6

Corporate Financing under Asymmetric Information

6.1 Introduction

There is a fair amount of empirical evidence, some of it reviewed in Chapters 1 and 2, showing that securities are often issued under unequal access to information. This chapter investigates the consequences of such informational asymmetries for financing decisions.

Suppose that a firm wants to raise funds on the capital market. The standard motivation for issuing claims, and the one that has been emphasized in previous chapters, is the financing of projects: initial financing, reinvestments, and expansions associated with new projects. An alternative motivation for issuance is risk sharing. For example, a risk-averse entrepreneur may want to diversify her portfolio by selling some of her shares in the firm. Third, the issuance may be motivated by liquidity reasons: an entrepreneur or a venture capitalist may want to cash in to be able to move on to other projects; or a bank may want to securitize loans in order to increase its loanable funds. In all three cases, the issuance is motivated by the existence of gains from trade between the issuer and potential investors. A fourth motivation, though, is unrelated to the existence of gains from trade: the issuer may want to push overvalued assets to investors.

The firm may use a private placement to a small group of knowledgeable investors, conduct an initial public offering, or, if it has already gone public, a seasoned offering. When issuing (buying) new claims, the firm (its investors) should be preoccupied with two types of informational asymmetries: between the issuer and the investors, and among investors.

This chapter studies asymmetric information between insiders and investors and the concomitant lemons problem. Investors have imperfect knowledge of the firm's prospects, the value of assets in place, the value of pledged collateral, the issuer's potential private benefit, or any other firm characteristics that affect the profitability of investment. Accordingly, investors are concerned that they might purchase overvalued claims.

A standard theme of information economics is that gains from trade are often left unexploited in markets plagued by adverse selection. In a famous article, Akerlof (1970) showed how markets for used wares may shrink or even disappear when sellers are better informed about their quality than buyers. The application of this general idea to credit markets is that the issuer may raise less funds or raise funds less often when the capital market has limited access to information about the firm. *Market breakdown*, the fact that potential issuers may refrain altogether from going to the capital market or, less drastically, limit their recourse to that market, and *cross-subsidization*, which, in its most basic form, refers to good borrowers being forced, by the suspicion of low-quality borrowing, to issue high-interest debt or to substantially dilute their equity stake, are studied in Section 6.2.

While this section focuses on the simple environment in which good borrowers are unable to separate from bad ones (except, when there are assets in place, by forgoing attractive investment opportunities), it already delivers a rich set of empirical predictions, some of which historically motivated the theory in the first place.

First, adverse selection can account for the negative stock price reaction associated with equity offerings. This negative stock price reaction is not an obvious phenomenon. After all, investors may learn from an announcement of a seasoned security offering that the firm enjoys new and attractive investment opportunities. The negative stock price reaction, however, can be rationalized by the investors' concern that the issue is motivated by the desire to depart with overvalued assets. An issuer who knows that assets in place are undervalued by investors (a "good borrower") is reluctant to issue shares under terms that would be too favorable to investors. The issuer may then prefer to forgo a profitable investment opportunity (and possibly remain private in the process). Share issues are then a bad signal about firm profitability.[1] It can further be shown that the stock price reaction is less negative in good times, i.e., during booms.

Second, the analysis provides some foundation for the pecking-order hypothesis. According to Myers's (1984) and Myers and Majluf's (1984) pecking-order hypothesis,[2] firms prefer to use "internal finance" (initial equity, retained earnings) to finance their investments. If internal finance is an insufficient source of funds and external finance is required, firms first issue debt, the safest security, then hybrid securities such as convertibles, and finally, as a last resort, equity. The idea is that neither internal finance nor default-free debt suffers from the informational asymmetries and the cross-subsidization traditionally associated with external finance. If these do not suffice to meet the firm's financing needs, the firm will still strive to issue *low-information-intensity claims*, that is, claims whose valuation is the least affected by the asymmetry of information.

The pecking-order hypothesis has received substantial empirical support. The primary source of financing for mature firms (see Chapter 2) is retentions; and outside finance is mainly debt finance, since seasoned equity issues are relatively rare. Another stylized fact corroborating the pecking-order hypothesis is the absence of stock price reaction upon the announcement of a debt issue, in sharp contrast with the decline for a seasoned equity issue.

As usual, things are more complicated than is suggested by this interesting hypothesis. First, while entrepreneurial equity accumulated from previous projects is indeed free from asymmetric information problems, retained earnings are, in practice, endogenous; in particular, the management of a firm may need to convince its shareholders not to distribute large dividends and to keep cash for reinvestments. Whether shareholders are willing to go along with the management's recommendation depends, inter alia, on their belief about the relative profitability of reinjecting cash into the firm and disgorging it. So, "internal finance" is not free of informational problems. Second, what constitutes low-information-intensity financing depends on the type of information that is privy to the issuer, and thus one cannot always equate low-information-intensity financing with debt financing. Third, there are other forces, studied in this book, than asymmetric information that may introduce departures from Myers and Majluf's pecking-order hypothesis and generate alternative pecking orders. For example, cash-poor firms' viability concerns seriously limit their demand for debt finance (Chapter 5); and the entrepreneurs' and large investors' exit strategies require issuing equity or more generally "information-intensive" claims (Chapters 4 and 9). Indeed, the empirical evidence is that small, high-growth firms do not behave at all according to the pecking-order hypothesis, even though these firms are fraught with asymmetric information and therefore would be good candidates for a financing pattern fitting Myers and Majluf's pecking order (Frank and Goyal 2003). But Myers and Majluf's pecking-order hypothesis remains a good starting point for the analysis.

Finally, the analysis of Section 6.2 provides a simple rationale for market timing—the fact that equity issues are more frequent after the firm's stock price or the stock market rises. The idea is simply that in such circumstances the concerns about adverse selection may be dwarfed by the fundamentals, enabling issuers to raise equity.

The second theme borrowed from information economics (Spence 1974; Rothschild and Stiglitz 1976; Wilson 1977) is that the informed side of a market is likely to introduce or accept distortions in contracting so as to signal attributes that are

1. A similar reasoning applies to share buybacks (in 2004, companies announced plans to repurchase $230 billion of their stocks). As Dobbs and Rehm (2005) note, a share repurchase conveys several signals: (a) the management's intention not to engage in a wasteful acquisition or capital expenditure, (b) the management's confidence that the company will not need the cash to cover future expenditures, and (c) the absence of new investment opportunities. Despite the third signal, financial markets in general applaud firms' moves to buy shares back.

2. See, for example, Chapter 18 of Brealey and Myers (1988) for a presentation and Harris and Raviv (1992) for an extensive discussion.

attractive to the uninformed side of the market. More concretely, a good borrower will try to demonstrate attractive prospects to the investors by introducing distortions that are costly to her, but that would be even costlier to a bad borrower. Depending on the setting, this may mean investing too little or too late, resorting to a private placement and to the enlisting of a costly monitor, diversifying the issuer's portfolio insufficiently, underpricing claims, hoarding insufficient liquidity, distributing dividends, or resorting excessively to debt.

Section 6.3 thus studies various dissipative signals that good borrowers use in order to reassure investors and obtain good financing conditions or financing at all: costly collateral pledging, underpricing, suboptimal risk sharing, short-term finance, and hiring of a monitor.

Before proceeding, a brief discussion of the relationship of this chapter to the literature as well as some of the missing topics may be useful. (The rest of the introduction can be skipped in a first reading.)

6.1.1 Methodological Issues

While much progress has been made in the last twenty years toward the understanding of market breakdown and costly signaling, most papers in the literature make assumptions that ought to be relaxed in order to confirm the validity of the arguments. One can divide the criticisms into three categories.

Unconventional goals of the issuer. The literature has analyzed situations with two parties: the "issuer" and the "capital market." The issuer, who is better informed than the capital market, stands for "management" or a "small group of well-informed insiders." There is little difficulty in interpreting this theoretical framework in a situation where the issuer is an entrepreneur who has not yet issued claims, privately or publicly.

The interpretation, however, becomes more complex when management already faces existing claimholders.[3] This raises two issues. First, *who is in charge of financing decisions?* The literature generally assumes that the management is. This assumption is objectionable on both institutional and theoretical grounds. In practice, management ordinarily does not have formal authority (explicit control rights) over financing decisions. The venture capitalist usually controls issuances of the start-up corporation. The board of directors and shareholders review decisions such as dividend distribution, issuance of shares, sale of assets, and so forth. Neither is it *a priori* clear, from a theoretical perspective, why management, which faces a conflict of interest, should have control over its financial structure.

Yet, while the assumption that the management controls the financing does not *a priori* hold on institutional or theoretical grounds, the opposite assumption, that management has no say in financing decisions, largely oversimplifies reality. Management does, in practice, have a sizeable influence on financing decisions. Fortunately, the two viewpoints can be reconciled by introducing a distinction between formal and real authority on financing decisions. Management may not have the formal right to pick financing decisions, but, *precisely because it is superiorly informed*, it has substantial real control over such decisions.[4]

Reflecting this tension between formal rights over financial decisions conferred upon potentially uninformed parties and partial control by management, many papers, including a number of pioneering works in the area (e.g., Ross 1977; Bhattacharya 1979; Myers and Majluf 1984; Miller and Rock 1985) assume that management has the formal right to design the issuance, but internalizes other considerations besides its own welfare. Namely, it is assumed that management benefits directly when securities

3. For instance, a start-up company is partly owned by one or several venture capitalists; a publicly traded corporation already has debt and equity when undertaking a seasoned offering. A coherent interpretation of the theoretical construct then consists in assuming that (i) management and the existing claimholders are symmetrically informed, and are better informed than the new investors, and (ii) management and existing claimholders can redistribute utility among themselves through secret deals. (The need for secrecy arises from the fact that transfers between management and existing claimholders that are observed by new investors convey information about the private information held by the coalition.) Management and existing claimholders may then be viewed as a coalition of well-informed insiders. For this interpretation to hold, it must also be the case that (iii) existing claimholders for some reason (capital requirements faced by intermediaries, undiversified portfolio, or other) are not able to bring in the new funds themselves; otherwise, the new investors would infer that the issuance is overvalued and that they are being ripped off by existing claimholders, and so they would not want to purchase the new claims.

4. We will come back to formal and actual control in Chapter 10.

are highly valued by the market (Ross), or attempts to maximize the value of old (or possibly all) shareholders (Myers and Majluf, Bhattacharya), or else chooses dividends so as to manipulate the current stock price (Miller and Rock). These attempts at reconciling the facts that management has some real, but no formal, control over financing decisions are not arbitrary, although they are reduced forms. In practice, management does care about the capital market's opinion, and tries to some extent to keep its shareholders happy. Such an internalization of the opinion and welfare of others is, however, endogenous. *Management cares solely about its own well-being*, and it is only to the extent that its incentive scheme makes it sensitive to the welfare of others that such concerns may arise. It is thus desirable to build on the reduced forms considered in these papers, and to endogenize the management's degree of authority over financial decisions and its internalization of investors' preferences.

Limitations on the set of issuable securities. Most of the literature presupposes the type of security (usually equity) being issued.[5] This approach has the advantage of simplicity as it abstracts from security design. It also offers interesting insights into the information intensity of various securities and the signaling costs attached to them. It thus supplies a useful building block, although it cannot address the issue of how asymmetric information impacts on the choice of securities.

Two further caveats. The literature describes the issuance as a signaling game, that is, as a two-stage game in which, first, the informed issuer designs the claims and structures their pricing and, second, the uninformed capital market decides whether to purchase the claims. As is well-known, such games are usually plagued by a large multiplicity of (perfect Bayesian) equilibria.[6] Contributions usually derive their insights from the examination of a specific equilibrium. The literature also does not usually make full use of contracting possibilities, even if the type of security to be issued is exogenous. Technically, issuance is a "mechanism designed by an informed principal."[7] In the parlance of this theory, the issuer is the "principal," namely, the party who designs the mechanism, and the capital market the "agent."[8] For the sake of completeness and to obtain sufficient conditions for uniqueness of equilibrium in the issuance game, we will describe this approach in the supplementary section.

6.1.2 Some Limitations of this Chapter

No asymmetric information among investors. This chapter focuses on informational asymmetries between issuers and investors. Because this would require reviewing auction theory, it does not survey the large literature on asymmetries of information among investors bidding for financial claims at initial public offerings or seasoned equity offerings. A well-known paper by Rock (1986) shows that, in fixed-price offerings, underpricing is needed to compensate small, uninformed investors for the winner's curse (the fact that winning at a common value auction reveals that the other informed bidders were unwilling to pay much for the shares). Fixed-price offerings are not optimal procedures in such environments. The subsequent literature (Benveniste and Spindt 1989; Benveniste and Wilhelm 1990; Spatt and Srivastava 1991) therefore

5. For example, in Stiglitz and Weiss (1985), one of the early papers on corporate finance under asymmetric information, firms differ in their riskiness (in the sense of second-order stochastic dominance). Stiglitz and Weiss assume that lenders can offer only debt contracts, and show that the repayment probability decreases with the rate of interest offered by lenders, and that the loan market is characterized by credit rationing. However, the assumptions of the model predict that investors should instead offer equity contracts, in which case there would be no adverse selection (all firms have the same mean income) and no credit rationing (Hart 1985).

6. For studies of signaling games, see, for example, Fudenberg and Tirole (1991, Sections 8.2 and 11.2), Myerson (1991, Section 6.7), and Osborne and Rubinstein (1994, Sections 13.3 and 13.4).

7. See Myerson (1983) and Maskin and Tirole (1990, 1992). An alternative strategy for modeling a competitive capital market would consist in assuming that the competitive lenders make contract offers to the informed entrepreneur. That is, we could consider a competitive capital market *screening* the informed borrower rather than the situation in which the informed borrower *signals* to the competitive capital market (see, for example, Rothschild and Stiglitz (1976), Wilson (1977), and Hellwig (1987) for screening approaches to the description of insurance markets). The study of competitive screening is, however, complex and not yet settled.

8. This theory shows that it may be optimal to include later options for the contract designer into the design that provide the informed principal with choices to be made after the claims have been purchased. The basic idea of these options is to protect the capital market against bad surprises by confronting the issuer with an *ex post* choice (we will illustrate this rather abstract point later). Such options drastically reduce the multiplicity of equilibria, to the point that there exists a unique perfect Bayesian equilibrium of the issuance game over some range of parameters.

adopted a mechanism-design approach. Biais et al. (2002) generalize the optimal-mechanism-design approach to situations in which there is an agency problem between the underwriter and the issuer (as in Baron 1982).[9]

Investors have no informational advantage over issuers. While most informational asymmetries relate to insiders' private knowledge about assets in place and prospects, it is easy to envision situations in which the asymmetry of information operates in the reverse direction, namely, in which investors are better informed on some dimensions. For example, venture capitalists are usually better able than unseasoned entrepreneurs to assess a business model or prospects of a product. In this chapter we will simplify the analysis by assuming that insiders are better informed than investors.[10]

No signal sent to third parties. This chapter focuses on the information conveyed by the issuance to investors. For conciseness, we do not cover an interesting literature that analyzes the informational impact of financial decisions on third parties, such as product-market competitors or suppliers (see Gertner et al. 1988; Poitevin 1989; Bhattacharya and Chiesa 1995; Yosha 1995). For instance, a firm may be eager to signal to investors that the demand for its product is high, as this may allow it to obtain more financing, but still be reluctant to convey such information to potential entrants in that market, whose entry it wants to deter. In contrast, there is no tension for the firm when signaling that it has low costs simultaneously to the capital and product markets when it wants to deter potential entrants.[11]

6.2 Implications of the Lemons Problem and of Market Breakdown

A number of important insights can be gleaned from the following barebones model, in which the borrower has private information about the probability of success.

Privately-known-prospects model. A borrower/entrepreneur has no funds ($A = 0$) to finance a project costing I. The project yields R in the case of success and 0 in the case of failure. The borrower and the lenders are risk neutral, and the borrower is protected by limited liability. The interest rate in the economy is normalized at 0.

The borrower can be one of two types. A good borrower has a probability of success equal to p. A bad borrower has a probability of success q. Assume that $p > q$ and that $pR > I$ (at least the good type is creditworthy). There are two subcases, which we will treat separately:

either $pR > I > qR$
(only the good type is creditworthy),

or $pR > qR > I$
(both types are creditworthy).

The borrower has private information about her type. The capital market, which is competitive and demands an expected rate of return equal to 0, puts probabilities α and $1-\alpha$ on the borrower being a good or a bad type, respectively. Under asymmetric information, the capital market does not know whether it faces a "p-borrower" (a good borrower) or a "q-borrower" (a bad borrower).[12] Let

$$m \equiv \alpha p + (1-\alpha)q$$

denote the investors' prior probability of success.

Note that we have left out for the moment moral hazard in the definition of the privately-known-prospects model. The coexistence of moral hazard

9. Another well-known contribution on competition among asymmetrically informed investors is Broecker (1990), who assumes that investors receive private signals about the firm's profitability (but are still less well informed than the borrower) and compete in reimbursement rules for the borrower's business. See also Milgrom and Weber's classic paper (1982) on auctions with common values, and the large subsequent literature.

10. In Inderst and Müller (2005b), a borrower applies to a lender for a loan. The initial contract is drawn under symmetric information. The lender then acquires private, soft information about the quality of the borrower. Because the lender does not internalize the borrower's rent from being funded, the lender denies rationally, but inefficiently, credit for a range of signals. In another recent paper, Inderst and Müller (2005a) add collateral and show that this improves the efficiency of the lender's credit decision by flattening the borrower's repayment schedule.

11. There is a separate literature on the disclosure of proprietary information, arguing that private financing may make it possible to reveal information to an investor without revealing it to competitors (see Campbell 1979; Campbell and Kracaw 1980). In Bhattacharya and Ritter (1983), the firm chooses how much information to reveal; it attempts to reveal its true value to investors and does not reveal all the information that its competitors would like to learn.

12. Here we present the model in terms of a single borrower whose quality is unknown. Equivalently, the model represents a situation in which there are lots of entrepreneurs, a fraction α of which are high-quality ones, and in which investors are unable to tell borrowers apart in terms of quality.

with adverse selection is not necessary for most applications (for which one can therefore ignore private benefits, $B = 0$ in the notation of the book, and thereby remove the moral-hazard component) since adverse selection by itself creates an agency cost and a concomitant credit rationing, and triggers a number of interesting institutional responses. Ignoring moral hazard therefore simplifies the presentation. (In Application 6, however, we will add *ex post* moral hazard in the context of *ex ante* private information about the likelihood of a liquidity shock; in that application, moral hazard will generate a rent from continuation, and *ex post* credit rationing, and thereby create a cost of financing through short-maturity liabilities.) Note also that we assume that the entrepreneur has no cash on hand ($A = 0$), and so she cannot signal her trust in the project by investing her personal wealth into it. Cash on hand will play a key role in Application 8 below.

6.2.1 Market Breakdown and Cross-Subsidization

6.2.1.1 Symmetric Information

To set a benchmark, first consider financing when the investors know the project's prospects.

The good entrepreneur obtains financing. One optimal arrangement[13] for her is to secure the highest level of compensation, R_b^G in the case of success, consistent with investors' breaking even on average:

$$p(R - R_b^G) = I.$$

If $qR < I$, the bad borrower does not want to invest because, under symmetric information, she would receive the NPV, $qR - I < 0$ if she could secure funding. Besides, she cannot obtain financing anyway because the pledgeable income, qR, is smaller than the investors' outlay, I.

If $qR > I$, then the bad borrower receives funding and secures compensation R_b^B in the case of success, where

$$q(R - R_b^B) = I.$$

Clearly,

$$R_b^B < R_b^G.$$

6.2.1.2 Asymmetric Information

The symmetric-information outcome, however, is not robust to asymmetric information, as the bad borrower can, by mimicking the good borrower, derive utility qR_b^G that is greater than that (either 0 or qR_b^B) she obtains by revealing her type.[14]

Let us assume that the only feasible financial contracts are contracts that give the borrower a compensation $R_b \geqslant 0$ in the case of success and 0 in the case of failure. (The validity of this assumption will be discussed in the remark below on the optimality of contracts.) Such contracts necessarily pool the two types of borrower as each prefers receiving financing to not being funded, and conditional on being funded, prefers contracts with a higher compensation. The investors' profit for such a contract is therefore on average:

$$[\alpha p + (1 - \alpha)q](R - R_b) - I = m(R - R_b) - I.$$

No lending: $mR < I$. This case can arise only if the bad borrower is not creditworthy. It then arises whenever the probability that the borrower is a bad borrower is large enough, or

$$\alpha < \alpha^*,$$

where

$$\alpha^*(pR - I) + (1 - \alpha^*)(qR - I) = 0.$$

Because the borrower cannot receive a negative compensation ($R_b \geqslant 0$), investors lose money if they choose to finance the project. Accordingly they do not and the market breaks down.

The good borrower is therefore hurt by the suspicion that she might be a bad one. There is *underinvestment.*

13. Here there is some indeterminacy as to the way the entrepreneur is compensated: the contract can specify any reward $R_b \leqslant R_b^G$ in the case of success, together with, for example, a lump-sum payment (sign-up fee or advances) $T \geqslant 0$ such that investors break even:

$$p(R - R_b) = I + T.$$

Equivalently, the entrepreneur could receive no lump-sum payment up front and receive cash even in the case of failure.

Our choice of contract, in which the borrower receives nothing in the case of failure, will facilitate the comparison with the outcome under asymmetric information.

14. The same lack of incentive compatibility holds *a fortiori* for any of the contracts that are optimal for the good borrower under symmetric information (see the previous footnote), as the reader will check. As we will later observe, the bad borrower is least tempted to choose the good borrower's contract if the latter rewards the borrower only for a good outcome.

Lending: $mR \geqslant I$. This case corresponds either to the situation in which both types are creditworthy or to that in which the bad borrower is not creditworthy but $\alpha \geqslant \alpha^*$.[15]

The borrower's compensation R_b is then set so that investors break even *on average*:

$$m(R - R_b) = I.$$

This implies that, *ex post*, investors make money on the good type ($p(R - R_b) > I$) and lose money on the bad type ($q(R - R_b) < I$): there is *cross-subsidization*.

Note also that

$$R_b < R_b^G$$

(and $R_b > R_b^B$ if the bad borrower is creditworthy). The good borrower is still hurt by the presence of bad ones, although to a lesser extent than when the market breaks down. The good borrower must content herself with a lower compensation (i.e., a higher cost of capital) in the case of success than under symmetric information. Put differently, and interpreting the investors' share as a risky loan with nominal interest rate r such that $R - R_b = (1 + r)I$, then $r > r^G$, where r^G is the rate of interest that the good borrower could obtain under symmetric information: $R - R_b^G = (1 + r^G)I$.

When the bad borrower is not creditworthy, then the outcome is *overinvestment*, as was pointed out in particular by De Meza and Webb (1987), one of the early papers in this literature. Adverse selection (i.e., asymmetric information) reduces the quality of loans.

Remark (a measure of adverse selection). The condition

$$mR \geqslant I$$

can be rewritten as

$$\left[1 - (1 - \alpha)\left(\frac{p - q}{p}\right)\right] pR \geqslant I.$$

We can thus define an index of adverse selection:

$$\chi \equiv (1 - \alpha)\left(\frac{p - q}{p}\right).$$

In the absence of signaling possibility, the good borrowers' pledgeable income, pR, is discounted by the presence of bad borrowers. The discount is measured by the product of the probability of bad types, $1 - \alpha$, times the likelihood ratio, $(p - q)/p$.[16] This discount is the counterpart of the agency cost that obtains under moral hazard (and is equal to the product of the private benefit B divided by the likelihood ratio $(p_H - p_L)/p_H$).[17]

Alternatively, we can measure the cost incurred by the good borrower due to asymmetric information. Instead of receiving the NPV,

$$pR - I,$$

attached to her type, she receives

$$pR_b = p\left(R - \frac{I}{m}\right)$$

or, after some manipulation,[18]

$$pR_b = (pR - I) - \frac{\chi}{1 - \chi} I.$$

Remark (optimality of contracts). Whether the market breaks down or not, a good borrower is hurt by the presence of bad borrowers and therefore would like to separate from bad borrowers if she could. Could she do better than demanding some compensation R_b in the case of success and 0 in the case of failure? Relatedly, could an investor make money by offering a more sophisticated contract to the entrepreneur? The answer to these questions (which are studied in Section 6.5) turns out to be "no" when both types are creditworthy. Intuitively, lending is then efficient and so contractual innovations, keeping investor profitability constant, just amount to redistributing wealth between the good and bad borrowers. A contract that rewards the borrower only in the case of success best reflects the good borrower's comparative advantage, as she is more likely

15. The former situation can be subsumed in the latter one by setting $\alpha^* = 0$.

16. The likelihood ratio can be defined by $(p - q)/p$, $(p - q)/q$, or p/q, indifferently. That $(1 - \alpha)$ enters the measure of adverse selection comes from the fact that good borrowers cannot be distinguished from bad ones in this section. As we will see in Section 6.3, the likelihood ratio, but not the prior α, plays a role in the characterization of a separating equilibrium (the prior plays a role, however, in determining whether the separating equilibrium is unique or dominated by a pooling outcome).

17. The agency cost in the moral-hazard case was expressed in absolute terms while it is here convenient to write it as a fraction of total income so as to let the likelihood ratio appear.

18. Note that this expression holds only when financing can be secured, i.e., when $(1 - \chi)pR \geqslant I$. Under this restriction one indeed checks that $pR_b \geqslant 0$.

to succeed than the bad one. It thereby minimizes the subsidizing of the bad borrower by the good one.

By contrast, when the bad borrower is not creditworthy, the pooling allocation implies overinvestment. It would be more efficient to give a lump-sum payment to bad borrowers to "go away" and accept not to invest; this policy, however, raises concerns about its feasibility (see Section 6.5).

6.2.2 Extensions and Applications

Application 1: Market Timing

Firms tend to issue shares when stock[19] prices are high.[20] As discussed in Section 2.5, there are several possible reasons for this. A commonly advanced one is that adverse selection becomes less relevant during booms.

To see this, let us assume that the probability of success is the sum of the firm's type (p or q, good or bad) and a publicly observable shift parameter $\tau \gtrless 0$ that indexes the firm's, the industry's, or the economy's publicly observable prospects: the probabilities of success are then $p + \tau$ and $q + \tau$ for the good and bad borrowers, respectively. The condition for financing becomes

$$[\alpha(p + \tau) + (1 - \alpha)(q + \tau)]R > I$$

or

$$(m + \tau)R > I.$$

Thus the better the market conditions (the larger τ is), the more likely it is that firms can obtain financing. During booms, the intrinsic value of the project becomes large relative to the lemons problem.[21] The reader will indeed check that the index χ of adverse selection is smaller when market conditions improve.

19. Note that we have not yet distinguished between risky debt and equity. See Application 3 below, though.

20. More generally, equity market timing is the practice of issuing shares at a high price and repurchasing them at a low price. Also, "market timing" sometimes refers to the attempt by borrowers to sell equity when it is overvalued. We here mean that borrowers issue equity during good times.

21. We derived this result in the case of a separable production function (additive in probabilities). More generally, an increase in the average probability of success facilitates financing.

Note also that the more general point is that credit rationing is alleviated during booms, whether it is due to adverse selection or moral hazard.

Application 2: Assets in Place, the Negative Stock Price Reaction, and the Going-Public Decision

Let us next suppose that the entrepreneur already owns a project that, without further investment, will succeed with probability p or q, yielding profit R. As before, the entrepreneur knows the probability of success while the investors put probability α on p and $(1 - \alpha)$ on q. Thus, in the absence of further information (and so the investors' expectation of the probability of success is m), the assets in place are undervalued (respectively, overvalued) if the true probability of success is p (respectively, q).

For computational simplicity, we will assume that the entrepreneur initially owns all shares. But nothing is altered if she owns only a fraction of the shares. By "stock price reaction upon the announcement of an equity issue," we mean the difference between the total value of shares (whoever owns them) before and after the announcement. This notion corresponds to the approach taken by event studies in empirical work.

An equity offering may be motivated by a profitable "deepening investment" (more generally, the key feature is that one cannot contract on the cash flow generated by this investment separately from that generated by assets in place: the incomes generated by the two are intertwined or fungible[22]). At cost I, the probability of success can be raised by an amount τ such that

$$\tau R > I.$$

That is, investing is efficient for both types of borrowers. Note that we assume for the moment that the increase in profitability is uniform across types: the probability of success becomes $p + \tau$ for a good borrower and $q + \tau$ for a bad one.

The entrepreneur, however, has no cash on hand. Accordingly, the full amount I must be raised from investors. The entrepreneur must therefore issue new shares, thereby reducing the fraction of shares she owns.

A key insight is that relinquishing shares to investors is relatively less costly to the borrower with overvalued assets in place (the bad borrower) than to

22. Otherwise, it would be optimal for the good borrower to engage in project finance so as to avoid having to cross-subsidize the bad one.

the borrower with undervalued assets in place (the good borrower). Thus, if the good borrower conducts an equity offering, so does the bad one.

Let us therefore investigate the possibility of an (efficient) pooling equilibrium. The entrepreneur must offer a stake R_l in success to the investors such that

$$[\alpha(p+\tau)+(1-\alpha)(q+\tau)]R_l = I \iff (m+\tau)R_l = I,$$

where, as earlier, $m \equiv \alpha p + (1-\alpha)q$ is the prior mean probability of success. There exists a unique R_l, $0 < R_l < R$, satisfying this condition.

The good borrower, though, can guarantee herself pR by not diluting her stake.[23] Thus, she is willing to issue new shares only if

$$(p+\tau)(R-R_l) \geqslant pR \iff \tau R \geqslant \frac{p+\tau}{m+\tau}I. \quad (6.1)$$

After some manipulation, condition (6.1) can be rewritten to show that the value of investment, $\tau R - I$, must exceed some strictly positive hurdle,

$$\tau R - I \geqslant \frac{\chi_\tau}{1-\chi_\tau}I,$$

where χ_τ is the post-investment index of adverse selection,

$$\chi_\tau = \frac{(1-\alpha)[(p+\tau)-(q+\tau)]}{p+\tau} = \frac{(1-\alpha)(p-q)}{p+\tau}$$

(so $\chi_0 = \chi$).

Condition (6.1) is always satisfied if there is little adverse selection (χ_τ is close to 0) or if the deepening investment is very profitable ($\tau R/I$ is large).

We are thus led to consider two situations:

Pooling equilibrium. If condition (6.1) holds, then both types conduct an equity offering.[24] If the accrual of this deepening investment is anticipated,[25] the total value of shares *before and after* the seasoned equity offering is

$$(m+\tau)R - I.$$

There is no stock price reaction to the offering, which is perfectly anticipated and uninformative.

Separating equilibrium. More interestingly, suppose that condition (6.1) is violated. The good borrower then does not raise funds. The bad borrower still does, but under market conditions that are not as favorable as in a pooling equilibrium. Because the investors know that the equity offering reveals overvalued assets, they demand a higher stake $R_l^B > R_l$ such that

$$(q+\tau)R_l^B = I.$$

The good borrower does not want to raise funds because

$$(p+\tau)(R-R_l^B) < pR \iff \tau R < \frac{p+\tau}{q+\tau}I, \quad (6.2)$$

which holds if condition (6.1) is violated.

The announcement of a seasoned equity offering then leads to a *negative stock price reaction.* The pre-announcement total value of shares is[26]

$$V_0 = \alpha[pR] + (1-\alpha)[(q+\tau)R - I].$$

After the announcement, it becomes

$$V_1 = (q+\tau)R - I.$$

Hence,

$$V_0 > V_1 \iff pR > (q+\tau)R - I.$$

But we know that

$$pR > (p+\tau)\left(R - \frac{I}{q+\tau}\right),$$

and so *a fortiori*

$$V_0 > V_1.$$

23. That this "reservation utility" depends on the borrower's type is the essential difference with the barebones model. Here, in the jargon of incentive theory, "reservation utilities are type-contingent." See Jullien (2000) for the state-of-the-art treatment of adverse selection with type-contingent reservation utilities.

24. This pooling equilibrium is not unique whenever

$$(p+\tau)I/(m+\tau) \leqslant \tau R \leqslant (p+\tau)I/(q+\tau);$$

indeed, if investors believe that an equity offering comes from a bad borrower and $\tau R \leqslant (p+\tau)I/(q+\tau)$, then the good type indeed prefers not to raise funds. However, the pooling equilibrium is the *Pareto-dominant* equilibrium (it is the best equilibrium for both the good and the bad borrower), and so we will focus on it.

Note also that if condition (6.1) holds, then the bad borrower definitely prefers to raise funds since the analogous condition for her is

$$\tau R \geqslant \frac{q+\tau}{m+\tau}I,$$

which is always satisfied.

25. Otherwise, the news of the existence of an investment opportunity by itself raises the value of shares.

26. As in the previous footnote, note that we assume that the investment opportunity is perfectly anticipated by the capital market. Otherwise, the issue of new securities could convey good news about the firm's opportunity set and the concomitant boost in share price might dominate the effect unveiled here.

Combining both cases, we see that the pooling equilibrium (condition (6.1)) is more likely to obtain if the project being financed is more valuable (τ increases or I decreases). We therefore conclude that price reaction on average should be less negative in booms.

Furthermore, and again combining the two cases, *the negative price reaction is smaller when the volume of equity offering, as measured by the amount collected in the offering,*[27] *is large.* Actually, in our example, the price reaction is 0 when both types issue shares. More generally, with a continuum of types, the price reaction is always negative, as long as some types refrain from issuing equity (see Exercise 6.5).

Remark (correlation between value of assets in place and profitability of investment). The analysis can be straightforwardly extended to allow for increases in the probability of success to be positively or negatively correlated with the value of assets in place. Let τ_G and τ_B denote the increases in the probability of success for the good and bad types, respectively. Investors know the values τ_G and τ_B, but do not know which obtains (otherwise they would also know whether the borrower is good or bad if $\tau_G \neq \tau_B$). Assume $p + \tau_G > q + \tau_B$ and so who is a "good borrower" does not vary with investment. The average increase τ is equal to $\alpha\tau_G + (1 - \alpha)\tau_B$. The condition for both types conducting a seasoned equity offering is now

$$(p + \tau_G)\left(R - \frac{I}{m + \tau}\right) \geqslant pR.$$

An increase in correlation corresponds to an increase in τ_G keeping τ constant. Thus, the good borrower is more likely to issue shares, the higher the correlation, as might have been expected.

Remark (going-public decision). Although too simplistic, this model sheds some light on the going-public decision. Think about the firm's resorting to the capital market as a process through which an entrepreneur (or more generally an entrepreneur and a close set of well-informed financiers: venture capitalist, friends, or family holding an equity-like stake) decides to tap further financing and dilute her own stake in order to expand. Then the entrepreneur will tend to remain private when optimistic about the firm's prospects. Of course, the model abstracts from many interesting issues (studied later in the book) associated with the going-public process, such as the certification by an investment banker, the acceptance of strong disclosure requirements, and possibly the loss of control over the firm. But its basic point—that entrepreneurs who feel that assets in place are undervalued by the market tend to forgo profitable investment opportunities and to remain private—is a robust one (see Chemmanur and Fulghieri 1999).

27. This amount is I in the pooling equilibrium and $(1 - \alpha)I$ on average in the separating one.

Application 3: Pecking-Order Hypothesis

An important theme in corporate finance is that adverse selection calls for the issuance of debt claims. As we discussed in the introduction, Myers (1984) and Myers and Majluf (1984) have formulated a pecking-order hypothesis that places debt as the preferred source of external financing. Recall that these authors argue that sources of financing can be ranked according to their information intensity, from low to high information intensity: (1) internal finance (entrepreneur's cash, retained earnings), (2) debt, (3) junior debt, convertibles, and (4) equity.

The pecking-order hypothesis is based on the investors' concern about the value of the claim they acquire. It is clear, for example, that *default-free debt* creates no concern for investors as to the value of their claim. We first provide conditions under which debt is indeed the preferred source of financing under asymmetric information about the firm's prospects,[28] and then discuss the robustness of the pecking-order hypothesis.

As discussed in Chapter 3, there is no distinction between debt and equity claims when the profit is either R or 0. Let us therefore add a salvage value of the assets R^F: the profit in the case of failure is $R^F > 0$ and that in the case of success is $R^S = R^F + R$, where R still denotes the profit increment. Except for the introduction of a salvage value, the model is

28. We know that under moral hazard and risk neutrality, the entrepreneur should offer a debt contract to investors so as to mitigate the moral-hazard problem (see Sections 3.4 and 3.5). We show that the same point holds under adverse selection, even when there is no moral hazard.

otherwise that of Section 6.2.1: there are no assets in place. The investment cost I must be entirely defrayed by the investors. The probability of success is p for a good borrower (probability α) and q for a bad one (probability $1-\alpha$). The prior mean probability of success is $m \equiv \alpha p + (1-\alpha)q$.

Let us assume that

$$mR^{\mathrm{S}} + (1-m)R^{\mathrm{F}} > I$$

and so there is enough pledgeable income to secure funding even when the bad borrower pools with the good one.

Let $\{R_{\mathrm{b}}^{\mathrm{S}}, R_{\mathrm{b}}^{\mathrm{F}}\}$ denote the (nonnegative) rewards of the borrower in the cases of success and failure. Assuming that the borrower receives funding, the investors' breakeven condition is

$$m(R^{\mathrm{S}} - R_{\mathrm{b}}^{\mathrm{S}}) + (1-m)(R^{\mathrm{F}} - R_{\mathrm{b}}^{\mathrm{F}}) \geqslant I.$$

The good borrower maximizes her expected payoff

$$pR_{\mathrm{b}}^{\mathrm{S}} + (1-p)R_{\mathrm{b}}^{\mathrm{F}}$$

subject to the breakeven constraint. At the optimum, the investors' breakeven condition is satisfied with equality. It can be rewritten as

$$[p - (1-\alpha)(p-q)](R^{\mathrm{S}} - R_{\mathrm{b}}^{\mathrm{S}}) + [1 - p + (1-\alpha)(p-q)](R^{\mathrm{F}} - R_{\mathrm{b}}^{\mathrm{F}}) = I.$$

The good borrower's utility is then equal to

$$\begin{aligned} pR_{\mathrm{b}}^{\mathrm{S}} + (1-p)R_{\mathrm{b}}^{\mathrm{F}} &= [pR^{\mathrm{S}} + (1-p)R^{\mathrm{F}} - I] \\ &\quad - (1-\alpha)(p-q)[(R^{\mathrm{S}} - R_{\mathrm{b}}^{\mathrm{S}}) - (R^{\mathrm{F}} - R_{\mathrm{b}}^{\mathrm{F}})]. \end{aligned}$$

On the right-hand side of this equality, the first term in brackets represents the NPV of the good borrower, namely, what she would receive under symmetric information. The second term as usual refers to the adverse-selection discount.

The good borrower wants to minimize this discount while satisfying the investors' breakeven constraint.[29] Because the discount increases with $R_{\mathrm{b}}^{\mathrm{F}}$ and decreases with $R_{\mathrm{b}}^{\mathrm{S}}$, the good borrower sets

$$R_{\mathrm{b}}^{\mathrm{F}} = 0.$$

Then, $R_{\mathrm{b}}^{\mathrm{S}}$ is determined by the investors' breakeven constraint:

$$m(R^{\mathrm{S}} - R_{\mathrm{b}}^{\mathrm{S}}) + (1-m)R^{\mathrm{F}} = I.$$

To sum up this analysis, the borrower commits the entire salvage value as safe debt issued to investors. The borrower further issues risky equity with stake $R^{\mathrm{S}} - R_{\mathrm{b}}^{\mathrm{S}}$ in the case of success (and 0 in the case of failure) so as to make up for the shortfall in pledgeable income:

$$m(R^{\mathrm{S}} - R_{\mathrm{b}}^{\mathrm{S}}) = I - R^{\mathrm{F}}.$$

Thus, the firm first issues safe debt with a debt obligation D given by

$$D = R^{\mathrm{F}},$$

and, second, supplements the capital thus raised through an equity issue entitling shareholders to a fraction R_{l}/R of profits in excess of R^{F}, where

$$mR_{\mathrm{l}} = I - D.$$

Note that the borrower must issue more equity, the more acute the adverse-selection problem (the lower m is) or the higher the investment cost.

Intuitively, the borrower starts by issuing the claim that is least exposed to adverse selection, here the safe-debt claim. Doing so allows the good borrower to *minimize the cross-subsidization* with

29. Alternatively, we can use Lagrangian techniques. Let μ denote the shadow price of the investors' breakeven constraint, and $\mathcal{L}$ the Lagrangian of the program:

$$\mathcal{L} \equiv pR_{\mathrm{b}}^{\mathrm{S}} + (1-p)R_{\mathrm{b}}^{\mathrm{F}} + \mu[m(R^{\mathrm{S}} - R_{\mathrm{b}}^{\mathrm{S}}) + (1-m)(R^{\mathrm{F}} - R_{\mathrm{b}}^{\mathrm{F}}) - I].$$

Then

$$\frac{\partial \mathcal{L}}{\partial R_{\mathrm{b}}^{\mathrm{S}}} = p - \mu m \quad \text{and} \quad \frac{\partial \mathcal{L}}{\partial R_{\mathrm{b}}^{\mathrm{F}}} = (1-p) - \mu(1-m).$$

Because

$$\frac{p}{m} > 1 > \frac{1-p}{1-m},$$

necessarily,

$$\frac{\partial \mathcal{L}}{\partial R_{\mathrm{b}}^{\mathrm{F}}} \geqslant 0 \quad \text{implies that} \quad \frac{\partial \mathcal{L}}{\partial R_{\mathrm{b}}^{\mathrm{S}}} > 0,$$

and, conversely,

$$\frac{\partial \mathcal{L}}{\partial R_{\mathrm{b}}^{\mathrm{S}}} \leqslant 0 \quad \text{implies that} \quad \frac{\partial \mathcal{L}}{\partial R_{\mathrm{b}}^{\mathrm{F}}} < 0.$$

Thus we are led to consider two cases (the second is studied only for the sake of completeness): (i) $\partial\mathcal{L}/\partial R_{\mathrm{b}}^{\mathrm{F}} < 0$ (the most interesting case). Then $R_{\mathrm{b}}^{\mathrm{F}} = 0$. (ii) $\partial\mathcal{L}/\partial R_{\mathrm{b}}^{\mathrm{F}} \geqslant 0$. In this case, $\partial\mathcal{L}/\partial R_{\mathrm{b}}^{\mathrm{S}} > 0$. And so, if there is no bound on $R_{\mathrm{b}}^{\mathrm{S}}$, $R_{\mathrm{b}}^{\mathrm{S}}$ must be increased as much as possible (and $R_{\mathrm{b}}^{\mathrm{F}}$ must decrease accordingly to keep the breakeven constraint satisfied) until $R_{\mathrm{b}}^{\mathrm{F}} = 0$, in which case we are back to case (i). But it is probably more reasonable to add the constraint that $R_{\mathrm{b}}^{\mathrm{S}} \leqslant R$. Otherwise, the borrower could in the case of failure borrow R from a third party and reimburse this third party from the reward, $R_{\mathrm{b}}^{\mathrm{S}}$, received from the apparent "success." Thus, case (ii) corresponds to the uninteresting case in which $I < R^{\mathrm{F}}$, that is, the investment is "self-financing." In this case, the entrepreneur issues only safe debt. The pecking order still applies, although in a rather trivial way.

the bad borrower. The more sensitive the investors' claim to the borrower's private information, the higher the return that the investors demand from a good borrower to make up for the money they lose on the bad one. As we will observe in Section 6.3, *this principle of issuing low-information-intensity claims carries over to situations in which the good borrower has the means, and not only the incentive, to separate from the bad one.*

How robust is the debt bias to the specification of the income space? Section 6.6 considers the case of a *continuum* of possible incomes. It builds on Innes (1990, see Section 3.5) and DeMarzo and Duffie (1999).[30] It derives conditions (basically, the conditions obtained by Innes in the moral-hazard, no-adverse-selection setup)[31] under which a good borrower separates from a bad one by offering a standard debt contract.

Are low-information-intensity claims always debt claims? The debt bias principle must be qualified in four important respects:

Insurance. First, forces other than signaling may alter the nature of the securities issued. This point is well illustrated by the Leland–Pyle–Rothschild–Stiglitz model of diversification by a risk-averse entrepreneur, reviewed in Application 8. We will derive conditions under which the bad borrower obtains full insurance, and even the good borrower is partially insured. Their contracts cannot therefore be viewed as insider equity contracts.

Exit strategy. Second, and more interestingly, the issue may not only serve the "*ex post*" goal of obtaining the best possible terms for the issuer at the issuing date. The issue may also reflect an "*ex ante*" objective of providing the issuer with good incentives to create value before the issuing date. As we alluded to in Section 4.4 and will emphasize in Chapter 9, it may then be optimal for the issuer to commit to float information-intensive securities because such securities induce value measurement by the market and allow insiders to be compensated for their past performance; that is, the floating of information-intensive securities enables partial or full exit strategies.

Nature of informational asymmetry. Third, what constitutes a low-information-intensity claim depends on the form of informational asymmetry. We have seen that, when information relates to the probability of success, signaling tends to result in the issuance of a standard debt contract.

Suppose that the asymmetry of information is also related to the *riskiness* of the distribution, and that the good borrower has a less risky distribution than the bad one. Then it is clear that a debt contract may no longer reflect the good borrower's comparative advantage; for, the debt contract provides the bad borrower with a substantial rent when the income is very high.

To illustrate this point in a trivial manner, suppose that there are three possible levels of income: low, middle, and high. A good type always obtains the middle income. A bad type obtains either the low or the high income. The firm's expected income is higher for the good type. The good type then signals herself by issuing a claim that distributes everything to investors when the firm's income is either low or high, but less than the firm's income when the firm obtains the middle income. Such a claim, which may not violate the monotonicity of the investors' claim with the firm's income, does not resemble a debt claim because it distributes the firm's income to investors when income is high.

A more sophisticated illustration of the principle that low-information-intensity securities need not be debt claims is Stein's (1992) rationalization of convertible bonds as reducing the investors' exposure to low-profitability, high-risk borrowers when the former observe signals about the borrower's type after purchasing the securities.

Rent extraction. We have assumed that the entrepreneur or manager faces a competitive financial market. Investors cannot then attempt to extract the good borrower's rent. The pecking-order hypothesis

30. DeMarzo and Duffie consider a "hidden-knowledge" model rather than an "adverse-selection" one (that is, the issuer learns her information *after* the contract is signed) and look at a variable investment scale. They also make an assumption that is weaker than the monotone likelihood ratio property assumed in the appendix.

Other papers that argue that debt contracts are a natural response to adverse selection include Allen and Gale (1992) and Nachman and Noe (1994), which both use Banks and Sobel's (1987) "divinity refinement" to select pooling at a debt contract. For more on security design under adverse selection, see, in particular, Boot and Thakor (1993) and Demange and Laroque (1995).

31. For readers who have covered Section 3.5, the optimality of a debt claim for investors depends on the assumption that the investors' claim is monotonic.

actually states that the good borrower maximizes this rent by issuing low-information-intensity securities, thereby minimizing the cross-subsidization of the bad borrower.

Suppose in contrast that investors have some market power. For example, they may have control over the managerial position; or a venture capitalist or a large investor might have a smaller informational handicap vis-à-vis the borrower than other investors. Then the investors will want to extract some of the good borrower's rent. Rent extraction is best performed when the borrower's stake is least sensitive to her private information—the case of a fixed compensation[32]—that is, when the investors' stake (which is complementary to that of the borrower) is derived from *high*-information-intensity securities!

Of course, providing the borrower with a fixed stake, namely, a wage that is not contingent on performance is not desirable when the borrower must exert effort. There is then an incentive-rent extraction tradeoff (see Laffont and Tirole 1986). Furthermore, there is now scope for separation: confident borrowers will tend to select high-powered incentive schemes along the lines of the pecking-order hypothesis, while less confident ones will go for safer compensation (higher fixed wage, lower volume of stock options). To use an analogy, regulated utilities that are confident in their ability to reduce cost tend to choose price caps or sliding-scale plans rather than low-powered cost-of-service regulation.[33]

6.3 Dissipative Signals

Section 6.2 focused on environments in which good borrowers could not separate from bad ones (except by forgoing profitable investment opportunities, when there are assets in place). In practice, borrowers often try to convey the quality of the securities they issue through "dissipative signals"; these dissipative signals are the counterpart in an adverse-selection context of the "value-decreasing concessions" in the moral-hazard context. This section describes some frequently used dissipative signals, without any attempt at exhaustivity.

Application 4 considers the reduction in the asymmetry of information between borrower and lenders through the costly certification by an informed investor or other party or through a disclosure policy. Applications 5–9 then analyze how the good borrower may try to signal her residual private information (that is, the information that is still private after certification and disclosure) through financial structure choices. The key theme in those applications is that, in order to separate, the good borrower must offer contractual terms that do not appeal to a bad one and allow lenders to break when they know that they are facing a good borrower. This will lead us to the general principle that, as in the pecking-order theory, the response to the lemons problem is the issuance of low-information-intensity securities, i.e., securities for which investors are not "too exposed" to errors in their assessment of the borrower's type.[34]

Application 4: Certification

As we have seen, adverse selection in general leads to cross-subsidization or market breakdown, which are costly to good borrowers or issuers. Therefore, good issuers have an incentive to try to mitigate the investors' informational disadvantage. The asymmetry of information can be reduced through disclosure to investors of information about the firm's prospects. Another form of disclosure bears on past repayments (see Exercise 6.7, based on Padilla and Pagano (1997), on information sharing among lenders). But, while disclosure is not to be neglected, it is most effective for "hard information," that is, information that can be verified by the investors once disclosed by the issuer.[35] Disclosure is a less effective

32. Using the notation of Application 3, the borrower's utility is $\theta R_b^S + (1-\theta)R_b^F$, where $\theta \in \{p, q\}$. The derivative of this utility with respect to θ is $R_b^S - R_b^F$. And so the utility (rent) grows most slowly (actually not at all) with the borrower's type when $R_b^S = R_b^F$.

33. Yermack (1997) analyzes stock option awards to CEOs of large U.S. corporations between 1992 and 1994. He finds that the average cumulative abnormal stock return in the 50 days following the award is slightly above 2% (the award is not disclosed until several months after the fiscal year ends, so the market cannot react to the news of a more incentivized CEO). Yermack's interpretation is that managers who receive private information about impending improvements in corporate performance may influence compensation committees towards more performance-based compensation. The story is thus a bargaining analog of the compensation-menu theory just alluded to.

34. This definition of a low-information-intensity security is vague. The supplementary section gives a general and rigorous definition. Besides, what constitutes a low-information-intensity security will become clear in specific applications.

35. See Grossman (1980), Grossman and Hart (1980), Milgrom (1981), and Milgrom and Roberts (1986) for the theory of disclosure.

means of reducing informational asymmetries if the information is "soft," that is, cannot be verified by the investors.

Lending by an informed party (whether a bank, a peer, or a trade creditor) is a signal that the informed party is confident about the possibility of repayment. Such "informed lending" is therefore likely to bring along less well-informed investors.[36] Monitoring will be studied in depth in a moral-hazard context in Part III of this book. Let us here mention that similar ideas have been developed in an adverse-selection context; for example, Ghatak and Kali (2001) analyze "positive associative matching" in a world of joint liability (see also Section 4.5 of this book); when entrepreneurs are made liable for the loans issued to other entrepreneurs through cross guarantees, good borrowers have a strong incentive to associate themselves with a safe partner.

More generally, issuers can reduce informational asymmetries by borrowing from well-informed investors or by asking them to certify the quality of the issue. There is a large variety of certifying agents: underwriters,[37] rating agencies, auditors, venture capitalists. Of course, it must be the case that the certifying agent has an incentive to become well-informed about the firm's prospects and to take actions that properly convey their information to the prospective investors. The "actions" can be a rating, a report, or a subscription to the issue (or, in the case of a venture capitalist, the action of keeping a non-negligible stake in the firm).[38] And, in all cases, reputation helps keep the certifier honest (indeed, reputation is the only such incentive for a rating agency, which does not take a stake in the firm). We refer to Baron (1982), Raviv (1989), and Chapter 9 for a discussion of monitors' incentives. Here we content ourselves with a simple analysis in which the certification is modeled in reduced form as the purchase, at cost $c > 0$, of a signal that perfectly reveals the borrower's type.

Recall that in the privately-known-prospects model (without assets in place) and in the absence of certification, funding, if any, implies an entrepreneurial reward R_{b} in the case of success given by

$$m(R - R_{\mathrm{b}}) = I,$$

where $m = \alpha p + (1 - \alpha)q$ is the prior mean probability of success. Let us assume that $mR > I$ and so funding is indeed feasible; the good borrower is then concerned by cross-subsidization.[39]

Suppose that at cost c, the borrower can have access to a reputable certifier who then provides accurate evidence regarding the quality of the project; that is, other investors will then know whether the borrower's probability of success is p or q.[40] (Note that the borrower has no cash to pay the certifier up front. One can imagine that the borrower gives the certifier shares in the firm; these shares can further ensure that the certifier will incur the monitoring cost (see Chapter 9).)

A bad borrower obviously has no incentive to pay a cost c to reveal to the capital market that the probability of success is only q. By resorting to a certifier,

A key insight of this literature is that hard information is, under weak conditions, disclosed if it is known to be held by the issuer. The intuition is that a good issuer benefits from disclosing and thus discloses. An average issuer must then disclose not to be pooled with bad ones. And so even a bad issuer can disclose. A limitation on disclosure occurs when the issuer may or may not have the hard information. An issuer with bad information may then claim not to have any information (see, for example, Tirole (1986) and Okuno-Fujiwara et al. (1990) for models with this feature).

These models assume that information once disclosed is assimilated by investors. Fishman and Hagerty (2003) study an interesting model of disclosure in which a fraction of investors do assimilate the disclosed information while the remaining fraction only observe that there has been disclosure. They show that there may be an equilibrium with no voluntary disclosure, that investors, but not issuers, should support mandatory disclosure, and that mandatory disclosure rules are more likely with regards to information that is difficult to understand.

Finally, Dewatripont and Tirole (2005) study the efficacy of communication that is neither hard nor soft in that its understanding by the receiver depends on the sender's and the receiver's efforts to communicate, which in equilibrium depend on the congruence of their objectives.

36. See, for example, Rochet and Tirole (1996a,b) for investigations of this idea in the context of interbank loans.

37. In the United States underwriters are employed in over 80% of the offerings (Smith 1977). In contrast, according to Marsh (1979), 99% of the new equity in the United Kingdom in the mid 1970s was raised through rights offers (in which current shareholders receive a right from the firm giving them an option to purchase additional shares at a prespecified price).

38. There is, for example, a large empirical literature on certification in initial public offerings. See, for example, Megginson and Weiss (1991) and the references therein.

39. What follows holds *a fortiori* in the "no lending" case. In this case, the good borrower receives 0 in the absence of certification. Hence, provided that certification is feasible (i.e., $pR \geqslant I + c$), the good borrower will be certified.

40. Exercise 6.6 allows for noisy signals about borrower quality.

a good borrower can obtain compensation $\hat{R}_b^G$ in the case of success given by

$$p(R - \hat{R}_b^G) = I + c.$$

The good borrower prefers to resort to a certifier if and only if[41]

$$\hat{R}_b^G > R_b \iff R - \frac{I + c}{p} > R - \frac{I}{m},$$

or, after some manipulation,

$$\frac{c}{I + c} < (1 - \alpha)\left(\frac{p - q}{p}\right).$$

This latter condition compares the certification cost, c, expressed as a fraction of the amount of funds to be raised, $I+c$, with our measure of adverse selection χ, which, recall, is equal to the probability of a bad type, $1 - \alpha$, times the likelihood ratio, $(p - q)/p$.

Chemmanur and Fulghieri (1994) argue that the cost of diversification "c" may be the lack of diversification of the certifier when the latter, unlike here, is risk averse. They consider a firm's decision to raise external finance either by placing shares privately with a risk-averse large investor such as a venture capitalist or selling shares to a wider constituency, for example, through an IPO, assuming that information acquisition is needed to raise funds. The issuer then trades off the risk premium demanded by the large investor, and the duplication of information under decentralized monitoring in a wider capital market.[42]

Application 5: Costly Collateral Pledging

This section studies the possibility of signaling by pledging collateral (Besanko and Thakor 1987; Bester 1985, 1987; Chan and Kanatas 1985).[43] It builds on the idea, already exploited in Chapter 4, that collateral is valued less highly by the lenders than by the borrower. It shows how a borrower may want to pledge collateral, even though she would not need to do so if information were symmetric. To give the gist of the argument in the simplest possible setting, we extend the privately-known-prospects model as follows: while the borrower still has no cash on hand (in the notation of previous chapters, $A = 0$), she has (a sizeable amount of) assets that can be pledged to investors. That such assets are more valuable to the borrower than to the investors (see Section 4.3 for a fuller discussion), is formalized in the usual way: a transfer of assets valued $C \geqslant 0$ by the borrower has value βC, $0 \leqslant \beta < 1$, for the investors.

Assumption 6.1. *Under symmetric information even the bad borrower does not need to pledge collateral to receive funding:*

$$0 < \tilde{V} \equiv qR - I < V \equiv pR - I.$$

Symmetric information. If the lenders knew the borrower's prospects, the borrower's utility would be equal to the project's NPV, V for the good borrower and $\tilde{V}$ for the bad one, since the project has positive NPV and the entire income is pledgeable (see Section 3.2). To obtain utility V under symmetric information, the good borrower would demand a reward R_b^G in the case of success such that lenders break even when the probability of success is p:[44]

$$p(R - R_b^G) = I.$$

Indeed, her utility would then be equal to

$$pR_b^G = pR - I = V.$$

41. To be more precise, multiple equilibria coexist over a range of parameters, namely,

$$(1 - \alpha)\left(\frac{p - q}{p}\right) \leqslant \frac{c}{I + c} \leqslant \frac{p - q}{p}.$$

Then, "no certification" and "certification of the good borrower only" are both equilibria (there also exists a third equilibrium, in which the good borrower randomizes between being certified and not being certified). The equilibrium is unique only if we focus on *Pareto-dominant* equilibria. In the range with multiple equilibria, both types are better off if the good borrower does not get certified (the "no certification" equilibrium) as the lack of certification then carries no stigma.

42. Lerner and Tirole (2005) analyze forum shopping, that is, the choice of congruence between the certifier on the one hand and the certified agent (here, the issuer) and the buyers (here, the investors) on the other. In the financial context of investment banking, relationship banking, venture capital, or ratings, the congruence is determined by the financial stake, if any, of the certifier in the issuer and by the certifier's willingness to attract future issuers' business. In the basic model, the issuer has no private information about the quality of issued securities; the issuer chooses a level of congruence as well as concessions made to investors (for example, price, collateral pledging, or control rights) and the certifier studies the quality. Issuers with *a priori* more attractive offerings choose more complacent certifiers and make fewer concessions. When the issuer has private information (that is correlated with the certifier's future assessment), then in a separating equilibrium, confident issuers (the "good borrowers") select tougher (less complacent) certifiers than under symmetric information, and also tougher ones than less confident issuers.

43. See Coco (2000) for a survey of the use of collateral.

44. Again, this contract is not uniquely optimal. Any compensation scheme that lets the investors break even and does not give a negative income to the borrower in any state of nature is optimal.

Similarly, under symmetric information the bad borrower would demand R_b^B such that

$$q(R - R_b^B) = I,$$

and would obtain utility

$$qR_b^B = qR - I = \tilde{V}.$$

Note that

$$R_b^G = \frac{V}{p} \quad \text{and} \quad R_b^B = \frac{\tilde{V}}{q}.$$

Asymmetric information. As before, when the lenders do not know the borrower's type, the good borrower can no longer obtain her full information utility: if the good borrower were to get financing when demanding reward $R_b^G = V/p$, the bad borrower would want to mimic this demand and obtain utility

$$qR_b^G = qR - \frac{q}{p}I > qR - I = \tilde{V}.$$

That is, by mimicking the good borrower, the bad borrower could reduce her payment to investors and increase her own expected return. The investors, however, should anticipate this "pooling behavior" and refuse to lend since

$$[\alpha p + (1-\alpha)q](R - R_b^G) < I.$$

Can the good borrower credibly signal her type by pledging costly collateral C to be seized by the lenders in the case of failure? That is, can she offer contractual terms that do not appeal to a bad borrower and allow lenders to break even when they know that they face a good borrower? We look for a "separating equilibrium" (we will later ask whether there can be other equilibrium allocations). Consider thus the problem of choosing a reward R_b and an amount of collateral C to be pledged by the good borrower in the case of failure subject to the lenders' breaking even when the corresponding probability of success is p, and to the bad borrower's not wanting to offer contractual terms $\{R_b, C\}$. Note that we assume that the good borrower offers no collateral in the case of success; we will later check that this is indeed the case. Intuitively, posting collateral in the case of success is more costly to a good than to a bad borrower because the good borrower is more likely to succeed, and so such a bond is not a good separating device.

A bad borrower, who in equilibrium is recognized by the lenders, must obtain utility $\tilde{V}$: she cannot obtain more while being funded, and, on the other hand, she can guarantee herself $\tilde{V}$ by pledging no collateral and demanding her full-information reward R_b^B in the case of success,

$$q(R - R_b^B) = I.$$

The lenders then take no risk in lending to the borrower since at worst the borrower is a bad borrower and the lenders still break even.

So, consider the following program, which maximizes the good borrower's utility subject to the constraints that the investors break even when recognizing a good project and that the bad borrower does not want to mimic the good one:

$$\max_{\{R_b, C\}} \{pR_b - (1-p)C\}$$

s.t.

$$p(R - R_b) + (1-p)\beta C \geqslant I,$$

$$qR_b - (1-q)C \leqslant \tilde{V}.$$

Both constraints in this program must be binding. If the "mimicking constraint" that the bad borrower does not want to offer contractual terms $\{R_b, C\}$ were not binding, the good borrower would choose $R_b = R_b^G$ and $C = 0$, which, we know, would induce mimicking. The breakeven constraint must also be binding.[45]

The two constraints thus define two equations with two unknowns, yielding, after some computations,

$$R_b^* = R - \left[\frac{(1-q) - \beta(1-p)}{p(1-q) - \beta q(1-p)}\right] I > R_b^G \qquad (6.3)$$

and

$$C^* = \frac{I}{1 + q(1-p)(1-\beta)/(p-q)} > 0. \qquad (6.4)$$

It is also straightforward to show that the good borrower is better off offering these costly contractual terms and being recognized as a good type than being thought of as being a bad type:

$$pR_b^* - (1-p)C^* > pR_b^B \qquad (6.5)$$

45. Otherwise C and R_b would go to infinity while

$$\frac{dR_b}{dC} = \frac{1-q}{q},$$

but this would violate the breakeven constraint.

(which we already knew, since contractual terms $\{R_b = R_b^B,\ C = 0\}$ satisfy the constraints of the program).[46]

Signaling can occur here because it is *relatively* more costly for a bad borrower to pledge collateral than for a good one to. Again, the cost of pledging collateral is higher for a bad borrower, while a higher reward R_b in the case of success is valued more by a good borrower than by a bad one since $p > q$. (The reader knowledgeable in information economics will here recognize that the "Spence–Mirrlees" or "sorting" condition is satisfied.)

Determinants of collateralization. Condition (6.4) implies the following.

- The good borrower must pledge more collateral when collateral pledging becomes cheaper for the borrower ($\partial C^*/\partial\beta > 0$). That is, for β high, the borrower must pledge substantial amounts of collateral. (Recall that we have assumed that the borrower has a "sizeable amount of assets." If this is not the case, the good borrower may not be able to signal her type as well as is described here.)
- The good borrower must pledge more collateral, the stronger the asymmetry of information ($\partial C^*/\partial q < 0$). Here, keeping p constant, consider the impact of a decrease in q (keeping Assumption 6.1 satisfied, though) on the level of collateral. Investors are more concerned by the borrower's type when q is small; in contrast, C^* tends to 0 (and R_b^* to R_b^G) when q tends to p, as we would expect.

Note, however, that this positive covariation between collateralization and informational asymmetry holds under the assumption that both types are creditworthy in the absence of collateral (Assumption 6.1). Suppose in contrast that a bad borrower never succeeds: $q = 0$.[47] Then the good borrower does not need to pledge any collateral in order to signal her type. So, the positive covariation between collateralization and informational asymmetry, which is a nice testable implication of the theory, does not hold in general. Its testing requires some conditioning, whose validity may be difficult to assess empirically.

Lastly, let us note another testable implication of the theory: good borrowers pledge more collateral than bad ones (here, the bad borrower pledges no collateral at all). This testable implication is fragile as well, since we know from Section 4.4 that, under symmetric information and moral hazard, it may be the case that only a bad borrower pledges collateral; for, a borrower may need to make up for his lack of pledgeable income by offering some costly collateral. So, the positive covariation between the project's NPV and the degree of costly collateralization is contingent on the source of the agency cost (adverse selection rather than moral hazard). The empirical evidence (Berger and Udell 1990; Booth 1992) tends to support the view that good borrowers post less collateral.

Full analysis. The analysis above is incomplete in two respects.

First, we implicitly assumed that the only way for a good borrower to separate from a bad one is to offer some costly collateral in the case of failure. Could the borrower signal her type in other ways? Other departures from the symmetric-information contract are (i) a random probability of financing of the investment, (ii) a positive amount of collateral in the case of success, and (iii) a positive reward for the borrower in the case of failure. Intuitively, the borrower's offering to receive a reward in the case of failure should make the investors suspect that the borrower has a high probability of failure and thus should not be a good signaling device. Neither should a random probability of financing be, since a good borrower values undertaking the project more than a bad one. Finally, and as we have already argued, a positive collateral in the case of success is less costly to a bad type than to a good type and is thus not a good signaling device. Section 6.7 allows for the possibility of separating via means other than collateral pledging. It shows that it is indeed efficient for the good borrower to pledge collateral in

46. The good type offering $\{R_b^*, C^*\}$ and the bad type offering $\{R_b^B, 0\}$ is therefore a (perfect Bayesian) equilibrium. To complete the description of this separating equilibrium, specify, for example, that any "off-the-equilibrium-path" contract, that is, any contract that differs from these two contracts, is perceived by the capital market as emanating from the bad borrower.

47. $q = 0$ is admittedly an extreme case because the bad borrower does not strictly gain from pooling with the good borrower even in the absence of collateral pledging. But the reasoning holds more generally for q small.

the case of failure, if she wants to separate from the bad one.[48]

Second, we have not yet investigated uniqueness. There might exist other separating, pooling, or hybrid equilibria. Section 6.7 shows that the allocation $\{R_b^*, C^*\}$ for the good type and $\{R_b^B, 0\}$ for the bad type is the unique (perfect Bayesian) outcome when the capital market's prior belief that the borrower is good is lower than some threshold, that is, if and only if[49]

$$\alpha \leqslant \alpha^* \quad \text{for some } \alpha^*,\ 0 < \alpha^* < 1.$$

Remark (signaling through weak entrenchment). As was shown in Section 4.3.6, "posting one's job as collateral" is formally akin to posting more familiar forms of collateral. Assume that the manager has private information about her quality rather than about the quality of the current project. A good manager would like to convey her information to investors. Because a good manager is more likely than a bad one to deliver a high performance and see her appointment renewed, she can use a low degree of entrenchment, in the sense of a low protection against managerial turnover, to signal her quality. In practice, the composition of the board of directors and the design of takeover defenses affect the ease with which shareholders can remove existing management. Furthermore, managerial turnover is (both theoretically and empirically) associated with bad news about firm performance. In this context, a good manager, who is less likely to fail, bears a lower cost from jeopardizing her job in the case of failure than a bad one. Thus, weak protection against managerial turnover is an effective signaling device.

The previous analysis of collateral pledging showed that a good borrower both demands a higher reward R_b in the case of success and posts a higher level of collateral in the case of failure. Relabeling the variables, the analysis thus also predicts a *negative covariation between managerial equity and job protection*: a confident manager will opt both for low job protection, as we just argued, and high-powered incentives (i.e., high sensitivity of compensation to performance).[50] This prediction seems to be supported empirically; in particular, Subramanian et al. (2002) find that managers with the steeper incentives are also more likely to be fired after a poor performance.

Application 6: Short-Term Maturities

Chapter 5 showed that firms that generate too little cash flow to meet their liquidity needs do not want to adopt a wait-and-see attitude but rather should secure resources early on in order not to face credit rationing at intermediate stages. This section shows that in a situation of asymmetric information about the firm's prospects, a firm may want to signal its creditworthiness by securing less resources (liquidity) for the future than would be efficient under symmetric information. In essence, a good borrower can convey that she is confident about the firm's prospects and that she is not afraid of going back to the capital market at an intermediate stage.

Let us consider the following variant of the model of debt maturities set up in Section 5.2. At date 0 the entrepreneur has a project of fixed size I, has wealth A, and must borrow $I - A$. At date 1, the investment yields a deterministic and verifiable short-term (date-1) profit $r > 0$. With probability λ, continuation requires reinvesting ρ (the liquidation value

48. Technically, the separating allocation $\{R_b^*, C^*\}$ for the good type and $\{R_b^B, 0\}$ for the bad type is the "low-information-intensity optimum," that is, the allocation that maximizes the good borrower's utility subject to the investors' breakeven condition (or, more generally, subject to the capital market not losing money on any type) and to the bad borrower not receiving a rent.

49. Intuitively, the only way for the good type to obtain a higher utility than that of the separating allocation is to relax the mimicking constraint by letting the bad borrower obtain more than $\tilde{V}$ when mimicking. This implies, however, that the investors lose money on the bad borrower (and thus the bad borrower must pool with the good one). The cross-subsidization is, however, costly to the good borrower, as the profit made by investors on the good borrower must offset their loss on the bad borrower times the ratio $(1-\alpha)/\alpha$ of bad to good borrowers.

Note furthermore that the good borrower can guarantee herself the separating payoff pR_b^*. (The following reasoning paraphrases that in the supplementary section for the reader who will have skipped that section.) It suffices that she offers a pair of options $\{R_b^*, C^*\}$ and $\{R_b^B, 0\}$, from which she will choose after the investors agree to finance the project. The investors are guaranteed to break even regardless of the borrower's type, since the good borrower will choose $\{R_b^*, C^*\}$ from (6.5), and the bad borrower will choose $\{R_b^B, 0\}$ from the program above. On the other hand, if α is high, it becomes optimal for the good borrower to pool with the bad one: see Section 6.7 for a description as well as for a computation of the best equilibrium for the good type.

50. This assumes that the manager does not have so much cash on hand that her number of shares allows her to control the board of directors. If this were the case (e.g., as in family firms), then high stakes would also be associated with strong entrenchment.

is equal to 0); with probability $1 - \lambda$, continuation requires no reinvestment.[51]

In the case of continuation, the firm at date 2 yields R in the case of success and 0 in the case of failure. The probability of success is p_H in the case of good behavior and $p_L = p_H - \Delta p$ in the case of misbehavior (which yields private benefit B). Moral hazard is introduced in order to create an entrepreneurial rent from continuation, or, equivalently, a cost for the entrepreneur associated with early termination. Put differently, moral hazard introduces a friction in the date-1 refinancing market. Let

$$\rho_1 \equiv p_H R \quad \text{and} \quad \rho_0 \equiv p_H\left(R - \frac{B}{\Delta p}\right)$$

denote the continuation NPV and pledgeable income, respectively.

Assume that

$$\min\{\rho_1, r\} > \rho > \rho_0.$$

The left inequality states that, viewed at date 1, continuation is always a positive-NPV proposition ($\rho_1 > \rho$) and that the short-term income suffices to meet the liquidity shock ($r > \rho$). The right inequality implies that in the absence of retentions (date-1 income that is not redistributed to investors) or credit line, the borrower cannot meet the liquidity shock by returning to the capital market ($\rho > \rho_0$). Finally, assume that the project cannot be financed in the absence of a positive probability of continuation,

$$I > A + r,$$

and that the project has a positive NPV,

$$r + \rho_1 - \lambda\rho > I.$$

Figure 6.1 summarizes the timing.

Symmetric information. We will consider an asymmetry of information about the probability λ of a liquidity shock. But suppose, first, that the entrepreneur and the investors are symmetrically informed, and that

$$I - A \leqslant r + \rho_0 - \lambda\rho,$$

which implies that investors are willing to finance the project even with certain continuation.

51. As usual, the entrepreneur is risk neutral and protected by limited liability; and the investors are risk neutral and demand a 0 rate of return.

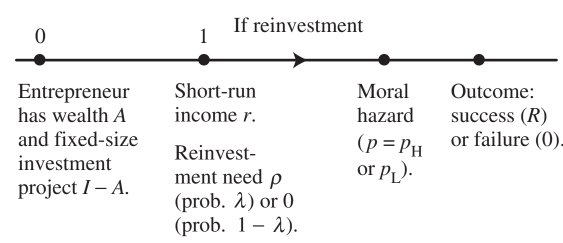

Figure 6.1

Let us show that, under symmetric information, the contract between the investors and the entrepreneur allows the latter to always bring the project to completion, and that this optimum can be implemented by a level of short-term debt

$$d \leqslant r - (\rho - \rho_0),$$

a reinvestment of remaining earnings, if any, in bonds (yielding a zero rate of interest at date 2), a reward R_b for the entrepreneur in the case of success, and the remaining income going to the investors at date 2.

Letting x denote the probability of continuation in the case of a shock, the NPV is

$$U_b = r + [1 - \lambda + \lambda x]\rho_1 - \lambda x\rho - I.$$

Hence, $x = 1$ is optimal. The condition

$$d \leqslant r - (\rho - \rho_0)$$

allows continuation even in the case of a liquidity shock: the borrower can use retentions $(r - d)$ together with what can be raised in the capital market (ρ_0) to meet shock ρ.

Asymmetric information. Assume now that the investors are imperfectly informed about the probability of shock. This probability is

$$\begin{aligned} &\lambda && \text{with probability } \alpha, \\ &\tilde{\lambda} > \lambda && \text{with probability } 1 - \alpha. \end{aligned}$$

The entrepreneur knows which obtains. Assume that even the bad borrower (whose probability of a shock is $\tilde{\lambda}$) can continue with probability 1 under symmetric information:

$$I - A \leqslant r + \rho_0 - \tilde{\lambda}\rho.$$

Thus the good borrower is concerned solely by cross-subsidies to the bad one.

We focus (without loss of generality) on contracts specifying a short-term debt $d \in [0, r]$ at date 1, a reward $R_b^+ \geqslant B/\Delta p$ in the case of no shock and success, and a reward $R_b^- = B/\Delta p$ in the case of a shock, continuation, and success (R_b^+ and R_b^- are the only incomes received by the entrepreneur, who receives nothing in the case of failure or early termination). Intuitively, large rewards R_b^- (i.e., in excess of the incentive payment $B/\Delta p$) in the case of a shock, continuation, and success are relatively more attractive to the bad borrower and so will not be used by the good borrower, who has a relative preference for being rewarded more in the absence of shock. The rationale for focusing on such contracts as well as the equilibrium analysis are provided in Section 6.8. The main predictions of the model are as follows:

(i) In a separating equilibrium the bad borrower gets her symmetric-information allocation and therefore continues with probability $x = 1$. By contrast, the good borrower uses a suboptimally low probability of continuation in order to separate from the bad borrower: $x < 1$. Liquidation is as costly to her as to a bad borrower when a shock occurs but is relatively less costly overall, as the shock occurs less often.

(ii) The good borrower grants herself a higher reward R_b^+ in the absence of a shock and in the case of success than under symmetric information: because she reduces her liquidity hoarding relative to the symmetric-information case, investors are willing to increase her compensation. But, as usual, the good borrower is worse off than under symmetric information; she sacrifices continuation, which is a more efficient "currency," that is, a more efficient form of "payment" to the entrepreneur than monetary compensation (as long as $\rho < \rho_1$ and $R_b^+ \geqslant B/\Delta p$).

(iii) There exists a threshold α^* such that the separating equilibrium described above is the unique equilibrium whenever $\alpha \leqslant \alpha^*$. Other equilibria exist when $\alpha > \alpha^*$; they involve some pooling and are preferred by both types to the separating equilibrium.

Returning to the first implication, the discrete-shock model has a slightly awkward feature: the random probability of continuation in the case of a shock. This can be implemented either through a "random credit line" or, equivalently, through a "random debt": $d \geqslant r - (\rho - \rho_0)$ with probability $1 - x$ (precluding reinvestment in the case of a shock since $\rho + d > r + \rho_0$) and $d < r - (\rho - \rho_0)$ with probability x. In this sense, the debt is larger than under symmetric information (for which $x = 1$). The particular conclusion of a stochastic debt is rather unrealistic, but it is an artefact of the discrete-shock version: with a continuum of shocks (a continuous distribution $F(\rho)$ as in Chapter 5), the *short-term debt* d for the good borrower is deterministic and *larger than under symmetric information* (we leave it to the reader to demonstrate this property).

Relationship to the literature. The idea that short-term debt can be used as a signal of high-quality borrowing, which was first explored in a different context by Diamond (1991, 1993),[52] relates to a more general theme in the economics of adverse selection. Namely, (costly) short-term contracting may be a way of signaling that one is confident about the future and that one does not fear having to recontract at later stages. In Aghion and Bolton (1987), a supplier has superior information about the probability of entry of a competitor and would like to signal that this probability of entry is low in order to obtain better terms of trade when contracting today with buyers. Aghion and Bolton show that the supplier can signal to buyers that entry is unlikely by offering a contract specifying no penalty for breach if the buyer later switches to a different supplier; this is, in essence, a short-term contract. The point is that imposing no penalty for breach is less costly to the supplier when the probability of entry by a rival is small and so the "sorting condition" is satisfied. Hermalin (2002) considers a labor relationship in which a long-term contract between an employer and an employee specifying a penalty for breach induces the employer to provide general purpose on-the-job training to the employee. Hermalin shows that a worker with private information about her talent may want to signal a high talent by offering no

52. Ross (1977) also modeled debt as a signal of quality. Ross's model was not concerned with the maturity structure, but rather with the cost imposed on managers by bankruptcy. Under costly bankruptcy, issuing debt is relatively less costly for a borrower who knows that the probability of low profit is small.

penalty for breach in order to prove that she is not afraid of going back to the labor market, even though such a short-term contract deprives her of on-the-job training. In Diamond (1991), a borrower enters into a short-term borrowing contract in order to signal her creditworthiness. Diamond's model, unlike the one considered here, assumes that cash flows are not verifiable (but they are observable). Diamond shows that borrowers with high (respectively, intermediate, low) ratings use short- (respectively, long-, short-) term debt, where the rating refers to the *ex ante* probability of a good type.[53]

Finally, we have assumed, as elsewhere in this book, that entrepreneurs are rational. Landier and Thesmar (2004) study a competitive credit market in which optimistic and realistic entrepreneurs coexist. To some extent, optimistic entrepreneurs are akin to the confident borrowers (p-borrowers) of our adverse-selection model. Indeed, optimistic borrowers in Landier and Thesmar opt for shorter debt maturities than realistic entrepreneurs, as they (mistakenly) believe that they are unlikely to face difficult circumstances; relatedly, they are more willing to transfer control in such circumstances (for contingent transfers of control, see Chapter 10). Some features are different in a behavioral world, though. First, investors obviously pay the optimistic entrepreneurs "with dreams," yielding abnormally low returns to entrepreneurship (investors, however, do not benefit from the entrepreneurs' irrationality, since competition in the financial market drives investor profits to 0). Second, contracts may end up being contingent on variables that the borrower has no control over, violating a standard principle of agency theory.[54] Landier and Thesmar test their model on French entrepreneurship data and find a positive correlation between optimistic expectation errors (that they measure by comparing reported entrepreneurial expectations on future business growth and actual performance) and the use of short-term debt.

Application 7: Payout Policy

Large and well-established firms distribute a substantial fraction of their earnings in payouts (dividends and stock repurchases). For example, in 1999, U.S. corporations paid \$350 billion in dividends and repurchases, plus an extra \$400 billion on liquidation dividends associated with mergers and acquisitions. Indeed, most firms pay dividends while also raising debt or equity.

Payout behavior exhibits well-known patterns.[55] A key pattern for this chapter is that payout announcements affect stock prices and convey information beyond that contained in earnings announcements. The firm's stock price substantially increases (respectively, decreases) upon the announcement of an increase (respectively, decrease) in payout. This reaction is particularly strong for low-capitalization firms. All this suggests that dividends convey information held by the firm's insiders, but not by the stock market. This application focuses on this pattern and more generally on the *level* of payout; it thereby neglects interesting questions related to the choice of payout *structure* between dividends and share repurchases.[56]

Financial economists have repeatedly argued that dividends are used by a firm's insiders as signals. In particular, Bernheim and Wantz (1995) provide evidence that dividends are often motivated by signaling concerns rather than a disposal of free cash

53. Similar ideas have also been expressed in a screening setup, i.e., a setup in which the uninformed parties make the offers. In particular, in Michelacci and Suarez (2004), firms post employment contracts and learn the workers' abilities only after the workers have taken the job. Fixing the wage in advance has the benefit of eliminating holdup problems associated with bargaining after relationship-specific investments have been sunk by the parties. Alternatively, the firms can leave scope for recontracting or bargaining; this helps them address the adverse-selection problem, as high-ability workers, whose wage is higher under *ex post* bargaining than that of low-ability workers, may find such open-ended contracts more attractive than a fixed-wage contract. As a result, contracts tend to be too open-ended, which reduces aggregate income.

54. Namely, the sufficient statistic theorem (see Chapter 3).

55. See, for example, Allen and Michaely (1995, 2004) for exhaustive overviews and Karpoff and Thorley (1992) for a brief survey of the main facts. A large literature has been preoccupied with the firms' motivation to pay dividends, whether for signaling or for other reasons. Papers in this strand of research include Allen et al. (2000), Araujo et al. (2004), Benartzi et al. (1997), Bernheim (1991), and Healy and Palepu (1988).

56. A well-known puzzle is why corporations have traditionally favored dividends even in countries where the latter are taxed at the ordinary tax rate while share repurchases are taxed on a capital gain basis, which, combined with the ability to postpone the realization of capital gains, results in a lower effective tax rate (share repurchases caught up with dividends in the late 1990s).

Another interesting fact is that dividends are smoother (vary less over time) than share repurchases. Theories of why firms may opt for dissipative dividends include Ofer and Thakor (1987) and Hausch and Seward (1993).

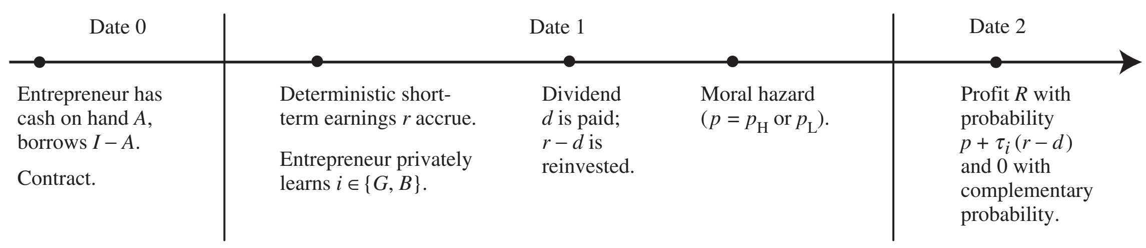

Figure 6.2

flows. While interesting, the theoretical literature on dividends as signals is not without conceptual difficulties, though (accordingly, payout theory is still a little unsettled even though useful insights have already been gleaned): most papers, including the seminal ones (e.g., Bhattacharya 1979; John and Williams 1985; Miller and Rock 1985), assume that (a) managers select dividends and (b) their choice aims at maximizing some weighted average of the firm's current value and its true value. In practice, dividends are announced by the board of directors; and, especially, managers react to the incentives that have been designed for them, and so one cannot address the determination of the payout policy without also investigating that of managerial incentive schemes (Dybvig and Zender 1991).

Consider the tradeoff facing a manager when she proposes to shareholders a level of payouts (let us call these from now on "dividends"). Managers' monetary compensation is directly affected by the payout; how much so depends on how frontloaded or backloaded the managerial compensation scheme is (that is, how aligned it is with the welfare of current versus future shareholders); for example, incentives that would be based on the long-term value of the shares would discourage managers from proposing dividends. Of course, and as was already noted, this front- or backloading is endogenous, and therefore the direct effect can be controlled through the design of the managerial compensation scheme.

Besides this direct effect, dividend distribution also has an indirect impact on managerial welfare to the extent that it conveys information about managerial performance or about the state of the firm. The distribution of dividends may be costly for several reasons (even ignoring tax considerations). First, dividends drain cash out of the firm and therefore reduce the amount that is reinvested or else used as cushion for the future (which, as we know from Chapter 5 or the previous application, are useful when there is a cost of outside finance). Second, it may be costly to gather the cash: for example, illiquid assets with value initially known only by the managers may need to be sold, securitized, or certified creating a dissipative cost. Despite these costs, managers may be under pressure to propose dividends. First, and in a logic similar to that of Application 6, managers may want to signal that they are confident that they will not need a large financial cushion in the future, making the shareholders more prone today to permit the continuation of operations or even to reinvest in the firm. Second, and as we will see in Chapter 7, managers may be keen to use dividends to demonstrate the existence/reality of cash (or valuable assets) when their job is at stake; that is, we would expect firms to disgorge more cash when there is a threat of CEO employment termination.

We will content ourselves with an analysis of dividend payments in a situation described in Figure 6.2, in which the entrepreneur learns information about the marginal benefit of investment and therefore of retained earnings. (A very similar analysis can be performed for the case in which the manager privately observes earnings.)

The model is the standard fixed-investment one. There is no asymmetry of information at the contracting date, date 0. The date-1 earnings r can be used to pay a dividend d or to reinvest J in the firm: $r = d + J$. Reinvestment increases the probability of success by $\tau_i(J)$, where $i \in \{G, B\}$ is privately learned at date 1 by the entrepreneur: $i = G$ with probability α and $i = B$ with probability $1 - \alpha$. A higher reinvestment increases the probability of success:

$$\tau_i' > 0.$$

That $i = G$ corresponds to good news about profitability can be expressed as

$$\tau_G(J) > \tau_B(J) \quad \text{for all } J.$$

For simplicity, we assume that, due to indivisibilities in the reinvestment function,

$$J \in \{0, r\}.$$

That is, it is optimal to reinvest all or none of the earnings. Let us first assume that reinvestment is useful only if $i = B$:

$$[\tau_B(r) - \tau_B(0)]R > r > [\tau_G(r) - \tau_G(0)]R.$$

Moral hazard is described as usual: the entrepreneur chooses between p_H (no private benefit) and p_L (private benefit B).

We look at the case in which the contract involves reinvestment when $i = B$ and none when $i = G$. This will be the case if α is not too large or if the benefits from reinvestment when $i = B$ are substantial.[57]

The NPV is then given by

$$\text{NPV} = \alpha[r + [p_H + \tau_G(0)]R] + (1-\alpha)[p_H + \tau_B(r)]R.$$

Let us first obtain the pledgeable income, assuming as usual that inducing effort is optimal. Let $R_b^r \geqslant B/\Delta p$ and $R_b^0 \geqslant B/\Delta p$ denote the entrepreneur's rewards in the case of success when the entrepreneur distributes dividend $d = r$ and does not distribute any dividend, respectively (the rewards in the case of failure can without loss of generality be set equal to 0). For the entrepreneur to distribute short-term profit r when $i = G$, she must be rewarded with a short-term payment r_b^r when she offers to pay dividend $d = r$. Incentive compatibility relative to dividend payment when $i = G$ requires that

$$r_b^r + [p_H + \tau_G(0)]R_b^r \geqslant [p_H + \tau_G(r)]R_b^0.$$

Conversely, the entrepreneur must choose to reinvest when $i = B$:

$$[p_H + \tau_B(r)]R_b^0 \geqslant r_b^r + [p_H + \tau_B(0)]R_b^r.$$

This latter incentive constraint will later be shown to be nonbinding for the determination of the pledgeable income. The investors' expected gross return is

$$\alpha[(r - r_b^r) + [p_H + \tau_G(0)](R - R_b^r)] + (1-\alpha)[p_H + \tau_B(r)](R - R_b^0).$$

Using the incentive constraint relative to dividend payment when $i = G$ as well as the minimum stake $B/\Delta p$ for the rewards, the pledgeable income, that is, the highest expected income that can be pledged to investors while satisfying the various incentive constraints, is

$$\mathcal{P}^* \equiv \alpha\left[r + [p_H + \tau_G(0)]R - [p_H + \tau_G(r)]\frac{B}{\Delta p}\right] + (1-\alpha)[p_H + \tau_B(r)]\left(R - \frac{B}{\Delta p}\right).$$

Let us now show that a simple incentive scheme specifying managerial equity shares s_1 and s_2 in periods 1 and 2, respectively, induces management to propose the proper state-contingent dividend.

At date 2, the entrepreneur must hold a fraction,

$$s_2 \geqslant \frac{B/\Delta p}{R},$$

of the shares in order to exert effort. Because $r_b^r = s_1 r$, the dividend is paid in state $i = G$ if

$$s_1 r + s_2[p_H + \tau_G(0)]R \geqslant s_2[p_H + \tau_G(r)]R \iff s_1 r \geqslant s_2[\tau_G(r) - \tau_G(0)]R.$$

Thus, s_1/s_2 must exceed some threshold θ^* in order to induce dividend payments:

$$\frac{s_1}{s_2} \geqslant \theta^* \equiv \frac{[\tau_G(r) - \tau_G(0)]R}{r}.$$

This threshold θ^* is lower than 1 since $r > [\tau_G(r) - \tau_G(0)]R$. Conversely, s_1/s_2 should not exceed some other threshold $\theta^{**} > 1$, otherwise there would be a dividend payment even when $i = B$:

$$\frac{s_1}{s_2} \leqslant \theta^{**} \equiv \frac{[\tau_B(r) - \tau_B(0)]R}{r}.$$

Incentives must be properly balanced.[58]

Let us now return to the computation of the pledgeable income. This upper bound on what can

57. Otherwise, the optimal (deterministic) policy would be a mandatory dividend policy ($d = r$), which is equivalent to the existence of short-term debt.

58. We cannot in general conclude whether s_1 should be larger or smaller than s_2. However, in the case in which pledgeable income is very scarce, i.e., when $\mathcal{P}^*$ is only slightly above $I - A$, then $s_1 < s_2$.

be promised to investors while preserving the entrepreneur's incentive to exert effort and to distribute dividends efficiently holds only if the ignored constraint (that relative to the absence of dividend payment when $i = B$) is satisfied. To show that $\mathcal{P}^*$ can be obtained, let

$$s_2 = \frac{B/\Delta p}{R} \quad \text{and} \quad s_1 = \theta^* s_2.$$

Then the investors' expected gross return is indeed $\mathcal{P}^*$ and because $s_1/s_2 < \theta^{**}$, the ignored constraint is indeed satisfied.

Finally, we can illustrate the *positive stock price reaction to a dividend announcement* despite the fact that a dividend signals poor reinvestment prospects, and not only a high value of assets in place. The *ex ante* value of a share is

$$V_0 = \alpha[r + [p_H + \tau_G(0)]R] + (1-\alpha)[p_H + \tau_B(r)]R.$$

Upon announcement of a dividend, the value jumps to

$$V_1 = r + [p_H + \tau_G(0)]R.$$

Thus

$$V_1 - V_0 = (1-\alpha)[r - [\tau_B(r) - \tau_G(0)]R],$$

and so

$$V_1 > V_0 \quad \Longleftrightarrow \quad r > [\tau_B(r) - \tau_G(0)]R.$$

But

$$\tau_B(r) < \tau_G(r) \quad \text{and} \quad r > [\tau_G(r) - \tau_G(0)]R$$

by assumption. Thus, V_1 indeed exceeds V_0 (and conversely upon an announcement of no dividend).

In the case in which reinvestment is profitable only if $i = G$, the stock price reaction to a dividend announcement is *a fortiori* positive, because the dividend then signals both a high value of assets in place and a profitable reinvestment. One can also construct cases, though, in which a dividend announcement is accompanied with a negative stock price reaction. If the capital market is not uncertain about the value of assets in place, and, provided that finding new investment opportunities is not subject to managerial moral hazard and that proper managerial incentives have been designed, then a dividend is a signal that the manager was unable to find an attractive reinvestment opportunity.

Application 8: Diversification and Incomplete Insurance

Leland and Pyle (1977), in one of the pioneering papers in the signaling literature, consider a situation in which a risk-averse entrepreneur has a substantial stake (perhaps the entire stake) in her firm and wants to diversify her portfolio. The issuance of claims is thus not necessarily motivated by the desire to undertake a new project or to expand an existing one. Rather, gains from trade result from risk sharing with investors who are less exposed to the firm's specific risk or have a higher risk tolerance.

Diversification may, however, be costly due to adverse selection. To illustrate this, suppose that investors are risk neutral with respect to the firm's risk, say, because the firm's risk is idiosyncratic (i.e., is specific to the firm and not governed by economy-wide fluctuations) and can be diversified away. Under symmetric information about the firm's characteristics and in the absence of moral hazard, the entrepreneur optimally obtains full insurance and the risk attached to the firm's income is fully borne by the investors. This is, in general, not so under asymmetric information, since investors are concerned that they might be purchasing a "lemon." In a nutshell, a good borrower is willing to bear risk in order to "demonstrate" that she is confident about the firm's prospects. Although imperfect diversification has a cost, it allows a good borrower to obtain a better price for the claims she issues.

We develop the Leland–Pyle model in an optimal contracting framework similar to that of Stiglitz (1977) and Rothschild and Stiglitz (1976). We use the privately-known-prospects model (see Section 6.2), in which the entrepreneur has no initial cash ($A = 0$) and the following twists are added:

- there is no need for financing ($I = 0$), that is, the entrepreneur's resorting to investors is solely motivated by diversification or insurance concerns;
- while the investors are risk neutral, the entrepreneur is risk averse (this is the only time we invoke risk aversion in this chapter); the entrepreneur has increasing and strictly concave utility function $U(w)$, where w is her final wealth.

As in the rest of this chapter, the entrepreneur initially owns the firm entirely and issues claims to investors.

Symmetric information. Under symmetric information about her type, the good borrower would offer to receive income R_b^S in the case of success and R_b^F in the case of failure so as to maximize her utility subject to the investors' breakeven constraint:

$$\max_{\{R_b^S, R_b^F\}} \{pU(R_b^S) + (1-p)U(R_b^F)\}$$

$$\text{s.t.}$$

$$p(R - R_b^S) + (1-p)(-R_b^F) \geqslant 0.$$

As is well-known, the solution to this program provides the entrepreneur with full insurance:

$$R_b^S = R_b^F = R_b^G,$$

where

$$R_b^G = pR.$$

That is, the good entrepreneur receives a constant income equal to the firm's expected income pR.

Similarly, under symmetric information, the bad borrower contracts for a constant income R_b^B given by

$$R_b^B = qR < R_b^G.$$

To summarize the symmetric-information case, the entrepreneur sells out her entire stake in the firm at a price equal to the firm's expected income, pR for the good type and qR for the bad type.[59] The symmetric-information solution is represented by points G and B on the 45° line in Figure 6.3. This diagram depicts allocations in the space of borrower incomes $\{R_b^S, R_b^F\}$. The no-contract outcome is the point R = $(R, 0)$ and is the same for both types.

Asymmetric information. The good borrower can no longer obtain a constant income equal to R_b^G under asymmetric information. If this were so, the bad borrower could guarantee herself a rent equal to $R_b^G - R_b^B = (p-q)R$ over her symmetric-information utility by mimicking the good borrower. Investors would lose $(1-\alpha)(R_b^G - R_b^B)$ on bad borrowers, which they would need to recoup on good ones.

59. Needless to say, the entrepreneur would not sell her entire stake if we reintroduced moral hazard. We ignore moral hazard for expositional simplicity, but the conclusions are robust to its presence.

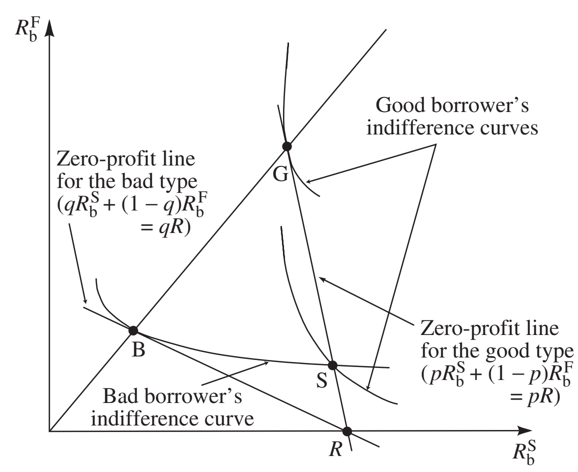

Figure 6.3

Consider now the problem of maximizing the good borrower's utility subject to the investors' breaking even on that borrower, and to the good borrower's allocation not being preferred by the bad borrower to her symmetric-information allocation (that is, to the constraint that the bad borrower obtains no rent over his symmetric-information payoff):

$$\max_{\{R_b^S, R_b^F\}} pU(R_b^S) + (1-p)U(R_b^F)$$

$$\text{s.t.}$$

$$p(R - R_b^S) + (1-p)(-R_b^F) \geqslant 0,$$

$$qU(R_b^S) + (1-q)U(R_b^F) \leqslant U(R_b^B).$$

That both constraints in this program must be binding can be inferred from Figure 6.3. The allocation $\{R_b^S, R_b^F\}$ must be below the bad borrower's indifference curve passing through point B, and below the zero-profit line corresponding to the good borrower. A key property is that the good borrower's indifference curves have higher absolute slopes than the bad borrower's indifference curves at any given point.[60] That is, the good borrower requires a higher

60. At an arbitrary point $\{R_b^S, R_b^F\}$, the slope is equal (in absolute value) to

$$\frac{p}{1-p}\frac{U'(R_b^S)}{U'(R_b^F)}$$

for the good borrower and

$$\frac{q}{1-q}\frac{U'(R_b^S)}{U'(R_b^F)}$$

for the bad borrower.

increase in her income in the case of failure for a given decrease in her income in the case of success to keep her utility constant, compared with the bad borrower. In other words, the good borrower is less eager to obtain insurance because she has a higher probability of success than a bad borrower.

The solution of the program is therefore obtained by taking the intersection of the two constraints and is depicted by point S in Figure 6.3, where "S" stands for "separating" equilibrium. It is indeed an equilibrium for the bad borrower to sell out at price R_b^B and obtain full insurance (that is, choose point B) and for the good borrower to limit her portfolio diversification to point S.[61]

The properties of the separating allocation analyzed above fit with the general theme that a good borrower tries to signal good prospects by increasing the sensitivity of her own returns to the firm's profit. She concomitantly reduces the sensitivity of the investors' return to the firm's profit relative to the symmetric-information optimum.

Determinants of diversification. Keeping p constant, when the bad borrower's probability of success q decreases, point B in Figure 6.3 moves down along the diagonal, and so point S moves away from the full insurance point G and closer to the no-insurance point R $= (R, 0)$ on the investors' zero-profit line for the good borrower, and so the good borrower diversifies less.

Note also that a limited diversification is good news about the firm's prospects since only good borrowers are willing to bear the associated risk. Thus, in a more general model in which the entrepreneur initially owns a fraction of, but not the entire, equity, the news that the entrepreneur sells her entire stake in the firm generates a negative stock price reaction. Put differently, a limited equity offering creates a positive stock price reaction.

Full analysis. A direct application of the results obtained in the supplementary section shows that the allocation $\{S, B\}$, that is, S for the good borrower and B for the bad one, is "interim efficient" if and only if the proportion of good borrowers lies below some threshold α^*, where

$$0 < \alpha^* < 1.$$

Thus, the separating allocation $\{S, B\}$ with suboptimal diversification for the good borrower is the unique (perfect Bayesian) equilibrium for $\alpha \leqslant \alpha^*$.

Application 9: Underpricing

There is substantial evidence of underpricing in IPOs and SEOs.[62] There are multiple interpretations for this underpricing (see Ritter (2003) for an overview). The most common one, mentioned in the introduction to this chapter and in Section 2.4.2, refers to a specific design for selling the securities combined with asymmetric information among investors, giving rise to a concern about the "winner's curse." Another theory suggests that underpricing stems from collusion between the investment bank underwriting (and thereby certifying) the issue and institutional investors against naive entrepreneurs.[63] This section develops a signaling explanation.

Underpricing is a most primitive signaling device, used only when a good borrower does not have cheaper means of setting herself apart from a bad one.

We illustrate the possibility of underpricing in a model in which only good borrowers are creditworthy under symmetric information. The model is the privately-known-prospects model, except that we assume that the borrower initially has cash A ($A > 0$ will play an important role in the signaling behavior, as we will see), and the following.

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61. To avoid the possibility that either type prefers to offer an allocation outside $\{B, S\}$, it suffices to specify that such an allocation would generate the belief that the borrower is a bad borrower.

62. See, for example, Ibbotson (1975), Ibbotson and Jaffe (1975), Ritter (1984), and Smith (1977), who provide evidence of underpricing for both unseasoned and seasoned issues. For unseasoned issues, Ibbotson found an average discount relative to the aftermarket price of 11.4%; Ibbotson and Jaffe estimate the average discount at 16.8%.

63. There is also a potential for collusion against more naive investors; for instance, in a hot market, stakes are high and investment banks' reputational constraints are less effective.

There is a large literature as well as an empirical controversy as to whether issuers and investment bankers underprice as an insurance against the threat of litigation risk. For example, Titnic (1988) indeed found that underpricing increased following the enactment of the 1933 Securities Act, which increased litigation risk. In contrast, Zhu (2004) finds an increase in IPO underpricing following the 1995 enactment of the Private Securities Litigation Reform Act, which made litigation harder. See, for example, Zhu (2004) and Lowry and Shu (2002) for a discussion of the econometric issues in measuring the impact of the litigation threat.

Assumption 6.2. *Only the good borrower is creditworthy:*

$$qR < I - A < pR.$$

That is, the pledgeable income exceeds the funding need, $I - A$, only for the good borrower.

If investors knew the borrower's type, the good type, who would be the only one to be financed, would offer to keep R_b^G in the case of success, where R_b^G is such that the issue is sold at par:[64]

$$p(R - R_b^G) = I - A.$$

Assumption 6.3. $A < qR_b^G$.

Assumption 6.3 can be interpreted in the following way. The condition $A < qR_b^G$ states that the bad borrower would be willing to commit her entire wealth in order to have access to the contractual terms obtained by the good borrower under symmetric information. This condition means that the bad type is eager to pool with the good type and will imply that the good type's utility is reduced by the asymmetry of information, or, in other words, that the good type would be strictly better off if she could disclose credible information about the quality of borrowing.

We proceed heuristically. Formal results are stated below and proved in Section 6.9. Can a good borrower get funded by offering contractual terms that are both unappealing to a bad type, who would then prefer not to be funded, and allow lenders to break even? As we have seen, such separation requires that the good borrower be less greedy than under symmetric information and thus offer $R_b < R_b^G$. The highest reward that is unappealing to a bad borrower, R_b^*, is given by

$$qR_b^* = A. \tag{6.6}$$

Note that (6.6) assumes that the borrower commits her entire wealth A. The intuition as to why this must be so is that the good borrower wants to pledge as much as possible as a signal that she is confident about future returns.

Are investors willing to finance the project when the borrower offers to bring in her entire wealth and demands a reward equal to R_b^* (or slightly less)? "Knowing" that this offer can only emanate from a good borrower, the investors' expected profit is

$$p(R - R_b^*) - (I - A) = p(R_b^G - R_b^*) > 0. \tag{6.7}$$

So, the issue is not only subscribed. It is also *underpriced*, i.e., investors more than break even. This means that there must be rationing at the issuance.[65] In a sense, the good borrower "burns money" (here in the sense of leaving money on the table) in order to signal to investors that they are buying into a high-quality loan.

Determinants of underpricing. In the range of parameters satisfying Assumptions 6.2 and 6.3, underpricing is equal to $p(R_b^G - R_b^*)$ in absolute terms and to

$$\frac{p(R_b^G - R_b^*)}{p(R - R_b^G)} = \frac{p(R_b^G - R_b^*)}{I - A} = \frac{pR - I - ((p - q)/q)A}{I - A}$$

in relative terms.

Relative underpricing decreases with the extent of adverse selection, as measured by the likelihood ratio, $(p - q)/q$. When the two types become more similar, i.e., q increases keeping p fixed (still under Assumption 6.2), the good borrower must underprice more in order to make the issue unappealing to a bad borrower.

Full analysis. The analysis above is incomplete in two respects.

First, we implicitly assumed that the good borrower separates from a bad one by demanding a lower share of the pie in the case of success. Could the good borrower distort her contractual terms in other ways so as to reduce the cost of signaling her type? The other possible departures from the symmetric-information contract are (i) a random probability of financing, (ii) providing the borrower with an *ex post* choice between funding and a

64. Again, this contract is not uniquely optimal: any contract specifying nonnegative rewards for the manager and letting investors break even will do.

65. The good borrower could equivalently publicly "burn" an amount of money equal to the left-hand side of (6.7), and then the investors would break even. Underpricing seems a more robust signaling device, though. For example, if the investors supply any noncontractible input, however tiny, that increases the probability of success, raising the investors' stake rather than purely burning money is a more efficient signaling device. Furthermore, as Allen and Faulhaber (1989) argue, underpricing reduces the probability of a lawsuit when the outcome turns out to be adverse.

lump-sum transfer without funding, and (iii) an incomplete commitment of the borrower's wealth. Intuitively, the last departure should not signal that the borrower is a good one. As for the first departure, the borrower could pay an application fee in exchange for a random chance of getting funded. But this is a less efficient signaling method than taking a lower share in the case of success and being funded with probability 1. Section 6.9 shows that the separating allocation defined by (6.7) is indeed the low-information-intensity optimum, that is, the allocation that maximizes the good borrower's utility subject to the bad borrower not receiving a rent (or more generally subject to the capital market not losing money on any type). By contrast, the second departure introduces new, pooling equilibria, as we discuss below.

Second, we have not yet investigated uniqueness. There might exist other separating, pooling or hybrid equilibria. Section 6.9 shows that the separating allocation is not the unique equilibrium outcome for any α (that is, $\alpha^* = 0$). Indeed, there exist pooling equilibria in which both types are better off than in the separating equilibrium. These pooling equilibria involve the borrower choosing after contracting with the investors between (a) investment and no lump-sum payment (the borrower is rewarded only in the case of success) and (b) no investment and a positive lump-sum payment. In a sense, the bad type (who chooses option (b)) is bribed to "go away" and not invest. The pooling equilibrium is sustained by the investors' belief that this option-contract offer is selected by both types, and so their posterior belief just after the contract is offered (but before the option is exercised) is the same as the prior belief.

As the probability of a good type converges to 0, so does the lump-sum payment and thus the pooling equilibrium converges to the separating one. Note, furthermore, that the pooling equilibrium involves no underpricing (the investors make money on the good type, but lose as much in expectation on the bad one).[66]

Intermediate signals. Good borrowers are willing to use a low IPO price in order to signal the quality of their project in Allen and Faulhaber (1989) as well. The specifics of modeling are slightly different from those described here in that (a) the entrepreneur need only finance an amount I of investment initially and will later need to finance the complementary amount J to implement the project, and (b) a public signal correlated with the entrepreneur's initial information about the quality of the project is publicly learned before the firm conducts the seasoned offering allowing to defray J.[67]

We therefore conclude that underpricing as a signal is a possibility, not a necessity.

Supplementary Section

6.4 Contract Design by an Informed Party: An Introduction

We noted that the proper modeling of the situation in which an informed party issues claims in a competitive capital market is one of contract design by an informed principal. The purpose of this section is to give an introduction to the relevant techniques and results, developed in Maskin and Tirole (1992). While the section is mathematically straightforward, it is more abstract and formal than the rest of the chapter and of the book. We focus on two potential types for the borrower, a "good type" and a "bad type"; the results derived in this section hold for an arbitrary number of types.

A borrower who attempts to raise funds from lenders has private information about some characteristic (private benefit, value of assets in place, prospects of the firm, value of collateral) that affects the lenders' payoff. The borrower may have type b or $\tilde{b}$. While the borrower knows her type, the lenders only know that this type is b with probability α and $\tilde{b}$ with probability $1 - \alpha$.

66. Namely, both types of borrower offer a contract in which they bring in A and which gives them, if investors accept, an option between (i) going ahead with the investment and receiving $\hat{R}_b \in (R_b^*, R_b^G)$ in the case of success, and (ii) refraining from investing and receiving cash payment $q\hat{R}_b (> A)$. The good borrower exercises the first option and the bad borrower the second. The investors offset their loss (which would be equal to 0 if $\hat{R}_b = R_b^*$) on the bad borrowers by a profit on the good borrowers (which would be strictly positive if $\hat{R}_b = R_b^*$):

$$\alpha[p(R - \hat{R}_b) - (I - A)] - (1 - \alpha)(q\hat{R}_b - A) = 0.$$

67. Other related models of IPO underpricing include Grinblatt and Hwang (1989) and Welch (1989).

Figure 6.4

Let us, abstractly, denote the contractual terms faced by the borrower by c. Let $U_{\mathrm{b}}(c)$ and $\tilde{U}_{\mathrm{b}}(c)$ denote the two types' net utilities for arbitrary contractual terms c.[68] Let $U_{\mathrm{l}}(c)$ and $\tilde{U}_{\mathrm{l}}(c)$ denote the investors' expected profit when contractual terms are c and the borrower turns out to have type b and $\tilde{b}$, respectively.

Example (privately-known-prospects). In Section 6.2, the borrower had possible types $b = p$ and $\tilde{b} = q$. The contractual terms c were just the borrower's reward $R_{\mathrm{b}}^{\mathrm{S}}$ in the case of success. More generally, they also contain the probability of investment, x, her reward in the case of failure, $R_{\mathrm{b}}^{\mathrm{F}}$, and in the absence of investment, R_{b}^{0}, even though the latter in equilibrium can be taken to be equal to 1, 0, and 0, respectively (see Section 6.5). We have

$$U_{\mathrm{b}}(c) = x[pR_{\mathrm{b}}^{\mathrm{S}} + (1-p)R_{\mathrm{b}}^{\mathrm{F}}] + (1-x)R_{\mathrm{b}}^{0},$$
$$\tilde{U}_{\mathrm{b}}(c) = x[qR_{\mathrm{b}}^{\mathrm{S}} + (1-q)R_{\mathrm{b}}^{\mathrm{F}}] + (1-x)R_{\mathrm{b}}^{0},$$
$$U_{\mathrm{l}}(c) = x[p(R - R_{\mathrm{b}}^{\mathrm{S}}) - (1-p)R_{\mathrm{b}}^{\mathrm{F}}] - (1-x)R_{\mathrm{b}}^{0},$$
$$\tilde{U}_{\mathrm{l}}(c) = x[q(R - R_{\mathrm{b}}^{\mathrm{S}}) - (1-q)R_{\mathrm{b}}^{\mathrm{F}}] - (1-x)R_{\mathrm{b}}^{0}.$$

In other applications, contractual terms also include the amount of collateralized assets, the levels of liquidity hoarded at date 0, or of the short-term debt repayment, etc. For more generality, c and $\tilde{c}$ can also be taken to be random.

Figure 6.4 describes the timing of the *issuance game*. As earlier, we assume that the borrower designs the issue and offers the associated claims to a competitive capital market. Investors purchase the claims if and only if they expect a nonnegative profit. Lastly, the borrower chooses some action(s).

A few clarifications are in order. First, we allow for post-contracting actions by the borrower in order to accommodate situations in which the borrower can waste resources (as in Chapters 3–5).[69] Second, we said that investors subscribe "if and only if they expect a nonnegative profit." The expectation should be taken relative to the updated beliefs, that is, the investors' beliefs after they observe the contract offer and thus possibly learn something about the borrower. Third, we will analyze the perfect Bayesian equilibrium (or equilibria) of the issuance game.[70]

Fourth, a "contract" can in principle be anything that the borrower sees fit to design. However, for the purpose of the analysis, it can be shown that there is no loss of generality in assuming that the borrower offers an "option contract" $(c, \tilde{c})$, that is, as many contractual terms as there are possible types. The terminology "option contract" comes from the fact that, if the investors subscribe (accept the contract), the borrower must then exercise her built-in option and choose between c and $\tilde{c}$. The choice of contractual terms is then included in the "actions" to be taken *ex post* by the borrower. It can further be shown that there is no loss of generality in assuming that the option contract is "incentive compatible," that is, that type b prefers contractual terms c to $\tilde{c}$ and type $\tilde{b}$ prefers $\tilde{c}$ to c (the reader knowledgeable in information economics will here recognize a version of the "revelation principle").

The reader may at this stage wonder why a borrower might want to offer contractual terms not only for her own type, but also for the other type, a type that she actually does not have, when she will end up choosing the contractual terms that are fitted to her own type anyway. While the reason will become clear both in the abstract treatment below and in the applications, it is worth sketching it now: while option contracts do not augment the set of equilibrium allocations relative to "simple contracts," in which the borrower offers a single contractual term (that is, the equilibrium allocations are also equilibrium

68. So, for example, if the borrower has initial cash A, and has quasi-linear preferences, the net utility is equal to the gross utility minus A.

69. We could also allow for *ex post* actions by active investors as in Parts III and IV.

70. Very roughly speaking, a perfect Bayesian equilibrium of a game is a set of strategies and beliefs such that at any stage of the game players act optimally given their beliefs at that stage (the equilibrium is "perfect") and beliefs are updated by the players according to Bayes' rule using equilibrium strategies and observed actions (the updating is Bayesian). See, for example, Fudenberg and Tirole (1991, Chapter 8) for a formal definition.

Here investors are assumed to update their beliefs about the borrower's type using the borrower's equilibrium type-contingent contract offer and the actual contract offer. The previous condition, that they subscribe if and only if they expect a nonnegative profit given their updated beliefs, is an optimization requirement.

allocations when one focuses on simple contracts), option contracts help eliminate “bad expectations.” For example, the good borrower b may not be able to obtain contractual terms c by offering the simple contract c because investors may be convinced that such an offer stems from a bad borrower and that they will lose money ($\tilde{U}_{\text{l}}(c) < 0$). However, if the good borrower appends to c another option, namely, contractual terms $\tilde{c}$, that a bad borrower prefers to c ($\tilde{U}_{\text{b}}(\tilde{c}) > \tilde{U}_{\text{b}}(c)$) and yet allows investors to break even ($\tilde{U}_{\text{l}}(\tilde{c}) \geqslant 0$), then the good borrower “guarantees” that investors will not lose money regardless of their expectations, and can thus safely enjoy contractual terms c. We will come back to this idea later.

The characterization of the equilibrium (or equilibria) of the issuance game requires defining a couple of intuitive notions. Let an *allocation* be a pair of (possibly identical) type-contingent contractual terms $(c, \tilde{c})$. That is, it defines contractual terms c for type b and $\tilde{c}$ for type $\tilde{b}$. (Note that an option contract defines an allocation.)

Definition. An allocation $(c, \tilde{c})$ is *incentive compatible* if type b prefers c to $\tilde{c}$ and type $\tilde{b}$ prefers $\tilde{c}$ to c:

$$U_{\text{b}}(c) \geqslant U_{\text{b}}(\tilde{c}) \quad \text{and} \quad \tilde{U}_{\text{b}}(\tilde{c}) \geqslant \tilde{U}_{\text{b}}(c).$$

Because the borrower's type is not observed, a given type can always mimic what the other type does, and so equilibrium allocations must be incentive compatible.

Definition. An incentive-compatible allocation $(c, \tilde{c})$ is *profitable type-by-type* if

$$U_{\text{l}}(c) \geqslant 0 \quad \text{and} \quad \tilde{U}_{\text{l}}(\tilde{c}) \geqslant 0.$$

Definition. An incentive-compatible allocation $(c, \tilde{c})$ is *profitable in expectation* (relative to the prior beliefs) if

$$\alpha U_{\text{l}}(c) + (1 - \alpha)\tilde{U}_{\text{l}}(\tilde{c}) \geqslant 0.$$

An incentive-compatible allocation $(c, \tilde{c})$ that is profitable in expectation is *interim efficient* if it is Pareto-optimal for the two types of borrower in the set of incentive-compatible, profitable-in-expectation allocations.

We now ask, what can a borrower guarantee herself given that the lenders may have arbitrary expectations about her type (what she can guarantee herself evidently depends on her actual type)? The answer relies on the following definition.[71]

Definition. Utility $U_{\text{b}}(c_0)$ for borrower type b is the *low-information-intensity optimum* for that type if c_0 maximizes type b's utility in the set of incentive-compatible, profitable-type-by-type allocations. That is, it is (part of) the solution to the following program.

Program I (type b):

$$\max_{\{c,\tilde{c}\}} U_{\text{b}}(c)$$
$$\text{s.t.}$$
$$U_{\text{b}}(c) \geqslant U_{\text{b}}(\tilde{c}),$$
$$\tilde{U}_{\text{b}}(\tilde{c}) \geqslant \tilde{U}_{\text{b}}(c),$$
$$U_{\text{l}}(c) \geqslant 0,$$
$$\tilde{U}_{\text{l}}(\tilde{c}) \geqslant 0.$$

The low-information-intensity optimum $\tilde{c}_0$ for type $\tilde{b}$ is defined similarly (Program I (type $\tilde{b}$)).

The payoff pair $(U_{\text{b}}(c_0), U_{\text{b}}(\tilde{c}_0))$ is called the *low-information-intensity optimum.* (By abuse of terminology, we will sometimes call the allocation $(c_0, \tilde{c}_0)$ itself the low-information-intensity optimum.)

The allocation $(c_0, \tilde{c}_0)$, even though it is derived from two independent programs, is itself incentive compatible. (Suppose, for example, that type $\tilde{b}$ strictly prefers c_0 to $\tilde{c}_0$. Then the solution $(c_0, \tilde{c})$ of Program I (type b) defining c_0 satisfies the constraints of Program I (type $\tilde{b}$) defining $\tilde{c}_0$ (they are the same), and furthermore

$$\tilde{U}_{\text{b}}(\tilde{c}) \geqslant \tilde{U}_{\text{b}}(c_0) > \tilde{U}_{\text{b}}(\tilde{c}_0).$$

Thus, $\tilde{c}_0$ cannot be the low-information-intensity optimum for type $\tilde{b}$ after all.)

The low-information-intensity optimum plays a key role in most of the financial economics literature on signaling. We will derive it repeatedly in the applications below. A trivial but very useful result (the following lemma) is that the borrower in equilibrium must obtain at least her low-information-intensity optimum.

71. The low-information-intensity optimum is called the “Rothschild–Stiglitz–Wilson” allocation in Maskin and Tirole (1992) after the influential papers of Rothschild and Stiglitz (1976) and Wilson (1977), in which the low-information-intensity optimum plays a central role.

Lemma 6.1. *The borrower can guarantee herself her low-information-intensity optimum* ($U_\mathrm{b}(c_0)$ *if she has type* b, *and* $\tilde{U}_\mathrm{b}(\tilde{c}_0)$ *if she has type* $\tilde{b}$).

Proof. Suppose the borrower offers the "option contract" $(c_0, \tilde{c}_0)$; by this, we mean that if the lenders accept the contract, the borrower picks the contractual terms c_0 or $\tilde{c}_0$. Because $(c_0, \tilde{c}_0)$ is incentive compatible, lenders know that type b will pick c_0 and type $\tilde{b}$ will pick $\tilde{c}_0$. Because $U_\mathrm{l}(c_0) \geqslant 0$ and $\tilde{U}_\mathrm{l}(\tilde{c}_0) \geqslant 0$ (the allocation is profitable type-by-type), lenders know that they will break even whatever their belief about the borrower's type.[72] □

The key result (due to Maskin and Tirole 1992) is the following.

Proposition 6.1.

(a) *The issuance game has a unique perfect Bayesian equilibrium if the low-information-intensity optimum is interim efficient* (*relative to prior beliefs* $(\alpha, 1-\alpha)$). *The borrower then obtains her low-information-intensity optimum* ($U_\mathrm{b}(c_0)$ *for type* b, $\tilde{U}_\mathrm{b}(\tilde{c}_0)$ *for type* $\tilde{b}$).

(b) *If the low-information-intensity optimum is not interim efficient, then the set of equilibrium payoffs for the two types of borrowers is the set of payoffs that result from an incentive-compatible, profitable-in-expectation allocation and* (*weakly*) *Pareto-dominate the low-information-intensity optimum.*

The uniqueness result (part (a)) is straightforward: an equilibrium allocation must be incentive compatible, and (from Lemma 6.1) must weakly Pareto-dominate the low-information-intensity optimum. It cannot, however, strictly Pareto-dominate this optimum if the latter is (interim) efficient, and so it must yield the same utilities.

Proposition 6.1 provides a mechanical way of deriving the equilibrium or equilibria of the issuance game. Let us now show that, under a very weak condition, the equilibrium can be straightforwardly characterized. Let $\tilde{c}^{\mathrm{SI}}$ denote the *symmetric information* contractual terms for the bad borrower. It solves

$$\max_{\{\tilde{c}\}} \tilde{U}_\mathrm{b}(\tilde{c})$$
$$\text{s.t.}$$
$$\tilde{U}_\mathrm{l}(\tilde{c}) \geqslant 0.$$

Assumption 6.4 (weak monotonic profit[73]). *Investors make a nonnegative profit if the contractual terms are those of the bad borrower under symmetric information and the borrower is a good one:*

$$U_\mathrm{l}(\tilde{c}^{\mathrm{SI}}) \geqslant 0.$$

This assumption is in general satisfied when both types are creditworthy under symmetric information (and it is satisfied in all of our illustrations). It is always satisfied when the bad borrower is not creditworthy under symmetric information: in that case, $\tilde{c}^{\mathrm{SI}}$ is the absence of funding and thus $U_\mathrm{l}(\tilde{c}^{\mathrm{SI}}) = 0$.

Definition. The *separating allocation* is the allocation c^* for the good borrower and the symmetric-information contractual terms $\tilde{c}^{\mathrm{SI}}$ for the bad borrower, where c^* maximizes the good borrower's payoff subject to the investors breaking even for the good borrower and to the bad borrower not preferring c^* to $\tilde{c}^{\mathrm{SI}}$:

$$\max_{\{c\}} U_\mathrm{b}(c)$$
$$\text{s.t.}$$
$$U_\mathrm{l}(c) \geqslant 0,$$
$$\tilde{U}_\mathrm{b}(c) \leqslant \tilde{U}_\mathrm{b}(\tilde{c}^{\mathrm{SI}}).$$

Note that the separating allocation is profitable type-by-type.

Lemma 6.2. *Under the weak monotonic-profit assumption, the separating allocation is the low-information-intensity optimum.*

Proof. First, note that the bad borrower's symmetric-information program has the same objective function and fewer constraints than her low-information-intensity optimum program, Program I (type $\tilde{b}$). Hence,

$$\tilde{U}_\mathrm{b}^{\mathrm{SI}} \equiv \tilde{U}_\mathrm{b}(\tilde{c}^{\mathrm{SI}}) \geqslant \tilde{U}_\mathrm{b}(\tilde{c}_0).$$

72. We are a bit casual about the borrower's and the lenders' behaviors when they are indifferent. Proving that the equilibrium behavior following the offer of contract $(c_0, \tilde{c}_0)$ is indeed the one described in the proof requires taking limits of slightly perturbed contracts for which indifferences are broken (see Maskin and Tirole (1992) for the details).

73. We state the assumption for the case in which $\tilde{c}^{\mathrm{SI}}$ is unique. If there are multiple solutions to the symmetric-information program for the bad borrower, we require that $U_\mathrm{l}(\tilde{c}^{\mathrm{SI}}) \geqslant 0$ holds for at least one of them.

Conversely, the bad borrower can guarantee herself her symmetric-information payoff even under asymmetric information; for, suppose she offers $\tilde{c}^{\mathrm{SI}}$. From the weak monotonic-profit assumption, investors at least break even regardless of the borrower's type. Hence, they are willing to subscribe to the issue. Hence,

$$\tilde{U}_{\mathrm{b}}(\tilde{c}_0) = \tilde{U}_{\mathrm{b}}^{\mathrm{SI}},$$

and $\tilde{c}_0$ can be identified with $\tilde{c}^{\mathrm{SI}}$, without loss of generality.

Second, consider Program I (type b), yielding the low-information-intensity optimum for type b. It has the same objective function and is more constrained than the separating program. (Note that the constraint $\tilde{U}_{\mathrm{b}}(c) \leqslant \tilde{U}_{\mathrm{b}}(\tilde{c}^{\mathrm{SI}})$ in the separating program is replaced by the constraint $\tilde{U}_{\mathrm{b}}(c) \leqslant \tilde{U}_{\mathrm{b}}(\tilde{c})$ for some $\tilde{c}$ satisfying in particular $\tilde{U}_{\mathrm{l}}(\tilde{c}) \geqslant 0$; because $\tilde{U}_{\mathrm{l}}(\tilde{c}) \geqslant 0$ and $\tilde{U}_{\mathrm{l}}(\tilde{c}^{\mathrm{SI}}) \geqslant 0$, and $\tilde{c}^{\mathrm{SI}}$ maximizes $\tilde{U}_{\mathrm{b}}(\cdot)$ subject to this constraint $\tilde{U}_{\mathrm{l}}(\cdot) \geqslant 0$, $\tilde{U}_{\mathrm{b}}(\tilde{c}) \leqslant \tilde{U}_{\mathrm{b}}(\tilde{c}^{\mathrm{SI}})$. Thus the constraint $\tilde{U}_{\mathrm{b}}(c) \leqslant \tilde{U}_{\mathrm{b}}(\tilde{c})$ for some $\tilde{c}$ satisfying $\tilde{U}_{\mathrm{l}}(\tilde{c}) \geqslant 0$ is not looser than the constraint $\tilde{U}_{\mathrm{b}}(c) \leqslant \tilde{U}_{\mathrm{b}}(\tilde{c}^{\mathrm{SI}})$. It may be tighter given that the low-information-intensity optimum also requires $U_{\mathrm{b}}(c) \geqslant U_{\mathrm{b}}(\tilde{c})$.) Therefore,

$$U_{\mathrm{b}}(c^*) \geqslant U_{\mathrm{b}}(c_0).$$

Conversely, the good borrower can guarantee herself her separating allocation payoff; for, suppose that she offers profitable-type-by-type option contract $(c^*, \tilde{c}^{\mathrm{SI}})$. This allocation is indeed incentive compatible (by construction, $\tilde{U}_{\mathrm{b}}(c^*) \leqslant \tilde{U}_{\mathrm{b}}(\tilde{c}^{\mathrm{SI}})$; furthermore, if $U_{\mathrm{b}}(c^*) < U_{\mathrm{b}}(\tilde{c}^{\mathrm{SI}})$, $(c^*, \tilde{c}^{\mathrm{SI}})$, would not be the solution to the separating program, since it would be dominated by $(\tilde{c}^{\mathrm{SI}}, \tilde{c}^{\mathrm{SI}})$, which satisfies the constraints of this program from the weak monotonic-profit assumption). Hence, investors accept this option contract and so $U_{\mathrm{b}}(c^*) = U_{\mathrm{b}}(c_0)$. □

Lemma 6.3. *Under the weak monotonic-profit assumption, there exists a threshold level α^* for prior beliefs such that the low-information-intensity optimum (that is, the separating allocation under the weak monotonic-profit assumption) is interim efficient if and only if $\alpha \leqslant \alpha^*$.*

Proof. We have seen that the good borrower can obtain her separating payoff and the bad borrower her full information payoff. Looking at the program defining the separating allocation, it is clear that the good borrower cannot obtain more than her separating payoff unless the bad borrower obtains a rent beyond her symmetric-information payoff.

Let $\hat{\mathcal{R}} \geqslant 0$ denote the bad borrower's rent above her full information utility, and define the minimal loss incurred by investors on the bad type when the latter has extra rent $\hat{\mathcal{R}}$:

$$-\mathcal{L}(\hat{\mathcal{R}}) = \max_{\{\tilde{c}\}} \tilde{U}_{\mathrm{l}}(\tilde{c})$$
$$\text{s.t.}$$
$$\tilde{U}_{\mathrm{b}}(\tilde{c}) \geqslant \tilde{U}_{\mathrm{b}}^{\mathrm{SI}} + \hat{\mathcal{R}}.$$

$\mathcal{L}(\cdot)$ is an increasing function and (as long as investors break even under the symmetric-information allocation) $\mathcal{L}(0) = 0$. Consider the following program.

Program II:

$$\max_{\{c,\hat{\mathcal{R}}\}} U_{\mathrm{b}}(c)$$
$$\text{s.t.}$$
$$\alpha U_{\mathrm{l}}(c) - (1-\alpha)\mathcal{L}(\hat{\mathcal{R}}) \geqslant 0,$$
$$\tilde{U}_{\mathrm{b}}(c) \leqslant \tilde{U}_{\mathrm{b}}^{\mathrm{SI}} + \hat{\mathcal{R}}.$$

If $\hat{\mathcal{R}} > 0$ is strictly suboptimal, then the good borrower cannot obtain more than her low-information-intensity optimum; for, in any equilibrium of the issuance game, the investors must break even and so

$$\alpha U_{\mathrm{l}}(c) - (1-\alpha)\mathcal{L}(\hat{\mathcal{R}}) \geqslant 0$$

must hold.

If the optimum of Program II yields $\hat{\mathcal{R}} > 0$, then the solution to Program II dominates the low-information-intensity optimum for the good borrower and yields an upper bound on the good type's (perfect Bayesian) equilibrium payoff. This upper bound is attained if the good type prefers the allocation defined by Program II to the allocation $\tilde{c}$ that minimizes the loss $\mathcal{L}(\hat{\mathcal{R}})$ incurred by investors for the bad type. (The proof of these assertions follows the steps of the proof of part (b) of Proposition 6.1.)

Lastly, it is simple to observe that if the low-information-intensity optimum is interim efficient for some belief α, it is also interim efficient for all beliefs $\alpha' < \alpha$: suppose it were not. Then, there would exist $\hat{\mathcal{R}}$ and c such that $U_b(c) > U_b(c_0)$, $\alpha' U_l(c) \geqslant (1-\alpha')\mathcal{L}(\hat{\mathcal{R}})$ and $\tilde{U}_b(c) \leqslant \tilde{U}_b^{SI} + \hat{\mathcal{R}}$. But $\hat{\mathcal{R}}$ and c satisfy these conditions *a fortiori* for α, given that $\mathcal{L}(\hat{\mathcal{R}}) > 0$. □

We summarize our results in the following proposition.

Proposition 6.2. *Suppose that the weak monotonic-profit assumption holds. Then*

(a) *the separating allocation is the low-information-intensity optimum;*
(b) *there exists a threshold α^* such that the low-information-intensity optimum is interim efficient and is thus the unique (perfect Bayesian) equilibrium payoff vector of the issuance game if and only if $\alpha \leqslant \alpha^*$.*

A few comments on this definition are in order. First, Program II is of interest even when equilibrium is not unique ($\alpha > \alpha^*$). It defines an upper bound for the payoff for the good borrower in the set of feasible payoffs. Second, although α^* is usually positive (see examples below), it may be equal to 0. This is illustrated by the privately-known-prospects model of Section 6.2.1, when the bad borrower is not creditworthy. Indeed, in that model, the low-information-intensity optimum corresponds to the no-financing allocation. We leave it to the reader to check that it is interim efficient if and only if

$$[\alpha p + (1-\alpha)q]R \leqslant I,$$

that is, for $\alpha \leqslant \alpha^*$. In this case, we had indeed proved directly (that is, without the use of part (a) of Proposition 6.1) that the equilibrium, namely, complete market breakdown, is unique.

Third, when $\alpha > \alpha^*$, there are other equilibrium outcomes than the low-information-intensity optimum. The equilibrium exhibited in Section 6.2.1 is actually the one with the highest payoff for the good type and thus solves Program II. Proposition 6.1(b) can be used to obtain the set of equilibrium payoffs, which admits this equilibrium payoff as the upper bound for the good borrower and the low-information-intensity optimum as the lower bound for both types.

Appendixes

6.5 Optimal Contracting in the Privately-Known-Prospects Model

(For the technically minded reader only.) Consider the model of Section 6.2.1. In all generality, an allocation is a probability x that the investment be made and rewards R_b^S, R_b^F, and R_b^0 in the case of success, failure, and no investment, respectively. The payoff to type $r \in \{p, q\}$ for this allocation is then

$$U_b(r) = x[rR_b^S + (1-r)R_b^F] + (1-x)R_b^0.$$

Let $\{x, R_b^S, R_b^F, R_b^0\}$ denote the good type's allocation. Incentive compatibility (the fact that the bad type can mimic the good type) implies that the bad type's utility $\tilde{U}_b$ can be related to the good type's $U_b = U_b(p)$ in the following way:

$$\tilde{U}_b \geqslant U_b - x(p-q)(R_b^S - R_b^F).$$

Using this inequality and the investor's breakeven constraint,

$$\alpha[x(pR-I) - U_b] + (1-\alpha)[\tilde{x}(qR-I) - \tilde{U}_b] \geqslant 0,$$

where $\tilde{x}$ is the probability that the bad type invests, the best allocation for the good type solves

$$\max_{\{x, R_b^S, R_b^F, R_b^0\}} U_b(p)$$

s.t.

$$\alpha x(pR-I) + (1-\alpha)\tilde{x}(qR-I) - U_b(p) + (1-\alpha)x(p-q)(R_b^S - R_b^F) \geqslant 0.$$

We leave it to the reader to show that, at the optimum of this program, $R_b^F = R_b^0 = 0$, and

- if $qR - I > 0$, then $\tilde{x} = 1$, and the pooling allocation studied in the text is the optimal allocation for the good type;
- if $qR - I < 0$, then $\tilde{x} = 0$; incentive compatibility then requires a lump-sum payment for the bad type,
$$\tilde{R}_b^0 = qR_b^S.$$

Two remarks are in order concerning this lump-sum payment. First, the borrower obviously cannot go to the investors and just ask them to pay $\tilde{R}_b^0 > 0$ in exchange for no claims at all, as the investors would just refuse. The process through which this allocation can be implemented was studied in the supplementary section: the borrower offers a menu to the investors: $\{x = 1,\ R_b^S > 0,\ R_b^F = 0,\ R_b^0 = 0\}$ for the good type and $\{x = 0,\ \tilde{R}_b^0\}$ for the bad type and only selects in the menu once the investors have accepted to finance the investment. Because the menu is incentive compatible and satisfies the investors' breakeven condition, it is an equilibrium for the investors to indeed finance the project.

Second, the lump-sum-payment policy raises the concern that the payout $\tilde{R}_b^0$ attract "fake entrepreneurs," who do not even have a project (put differently, $1 - \alpha$ could quickly become very close to 1, leading to market breakdown after all).

6.6 The Debt Bias with a Continuum of Possible Incomes

Consider the privately-known-prospects model in Application 3, but assume that the firm's income is *continuous*. The entrepreneur and the investors are risk neutral. The entrepreneur has initial assets A and wants to finance a project costing $I > A$. There is no moral hazard. The income is distributed on $[0, \infty)$ according to density $p(R)$ and cumulative distribution $P(R)$ in the case of a good borrower, and to density $\tilde{p}(R)$ and cumulative distribution $\tilde{P}(R)$ in the case of a bad borrower. The definition of what constitutes a good borrower is linked to the monotone likelihood ratio property, according to which a higher income makes it more likely that it emanates from a good borrower.

Assumption 6.5 (monotone likelihood ratio property). *$p(R)/\tilde{p}(R)$ is increasing.*

We also make the following assumption.

Assumption 6.6 (only the good borrower is creditworthy). *Under symmetric information, only the good borrower would receive funding for the project:*

$$\tilde{V} \equiv \int_0^\infty R\tilde{p}(R)\,\mathrm{d}R - I < 0 < V \equiv \int_0^\infty Rp(R)\,\mathrm{d}R - I.$$

As in the previous sections, we look for a contract between the good borrower and the investors that maximizes the good borrower's payoff subject to the investors' breaking even for that type and to the bad borrower's preferring to keep cash A rather than mimicking the good borrower in order to get funding. Let $w(R)$ denote the borrower's income when the firm's income is R. We assume that $0 \leqslant w(R) \leqslant R$; see Section 3.6 for a discussion of this (rather strong) assumption of the investors' limited liability.

So, we solve

$$\max_{\{w(\cdot)\}} \int_0^\infty w(R)p(R)\,\mathrm{d}R$$

s.t.

$$\int_0^\infty [R - w(R)]p(R)\,\mathrm{d}R \geqslant I - A,$$

$$\int_0^\infty w(R)\tilde{p}(R)\,\mathrm{d}R \leqslant A,$$

$$0 \leqslant w(R) \leqslant R.$$

Ignoring the last constraint for the moment, the Lagrangian for this linear program is

$$\mathcal{L} = \int_0^\infty \left[1 - \lambda - \mu\frac{\tilde{p}(R)}{p(R)}\right] w(R)p(R)\,\mathrm{d}R + \lambda(V + A) + \mu A,$$

where λ and μ are the (positive) multipliers of the breakeven and the mimicking constraints. Using the monotone likelihood ratio property, there thus exists a threshold R^* (such that $p(R^*)/\tilde{p}(R^*) = \mu/(1-\lambda)$) such that

$$w(R) = \begin{cases} R & \text{if } R \geqslant R^*, \\ 0 & \text{if } R < R^*. \end{cases}$$

We thus obtain, and for the same reason, the result obtained by Innes (1990) in the moral-hazard version of the model.[74]

74. When are the two constraints binding and when is it possible for a good borrower to separate from a bad one? Let $R^*(A)$ be defined by

$$\int_{R^*(A)}^\infty R\tilde{p}(R)\,\mathrm{d}R = A.$$

The investors' profit from a good type is then

$$V + A - \int_{R^*(A)}^\infty Rp(R)\,\mathrm{d}R,$$

whose derivative with respect to A is equal to $1 - p(R^*)/\tilde{p}(R^*)$. From the monotone likelihood ratio property, this derivative is first positive and later negative. If A is small, the good borrower cannot separate from a bad one (she may still be able to get financing if α is large enough). One can show that there exists some A^* such that the two constraints are binding and the unique optimal contract is as described in the text. For $A > A^*$, this contract is optimal but no longer unique; all optimal contracts must still resemble it in that they must

Building further on Innes and on the discussion in Section 3.6, we note that this result does not quite vindicate the pecking-order hypothesis for risky debt. (Note, incidentally, that the firm cannot issue any safe debt since the lowest possible income is equal to 0.) While investors are residual claimants in case of default ($R < R^*$), they receive nothing otherwise.

To conform with the pecking-order hypothesis, one must add Innes's monotonic reimbursement assumption, according to which the investors' return, $R - w(R)$, should not decrease with the firm's income.[75] Then, as in Section 3.6 to which we refer for more detail, the optimal contract for the good borrower is a *standard debt contract*.

6.7 Signaling through Costly Collateral

The prerequisite for this appendix, which provides a rigorous analysis of Application 5, is the reading of the supplementary section.

First, we check that the weak monotonic-payoff assumption holds. Here

$$U_1(\tilde{c}^{\mathrm{SI}}) = p(R - R_{\mathrm{b}}^{\mathrm{B}}) - I$$
$$= (p - q)(R - R_{\mathrm{b}}^{\mathrm{B}}) > 0.$$

Application 5 in the text identified contractual terms with the borrower's reward $R_{\mathrm{b}}^{\mathrm{S}} = R_{\mathrm{b}}$ in the case of success and the amount of collateral $C^{\mathrm{F}} = C$ transferred to investors in the case of failure. More generally, we must allow for a reward $R_{\mathrm{b}}^{\mathrm{F}} \geqslant 0$ in the case of failure, a level of collateral C^{S} in the case of success, and a probability x of investment.[76] So Program II′ can be written

$$\max_{\{R_{\mathrm{b}}^{\mathrm{S}}, R_{\mathrm{b}}^{\mathrm{F}}, C^{\mathrm{S}}, C^{\mathrm{F}}, x, \tilde{\mathcal{R}}\}} x[p(R_{\mathrm{b}}^{\mathrm{S}} - C^{\mathrm{S}}) + (1-p)(R_{\mathrm{b}}^{\mathrm{F}} - C^{\mathrm{F}})]$$

s.t.

$$\alpha x[p(R - R_{\mathrm{b}}^{\mathrm{S}} + \beta C^{\mathrm{S}}) + (1-p)(-R_{\mathrm{b}}^{\mathrm{F}} + \beta C^{\mathrm{F}}) - I] - (1-\alpha)\mathcal{L}(\tilde{\mathcal{R}}) \geqslant 0,$$

$$x[q(R_{\mathrm{b}}^{\mathrm{S}} - C^{\mathrm{S}}) + (1-q)(R_{\mathrm{b}}^{\mathrm{F}} - C^{\mathrm{F}})] \leqslant (qR - I) + \tilde{\mathcal{R}}.$$

load reimbursements to investors onto the lower tail of the distribution.

75. This assumption is also made in DeMarzo and Duffie (1999).

76. There is no need to introduce collateral pledging in the absence of investment because this can be duplicated through a uniform increase in C^{F} and C^{S}. Similarly, there is no point introducing a payment in the absence of investment because it can be duplicated through a uniform increase in payment in the case of investment.

We leave it to the reader to check that

- $\mathcal{L}(\tilde{\mathcal{R}}) = \tilde{\mathcal{R}}$ (there is no dissipation of profit through collateral pledging in the program defining $\mathcal{L}(\cdot)$);
- there is no loss of generality involved in assuming, as we did in Section 6.3, that $x = 1$, $R_{\mathrm{b}}^{\mathrm{F}} = C^{\mathrm{S}} = 0$.

Letting $R_{\mathrm{b}}^{\mathrm{S}} = R_{\mathrm{b}}$ and $C^{\mathrm{F}} = C$, one can then show that the good type's utility increases with $\tilde{\mathcal{R}}$ if and only if[77]

$$\frac{(1-p)(q + p\alpha/(1-\alpha))}{p(1-q) - \beta q(1-p)}(1-\beta) > 1.$$

This condition is violated for $\alpha = 0$ and satisfied for α close to 1. More generally, it is satisfied for

$$\alpha > \alpha^*,$$

for some $\alpha^* \in (0, 1)$. Note, last, that α^* grows with β. One can also show that the optimal $\tilde{\mathcal{R}}$ is a nondecreasing function of α.

6.8 Short Maturities as a Signaling Device

In a separating equilibrium in Application 6, the bad type gets the symmetric-information payoff:

$$\tilde{U}_{\mathrm{b}} = r + \rho_1 - \tilde{\lambda}\rho - I.$$

The best separating allocation for the good type is given by

$$\max_{\{x, R_{\mathrm{b}}^{+}, R_{\mathrm{b}}^{-}\}} \{(1-\lambda)p_{\mathrm{H}}R_{\mathrm{b}}^{+} + \lambda p_{\mathrm{H}} x R_{\mathrm{b}}^{-} - A\}$$

s.t.

$$(\Delta p)R_{\mathrm{b}}^{+} \geqslant B, \qquad (\mathrm{IC}_{\mathrm{g}^+})$$

$$(\Delta p)R_{\mathrm{b}}^{-} \geqslant B, \qquad (\mathrm{IC}_{\mathrm{g}^-})$$

$$(1-\tilde{\lambda})p_{\mathrm{H}}R_{\mathrm{b}}^{+} + \tilde{\lambda}p_{\mathrm{H}}xR_{\mathrm{b}}^{-} - A \leqslant \tilde{U}_{\mathrm{b}}, \qquad (\mathrm{IC}_{\mathrm{bad}})$$

$$r + (1-\lambda)p_{\mathrm{H}}(R - R_{\mathrm{b}}^{+}) + \lambda x[p_{\mathrm{H}}(R - R_{\mathrm{b}}^{-}) - \rho] \geqslant I - A. \qquad (\mathrm{IR}_{\mathrm{l}})$$

The incentive constraint of the bad type ($\mathrm{IC}_{\mathrm{bad}}$) should bind. Otherwise the good type gets the symmetric-information contract with $x = 1$, $p_{\mathrm{H}}R_{\mathrm{b}}^{+} = \rho_1 - \rho_0 + \varepsilon^{+}$, and $p_{\mathrm{H}}R_{\mathrm{b}}^{-} = \rho_1 - \rho_0 + \varepsilon^{-}$, where

77. To show this, one first shows by contradiction that each constraint is binding. The two constraints then yield R_{b} and C.

$(1-\lambda)\varepsilon^+ + \lambda\varepsilon^- = r + \rho_0 - (I - A) - \lambda\rho$, and the bad type mimics the good type as

$$\begin{aligned}\tilde{U}_b - [(1-\tilde{\lambda})p_H R_b^+ + \tilde{\lambda} p_H R_b^- - A] &= (\tilde{\lambda}-\lambda)(\varepsilon^+ - \varepsilon^- - \rho) \\ &\leqslant (\tilde{\lambda}-\lambda)\left[\frac{r - (I-A) + \rho_0 - \rho}{1-\lambda}\right] \\ &< 0,\end{aligned}$$

where the first inequality results from the definition of ε^+ and ε^-, (IR_l) and the fact that $\varepsilon^- \geqslant 0$.

This also shows that

$$(IC_{bad}) \text{ binds} \quad \Longrightarrow \quad x < 1.$$

The lender should break even, that is, (IR_l) must bind. If it is not binding, by increasing the reward in the case of success and no shock and by decreasing the probability of continuation in the case of a shock, the good type can be made better off: increase R_b^+ by δR_b^+ and decrease x by δx such that (IC_{bad}) is unchanged, i.e., $(1-\tilde{\lambda})p_H \delta R_b^+ = \tilde{\lambda} p_H \delta x R_b^-$. Then the utility of the good type is increased by $((\tilde{\lambda}-\lambda)/\tilde{\lambda}) p_H \delta R_b^+ > 0$.

Intuitively, the good type should not be rewarded too much in the case of a liquidity shock in order to decrease the utility of the bad type pretending to be a good type. If (IC_{g^-}) is not binding, decrease the reward and increase the probability of continuation in the case of a shock such that the expected value of the entrepreneur in the case of a liquidity shock is unchanged. Keeping xR_b^- unchanged, decrease R_b^- by δR_b^- and increase x by δx. The only change is that (IR_l) is not binding anymore, which is not optimal.

In the end

$$R_b^- = \frac{B}{\Delta p},$$

$$(1-\tilde{\lambda})p_H R_b^+ + \tilde{\lambda} x(\rho_1 - \rho_0) - A = \tilde{U}_b,$$

$$r + (1-\lambda)(\rho_1 - p_H R_b^+) - \lambda x(\rho - \rho_0) = I - A.$$

Implementation. We need to implement R_b^+, x, and $R_b^- = B/\Delta p$ for the good type, $\tilde{R}_b^+$ and $\tilde{R}_b^-$ for the bad type. In a sense, the good type uses a larger short-term debt to signal his type. An awkward feature of the discrete setup considered here is that refinancing for the good type is random conditional on the realization ρ of the liquidity shock. This may be implemented, for example, through $d = r$ and a random credit line equal to ρ, which could be drawn with probability x only. With a continuous distribution for the liquidity shock, one would obtain the more natural result that d is smaller than ($\tilde{d}$ is the same as) under symmetric information.

That the equilibrium is unique for α below some α^* results from the general proposition proved in the supplementary section. For $\alpha > \alpha^*$, there exist (nonseparating) equilibria Pareto-dominating the separating one. In particular, for α close to 1, the good type is better off pooling with the bad type and being able to withstand the liquidity shock for certain, at the cost of a (slightly) smaller reward than under symmetric information.

6.9 Formal Analysis of the Underpricing Problem

The prerequisite for this appendix, which extends the analysis of Application 9, is the reading of the supplementary section.

6.9.1 Low-Information-Intensity Optimum

Let us solve the separating program for the model of Application 9. First, we must consider general contractual terms c. They consist in

- a probability $x \in [0,1]$ of funding,
- a reward $R_b^S \geqslant 0$ in the case of success,
- a reward $R_b^F \geqslant 0$ in the case of failure,
- an initial payment $\mathcal{A} \leqslant A$ by the borrower to the lenders (the borrower keeps $A - \mathcal{A}$); a negative $\mathcal{A}$ corresponds to a transfer from lenders to the borrower.

Let us solve for the low-information-intensity allocation:

$$\max_{\{x, R_b^S, R_b^F, \mathcal{A}\}} U_b(c) = x[pR_b^S + (1-p)R_b^F] - \mathcal{A}$$

s.t.

$$U_l(c) = x[p(R - R_b^S) + (1-p)(-R_b^F) - I] + \mathcal{A} \geqslant 0,$$

$$\tilde{U}_b(c) = x[qR_b^S + (1-q)R_b^F] - \mathcal{A} \leqslant 0.$$

Note that $x > 0$ (otherwise, the solution would yield $U_b(c) = 0$, which is impossible since the separating, underpricing allocation derived in the text provides the good type with a strictly positive net utility). Second, one can take $R_b^F = 0$; for, if $R_b^F > 0$, then a small change $\{\delta R_b^F < 0,\ \delta R_b^S > 0\}$ such that

$p\delta R_b^S + (1-p)\delta R_b^F = 0$ does not affect $U_b(c)$ and $U_l(c)$ and reduces $\tilde{U}_b(c)$. Third, suppose that $x < 1$. Then increasing x slightly, keeping xR_b^S constant, does not affect $U_b(c)$ and $\tilde{U}_b(c)$ and increases $U_l(c)$ (since $pR > I$). So, $x = 1$ given that $\tilde{U}_b(c) = 0$ (as was shown in the text, the full information solution does not hold under asymmetric information, and so the constraint $\tilde{U}_b(c) \leqslant 0$ must be binding). Hence, we can take $x = 1$, and because $\tilde{U}_b(c) = 0$

$$qR_b^S = \mathcal{A}.$$

We conclude that the low-information-intensity optimum is the allocation derived in Section 6.3.

Equilibrium uniqueness. We saw in the supplementary section that the issuance game admits a unique (perfect Bayesian) equilibrium if and only if the low-information-intensity optimum is interim efficient. We must therefore examine Program II (see the supplementary section). First, we minimize the investors' loss $\mathcal{L}(\tilde{\mathcal{R}})$ on the bad borrower when the bad borrower has net utility $\tilde{\mathcal{R}}$:

$$\min_{\{\tilde{x},\tilde{R}_b^S,\tilde{R}_b^F,\tilde{\mathcal{A}}\}} \mathcal{L}(\tilde{\mathcal{R}}) = -[\tilde{x}[q(R-\tilde{R}_b^S) + (1-q)(-\tilde{R}_b^F) - I] + \tilde{\mathcal{A}}]$$

s.t.

$$\tilde{x}[q\tilde{R}_b^S + (1-q)\tilde{R}_b^F] - \tilde{\mathcal{A}} \geqslant \tilde{\mathcal{R}},$$

where the notation mimics that just employed. And so

$$\begin{aligned}\mathcal{L}(\tilde{\mathcal{R}}) &= -\tilde{x}(qR-I) + \tilde{\mathcal{R}} \\ &= \tilde{\mathcal{R}}\end{aligned}$$

at the optimum (since $qR < I$).

The next program is the same as that for the low-information-intensity optimum except that (i) the breakeven condition is tightened by $(1-\alpha)\tilde{\mathcal{R}}$, and (ii) the mimicking condition is relaxed by $\tilde{\mathcal{R}}$:

$$\max_{\{x,\tilde{\mathcal{R}}\}} U_b(c)$$

s.t.

$$\alpha U_l(c) - (1-\alpha)\tilde{\mathcal{R}} \geqslant 0,$$

$$\tilde{U}_b(c) \leqslant \tilde{\mathcal{R}}.$$

By the same reasoning as for the low-information-intensity program, we can content ourselves with contractual terms c specifying $R_b^F = 0$. Then one can solve this program with respect to $(xR_b^S, x, \mathcal{A})$ rather than $(x, R_b^S, \mathcal{A})$ (it is a bit simpler) and show that

$$\mathcal{A} = A$$

and

$$\text{either } qR_b^S = A \text{ or } \tilde{R} > 0.$$

In sum, the good borrower can either leave no rent to the bad borrower and set

$$R_b^S = \frac{A}{q}$$

as in the separating allocation; or she can set $\tilde{\mathcal{R}} > 0$ and then R_b^S is determined by the investors' breakeven constraint:

$$\alpha[p(R-R_b^S) - (I-A)] + (1-\alpha)[-\mathcal{L}(\tilde{\mathcal{R}})] = 0,$$

where

$$\mathcal{L}(\tilde{\mathcal{R}}) = \tilde{\mathcal{R}} = qR_b^S - A.$$

And so

$$pR - I + A = \left[p + \frac{1-\alpha}{\alpha}q\right]R_b^S - \frac{1-\alpha}{\alpha}A.$$

She then gets a higher utility (whether she is a good or bad borrower) than in the separating equilibrium.

6.10 Exercises

Exercise 6.1 (privately known private benefit and market breakdown). Section 6.2 illustrated the possibility of market breakdown without the possibility of signaling. This exercise supplies another illustration. Let us consider the fixed-investment model of Section 3.2 and assume that *only the borrower knows the private benefit associated with misbehavior.* When the borrower has private information about this parameter, lenders are concerned that this private benefit might be high and induce the borrower to misbehave. In the parlance of information economics, the "bad types" are the types of borrower with high private benefit. We study the case of two possible levels of private benefit (see Exercise 6.2 for an extension to a continuum of possible types). The borrower wants to finance a fixed-size project costing I, and, for simplicity, has no equity ($A = 0$). The project yields R (success) or 0 (failure). The probability of success is p_H or p_L, depending on whether the borrower works or shirks, with $\Delta p \equiv p_H - p_L > 0$. There is no private benefit when working. The private benefit B enjoyed by the borrower when shirking is either $B_L > 0$ or $B_H > B_L$. The borrower will be labeled a "good borrower" when $B = B_L$ and a "bad borrower" when $B = B_H$. At the date of contracting, the borrower knows the level of her private benefit, while the capital market puts (common knowledge) probabilities α that the borrower is a good borrower and $1-\alpha$ that she is a bad borrower. All other parameters are common knowledge between the borrower and the lenders.

To make things interesting, let us assume that under asymmetric information, the lenders are uncertain about whether the project should be funded:

$$p_H\left(R - \frac{B_H}{\Delta p}\right) < I < p_H\left(R - \frac{B_L}{\Delta p}\right). \tag{1}$$

Assume that investors cannot break even if the borrower shirks:

$$p_L R < I. \tag{2}$$

(i) Note that the investor cannot finance only good borrowers. Assume that the entrepreneur receives no reward in the case of failure (this is indeed optimal); consider the effect of rewards R_b in the case of success that are (a) smaller than $B_L/\Delta p$, (b) larger than $B_H/\Delta p$, (c) between these two values.

(ii) Show that there exists α^*, $0 < \alpha^* < 1$, such that

- no financing occurs if $\alpha < \alpha^*$,
- financing is an equilibrium if $\alpha \geqslant \alpha^*$.

(iii) Describe the "cross-subsidies" between types that occur when borrowing is feasible.

Exercise 6.2 (more on pooling in credit markets). Consider the model of Exercise 6.1, in which the borrower has private information about her benefit of misbehaving, except that the borrower's type is drawn from a continuous distribution instead of a binary one. We will also assume that there is a monopoly lender, who makes a credit offer to the borrower. The borrower has no equity ($A = 0$).

Only the borrower knows the private benefit B of misbehaving. The lender only knows that this private benefit is drawn from an *ex ante* cumulative distribution $H(B)$ on an interval $[0, \bar{B}]$ (so, $H(0) = 0$, $H(\bar{B}) = 1$). (Alternatively, one can imagine that lenders face a population of borrowers with characteristic B distributed according to distribution H, and are unable to tell different types of borrower apart in their credit analysis.) The lender knows all other parameters. For a loan agreement specifying share R_b for the borrower in the case of success, and 0 in the case of failure, show that the lender's expected profit is

$$U_l = H((\Delta p)R_b)p_H(R - R_b) + [1 - H((\Delta p)R_b)]p_L(R - R_b) - I.$$

Show that

- the proportion of "high-quality borrowers" (that is, of borrowers who behave) is endogenous and increases with R_b;[78]
- adverse selection reduces the quality of lending (if lending occurs, which as we will see cannot be taken for granted);
- there is an externality among different types of borrower, in that the low-quality types (B large) force the lender to charge an interest rate that generates strictly positive profit on high-quality types (those with small B);
- the credit market may "break down," that is, it may be the case that no credit is extended at all even though the borrower may be creditworthy (that is, have a low private benefit). To illustrate this, suppose that $p_L = 0$ and H is uniform ($H(B) = B/\bar{B}$). Show that if
$$\frac{p_H^2}{\bar{B}}\frac{R^2}{4} < I$$
(which is the case for $\bar{B}$ large enough), no loan agreement can enable the lender to recoup on average his investment.

Exercise 6.3 (reputational capital). Consider the fixed-investment model. All parameters are common knowledge between the borrower and the investors, except the private benefit which is known only to the borrower. The private benefit is equal to B with probability $1 - \alpha$ and to b with probability α, where $B > b > 0$.

78. In this model, the loan agreement attracts all types of borrowers if it attracts any type willing to behave. It is easy to find variants of the model in which this is not the case and an increase in R_b attracts higher-quality borrowers, where "higher-quality" refers to an *ex ante* selection effect and not only to an *ex post* behavior like here.

(i) Consider first the one-period adverse-selection problem. Suppose that the borrower has assets $A > 0$ such that

$$p_H\left(R - \frac{b}{\Delta p}\right) > I - A > \max\left[p_H\left(R - \frac{B}{\Delta p}\right), p_L R\right].$$

Show that the project receives funding if and only if

$$(p_H - (1-\alpha)\Delta p)\left(R - \frac{b}{\Delta p}\right) \geqslant I - A.$$

(ii) Suppose now that there are two periods ($t = 1, 2$). The second period is described as in question (i), except that the belief $\tilde{\alpha}$ at date 2 is the posterior belief updated from the prior belief α, and that the borrower has cash A only if she has been successful at date 1 (and has 0 and is not funded if she has been unsuccessful). So, suppose that the first-period project is funded and that the borrower receives at the end of date 1 a reward A when successful and 0 when unsuccessful. The first-period funding is project finance and does not specify any funding for the second project. Suppose for notational simplicity that the private benefit is the same (B or b) in period 1 and in period 2. Let Δp_1 denote the increase in the probability of success when diligent in period 1. Assume that

$$\begin{aligned} b &< (\Delta p_1)A < B \\ &< (\Delta p_1)\left[p_L\left(R - \frac{I - A}{p_H - (1-\alpha_S)\Delta p}\right) + B\right] \end{aligned}$$

and

$$\begin{aligned} (p_H - (1-\alpha)\Delta p)&\left(R - \frac{b}{\Delta p}\right) \\ &< I - A \\ &< (p_H - (1-\alpha_S)\Delta p)\left(R - \frac{b}{\Delta p}\right), \end{aligned}$$

where $1 - \alpha_S \equiv (1-\alpha)p_L/((1-\alpha)p_L + \alpha p_H)$.

A "pooling equilibrium" is an equilibrium in which the borrower's first-period effort is independent of her private benefit. A "separating equilibrium" is (here) an equilibrium in which the b-type works and the B-type shirks in period 1. A "semiseparating" equilibrium is (here) an equilibrium in which in period 1 the b-type works and the B-type randomizes between working and shirking.

- Show that there exists no pooling and no separating equilibrium.
- Compute the semiseparating equilibrium. Does this model formalize the notion of reputational capital?

Exercise 6.4 (equilibrium uniqueness in the suboptimal risk-sharing model). In the suboptimal risk-sharing model of Application 8, prove the claim made in the text that the low-information-intensity optimum depicted by $\{S, B\}$ in Figure 6.3 is interim efficient if and only if the belief that the borrower is a good borrower lies below some threshold α^*, $0 < \alpha^* < 1$. (Verify the weak-monotonic-profit condition in the supplementary section, and show that α^* is in the interior of the interval $[0, 1]$.)

Exercise 6.5 (asymmetric information about the value of assets in place and the negative stock price reaction to equity offerings with a continuum of types). Consider the privately-known-prospects model of Application 2 in Section 6.2.2, but with a continuum of types. The entrepreneur already owns a project, which with probability p yields profit R and probability $1 - p$ profit 0. The probability p is private information of the borrower. From the point of view of the investors, p is drawn from cumulative distribution $F(p)$ with continuous density $f(p) > 0$ on some interval $[\underline{p}, \bar{p}]$. Assume that the distribution has monotone hazard rates:

$$\frac{f(p)}{F(p)} \quad \text{is decreasing in } p$$

and

$$\frac{f(p)}{1 - F(p)} \quad \text{is increasing in } p.$$

(This assumption, which is satisfied by most usual distributions, is known to imply that the truncated means $m^-(p)$ and $m^+(p)$ have slope less than 1:

$$0 < (m^-(p))' \equiv \frac{d}{dp}[E(\tilde{p} \mid \tilde{p} \leqslant p)] \leqslant 1$$

and

$$0 < (m^+(p))' \equiv \frac{d}{dp}[E(\tilde{p} \mid \tilde{p} \geqslant p)] \leqslant 1$$

(see, for example, An 1998).)

The model is otherwise as in Section 6.2.2. A seasoned offering may be motivated by a profitable deepening investment: at cost I, the probability of success can be raised by an amount τ such that

$$\tau R > I$$

(of course, we need to assume that $\bar{p} + \tau \leqslant 1$). The entrepreneur has no cash on hand, is risk neutral, and is protected by limited liability. The investors are risk neutral and demand a rate of return equal to 0.

(i) Show that in any equilibrium, only types $p \leqslant p^*$, for some cutoff p^*, raise funds and finance the deepening investment.

(ii) Show that $p^* > \underline{p}$ and that if $p^* < \bar{p}$, then

$$\frac{\tau R}{I} = \frac{p^* + \tau}{m^-(p^*) + \tau}.$$

Show that if the benefits from investment are "not too large," in that

$$\frac{\tau R}{I} < \frac{\bar{p} + \tau}{E[p] + \tau},$$

then indeed $p^* < \bar{p}$.

Show that if there are multiple equilibria, the one with the highest cutoff p^* Pareto-dominates (is better for all types than) the other equilibria.

(iii) Is there a negative stock price reaction upon announcement of an equity issue?

(iv) Focusing on an interior Pareto-dominant equilibrium, show that, when τ increases, the volume of equity issues increases.

Exercise 6.6 (adverse selection and ratings). A borrower has assets A and must find financing for a fixed investment $I > A$. As usual, the project yields R (success) or 0 (failure). The borrower is protected by limited liability. The probability of success is p_H or p_L, depending on whether the borrower works or shirks, with $\Delta p \equiv p_H - p_L > 0$. There is no private benefit when working. The private benefit enjoyed by the borrower when shirking is either b (with probability α) or B (with probability $1 - \alpha$). At the date of contracting, the borrower knows her private benefit, but the market (which is risk neutral and charges a 0 average rate of interest) does not know it. Assume that $p_L R + B < I$ (the project is always inefficient if the borrower shirks) and that

$$p_H\left(R - \frac{B}{\Delta p}\right) < I - A < p_H\left(R - \frac{b}{\Delta p}\right) \qquad (1)$$

and

$$[\alpha p_H + (1-\alpha)p_L]\left[R - \frac{b}{\Delta p}\right] < I - A. \qquad (2)$$

(i) Interpret conditions (1) and (2) and show that there is no lending in equilibrium.

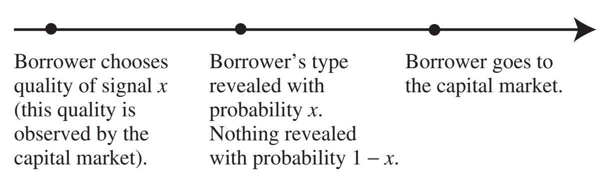

Figure 6.5

(ii) Suppose now that the borrower can at cost $r(x) = rx$ (which is paid from the cash endowment A) purchase a signal with quality $x \in [0, 1]$. (This quality can be interpreted as the reputation or the number of rating agencies that the borrower contracts with.) With probability x, the signal reveals the borrower's type (b or B) perfectly; with probability $1 - x$, the signal reveals nothing. The financial market observes both the quality x of the signal chosen by the borrower and the outcome of the signal (full or no information). The borrower then offers a contract that gives the borrower R_b and the lenders $R - R_b$ in the case of success (so, a contract is the choice of an $R_b \in [0, R]$). The timing is summarized in Figure 6.5.

Look for a pure strategy, *separating* equilibrium, that is, an equilibrium in which the two types pick different signal qualities.[79]

- Argue that the bad borrower (borrower B) does not purchase a signal in a separating equilibrium.
- Argue that the good borrower (borrower b) borrows under the same conditions regardless of the signal's realization, in a separating equilibrium.
- Show that the good borrower chooses signal quality $x \in (0, 1)$ given by
$$A = x(A - rx) + (1-x)\left[p_L\left(R - \frac{I - A + rx}{p_H}\right) + B\right].$$
- Show that this separating equilibrium exists only if r is "not too large."

Exercise 6.7 (endogenous communication among lenders). Padilla and Pagano (1997) and others have observed that information sharing about creditworthiness is widespread among lenders (banks,

79. One will assume that if the signal reveals the borrower's type, the investors put probability 1 on this type, even when they put weight 0 on the corresponding type after observing the quality of the signal.

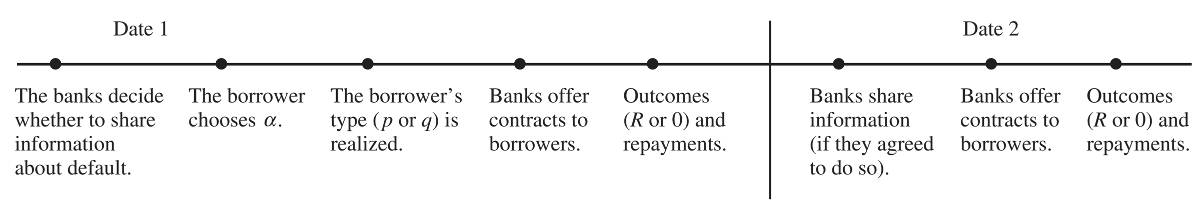

Figure 6.6

suppliers, etc.). For example, Dun & Bradstreet Information Services, one of the leading rating agencies, collects information from thousands of banks. Similarly, over 600,000 suppliers communicate information about delays and defaults by their customers; and credit bureaux centralize information about the consumer credit markets.

Padilla and Pagano (see also Pagano and Jappelli (1993) and the references therein) argue that information sharing has both costs and benefits for the banks. By sharing information, they reduce their differentiation and compete more with each other. But this competition protects their borrowers' investment and therefore enhances opportunities for lending. In a sense, the "tax rate" (the markup that banks can charge borrowers) decreases but the "tax base" (the creditworthiness of borrowers) expands. This exercise builds on the Padilla–Pagano model.

There are two periods ($t = 1, 2$). The discount factor between the two periods is δ. A risk-neutral borrower protected by limited liability has no cash on hand ($A = 0$). Each period, the borrower has a project with investment cost I. The project delivers at the end of the period R or 0. There is no moral hazard. The probability of success is p if the entrepreneur is talented (which has probability α), and q if she is not (which has probability $1 - \alpha$). We will assume that the market rate of interest in the economy is 0, that the lenders are risk neutral, and that only the good type is creditworthy:

$$pR > I > qR.$$

The date-1 and date-2 projects (if financed) are correlated and yield the same profit (they both succeed or both fail).

There are n towns. Each town has one bank and one borrower. The "local bank" has local expertise and thereby learns the local borrower's type; the other banks, the "foreign banks," learn nothing (and therefore have beliefs α that the entrepreneur is talented) at date 1. At date 2, the foreign banks learn

- only whether the borrower was financed at date 1, if there is no information sharing among banks;
- whether the borrower was financed at date 1 and whether she repaid (i.e., whether she was successful), if there is information sharing about riskiness.

In other words, information sharing is feasible on hard data (repayments), but not on soft data (assessment of ability).

Padilla and Pagano add two twists to the model. First, banks decide *ex ante* whether they will communicate information about default and they make this decision public. Second, the borrower's type may be endogenous (in which it refers more to an investment in the projects or industry than in "pure talent"): at increasing and convex cost $C(\alpha)$ $\{C' > 0, C'' > 0, C(0) = 0, C'(0) = 0, C'(1) = \infty\}$, the borrower develops a p project with probability α and a q project with probability $1 - \alpha$. C can be viewed as an investment cost and represents a nonmonetary cost borne by the borrower.

Contracts between banks and borrowers are *short-term* contracts. These contracts just specify a payment R_b for the borrower in the case of success during the period (and 0 in the case of failure). Furthermore, in each period, banks simultaneously make take-it-or-leave-it offers to borrowers. And at date 2, the incumbent bank (the bank that has lent at date 1) makes its offer after the other banks.

The timing is summarized in Figure 6.6.

(i) Suppose first that the probability α of being a p-type is exogenous (there is no borrower investment), that $[\alpha p+(1-\alpha)q]R-I+\delta(\alpha p+(1-\alpha)q)(R-I) < 0$, and that $qR - I + \delta q(R - I) < 0$. Show that the banks prefer not to share information.

(ii) Next, suppose that the borrower chooses α. Assuming that the two assumptions made in (i) still hold in the relevant range of αs (for example, $\alpha \in [0, \bar{\alpha}]$, where $\bar{\alpha}$ satisfies the conditions), show that the banks choose to share information.

Exercise 6.8 (pecking order with variable investment). Consider the privately-known-prospects model with risk neutrality and variable investment. For investment I, the realized income is either $R^{S}I$ (in the case of success) or $R^{F}I$ (in the case of failure), where $R^{S} > R^{F} \geqslant 0$. A good borrower has probability p_{H} of success when working and p_{L} when shirking; similarly, a bad borrower has probability q_{H} of success when working and q_{L} when shirking, where $p_{H} - p_{L} = \Delta p = q_{H} - q_{L}$, for simplicity. The entrepreneur's private benefit is 0 when working and BI when shirking. The entrepreneur is risk neutral and protected by limited liability; the investors are risk neutral and demand a rate of return equal to 0.

(i) Let $\tilde{U}_{b}^{SI}$ denote the bad borrower's gross utility under symmetric information.[80] Consider the problem of maximizing the good borrower's utility subject to the investors' breaking even on that borrower, to the mimicking constraint that the good borrower's terms not be preferred by the bad borrower to her symmetric-information terms, and to the no-shirking constraint. Let $\{R_{b}^{S}, R_{b}^{F}\}$ denote the (nonnegative) rewards of the good borrower in the cases of success and failure. Write the separating program.

(ii) Show that $R_{b}^{F} = 0$.

(iii) (Only if you have read the supplementary section.) Show that the separating outcome is the only perfect Bayesian equilibrium of the issuance game if and only if $\alpha \leqslant \alpha^{*}$ for some threshold α^{*}.

Exercise 6.9 (herd behavior). It is often argued that the managers of industrial companies, banks, or mutual funds are prone to herd.[81] They engage in similar investments with sometimes little evidence that their strategy is the most profitable. An economic agent may indeed select a popular strategy against her own information that another strategy may be more profitable. A number of contributions have demonstrated that herding behavior may actually be individually rational even though it is often collectively inefficient. The literature on herding behavior starts with the seminal contributions of Banerjee (1992), Bikhchandani et al. (1992), Scharfstein and Stein (1990), and Welch (1992); see Bikhchandani and Sharma (2001) for a survey of applications of this literature to financial markets.

There are several variants of the following basic argument. Consider first a sequence of agents $i = 1, 2, \dots$ choosing sequentially between strategies A and B. Agents receive their own signals; they observe previous decisions but not the others' signals. Suppose that agents 1 and 2 have, on the basis of their own information, selected A. Agent 3, observing the first two choices, may well then select strategy A even if her own signal favors the choice of B. Agent 4, not knowing agent 3's motivation to choose A, may then also choose strategy A even if his own signal points toward the choice of B. And so forth. It may therefore be the case that all agents choose A, even though the cumulative evidence, if it were shared, would indicate that B is the best choice.

The literature also analyzes herd behavior in situations in which agents have principals (that is, they are not full residual claimants for the consequences of their choices). In particular, such agents may adopt herd behaviors because of *reputational concerns* (see Chapter 7). Suppose, for instance, that a manager's job is rather secure; herding with the managers of other firms is then likely to be attractive to the manager: if the strategy fails, the manager has the excuse that other managers also got it wrong ("it was hard to predict"). Choosing an unpopular strategy, even if one's information points in that direction, is risky, as there will be no excuse if it fails. The literature on herd behavior has also investigated the use of benchmarking by principals in *explicit incentives* (compensation contracts) rather than in implicit ones (career concerns).

Let us build an example of herding behavior in the context of the privately-known-prospects model of Section 6.2. There are two entrepreneurs, $i = 1, 2$, operating in different markets, but whose optimal

80. This utility was derived in Section 3.4.2. It is equal to

$$\left[1 + \frac{q_{H}R - 1}{1 - q_{H}(R - B/\Delta p)}\right]A$$

if $q_{H}R \geqslant 1$, and to A otherwise.

81. One of the first empirical papers on herding behavior is Lakonishok et al. (1992). The large empirical literature on the topic includes Chevalier and Ellison (1999).

strategy is correlated. There are two periods, $t = 1, 2$. Entrepreneur i can raise funds only at date $t = i$ (so they secure funding sequentially). A project yields R when it succeeds and 0 when it fails. The entrepreneurs are risk neutral and protected by limited liability; the investors are risk neutral and demand a rate of return equal to 0. The entrepreneurs have no net worth or cash initially.

The two entrepreneurs each have to choose between strategy A and B. Strategies differ in their probability of success. A borrowing contract with investors specifies both the managerial compensation R_b in the case of success (and 0 in the case of failure) and the strategy that the entrepreneur will select.[82] Crucially, entrepreneur 2 and her potential investors observe the date-1 financing contract for entrepreneur 1. Entrepreneurs, but not investors, learn the state of nature.

Consider the following stochastic structure.

Unfavorable environment (probability $1 - \alpha$*).* The probabilities of success are, with equal probabilities, $(q, 0)$ for one project and $(0, q)$ for the other, where the first element is entrepreneur 1's probability of success and the second entrepreneur 2's. So entrepreneurs necessarily choose different projects if they apply for funding.

Favorable environment (probability α*).* With probability θ, the best project is the same for both and has probability of success p; the worst project for both has probability of success r, where

$$p > \max\{q, r\}.$$

With probability $1 - \theta$, the two entrepreneurs' best strategies differ: the probabilities of success are (p, r) and (r, p), respectively, for entrepreneur 1's and entrepreneur 2's best strategy (which are A or B with equal probabilities). Thus θ is the probability of correlation of the best strategies in a favorable environment; this probability is equal to 0 in the unfavorable environment.

Let $m \equiv \alpha p + (1 - \alpha)q$ and assume that

$$qR > I.$$

Show that funding and herding (with probability $\alpha(1 - \theta)$, entrepreneur 2 chooses entrepreneur 1's best strategy even though it does not maximize her probability of success) is an equilibrium behavior as long as

$$r\left[R - \frac{I}{\theta p + (1 - \theta)r}\right] \geqslant p\left[R - \frac{I}{q}\right].$$

Note that entrepreneur 2 is on average worse off than in an hypothetical situation in which investors did not observe the strategy of entrepreneur 1 (or that in which the optimal strategies were uncorrelated).

82. One will assume therefore that the first entrepreneur cannot condition her financing contract on the later choice of strategy by the second entrepreneur.

Exercise 6.10 (maturity structure). At date 0 the entrepreneur has cash on hand A and needs to finance an investment of fixed size I. At date 1, a deterministic income r accrues; a liquidity shock must be met in order for the firm to continue. Liquidation yields nothing. The probability of success in the case of continuation depends on a date-1 effort: for a good borrower, this probability is p_H or p_L depending on whether she behaves (no private benefit) or misbehaves (private benefit B); similarly, for a bad borrower, it is q_H or q_L. We assume that

$$p_H - p_L = q_H - q_L = \Delta p,$$

and so the incentive compatibility constraint in the case of continuation is the same for both types of borrower:

$$(p_H - p_L)R_b = (q_H - q_L)R_b = (\Delta p)R_b \geqslant B,$$

where R_b is the borrower's reward in the case of success.

The borrower knows at the date of contracting whether she is a "p-type" or a "q-type." Let

$$\rho_0^G \equiv p_H\left(R - \frac{B}{\Delta p}\right) \quad \text{and} \quad \rho_0^B = q_H\left(R - \frac{B}{\Delta p}\right)$$

denote the date-1 pledgeable incomes for the good and bad types.

The liquidity shock is deterministic and equal to ρ. Information is asymmetric at date 0, but the capital market learns the borrower's type perfectly at date 1, before the liquidity shock has to be met. Assume that

$$\rho_0^G > \rho > \rho_0^B.$$

Suppose further that under symmetric information only the good borrower is creditworthy (provided that she is incentivized to behave).

Assume that $r < I - A < r + [\rho_0^G - \rho]$. Show that the good borrower can costlessly signal her type.

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