions are based on Lorenz [1985,p.27].

1. *Deferred (ordinary) shares* are ordinary shares whose rights are deferred for a period of years or until some future event such as a quotation or sale of the company.
2. *Ordinary shares* have full equity and voting rights but no dividend commitment.
3. *Preferred ordinary shares* usually have full voting and equity rights, but often with a modest fixed dividend right and possibly also with right to *profits participation.*
4. *Preference shares* rank ahead of all types of ordinary shares upon liquidation. As with deffered shares, preference shares may be *convertible* into ordinary shares at some future date or event. They may be *irredeemable* or more frequently *redeemable*, either at par or at a premium. The dividend may be *cumulative* and often can be increased through *participating* in future profits. Convertibility will often be at a variable rate depending on profits performance over a period of years.

Appendix C: Computation of Zero-Distribution Profits

This appendix details the methodology for computing 'zero-distribution profits', which is defined as the after-tax profits with a zero dividend distribution. In contrast, the Profit and Loss account shows the firm's actual after-tax profit given the dividend pay-out made by the firm. Mayer & Alexander [1990] provide an equation for zero-distribution profits but they don't explain it's derivation or provide references. Moreover, from the discussion below it will become apparent that their definition is not quite correct.

We begin our analysis with some definitions. Let G be gross cash dividend payments and D = $(1-\tau_d)$G the net cash dividend, where τ_d is the rate of tax on dividends. Let Π_p be taxable profit and T(D) the corporate tax liability as a function of net dividends D. After-tax profits are defined as:

$$\Pi_A(D) \equiv \Pi_p - T(D) \qquad \text{(C1)}$$

Zero-distribution profit is defined to be $\Pi_A(0)$. Using (C1) with D=0 and then substituting for Π_p from (C1) with dividends D gives:

$$\begin{aligned} \Pi_A(0) &\equiv \Pi_p - T(0) \\ &= \Pi_A(D) + (T(D) - T(0)) \end{aligned} \qquad \text{(C2)}$$

From (C2) we see that zero-distribution profits equal after-tax profits plus the increase in corporate tax liability due to dividends D. Computation of the latter adjustment requires an understanding of UK tax imputation system.

The imputation system for dividends, kown as Advance Corporation Tax (ACT), was introduced in 1973 and is described in detail in Devereux [1986] and also in King [1983]. Under the ACT scheme the company is responsible for paying the income tax liability of it's shareholders on (cash) dividend income received. This liability is computed at the basic rate of income tax, say τ_b, so that $ACT(D) = \frac{\tau_b D}{1-\tau_b}$. Hence, the company pays profits tax of $\tau_c\max\{0,\Pi_p\}$, where τ_c is the tax rate on profits, plus ACT. However, to avoid double taxation of dividends, companies are also allowed to off-set a portion of the ACT against their own mainstream corporate tax liability. This is known as Recoverable ACT (RACT). The total corporate tax liability becomes:

$$T(D) = \tau_c\max\{0,\Pi_p\} + ACT(D) - RACT(D), \qquad \text{(C3)}$$

where

$$RACT = \max\{0,\min\{ACT+STC_{-1},\tau_b\Pi_p\}\} \qquad \text{(C4)}$$

and STC_{-1} is the stock of tax credits bought forward from the previous year.

The equation for RACT reflects two constraints. The first is the zero in $\max\{0,\min\{.,\tau_b\Pi_p\}\}$, which prevents the company from becoming a "money machine" when profits are negative, $\Pi_p<0$ (see King [1983]). The second constraint, represented by the min{} function, prevents the amount recovered from exceeding $\tau_b \Pi_p$, which would be the level of ACT if all profits were distributed. Finally, the stock of tax credits to be carried forward, STC, is (there are also carry forward constraints on STC, but they are not required in the following analysis, see Devereux [1986]):

$$STC = \max\{0, ACT + STC_{-1} - \tau_b \Pi_p\} \qquad (C5)$$

One approach to calculating T(D) − T(0) would be to compute (C3)–(C5) and other carry forward constraints. However, this complicated set of computations can be avoided by simply using information provided in balance sheets on ACT and STC. In the following we show that T(D) − T(0) = min{ACT,STC}. First, from (C3) we note that:

$$T(D) - T(0) = ACT(D) + [RACT(0) - RACT(D)] \qquad (C6)$$

Clearly, if $\Pi_p \leq 0$ then (C4) and (C6) imply T(D) − T(D) = ACT(D). This agrees with min{ACT,STC} since $\Pi_p \leq 0$ and $STC_{-1} \geq 0$ imply STC ≥ ACT. When $\Pi_p > 0$ there are three cases to consider:

Case (a): STC = 0. From (C5) this implies ACT + $STC_{-1} < \tau_b \Pi_p$ so that RACT(0) − RACT(D) ≡ $\min\{STC_{-1}, \tau_b \Pi_p\} - \min\{ACT(D) + STC_{-1}, \tau_b \Pi_p\} = -ACT(D)$. Hence T(D) − T(0) = 0, as predicted by min{ACT,STC}.

Case (b): STC > ACT. Again from (C5), STC > ACT implies $STC_{-1} > \tau_b \Pi_p$ and hence RACT(0) − RACT(D) = 0. Therefore T(D) − T(0) = ACT(D), which again equals min{ACT,STC}.

Case (c): 0 < STC < ACT. The LHS inequality implies $\tau_b \Pi_p < STC_{-1} + ACT(D)$ while the RHS inequality implies $STC_{-1} < \tau_b \Pi_p$. Thus RACT(0) − RACT(D) = $STC_{-1} - \tau_b \Pi_p < 0$, and T(D) − T(0) = ACT(D) + $STC_{-1} - \tau_b \Pi_p$ = STC, which also agrees with min{ACT,STC}.

Finally, it remains to point out that our equation T(D) − T(0) = min{ACT,STC} is not quite the same as in Mayer & Alexander. They specify that STC is the stock of tax credits bought forward from the previous period, whereas the discussion above shows that the correct interpretation of STC is as the stock of credits to be carried to the next period. Also in the actual computations we assume that companies claim all tax deductions available to them, so that taxable profits are equal to reported pre–tax profits.

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