STOCK MARKET EFFICIENCY AND ECONOMIC EFFICIENCY: IS THERE A CONNECTION?

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Abstract

In a capitalist economy prices serve to equilibrate supply and demand for goods and services, continually changing to reallocate resources to their most efficient uses. However, secondary stock market prices, often viewed as the most "informationally efficient" prices in the economy, have no direct role in the allocation of equity capital since managers have discretion in determining the level of investment. What is the link between stock price informational efficiency and economic efficiency?

We present a model of the stock market in which: (i) managers have discretion in making investments and must be given the right incentives; and (ii) stock market traders may have important information that managers do not have about the value of prospective investment opportunities. In equilibrium, information in stock prices will guide investment decisions because managers will be compensated based on informative stock prices in the future.

The stock market indirectly guides investment by transferring two kinds of information: information about investment opportunities and information about managers' past decisions. The fact that stock prices only have an indirect role suggests that the stock market may not be a necessary institution for the efficient allocation of equity. We emphasize this by providing an example of a banking system that performs as well.

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I. Introduction

In a capitalist society, prices for goods and service play the central role in resource allocation. The strength of capitalism lies in its ability to make these prices reflect essential information so that resources are deployed efficiently.

Consider a fishmonger whose prices for different kinds of fish change every day in response to availability. These prices have a direct effect on the behavior of customers entering the shop: if the price is high they may choose to eat beef for dinner instead. In other words, the allocation of fish to the most efficient uses (in this case, to the people with the highest marginal utility of fish consumption) is accomplished by price changes. These price changes directly regulate the use of the fish.

Now consider the equity capital market and its relation to the allocation of funds for capital investment. If a company's share price goes up, it is not obvious whether its access to equity capital will be altered. This is because stock prices differ from prices in the fish market and most other markets in three ways.

First, the equity price is not a marginal value but an average value. The stock market price is a secondary market price: it values the entire firm rather than a marginal investment. The role played by the stock price is the same as in the fish-market example only in the simple case where a newly organized firm issues equity for the first time to fund its investment. In this special case, if investors believe that the capital can be more efficiently deployed elsewhere, or if the expected returns on the project are insufficient to induce enough saving, then the price will be low and the project may not be undertaken. However only an insignificant fraction of investment capital is raised in this way: the vast majority of investment is funded by retained earnings, by seasoned equity issues, or by new non-equity external financing such as bank loans or bonds.

Second, decisions about the allocation of investment capital are generally delegated to managers with little or no ownership stake in the firm. Managers can decide on dividend policy, leverage, the timing of new issues of seasoned equity and other securities and therefore they have discretion over the amount of funding available for investing in new assets. The problem of giving managers appropriate incentives is complicated by the fact that their decisions may have implications for the long-term performance of the firm after they have left.

Third, the flow of information in a stock market may be bi-directional: the market may want to learn about the quality of the managers's decisions, but the manager may also want to learn the market's valuation of prospective investments. The stock price, although intrinsically irrelevant to the investment decision, may be useful indirectly because it conveys information about prospective investment projects and cash flows. For example a high stock price may signal to the manager that the market believes that the firm has profitable investment opportunities. The fact that the manager seeks to infer information from the price means that the stock price is different from the price of fish: the fishmonger's customers do not care that the market price reflects the marginal utilities of other consumers and the marginal costs of fishing. They need only compare the price to their own marginal valuation (see Hayek (1945)). In the stock market, managers (acting on the shareholders' behalf) care about other agents' information as reflected in the price, but the stock price is not the marginal cost of investment funds.

In a setting where consumers learn about product quality from the price, both effects may be present: consumers will first infer the quality from the price, then compare the price to their marginal valuation. Models of Rational Expectations Equilibrium (REE) capture both of these effects in general. At one extreme, Hayek's prices (e.g. the fishmonger example) have a direct allocative role and no indirect signalling role. When consumers buy fish it is important that the price reflects information, but the consumers care only about the price and do not need to infer the information that determined the price. In general, commodity prices may have both a direct allocative role and an indirect signalling role. For example, if consumers receive different private signals about the quality of fish, the price will convey information about quality as well as information about scarcity. In REE, an agent's demand for the fish will depend on the price through this quality inference. We argue that secondary equity prices are at the other extreme to Hayek's prices: they have an indirect signalling role but no direct allocative role.

These special features of the equity market raise the question of whether "efficient" stock prices are related to the efficient allocation of resources. In this paper we identify two roles for efficient stock prices in enhancing economic efficiency: a forward-looking or prospective role and a backward-looking or retrospective role. We consider a model which integrates a managerial agency problem with a stock market in which information acquisition is costly and prices are not fully revealing.

Managerial decisions and stock-price formation are linked. In the stock market, traders are willing to produce information (in addition to the manager's information) about the expected future profitability of current investment opportunities, and to trade on this information, if managers' investment decisions are guided by the price signals. Since, in this case, the information produced by the informed traders relates to an investment decision that has not yet been taken, we call this the "prospective" role of stock market prices.

Because of the agency problem, managers will not necessarily extract information from stock prices; they must be given appropriate incentives to make good investment decisions. These incentives are linked to the stock market because stock prices can be used to evaluate previous management decisions. Stock prices can then improve investment decisions by allowing more accurate monitoring of the quality of past managerial investment policy. We call this a "retrospective" role for stock market prices. To summarize, the stock market has an information-production role and a monitoring role.

The prospective role of stock prices arises because we allow the market to have information that the manager does not already have. This potentially allows the current stock price to be of value in making current investment decisions. If the price goes down, the manager is less likely to invest; if the price goes up, he is more likely to invest. Of course, in equilibrium, the price movement incorporates the fact that the manager's investment will, itself, depend on the price. The retrospective role of providing suitable managerial incentives arises because we assume that managers' investment decisions can affect the value of the firm over a horizon that may be significantly longer than their tenure. As a result compensation cannot be based on the realized returns resulting from their decisions, but if informed traders find it profitable to produce information about future profitability, then compensation may be based on the stock price. If the stock price is informative, such a compensation arrangement can ameliorate some of the affects of managerial discretion that can occur when the manager's objective function is different that those of the outside shareholders.

Our model shows how stock prices can serve to allocate equity capital. However, this arises in an indirect way: agents infer information about investment decisions from stock prices, even though the stock price is not the "cost of capital" for the investment. Since the only function of the price is the indirect one of conveying information, the question arises of whether the same information transfer could occur in an alternative institution without the price. Indeed, the two tasks of investment appraisal and monitoring management that stock market information is used for are precisely the functions that banks are supposed to perform in making loans. A large literature identifies the role of banks as information producers and monitors of management, e.g. Diamond (1984) and Boyd and Prescott (1986). To emphasize the difference between stock prices and other prices, we explore how a bank could replace the stock market in our model. Instead of informed traders making decisions about costly information production and possibly trading on their information, the bank hires loan officers who produce information which can be used for both prospective and retrospective evaluation. The same information is produced as in the stock market economy but it is not transmitted via prices.

There is a large body of research on welfare economics, and an equally large one on efficient markets theory. However, there has been relatively little work linking these two literatures. By and large welfare economists have not studied corporate control or asset pricing, while efficient-markets researchers have taken for granted that informational efficiency implies economic efficiency. For example, Fama (1976) writes:

> An efficient capital market is an important component of a capitalist system ... if the capital market is to function smoothly in allocating resources, prices of securities must be good indicators of value. (p. 133)

In welfare economics, there is a literature on the role of the stock market in the efficient allocation of risk (see Diamond (1967), Hirshleifer (1972) and Stiglitz (1981)), but relatively less work on its role in guiding investment in corporations. There are, however, two strands of literature that do link stock prices and investment decisions: q-theory in Economics and capital budgeting in Finance.

Tobin's (1969) theory is based on q, the ratio of current market value of assets to their cost. If $q > 1$, the firm should increase its capital stock. The theory links current stock prices to investment decisions in the spirit of Keynes (1936):

> ... daily revaluations of the Stock Exchange, though they are primarily made to facilitate transfers of old investments between one individual and another, inevitably exert a decisive influence on the rate of current investment. For there is no sense in building up a new enterprise at a cost greater than that at which a similar existing enterprise can be purchased; whilst there is an inducement to spend on a new project what may seem an extravagant sum, if it can be floated off on the Stock Exchange at an immediate profit. (p. 151)

q-theory is related to our model in that current stock prices play a role in determining whether new investment is desirable. As emphasized by Fischer and Merton (1984), "the stock market should be a predictor of the rate of corporate investment" (p. 84-85). As in our model, rising stock prices cause higher investment. The empirical evidence is consistent with this view: investment in plant and equipment increases following a rise in stock prices in all countries that have been studied. In fact, lagged stock returns outperform q in predicting investment. This is true both at the macroeconomic level and in cross-sections of firms. See Barro (1990), Bosworth (1975), and Welch (1994). In contrast to q-theory, the finance literature typically views the chain of causality differently: the information partition of managers is assumed to be finer than that of agents outside the firm. This precludes the possibility of managers learning from stock prices. For example, Korajczyk, Lucas and Macdonald (1990) and Lucas and Macdonald (1990) interpret the fact that positive abnormal stock returns (over a 200-day window) precede a seasoned equity issue as evidence of an adverse selection problem in issuing firms, rather than as evidence that rising stock prices send positive signals to managers.

We differ from q-theory in two main respects. First, we emphasize that firms are controlled not by owners but by managers. q-theory incorporates the prospective role of stock prices but not the retrospective role. The second difference relates to the distinction between marginal q and average q (see Hayashi (1982)). As the above quotation from Keynes makes clear, what is relevant is marginal q. Because, in our model, the informativeness of prices is endogenous, marginal q can only be computed as part of an equilibrium where agents form beliefs about the decision rules followed by other agents. In particular, stock market prices in our model only contain information about future projects that the market believes will be undertaken; this is because in equilibrium, managers will act on this information and so the informed traders will be able to make trading profits that offset their costs of producing the information. In contrast, q-theory takes stock prices, and hence q, as given.

Capital budgeting theory is a normative decision rule for evaluating investment projects: expected cash flows are discounted at suitably risk-adjusted rates of return. The discount rate is independent of current prices; the risk premium and β's are estimated using past prices. In principle expected cash flows should be conditional on all available information, which could include the current and past stock prices. In practice, capital budgeting theory does not explain where expected future cash flows come from. It is assumed that expected future cash flows are exogenous, implying that capital budgeting has little financial or economic content:

> ...we consider the investment decisions of firms whose shares are traded in perfect capital markets... Strictly speaking, such decisions are technological rather than 'financial' problems and so belong to the field of 'production.' For a variety of reasons, however, the general subject of 'capital budgeting' has come to be taught in finance courses... (Fama and Miller (1972, p. 108)).

In our model not all the relevant information is always known by the manager and, consequently, he can improve his decisions by using the prospective stock price. In other words, the stock market may have information that the manager does not have. The expected cash flows for the project are calculated using the stock price and, hence, are not exogenous.

The papers which are closest in spirit to ours are Henrotte (1992), Kihlstrom and Matthews (1990), and Bresnahan, Milgrom and Paul (1992). Bresnahan, Milgrom and Paul provide two separate models for the two roles of the stock price we discussed above, namely the prospective role (information in the stock price guides investment) and the retrospective role (using stock prices in compensation contracts). Henrotte focuses on the prospective role: in his model a firm adjusts its production level depending on its own internal information as well as other information inferred from the stock price. Kihlstrom and Matthews focus on the retrospective role: an entrepreneur who must make an unobservable costly effort to manage the firm sells part of his equity to outsiders. How much equity he retains determines his incentives for undertaking effort and this is priced correctly in equilibrium. The equity share that he retains may be interpreted as a compensation contract.

To summarize, this paper presents a view of the firm and the stock market with the following features:

- Information about an individual firm's prospects may flow from the stock market into the firm as well as in the other direction;

- Traders will make the effort to acquire this information only because managers will heed the resulting price signals;
- Firms are run by managers with discretion about the flow of investment capital into and out of the firm;
- Because managers' employment horizons are short compared to the horizons over which their decisions affect the firm, they may need to be motivated by compensation linked to share prices;
- Because the role of stock market prices is to signal information rather than to provide a direct allocative mechanism, other institutions, in particular banks, may be equally effective at producing and transferring the information.

The paper proceeds as follows. In Section II we set out the model and discuss the assumptions. In Section III we define and construct the equilibrium. Section IV discusses a comparison with a bank economy.

II. The Model

In this section we set out the model and assumptions. We study a multi-period model of a representative firm in stationary equilibrium. We start with an overview of the model and the equilibrium.

Each period, the firm's shares trade in a stock market in which some agents may undertake costly information acquisition. The share price will therefore tend to reflect this information.

Investment decisions are made by a sequence of managers. In a period when an investment opportunity arrives, the manager who has to make the investment decision can undertake a costly effort which may yield information about the value of a project. The manager can also infer information from the stock price (if it is informative in equilibrium). Then the investment decision is made. The following period, the manager leaves the firm, but the project returns are not realized until the period after that. As a result of this difference in horizons, executive compensation will be linked to the stock price to induce effort.

Only one project may be undertaken at a time. This means that in any given period, the firm will be in one of two states: either it is able to invest in a new project, or it already has a project underway that was started last period. We call the former state a "prospective" market because stock prices can potentially be used to guide investment decisions. The latter state is "retrospective" because the stock price's forecast of next period's return from the project can be used to evaluate the quality of last period's investment decision. We have designed the model for simplicity to separate the retrospective and prospective roles of stock price information by assuming that a new project cannot be started before any existing project has finished.

In equilibrium, traders will acquire and trade on information, so that both prospective and retrospective prices will be informative. The compensation contract will be optimally designed, based on the retrospective price, to induce the manager also to make an effort to produce information about the project value. However, sometimes the manager may make this effort but not receive any information and in that case he will infer information about the project value from the prospective market price.

We now turn to the details of the model.

A. The Firm: There is a representative all-equity firm with a single, perfectly divisible, share outstanding. Whenever the firm issues new equity, we assume for simplicity (and without loss of generality) that it simultaneously carries out a reverse stock-split to maintain the total number of shares at one.

B. Projects: The firm can invest in a project which requires \$1 of investment. The project does not return any cash flows the following period, but realizes a liquidating value the period after. Only one project can be undertaken at once: the firm cannot invest in a new project until the current one has been completed. The firm need not necessarily undertake a project, even if there is no existing project in progress (the investment decision is public information: everyone can see whether the firm has a project underway).

A project payoff (which occurs the period after next) is equally likely to be either H or L (H>L). There is no cash flow in the interim period. The random return is not publicly known until it actually arrives, but some agents may be able to discover it privately one or two periods in advance.

As a result of this technology, in any given period a firm can be in either one of two states. Either it has no current project and consequently is considering investing in a new project (prospective stock market), or it has a project underway and has no capital budgeting decision to take (retrospective stock market).

C. Discount rate: The discount rate is r, determined exogenously by an alternative activity in infinitely elastic supply.

D. Managers: Each firm is run by a manager who is hired in a competitive labor market. Managers have zero opportunity cost (this assumption is without loss of generality).

Although firms are long-lived, managers live for only two periods: they manage the business when young, and consume during retirement. The importance of this assumption is that a manager retires (and actually dies) before any project he initiated has come to fruition.

A manager can be in one of two situations. If the firm has no outstanding project when the manager is hired, then he is a "decision-maker": he will choose whether to invest in the new project. Otherwise, if there is a project underway, he has no decision to take: he is a "caretaker." A caretaker is purely vestigial (since he has no opportunity cost he does not require any compensation), and consequently is ignored in our analysis.

A decision-making manager who must decide whether to invest can choose to try and produce information on the project's value. To do this, he must exert effort that costs e.

However, this does not guarantee that he actually will receive information: if he makes the effort then with probability α he learns the project payoff.

Clearly, shareholders will have to provide a contract to motivate the manager if they want him to produce this information. Because the manager retires before the project value is realized, the contract cannot condition on the actual project performance. However, a contract linked to the stock price may provide adequate incentives. We will show that such a contract induces the manager to expend effort to produce a signal about the long-term project and, subsequently, make the correct investment decision.

E. Financing: A decision-making manager has complete discretion over the investment policy of the firm. Each period the firm may receive a cash flow from past investments which is paid out as a dividend. Then, if an investment is undertaken the cost is raised in a rights issue. There are no transaction costs of the rights issue.

F. The Stock Market: The firm's stock is traded in a competitive market-making system, as usual in the literature following Kyle (1985) and Glosten and Milgrom (1985). Traders submit market orders to a marketmaker who observes the order flow. An order can originate from either an informed trader (probability π) or a liquidity trader (probability $1-\pi$) but not both. The marketmaker sets prices to equal expected present value (discounted at rate r) conditional on the trading orders received, and meets the net order from an inventory of stock and cash.

G. Liquidity Traders: In each period the chance of a liquidity trader arriving to trade in the stock market is $1-\pi$; in that event he is equally likely to be buying or selling. The quantity traded in either case is x. The following period he reverses this trade. Note that this unwinding of trades one period later is not informative to the marketmaker so we will not include it in our definition of the order flow.

H. Informed traders: Each period, there is one informed trader who decides whether to bear a cost δ of producing information about the payoff of the project. If he incurs the cost, he learns the true value of the project with probability π. We assume that the decision to incur the cost of information production, δ, is a "career" decision: a trader decides whether or not to produce information before knowing whether the market will be prospective or retrospective.

In a prospective market, the trader may learn the payoff of the project under evaluation. In a retrospective market, the trader may learn the realization of the project undertaken last period.

I. Sequence of Events: When the stock market opens it will either be the case that a caretaker is being hired while a decision-maker is retiring (a retrospective market), or a decision-maker is being hired and the previous manager is retiring (a prospective market). In the latter case, the previous manager could be either a decision-maker who decided against investing last period, or a caretaker finishing up a project started two periods ago. The sequence of events is as follows.

Prospective market:

- Previous project (if any) liquidates.
- Previous manager retires and is compensated.
- Proceeds of project liquidation, net of managerial compensation, are paid out as dividend (rights issue if negative).
- Decision-maker hired. Decides whether to make an effort and, if so, learns project value with probability α.
- Prospective stock market trades occur.
- Decision-maker chooses whether to invest \$1 in the project and, if so, raises \$1 in a rights issue.

If no investment, then next period the firm returns to the prospective market. If the project was approved then the firm continues to the retrospective market next period:

Retrospective market:

- Decision-maker retires.
- Caretaker hired.
- Retrospective stock market trades occur.
- Decision-maker compensated based on stock price (using a rights offering).

Next period, go to a prospective market.

J. Exogenous Parameters

The exogenous parameters of the model are: H, L, r, e, α, π, x and δ. We assume that the parameters are such that some projects are positive net present value and others are negative NPV. We also require conditions on the parameters that ensure that the cost of information production is not prohibitive. These conditions are given in Appendix A.

K. Discussion of Assumptions

We do not provide a theory of the firm in this paper. In other words, we take for granted a number of characteristics of firms including: (i) the projects cannot be unbundled through time as "stand-alone" mini-firms; (ii) there are no owner-managers who can internalize the agency problem; (iii) managers have complete discretion over financing and investment decisions.

If (i) were not true, each project would be financed with a initial public offering and prices would be Hayek-prices, i.e. as we discussed in the introduction, they would be directly allocative. If (ii) and (iii) were not true, there would be no agency problem in the firm. These three assumptions are important distinguishing characteristics of the modern corporation and we study their consequences.

In reality managers have extensive discretion over dividend policy, leverage and new security issues. This gives them discretion over cash flows into and out of the firm. We have modelled this in a simple way by assuming that new investment capital is always raised via an equity rights issue (implicitly, we have also assumed that the issue is sufficiently discounted that its success can be guaranteed). Thus, in our model, an equity issue is effectively a negative dividend.

We have assumed that managers' tenures are shorter than project lives. This implies that managers cannot be compensated and motivated on the basis of the realized return from the project. In other words, in a situation where managers' investment decisions have long-term implications, accounting information is not sufficient to provide adequate managerial incentives. Because stock prices, unlike accounting information, incorporate expected future cash flows they can be used to motivate managers if they are sufficiently informative. This is the retrospective role of stock prices.

The structure of the model in which prospective and retrospective markets succeed each other as described above should not be taken literally. This sequencing is only for clarity. Clearly, one could construct a more complicated setting in which the stock price simultaneously provides prospective and retrospective information about multiple projects of varying vintage.

We assume that only one order will arrive in the stock market each period, as in Glosten and Milgrom (1985). This perfect negative correlation between informed trades and liquidity trades is merely designed for expositional convenience to simplify the calculation of prices that may arise in equilibrium. Since the order flow is either x or $-x$ there are only two possible prices, whereas there would be five possible prices otherwise.

The price formation mechanism we have adopted is standard. In the literature the marketmaker device for price formation is motivated as representing Bertrand competition between a specialist and a "crowd" of traders who compete for the order flow (e.g., Kyle (1985)). In our model it is not necessary to view the marketmaker as corresponding exactly to a specific trading mechanism. The marketmaker can be viewed implicitly as a large number of long-term shareholders. They are risk-neutral and are willing to hold the stock when cash flows are discounted at rate r.

In order for some agents to profitably trade on private information, it is necessary to have another group of agents who lose money when they trade. These are variously modelled in the literature as exogenous trades interpreted as "liquidity" traders, "noise" traders, "hedgers" and perturbations to security supply. An important question concerns the explicit modelling of the utility functions of these agents and their motives for trade. This question is addressed by Diamond and Verrechia (1981), Dow and Gorton (1994a, 1994b, 1995), and Bias and Hillion (1994). For simplicity we do not delve into these issues here and simply assume that liquidity trade is exogenous.

Our model incorporates roles for the stock market as an information conveyor, as a mechanism for corporate control, and as an institution providing liquidity. Two important themes that we have ignored are the role of takeovers in corporate control and the risk-sharing function of the stock market. We have emphasized managerial compensation as the corporate control device, rather than a takeover market, but that is for simplicity. Our model is certainly compatible with a takeover market; it is simply not needed in the equilibrium we construct.

In our analysis everyone is risk neutral and the role of the stock market is not connected with any considerations of efficient risk allocation. In principle, one could incorporate both ingredients (risk-sharing and information production) into the same analysis, but they do not appear to be linked so we have not explicitly included risk-sharing. However, as discussed above, the liquidity traders could be viewed as trading for hedging reasons.

An informed trader is an agent who has learned that the project payoff is H or L, i.e. exactly the same information that the manager may learn. This assumption is made for simplicity. The reader might well imagine that it would be more realistic to have the investment decision of the manager depend upon combining different pieces of information, one piece which the manager may learn by virtue of being an insider and another piece about external conditions relevant to the firm which is potentially provided via an informative stock price.

III. Equilibrium

In this section we define and construct the equilibrium.

A. Definition of Equilibrium

An equilibrium is:

(i) A pricing rule for the marketmaker that sets price equal to the asset's expected value conditional on the net order flow;

(ii) An investment policy for the manager which maximizes his expected compensation, given his remuneration contract and given the informativeness of stock prices;

(iii) A compensation contract chosen by the stockholders that induces the manager to maximize the value of the firm;

(iv) An optimal decision by traders on whether to produce information and, if so, a trading rule to maximize expected profits.

We consider only stationary equilibria.

B. The Manager's Information in Equilibrium

The equilibrium of the model has the following properties:

(1) Informed traders (both prospective and retrospective) choose to produce information;

(2) The optimal compensation contract induces the manager to produce information also.

We begin by specifying the manager's possible information sets in equilibrium. The manager makes an effort (so he may receive a signal) and the stock price on average contains information about the return on the project. The manager may learn that the project is high value (H) or low value (L) or he receives no signal at all (N). As will be seen below, the stock price takes one of two possible values: it may be high to reflect a buy order (B), or it may be low in response to a sell order (S).

So, when a manager decides whether to invest in the project his information consists of his private information, N, H, or L, and a price, B or S. The possible combinations, their probabilities and the project value in each case are:

1) HB: this means that the manager receives information that the project payoff will be H, and the stock price reflects a buy order. The probability of this event is:

$$\tfrac{1}{2}\alpha(\pi + \tfrac{1}{2}(1-\pi)) = \tfrac{1}{4}\alpha(1+\pi),$$

since the manager becomes informed with probability α and receives the good signal with probability ½. An informed trader arrives with probability π and, if so, will have received the signal H. If a liquidity trader arrives (probability $1-\pi$), he is equally likely to buy or sell.

2) HS: the probability of this event is $\tfrac{1}{4}\alpha(1-\pi)$.

Note that the probability of the event that the manager learns H, (i.e., the joint event (1) or (2)) is: $\tfrac{1}{2}\alpha$. The project payoff in both cases is H.

3) NB: the probability of this event is $(1 - \alpha)\tfrac{1}{2}$. The expected payoff of the project is: $L(\tfrac{1}{2})(1 - \pi) + H(\tfrac{1}{2})(1 + \pi)$, as shown in Appendix B. The expected payoff depends on the relative likelihood of an informed trader and a liquidity trader.

4) NS: the probability of this event is also $(1 - \alpha)\tfrac{1}{2}$. The expected payoff of the project is: $L(\tfrac{1}{2})(1 + \pi) + H(\tfrac{1}{2})(1 - \pi)$, as shown in Appendix B.

5) LB, and 6) LS: The probability of the event that the manager learns L (i.e., that either (5) or (6) happen) is: $\tfrac{1}{2}(1 - \alpha)$. The project payoff in both cases is L.

These six possibilities may be viewed as six different projects. The question is, which of these are positive net present value projects in equilibrium. The first three projects are positive NPV, and the others are negative NPV under the condition that:

$$\tfrac{1}{2}(1+\pi)H + \tfrac{1}{2}(1-\pi)L > (1+r)^2 > \tfrac{1}{2}(1-\pi)H + \tfrac{1}{2}(1+\pi)L,$$

as we have assumed (Appendix A).

C. The Marketmaker and Equilibrium Prices

We now derive the marketmaker's pricing rule to satisfy equilibrium condition (i), i.e. that the marketmaker sets price equal to the asset's expected value (discounted at r) conditional on the net order flow.

In both the prospective and the retrospective markets there are generally two possible prices, one for a buy order and one for a sell order. The price has the following general form:

p = present value of cash flow of current project

− present value of managerial compensation for current project

+ continuation value of the firm,

where the continuation value (CV) reflects the value of the firm's future positive-NPV projects.

In the prospective stock market there are two possible prices: $p_{B\rightarrow}$ for a buy order and $p_{S\rightarrow}$ for a sell order. A buy order could come from either a liquidity trader or an informed trader with favorable information, and the equilibrium will reflect the chances of each. Similarly a sell order could be caused by either liquidity trade or unfavorable information.

The possibilities for a retrospective market are more complicated. A retrospective market follows a prospective market in the previous period which had either a high price (buy order) or a low price (sell order). If the project was chosen despite a sell order last period, it is certainly a good project because it must have resulted from the manager receiving favorable information. We call this a 'fully revealing' retrospective market. In this case, the marketmaker sets the stock price at:

$$p_{\leftarrow} = H/(1+r) + CV/(1+r).$$

The other case occurs when the project was chosen when the stock price was high last period. The manager may or may not have received favourable private information. If he did not receive information, he must have been guided by the stock price which may or may not have reflected an informed buy order. So the retrospective trader may receive information that is not already publicly known. In this 'partially revealing' retrospective market, there are two possible prices: $p_{B\leftarrow}$ for a buy order and $p_{S\leftarrow}$ for a sell order.

We solve for the prices, $p_{B\rightarrow}$, $p_{S\rightarrow}$, $p_{B\leftarrow}$ and $p_{S\leftarrow}$ in Appendix B.

D. The Optimal Managerial Compensation Contract

We now turn to equilibrium conditions (ii): the investment policy for the manager maximizes his expected compensation, given the compensation contract; and (iii): the compensation contract is chosen by the stockholders to induce the manager to maximize the value of the firm.

The optimal compensation contract will induce the manager to make an effort to produce information. Compensation will be contingent on both the prospective and retrospective prices. We first consider the case where the prospective price is low. In this case, the following argument shows that compensation will be a constant, m_0.

Lemma 1 (Non-manipulation): When the prospective market price is low, it is not possible to give the manager a performance-based payment.

Proof: By hypothesis, the contract provides incentives so that the manager invests when he receives good news or when he does not receive information but the prospective market price is high. Therefore, the marketmaker who observes the manager investing when the price is low infers that the project is of high value and sets the price accordingly. So, in this event, the contract could in principle condition on whether the investment was undertaken. However, if the investment is undertaken the contract could not also condition on subsequent share price performance since there is only one possible price.

If the contract specifies different payments for investing and not investing, the manager will either always invest or never invest (depending on which payment in larger). This violates the hypothesis that the manager's investment decision depends on his information and on the prospective market price. ‖

Following a high price in the prospective market, there are three possibilities for the reward:

1. The manager chooses to invest in the project and next period the (retrospective) price is high: payment m_1.
2. The manager chooses to invest in the project and next period the (retrospective) price is low: payment m_2.
3. The manager does not invest: payment m_3.

We now characterize the optimal managerial compensation contract, i.e. optimal values of m_0, m_1, m_2, and m_3.

Proposition 1: The following system of payments constitutes an optimal contract for managerial compensation:

$$m_0 = e$$

$$m_1 = 2e/(1+\pi^2)$$

$$m_2 = 0$$

$$m_3 = e(1-\pi)/(1+\pi^2).$$

Proof: These four numbers must minimize the expected payment by the firm, while satisfying three types of incentive compatibility constraints: first, the manager must be induced to make an effort to produce information (the "effort constraint"); second, he must be induced to take the correct investment decisions (the "investment constraints"); third, he must not have an incentive to manipulate prices (the non-manipulation constraint, Lemma 1). The effort constraint is derived in Step 1; the incentive constraints are given in Step 2.

We start by computing the conditional probabilities, given the manager's information, of receiving each of the possible payments. Figure 1 shows how each of these four amounts may arise in equilibrium (the probabilities shown in the figure are derived in Appendix D). From the point of view of the manager, before he has chosen whether to make an effort, the chances of the different payments are as follows:

m_0: paid if the prospective price is low; this occurs with probability ½.

m_1: can occur in one of two ways:

(i) $p_{B\rightarrow}$ occurs, the manager gets a good signal, invests and then $p_{B\leftarrow}$ occurs. The probability is:

$½\ \alpha\ ½(1+\pi)\ ½(1+\pi) = (1/8)\alpha(1+\pi)^2.$

(ii) $p_{B\rightarrow}$ occurs, the manager gets no signal, invests and then $p_{B\leftarrow}$ occurs. The probability is:

$½\ (1-\alpha)\ ½(1+\pi^2) = ¼\ (1-\alpha)(1+\pi^2).$

The sum of the two probabilities is $¼(1 - ½\alpha + \alpha\pi - ½\alpha\pi^2 + \pi^2)$.

m_2: can occur in one of two ways, depending on whether the manager receives private information:

(i) $p_{B\rightarrow}$ occurs, the manager gets a good signal, invests and then $p_{S\leftarrow}$ occurs. The probability is:

$½\ \alpha\ ½(1+\pi)\ ½(1-\pi) = (1/8)\alpha(1-\pi^2).$

(ii) $p_{B\rightarrow}$ occurs, the manager gets no signal, invests and then $p_{S\leftarrow}$ occurs. The probability is:

$½\ (1-\alpha)\ ½(1-\pi^2) = ¼\ (1-\alpha)(1-\pi^2).$

The sum of the two probabilities is: $¼(1-½\alpha)(1-\pi^2)$.

m_3: is paid when $p_{B\rightarrow}$ occurs, the manager gets a bad signal, and does not invest. The probability is:

$$\tfrac{1}{2}\ \alpha\ \tfrac{1}{2}(1-\pi) = \tfrac{1}{4}\alpha(1-\pi).$$

Step 1: The effort constraint is:

$$m_0\ \tfrac{1}{2} + m_1\ \tfrac{1}{4}(1 - \tfrac{1}{2}\alpha + \alpha\pi - \tfrac{1}{2}\alpha\pi^2 + \pi^2)$$
$$+ m_2\ \tfrac{1}{4}(1-\tfrac{1}{2}\alpha)(1-\pi^2) + m_3\ \tfrac{1}{4}\alpha(1-\pi) \geq e. \quad (1)$$

Note that an optimal contract minimizes the expected payment to the manager, hence (1) will hold with equality.

Step 2: We now turn to the incentive compatibility conditions for the manager to take the correct investment decisions. First note that the manager is paid a constant amount when the prospective market price is low. Consequently incentive compatibility holds trivially.

When the prospective market price is high, there are three possible situations where the manager must take the correct investment decision (see Figure 1):

1. He must invest when he receives a good signal:

$$\tfrac{1}{2}(1+\pi)m_1 + \tfrac{1}{2}(1-\pi)m_2 \geq m_3. \quad (2)$$

2. He must not invest when he receives a bad signal:

$$m_3 \geq \tfrac{1}{2}(1-\pi)m_1 + \tfrac{1}{2}(1+\pi)m_2. \quad (3)$$

3. He must invest if he receives no signal:

$$\tfrac{1}{2}(1+\pi^2)m_1 + \tfrac{1}{2}(1-\pi^2)m_2 \geq m_3. \quad (4)$$

Note that (2) and (3) together imply that $m_1 \geq m_2$, which together with (4) implies that (2) holds strictly and therefore $m_1 > m_2$. This conforms with the economic intuition that the payment scheme must be increasing in the retrospective stock price to induce correct behavior.

The above four constraints do not uniquely determine the payments. It is immediate to verify that the payments given in the proposition satisfy all four constraints, with (1) holding with equality. ||

E. Traders Information-Production Decisions and Trading Rules

We now consider the final condition for equilibrium, i.e. (iv): an optimal decision by traders on whether to produce information and, if so, a trading rule to maximize expected profits. Since information is costly to produce, trading profits must be at least enough to cover this cost. The decision on producing information is a "career decision," i.e. traders make their decision before knowing whether they can trade is prospective or retrospective. In other words, they cannot specialize in being "retrospective" or "prospective" traders.

Proposition 2 (Traders Optimal Decisions): Traders choose to produce information.

Proof: We show that a trader's expected trading profit exceeds the cost of information production in both the prospective and retrospective markets. We consider each in turn.

Step 1: A trader in the prospective market who makes an effort and receives information is equally likely to receive good or bad news. If he receives good news he buys x shares of the stock at price $p_{B\rightarrow}$ and sells them one period later (in the retrospective market) at either $p_{B\leftarrow}$ or $p_{S\leftarrow}$. Since he has received good news, $p_{B\leftarrow}$ is more likely than $p_{S\leftarrow}$ (the probabilities are given in Appendix E). His payoff (per share) is:

$$- p_{B\rightarrow} + (1-\alpha)[\tfrac{1}{2}(1+\pi^2)p_{B\leftarrow} + \tfrac{1}{2}(1-\pi^2)p_{S\leftarrow}]/(1+r)$$
$$+ \alpha[\tfrac{1}{2}(1+\pi)p_{B\leftarrow} + \tfrac{1}{2}(1-\pi)p_{S\leftarrow}]/(1+r).$$

If he receives bad news, he sells x shares short at $p_{S\rightarrow}$ and covers his position by buying the same number of shares one period later. In this case, the manager will not invest as he relies on the price if he receives no signal, while if he does receive a signal it must also be unfavorable. Consequently the market one period later will be a prospective market in which it is equally likely for the price to be $p_{B\rightarrow}$ or $p_{S\rightarrow}$. His payoff per share in this case is:

$$p_{S\rightarrow} - (\tfrac{1}{2}p_{B\rightarrow} + \tfrac{1}{2}p_{S\rightarrow} - m_0)/(1+r).$$

Since effort costing δ produces information with probability π, he makes the effort if:

$$\tfrac{1}{2}\{-p_{B\rightarrow} + (1-\alpha)[\tfrac{1}{2}(1+\pi^2)p_{B\leftarrow} + \tfrac{1}{2}(1-\pi^2)p_{S\leftarrow}]/(1+r)$$

$$+ \alpha[\tfrac{1}{2}(1+\pi)p_{B\leftarrow} + \tfrac{1}{2}(1-\pi)p_{S\leftarrow}]/(1+r)\}$$

$$+ \tfrac{1}{2}\{p_{S\rightarrow} - (\tfrac{1}{2}p_{B\rightarrow} + \tfrac{1}{2}p_{S\rightarrow} - m_0)/(1+r)\}$$

$$\geq \delta/x\pi,$$

or:

$$p_{B\rightarrow}[-1 - \tfrac{1}{2}/(1+r)] + p_{S\rightarrow}[1 + \tfrac{1}{2}/(1+r)]$$

$$+ p_{B\leftarrow}[\tfrac{1}{2}(1 + \pi^2 - \alpha\pi^2 + \alpha\pi)]/(1+r)$$

$$+ p_{S\leftarrow}[\tfrac{1}{2}(1 - \alpha\pi)(1 - \pi)]/(1+r) + m_0/(1+r)$$

$$\geq 2\delta/x\pi.$$

By assumption (A.2) in Appendix A, this inequality is satisfied. Note from the solutions for the prices, given in Appendix B, that the prices do not depend on δ or x. Condition (A.2) therefore amounts to assuming that δ/x is sufficiently small.

Step 2: Traders choose to produce information and participate in the retrospective stock market. As was explained in Section III.B., above, the retrospective market can be of two types, depending on whether the price in the prospective market last period was high or low. If the price was low, then the project is certain to succeed and the informed trader's information has no value; this is the fully revealing retrospective market. Alternatively, the price was high, in which case the retrospective trader may receive information that is not already publicly known: a partially revealing retrospective market. Since the decision on information production is made before it is known which of these two situations applies, we take an average across the two cases.

In Appendix E we show that the probability of a retrospective market being partially revealing is:

$$\tfrac{1}{2}(2 - \alpha + \alpha\pi).$$

If a trader in the partially revealing retrospective market receives information, it is not equally likely to be good or bad news. If he receives good news he buys x shares of the stock at price $p_{B\leftarrow}$ and sells them one period later (in the prospective market) at either $p_{B\rightarrow}$ or $p_{S\rightarrow}$. Since the prices next period reflect information about the next possible project, their distribution is independent of the value of the current project. $p_{B\rightarrow}$ and $p_{S\rightarrow}$ are equally likely and the retrospective informed trader is, therefore, speculating on the cash flows that will arise before the price is set next period.

His payoff (per share) is:

$$- p_{B\leftarrow} + \tfrac{1}{2}p_{B\rightarrow}/(1+r) + \tfrac{1}{2}p_{S\rightarrow}/(1+r) - m_1 + H/(1+r)$$

where m_1 is the compensation for the retiring decision-maker manager, and H is the project dividend which will be paid next period. Note that the managerial compensation for the incoming caretaker is zero. It can be seen from Appendix E that the probability of receiving good news given that it is a partially revealing retrospective market is:

$$\pi(1+\pi)/(2 - \alpha + \alpha\pi).$$

If he receives bad news, he sells x shares short at $p_{S\leftarrow}$ and covers his position by buying the same number of shares one period later. Again, one period later there will be a prospective market in which it is equally likely for the price to be $p_{B\rightarrow}$ or $p_{S\rightarrow}$. His payoff per share in this case is:

$$+ p_{S\leftarrow} - \tfrac{1}{2}p_{B\rightarrow}/(1+r) - \tfrac{1}{2}p_{S\rightarrow}/(1+r) + m_2 - L/(1+r)$$

where m_2 is the compensation received by the retiring decision-making manager as a result of the low share price $p_{S\leftarrow}$ and L is the dividend which will be paid next period. It can be seen from Appendix E that the probability of receiving bad news given that it is a partially revealing retrospective market is:

$$\pi(1-\pi)(1-\alpha)/(2 - \alpha + \alpha\pi).$$

In the fully revealing retrospective market, the payoff to the retrospective trader is zero since the information about the value of the project is already known.

Since effort costing δ produces information with probability π, and that he trades x shares, he will make the effort if:

$$x\tfrac{1}{2}(2-\alpha+\alpha\pi)\{[\pi(1+\pi)/(2-\alpha+\alpha\pi)][-\,p_{B\leftarrow} + \tfrac{1}{2}p_{B\rightarrow}/(1+r) + \tfrac{1}{2}p_{S\rightarrow}/(1+r) - m_1$$
$$+ H/(1+r)] + [\pi(1-\pi)(1-\alpha)/(2-\alpha+\alpha\pi)][p_{S\leftarrow} - \tfrac{1}{2}p_{B\rightarrow}/(1+r) - \tfrac{1}{2}p_{S\rightarrow}/(1+r) + m_2$$
$$-L/(1+r)]\} \geq \delta.$$

Or:

$$p_{B\leftarrow}[-\,(1+\pi)] + p_{S\leftarrow}[(1-\pi)(1-\alpha)] + p_{B\rightarrow}[2\pi+\alpha-\alpha\pi]/(1+r) +$$
$$p_{S\rightarrow}[2\pi+\alpha-\alpha\pi]/(1+r) + H(1+\pi)/(1+r) - L(1-\pi)(1-\alpha)/(1+r)$$
$$-\,(1+\pi)m_1 - (1-\pi)(1-\alpha)m_2$$
$$\geq 2\delta/x\pi,$$

as we have assumed (A.3). Note from the solutions for the prices, given in Appendix B, that the prices do not depend on δ or x. Condition (A.3) therefore amounts to saying that δ/x is sufficiently small. ||

This completes the derivation of the equilibrium.

F. Remark on the Equilibrium

In the equilibrium of the model, stock prices convey information to managers that they use to allocate investment capital. Thus, the demand for investment capital (the value of the marginal product of capital curve) itself depends on the role of prices in equilibrium. The value of the marginal product of capital is not simply a description of the available technology. Standard neoclassical theory (e.g. q-theory) takes the marginal product of capital as a technologically-determined amount. One point of our paper is to emphasize that the relevant technology describes not only a description of the firm's production possibilities but also a description of the available technology for producing and transmitting information in the stock market.

This point is illustrated in Figure 2. The figure represents the aggregate supply and demand for capital in an economy populated by many firms of the type described in our model, each with identically independently distributed projects. The quantity of capital on the abscissa is expressed per firm in a prospective market situation. The ordinate measures the internal rate of return (IRR) on the various project types. The most profitable projects correspond to the case where the manager learns that the value of the project is H, in which case the IRR is $(H)^{1/2} - 1$. The fraction of firms where this occurs is $\frac{1}{2}\alpha$. The next most profitable projects occur when the manager does not receive a signal, but the prospective stock price reflects a buy order. The IRR is $[\frac{1}{2}(1+\pi)H + \frac{1}{2}(1-\pi)L]^{1/2} - 1$. A fraction $\frac{1}{2}(1-\alpha)$ of firms are in this situation. By assumption (A.1) the preceding two cases are the only positive net present value projects. Next, a fraction $\frac{1}{2}(1-\alpha)$ of firms have a low prospective stock price and the manager did not receive a signal. The IRR is $[\frac{1}{2}(1-\pi)H + \frac{1}{2}(1+\pi)L]^{1/2} - 1 < r$. Finally, in a fraction $\frac{1}{2}\alpha$ of the firms, the manager receives information that the project payoff would be L and the IRR is $(L)^{1/2} - 1 < r$. Hence, the marginal product of capital curve is not exogenous, but rather depends on the equilibrium process whereby prices aggregate information.

IV. The Bank Economy

Above we have described an economy in which stock prices transfer information about prospective investment opportunities and past investment decisions. However, the stock price serves no direct allocative role.

To emphasize this special nature of stock prices, and to show that capitalist economies do not therefore require stock markets, we now sketch a comparison with an economy without a stock market. In this economy investment decisions are made via a financial intermediary under the same information constraints as the above stock market economy. In the bank economy information is not produced or transmitted in the stock market. Instead, information is transmitted by direct communication between the firm and the provider of capital, i.e., the bank. We compare these two systems.

In the bank economy investment decisions are made by managers as before and information is produced by bank employees rather than traders. These loan officers, like our stock market traders, may receive information if they make a costly effort and in equilibrium they will need to be given the correct incentives to do so. Liquidity traders borrow from or deposit in the bank. Finally, the long-term shareholders, previously viewed as the marketmaker, own the firm. The role of the bank is to provide evaluations of possible investments and of managerial performance in regard to past investment decisions. In other words, the bank produces both prospective and retrospective information.

We will argue that the allocation of equity capital in the bank economy is at least as efficient as in the stock market economy. The allocation of equity capital in the stock market economy is second-best because stock prices are noisy. Therefore, a manager who is guided by the stock price may make an incorrect investment (given the trader's information). In this economy however, liquidity trade is necessary to allow informed traders to make enough profits to cover the cost of information production.

The bank economy is also in a second-best world. The bank produces and transfers both prospective and retrospective information to the firm. Because the bank faces an agency problem in hiring "loan officers" to produce information, noise will again be introduced into the information transmission process. In the stock market case, noise is introduced when decentralized groups, informed traders and liquidity traders, meet in the stock market. In the bank economy, decisions are taken within a large organization and noise is introduced as a result of agency problems within the organization.

A. The Firm

The firm faces the same investment opportunities as before. The manager of the firm, as before, may produce information by making an effort. In making his investment decision he can obtain advice from the bank. He retains the authority to invest or not: the bank will be willing to allow this discretion because it recognizes that the manager may have superior information.

The following ownership structures are equivalent: (i) the firm is owned by the long-term shareholders, but they are also willing to deposit funds in the bank at interest r; (ii) the bank is owned by the long-term shareholders and the firm is owned by the bank; (iii) any combination of the above.

B. The Bank

The bank hires agents to produce information about the firm's investment prospects and about the manager's past investment decisions. These "loan officers" have the same possibilities for producing information as the informed traders in the stock market model. Because producing information is costly, the bank must design a compensation scheme which induces them to make the effort.

C. Liquidity Traders

The liquidity traders are the same as before, except that instead of buying and selling stock, they deposit or borrow at the bank.

D. Loan Officers

Loan officers play the same role in the bank economy as the informed traders in the stock market economy. In the stock market economy, informed traders traded on the basis of their information. In the bank economy, loan officers will produce a report evaluating an investment. We assume that the loan officers are recruited from a large pool of candidates that consists almost entirely of incompetent agents who are incapable of producing information. Loan officers have limited liability which prevents them from being penalized for incorrect decisions. However, they can be rewarded for correct decisions. Candidate loan officers have an opportunity cost k that represents their wage in alternative employment and as before they incur δ of making an effort to produce information. If they do make the effort, they receive information with probability π. They live for two periods: in the first period they work for the bank and in the second period they are rewarded.

If a loan officer produces a report, he will be providing either prospective information or retrospective information. In the former case, he submits a report to the manager and the bank which indicates his view on whether the project being currently considered is of quality H or L. In the latter case, he submits a report on a project which was undertaken last period. Again, the report indicates that this project is of quality H or L. To encourage information production, the bank does not reveal the report of a prospective loan officer to the subsequent retrospective loan officer.

E. Equilibrium in the Bank Economy

Since the bank cannot observe whether a loan officer has made an effort, a contract must be designed to induce effort. The contract will depend on performance: the prospective loan officer is rewarded if his report agrees with the subsequent report of the retrospective loan officer, while the retrospective loan officer is rewarded if his report accurately describes the subsequent project realization. This contract must be designed so as to attract only competent candidates, and to induce them to work to produce information.

The contracting environment here is the same as in Dow and Gorton (1994b). Consequently, we simply state that the optimal contract is: (i) a positive payment, w, in case the report is corroborated next period; (ii), no payment in case the report conflicts with subsequent evidence; and (iii), no payment if the loan officer admits to having no information.

The reason for the optimality of this contract is as follows. By limited liability negative payments are impossible and, hence, the officer is not paid if the loan officer's report conflicts with subsequent evidence. Also, there is no payment if the loan officer admits to having no information. If there was a strictly positive payment in this event, the contract would attract a flood of incompetent applicants for the job of loan officer. Hence, the only outcome in which the loan officer is paid a reward is when his report is corroborated by subsequent information (i.e., the next loan officer's report in the case of a prospective report and the project realization in the case of a retrospective report).

Because of the threat of entry posed by incompetents, the contract cannot offer a payment in the event that the loan officer has, in fact, made an effort, but has received no information. Thus, when a loan officer makes an effort, but does not receive information his best strategy is to randomly report an evaluation. This means that the report will be true with probability π and will be randomly chosen with probability $1 - \pi$, i.e., the overall probability that a report is correct is $\frac{1}{2}(1+\pi)$. Note that this is exactly the same as the probability in the stock market economy that a buy order coincides with a high project value.

The accuracy of the prospective and retrospective evaluations in the bank economy is identical to that of the information in the stock market prices. As a result, the same managerial compensation contract (described in Proposition 1) will apply in the bank economy. So, the allocation of resources in the bank economy is the same as in the stock market economy: the manager will invest if he learns that the project will be high value or if he learns nothing, but the bank report on the project is favorable. One period later his compensation is based on the bank's retrospective evaluation of the project.

Our analogy between a bank economy and a stock market is clearly simplified and we do not interpret this result literally. However, the comparison makes the point that an alternative institution, such as a bank, may be equally capable of performing the two functions of the stock market that we have identified as providing the link between economic efficiency and financial market efficiency.

Appendix A: Conditions on Exogenous Parameters

As explained in section II.J, we require the following conditions on the exogenous parameters:

$$\tfrac{1}{2}(1+\pi)H + \tfrac{1}{2}(1-\pi)L > (1+r)^2 > \tfrac{1}{2}(1-\pi)H + \tfrac{1}{2}(1+\pi)L \qquad (A.1)$$

$$\begin{aligned} & p_{B\rightarrow}[-\,1 - \tfrac{1}{2}/(1+r)] + p_{S\rightarrow}[1 + \tfrac{1}{2}/(1+r)] \\ & \quad + p_{B\leftarrow}[\tfrac{1}{2}(1 + \pi^2 - \alpha\pi^2 + \alpha\pi)]/(1+r) \\ & \quad + p_{S\leftarrow}[\tfrac{1}{2}(1 - \alpha\pi)(1 - \pi)]/(1+r) + m_0/(1+r) \\ & \quad \geq 2\delta/x\pi \end{aligned} \qquad (A.2)$$

$$\begin{aligned} & p_{B\leftarrow}[-\,(1+\pi)] + p_{S\leftarrow}[(1-\pi)(1-\alpha)] + p_{B\rightarrow}[2\pi+\alpha-\alpha\pi]/(1+r) + \\ & \quad p_{S\rightarrow}[2\pi+\alpha-\alpha\pi]/(1+r) + H(1+\pi)/(1+r) - L(1-\pi)(1-\alpha)/(1+r) \\ & \quad - (1+\pi)m_1 - (1-\pi)(1-\alpha)m_2 \\ & \quad \geq 2\delta/x\pi \end{aligned} \qquad (A.3)$$

where the prices $p_{B\rightarrow}$, $p_{S\rightarrow}$, $p_{B\leftarrow}$ and $p_{S\leftarrow}$ are defined in Section III.D. and formulas expressing them in terms of exogenous parameters are given in Appendices B and C. Since these formulas are quite long we have not substituted for the prices here. The role played by (A.1) is explained in Section III.B. The roles played by (A.2) and (A.3) are explained in Propositions 2.

Appendix B: Calculation of Stock Prices

Prospective Stock Market Prices: In the prospective stock market there are two possible prices each period: $p_{B\rightarrow}$ for a buy order and $p_{S\rightarrow}$ for a sell order. In general we will refer to a price reflecting a buy order as a "high price" and a price reflecting a sell order as a "low price."

$p_{B\rightarrow}$ can arise as follows:

- A liquidity trader arrives and buys: this occurs with probability $(1-\pi)$ ½.
- A prospective informed trader arrives and buys. This happens if the trader learns that the current project will succeed. The probability of this event is π ½.

So, the conditional probability that the project, if chosen, would succeed, given that there is a buy order, is:

$$\pi_{B\rightarrow} \equiv (\pi + ½(1-\pi))/(\pi + (1-\pi)) = \pi + ½(1-\pi) = ½(1+\pi).$$

We now compute the price in this event. This depends on the expected payoff that the project would yield in two periods' time. Recall that with probability α the manager receives a signal and will ignore the stock price when making the investment decision. There are therefore three possibilities, with the following probabilities (conditional on a buy order):

1) The project value is H and the manager gets a signal. In this case the project payoff is certain to be H and the project is chosen so the value of the share is:

$$-1 - [½(1+\pi)m_1 + ½(1-\pi)m_2]/(1+r) + H/(1+r)^2 + CV/(1+r)^2,$$

where CV is the continuation value of a share in the firm as described and calculated in Appendix B below.

The probability of this event is $½(1+\pi)\alpha$. (See Figure 1.)

2) The manager does not receive a signal. Since the manager follows the stock price in this case, he invests also. The value is:

$$-1 - [½(1+\pi^2)m_1 + ½(1-\pi^2)m_2]/(1+r)$$

$$+ [\tfrac{1}{2}(1+\pi)H + \tfrac{1}{2}(1-\pi)L]/(1+r)^2 + CV/(1+r)^2,$$

and the probability of this event is $1-\alpha$.

3) The project value is L and the manager gets a signal. In this case the project payoff is certain to be L and the project is not chosen. The value of the share is:

$$[CV - m_3]/(1+r)$$

and the probability of occurrence is $\tfrac{1}{2}(1-\pi)\alpha$. (See Figure 1.)

Averaging over these three cases, the stock price set by the marketmaker on a buy order is:

$$\begin{aligned} p_{B\to} = {} & [1 - \tfrac{1}{2}\alpha(1-\pi)][- 1 + CV/(1+r)^2] + \tfrac{1}{2}\alpha(1-\pi)(CV - m_3)/(1+r) \\ & - [\tfrac{1}{2}\alpha(1+\pi)\tfrac{1}{2}(1+\pi) + (1-\alpha)\tfrac{1}{2}(1+\pi^2)]\ m_1/(1+r) \\ & - [\tfrac{1}{2}\alpha(1+\pi)\tfrac{1}{2}(1-\pi) + (1-\alpha)\tfrac{1}{2}(1-\pi^2)]\ m_2/(1+r) \\ & + \tfrac{1}{2}(1+\pi)\ H/(1+r)^2 \\ & + [(1-\alpha)\tfrac{1}{2}(1-\pi)]\ L/(1+r)^2. \end{aligned} \tag{B.1}$$

We now consider the price in the event of a sell order, $p_{S\to}$. In this case, as shown in Lemma 1, the manager's compensation is always m_0. A sell order can arise as follows:

- a liquidity trader arrives and sells, with probability $\tfrac{1}{2}(1-\pi)$.
- a prospective informed trader arrives and sells. This trader will have learned that the long-term project would realize L two periods from now. The probability of this event is $\tfrac{1}{2}\pi$.

So the conditional probability that the project would realize value H given that there is a sell order is:

$$\pi_{S\to} \equiv (\tfrac{1}{2})(\tfrac{1}{2})(1-\pi)/(\tfrac{1}{2}\pi + \tfrac{1}{2}(1-\pi)) = \tfrac{1}{2}(1-\pi).$$

We now compute the price in this event. There are four possibilities, with the following probabilities (conditional on a sell order):

1) The project value is H and the manager gets a signal. In this case the project payoff is

certain to be H and the project is chosen so the value of the share is:

$$-1 - m_0/(1+r) + H/(1+r)^2 + CV/(1+r)^2,$$

where CV is the continuation value of a share in the firm as described and calculated in Appendix C below.

The probability of this event is $\frac{1}{2}(1-\pi)\alpha$.

2) The project value is H but the manager does not receive a signal. Since the manager follows the stock price in this case, he does not invest so the value is $(CV - m_0)/(1+r)$. The probability of this event is $\frac{1}{2}(1-\pi)(1-\alpha)$.

3) The project value is L and the manager gets a signal. In this case the project payoff is certain to be L and the project is not chosen. The value of the share is $(CV - m_0)/(1+r)$ and the probability of occurrence is $\frac{1}{2}(1+\pi)\alpha$.

4) The project value is L but the manager does not receive a signal. Again he does not invest (since he follows the stock price) and the value is $(CV - m_0)/(1+r)$. The probability of this event is $\frac{1}{2}(1+\pi)(1-\alpha)$.

Averaging over these four cases, the stock price set by the marketmaker on a sell order is:

$$p_{S\rightarrow} = \tfrac{1}{2}(1-\pi)\alpha[-1 + H/(1+r)^2 + CV/(1+r)^2]$$
$$+ [1 - \tfrac{1}{2}(1-\pi)\alpha][(CV - m_0)/(1+r)]. \qquad (B.2)$$

Retrospective Stock Market Prices: In a retrospective market the firm has a project which was initiated last period and will mature next period. If last period's price reflected a sell order (i.e., $p_{S\rightarrow}$), then the project could only have been chosen because the manager received good news (H). This is the fully revealing retrospective market.

In this case, the marketmaker sets stock price at:

$$p_{\leftarrow} = H/(1+r) + CV/(1+r). \qquad (B.3)$$

The less degenerate case of a partially revealing retrospective market occurs when last period's price reflected a buy order ($p_{B\rightarrow}$). In this partially revealing retrospective stock market there are two possible prices: $p_{B\leftarrow}$ for a buy order and $p_{S\leftarrow}$ for a sell order. Before the marketmaker observes the order flow, his belief that the project is good, based on the fact that there was a buy order last period and that the project was undertaken, is:

$$\text{Prob}(H|p_{B\rightarrow}\ \&\ \text{invest}) = \text{Prob}(H\ \&\ p_{B\rightarrow}\ \&\ \text{invest})/\ \text{Prob}(p_{B\rightarrow}\ \&\ \text{invest})$$

$$= \tfrac{1}{2}(1+\pi)/[1 - \tfrac{1}{2}(1-\pi)\alpha].$$

$p_{B\leftarrow}$ can arise as follows:

- A liquidity trader arrives and buys: this occurs with probability $\tfrac{1}{2}(1-\pi)$.
- A retrospective informed trader arrives and buys. This trader will have learned that H will be realized next period. The probability of this event is $\tfrac{1}{2}\pi$.

So, the conditional probability of a good project if there is a buy order is:

$$\{\tfrac{1}{2}(1-\pi)\tfrac{1}{2}(1+\pi)/[1 - \tfrac{1}{2}(1-\pi)\alpha] + \tfrac{1}{2}\pi\ (1)\}\ /\ [\tfrac{1}{2}(1-\pi) + \tfrac{1}{2}\pi].$$

$$= [\tfrac{1}{2} - \pi^2 - \tfrac{1}{2}\alpha\pi(1 - \pi)]/[1 - \tfrac{1}{2}\alpha(1 - \pi)].$$

So:

$$p_{B\leftarrow} = [\tfrac{1}{2} - \pi^2 - \tfrac{1}{2}\alpha\pi(1 - \pi)]/[1 - \tfrac{1}{2}\alpha(1 - \pi)]\ (H)/(1+r)$$
$$+ \{1 - [\tfrac{1}{2} - \pi^2 - \tfrac{1}{2}\alpha\pi(1 - \pi)]/[1 - \tfrac{1}{2}\alpha(1 - \pi)]\}\ (L)/(1+r)$$
$$- m_1 + CV/(1+r). \quad \text{(B.4)}$$

$p_{S\leftarrow}$ can arise as follows:

- A liquidity trader arrives and sells: this occurs with probability $\tfrac{1}{2}(1-\pi)$.
- A retrospective informed trader arrives and sells. This trader will have learned that L will be realized next period. The probability of this event is $\tfrac{1}{2}\pi$.

So, the conditional probability of a good project if there is a sell order is:

$$\{\tfrac{1}{2}(1-\pi)\tfrac{1}{2}(1+\pi)/[1 - \tfrac{1}{2}(1-\pi)\alpha]\}\ /\ [\tfrac{1}{2}(1-\pi) + \tfrac{1}{2}\pi]$$

$$= (1-\pi)\tfrac{1}{2}(1+\pi)/[1 - \tfrac{1}{2}(1-\pi)\alpha].$$

So:

$$p_{S+} = \{(1-\pi)\tfrac{1}{2}(1+\pi)/[1 - \tfrac{1}{2}(1-\pi)\alpha]\}\ (H)/(1+r)$$
$$+ \{1 - (1-\pi)\tfrac{1}{2}(1+\pi)/[1 - \tfrac{1}{2}(1-\pi)\alpha]\}\ (L)/(1+r)$$
$$- m_2 + CV/(1+r). \qquad (B.5)$$

The five prices, (B.1) to (B.5), depend on CV which is given in (C.1) in terms of r and the exogenous parameters of the model.

Appendix C: Calculation of the Firm's Continuation Value (CV)

At a decision-making date (i.e. a prospective market), there are eight possible outcomes (see Figure 1):

1. The prospective price is high, the manager receives a good signal and invests, and the retrospective price next period is also high. This occurs with probability $\frac{1}{2}\ \alpha\ \frac{1}{2}(1+\pi)\ \frac{1}{2}(1+\pi)$ and the value in this case is:

   $- 1 - m_1/(1+r) + H/(1+r)^2 + CV/(1+r)^2.$

2. The prospective price is high, the manager receives a good signal and he invests, but the retrospective price is low. This occurs with probability $\frac{1}{2}\ \alpha\ \frac{1}{2}(1+\pi)\ \frac{1}{2}(1-\pi)$ and the value in this case is:

   $- 1 - m_2/(1+r) + H/(1+r)^2 + CV/(1+r)^2.$

3. The prospective price is high, the manager receives a bad signal and he does not invest. This occurs with probability $\frac{1}{2}\ \alpha\ \frac{1}{2}(1-\pi)$ and the value is:

   $(CV - m_3)/(1+r).$

4. The prospective price is high but the manager does not receive a signal. He invests nevertheless, and the retrospective price is also high. This occurs with probability $\frac{1}{2}\ (1-\alpha)\ \frac{1}{2}(1+\pi^2)$ and the value in this case is:

   $- 1 - m_1/(1+r) + (\frac{1}{2}(1+\pi)H + \frac{1}{2}(1-\pi)L)/(1+r)^2 + CV/(1+r)^2.$

5. The prospective price is high but the manager does not receive a signal. He invests nevertheless, and the retrospective price is low. This occurs with probability $\frac{1}{2}\ (1-\alpha)\ \frac{1}{2}(1-\pi^2)$ and the value in this case is:

   $- 1 - m_2/(1+r) + (\frac{1}{2}(1+\pi)H + \frac{1}{2}(1-\pi)L)/(1+r)^2 + CV/(1+r)^2.$

The following cases correspond to the lowest branch of Figure 1, where the manager receives fixed compensation m_0.

6. The prospective price is low, but the manager gets a good signal and invests. This occurs with probability ½ α ½$(1-\pi)$. The value is then:

$$-1 - m_0/(1+r) + H/(1+r)^2 + CV/(1+r)^2.$$

7. The prospective price is low, the manager gets a bad signal and he does not invest. This occurs with probability ½ α ½$(1+\pi)$. The value is then:

$$(CV - m_0)/(1+r).$$

8. The prospective price is low and the manager receives no signal so he does not invest. This occurs with probability ½$(1-\alpha)$ and value is as in case 7.

The continuation value of the firm is the expectation of the values in each of these eight events:

$$\begin{aligned} CV = {} & \tfrac{1}{2}\alpha[-1 + H/(1+r)^2 + CV/(1+r)^2] \\ & + \tfrac{1}{2}(1-\alpha)[-1 + (\tfrac{1}{2}(1+\pi)H+\tfrac{1}{2}(1-\pi)L)/(1+r)^2 + CV/(1+r)^2] \\ & + \tfrac{1}{2}CV/(1+r) - \tfrac{1}{4}[1-\tfrac{1}{2}\alpha(1-\pi)^2+\pi(\alpha+\pi)]\, m_1/(1+r) \\ & - \tfrac{1}{4}(1-\pi^2)(1-\tfrac{1}{2}\alpha)\, m_2/(1+r) - \tfrac{1}{4}\alpha(1-\pi)\, m_3/(1+r) \\ & - \tfrac{1}{2}\, m_0/(1+r). \end{aligned}$$

Solving for CV gives the solution:

$$\begin{aligned} CV = {} & \{\ \tfrac{1}{2}\alpha[-1 + H/(1+r)^2] \\ & + \tfrac{1}{2}(1-\alpha)[-1 + (\tfrac{1}{2}(1+\pi)H+\tfrac{1}{2}(1-\pi)L)/(1+r)^2] \\ & - \tfrac{1}{4}[1-\tfrac{1}{2}\alpha(1-\pi)^2+\pi(\alpha+\pi)]\, m_1/(1+r) \\ & - \tfrac{1}{4}(1-\pi^2)(1-\tfrac{1}{2}\alpha)\, m_2/(1+r) - \tfrac{1}{4}\alpha(1-\pi)\, m_3/(1+r) \\ & - \tfrac{1}{2}\, m_0/(1+r)\ \} \,/\, [1 - \tfrac{1}{2}/(1+r) - \tfrac{1}{2}/(1+r)^2]. \end{aligned} \tag{C.1}$$

Appendix D: Conditional Probabilities for Figure 1 and Proposition 1

This appendix gives the conditional probabilities shown in Figure 1 and needed for the proof of Proposition 1. Figure 1 shows the probability that the manager will invest given that he received a signal and that the price in the prospective market was high. This is probability is:

$$\text{Prob}(H|p_{B\rightarrow}\ \&\ \text{signal}) = \text{Prob}(H\ \&\ p_{B\rightarrow}\ \&\ \text{signal})/\text{Prob}(p_{B\rightarrow}\ \&\ \text{signal})$$

$$= [\alpha{\tfrac{1}{2}}\ ((1-\pi){\tfrac{1}{2}} + \pi)]/({\tfrac{1}{2}}\alpha)$$

$$= {\tfrac{1}{2}}(1+\pi).$$

Similarly, the probability that he does not invest in this case is given by:

$$\text{Prob}(L|p_{B\rightarrow}\ \&\ \text{signal}) = {\tfrac{1}{2}}(1-\pi).$$

For the figure and for the proof of Proposition 1 we need the probability that the price in the retrospective market next period will be high, given that this period the manager did not receive a signal and the price is high:

$$\text{Prob}(p_{B\leftarrow}|p_{B\rightarrow}\ \&\ \text{no signal}) = \text{Prob}(p_{B\leftarrow}\ \&\ H|p_{B\rightarrow}\ \&\ \text{no signal}) +$$

$$\text{Prob}(p_{B\leftarrow}\ \&\ L|p_{B\rightarrow}\ \&\ \text{no signal})$$

$$= \text{Prob}(H|p_{B\rightarrow}\ \&\ \text{no signal})\ \text{Prob}((p_{B\leftarrow}|H\ \&\ p_{B\rightarrow}\ \&\ \text{no signal}) +$$

$$\text{Prob}(L|p_{B\rightarrow}\ \&\ \text{no signal})\ \text{Prob}((p_{B\leftarrow}|L\ \&\ p_{B\rightarrow}\ \&\ \text{no signal})$$

$$= {\tfrac{1}{2}}(1+\pi){\tfrac{1}{2}}(1+\pi) + {\tfrac{1}{2}}(1-\pi){\tfrac{1}{2}}(1-\pi)$$

$$= {\tfrac{1}{2}}(1+\pi^2).$$

Similarly,

$$\text{Prob}(p_{S\leftarrow}|p_{B\rightarrow}\ \&\ \text{no signal}) = 1 - \text{Prob}(p_{B\leftarrow}|p_{B\rightarrow}\ \&\ \text{no signal})$$

$$= {\tfrac{1}{2}}(1-\pi^2).$$

Appendix E: Conditional Probabilities for Proposition 2

This appendix gives the conditional probabilities for the proof of Proposition 2. Although the algebraic derivation of these probabilities is quite long, it is a routine application of Bayes' Rule. We start with the case where the firm is currently in a prospective market (Case A). The probability of a high price in the retrospective market next period given that the project is good is:

$$\text{Prob}(p_{B\leftarrow}|H) = [\text{Prob}(p_{B\leftarrow} \text{ from an informed trader } \& \text{ H})$$
$$+ \text{Prob}(p_{B\leftarrow} \text{ from an uninformed trader } \& \text{ H})]/$$
$$[\text{Prob(informed trader } \& \text{ H}) + \text{Prob(uninformed trader } \& \text{ H})]$$
$$= [\pi \tfrac{1}{2} + (1-\pi)\tfrac{1}{4}]/[\pi \tfrac{1}{2} + (1-\pi)\tfrac{1}{2}]$$
$$= \tfrac{1}{2}(1+\pi).$$

Similarly,

$$\text{Prob}(p_{S\leftarrow}|H) = 1 - \text{Prob}(p_{B\leftarrow}|H) = \tfrac{1}{2}(1-\pi).$$

Next consider the firm in a retrospective market (Case B). There are two probabilities that are needed: the probability that the project will succeed given that we are in a partially revealing retrospective market; and the probability that a retrospective market is fully revealing.

The event of the market being retrospective is the same as the event that the investment is undertaken. The joint event of ($p_{B\rightarrow}$ & invest) corresponds to a partially revealing retrospective market; the joint event of ($p_{S\rightarrow}$ & invest) corresponds to a fully revealing retrospective market.

The probability that the project will succeed given that we are in a partially revealing retrospective market is:

$$\text{Prob}(H|p_{B\rightarrow} \& \text{ invest}) = \text{Prob}(H \& p_{B\rightarrow} \& \text{ invest})/\text{Prob}(p_{B\rightarrow} \& \text{ invest}).$$

$$\text{Prob}(p_{B\rightarrow} \& \text{ invest}) = \alpha\tfrac{1}{2}\pi + \alpha\tfrac{1}{2}(1-\pi)\tfrac{1}{2} + (1-\alpha)\pi\tfrac{1}{2} + (1-\alpha)(1-\pi)\tfrac{1}{2}$$
$$= \tfrac{1}{2}\alpha\tfrac{1}{2}(1+\pi) + \tfrac{1}{2}(1-\alpha)$$

$$= \tfrac{1}{2} - \tfrac{1}{4}\alpha + \tfrac{1}{4}\alpha\pi,$$

as can be seen from Figure 3. Similarly,

$$\text{Prob}(\text{H} \ \& \ p_{B\rightarrow} \ \& \ \text{invest}) = \text{Prob}(p_{B\rightarrow} \ \& \ \text{invest}) - \tfrac{1}{2}(1-\alpha)(1-\pi)\tfrac{1}{2}$$

$$= \tfrac{1}{2}\alpha\tfrac{1}{2}(1+\pi) + \tfrac{1}{2}(1-\alpha) - \tfrac{1}{2}(1-\alpha)(1-\pi)\tfrac{1}{2}$$

$$= \tfrac{1}{4}(1+\pi).$$

Hence,

$$\text{Prob}(\text{H} | p_{B\rightarrow} \ \& \ \text{invest}) = (1+\pi)/(2 - \alpha + \alpha\pi).$$

Similarly,

$$\text{Prob}(\text{L} | p_{B\rightarrow} \ \& \ \text{invest}) = 1 - \text{Prob}(\text{H} | p_{B\rightarrow} \ \& \ \text{invest})$$

$$= (1-\alpha)(1-\pi)/(2 - \alpha + \alpha\pi).$$

The probability that a retrospective market is fully revealing is given by:

$$\text{Prob}(p_{S\rightarrow} \ \& \ \text{invest} | \text{invest}) = \text{Prob}(p_{S\rightarrow} \ \& \ \text{invest})/\text{Prob}(\text{invest}).$$

$$\text{Prob}(p_{S\rightarrow} \ \& \ \text{invest}) = \alpha\tfrac{1}{2}(1-\pi)\tfrac{1}{2}$$

$$= \tfrac{1}{4}\alpha - \tfrac{1}{4}\alpha\pi.$$

$$\text{Prob}(\text{invest}) = \text{Prob}(p_{B\rightarrow} \ \& \ \text{invest}) + \text{Prob}(p_{S\rightarrow} \ \& \ \text{invest})$$

$$= \tfrac{1}{2} - \tfrac{1}{4}\alpha + \tfrac{1}{4}\alpha\pi + \tfrac{1}{4}\alpha - \tfrac{1}{4}\alpha\pi$$

$$= \tfrac{1}{2}.$$

It follows that:

$$\text{Prob}(p_{S\rightarrow} \ \& \ \text{invest} | \text{invest}) = \tfrac{1}{2}\alpha(1-\pi),$$

and

$$\text{Prob}(p_{B\rightarrow} \ \& \ \text{invest} | \text{invest}) = 1 - \tfrac{1}{2}\alpha(1-\pi).$$

$$= \tfrac{1}{2}(2 - \alpha + \alpha\pi).$$

References

Barro, Robert J. (1990), "The Stock Market and Investment," *Review of Financial Studies* 3:115-131.

Biais, Bruno and Pierre Hillion (1994), "Insider and Liquidity Trading in Stock and Options Markets," *Review of Financial Studies* 7(4): 743-780.

Bosworth, Barry (1975), "The Stock Market and the Economy," *Brookings Papers on Economic Activity* 2: 257-300.

Boyd, John, and Edward Prescott (1986), "Financial Intermediary-Coalitions," *Journal of Economic Theory* 38: 211-32.

Bresnahan, Timothy, Paul Milgrom and Jonathan Paul (1992), "The Real Output of the Stock Exchange," in *Output Measurement in the Service Sectors*, edited by Zvi Griliches (University of Chicago Press, Chicago) 195-216.

Diamond, Douglas (1984), "Financial Intermediation and Delegated Monitoring," *Review of Economic Studies* 51: 393-414.

Diamond, Douglas and Robert E. Verrechia (1981), "Information Aggregation in a Noisy Rational Expectations Economy," *Journal of Financial Economics* 9: 221-35.

Diamond, Peter (1967), "The Role of a Stock Market in a General Equilibrium Model with Technological Uncertainty," *American Economic Review*, 57: 759-773.

Dow, James and Gary Gorton (1994a), "Arbitrage Chains," *Journal of Finance* 49: 819-849.

Dow, James and Gary Gorton (1994b), "Noise Trade, Delegated Portfolio Management and Economic Welfare," working paper, LBS and Wharton School, NBER discussion paper #4858, CEPR Financial Markets Network discussion paper #54.

Dow, James and Gary Gorton (1995), "Profitable Informed Trading in a Simple General Equilibrium Model of Asset Pricing," NBER discussion paper #4315, *Journal of Economic Theory*, forthcoming.

Fama, Eugene F. (1976), *Foundations of Finance*, Basic Books, New York.

Fama, Eugene F. and Merton H. Miller (1972), *The Theory of Finance* (Dryden Press, Hinsdale, Illinois).

Fischer, Stanley and Robert C. Merton (1984), "Macroeconomics and Finance: the Role of the Stock Market," *Carnegie-Rochester Conference Series on Public Policy* 21: 57-108.

Glosten, Lawrence and Paul Milgrom (1985), "Bid, Ask, and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders," *Journal of Financial Economics* 14: 71-100.

Hayashi, Fumio (1982), "Tobin's Marginal and Average q: a Neoclassical Interpretation," *Econometrica* 50: 213-224.

Hayek, Friedrich A. (1945), "The Use of Knowledge in Society," *American Economic Review* 35.

Henrotte, Philippe (1992), "Market Behavior with Endogenous Production and Asymmetric Information," Stanford University working paper.

Hirshleifer, J. (1972), "The Private and Social Value of Information and the Reward to Inventive Activity," *American Economic Review* 61: 561-574.

Keynes, John Maynard (1936), *The General Theory of Employment Interest and Money* (London: Macmillan).

Kihlstrom, Richard and Steven Matthews (1990), "Managerial Incentives in an Entrepreneurial Stock-Market Model," *Journal of Financial Intermediation* 1: 57-79.

Korajczyk, Robert A., Deborah J. Lucas, and Robert L. McDonald (1990), "Understanding Stock Price Behavior around the Time of Equity Issues," in *Asymmetric Information, Corporate Finance and Investment,* edited by R. Glenn Hubbard (National Bureau of Economic Research and University of Chicago Press).

Kyle, Albert S. (1985), "Continuous Auctions and Insider Trading," *Econometrica* 53: 1315-35.

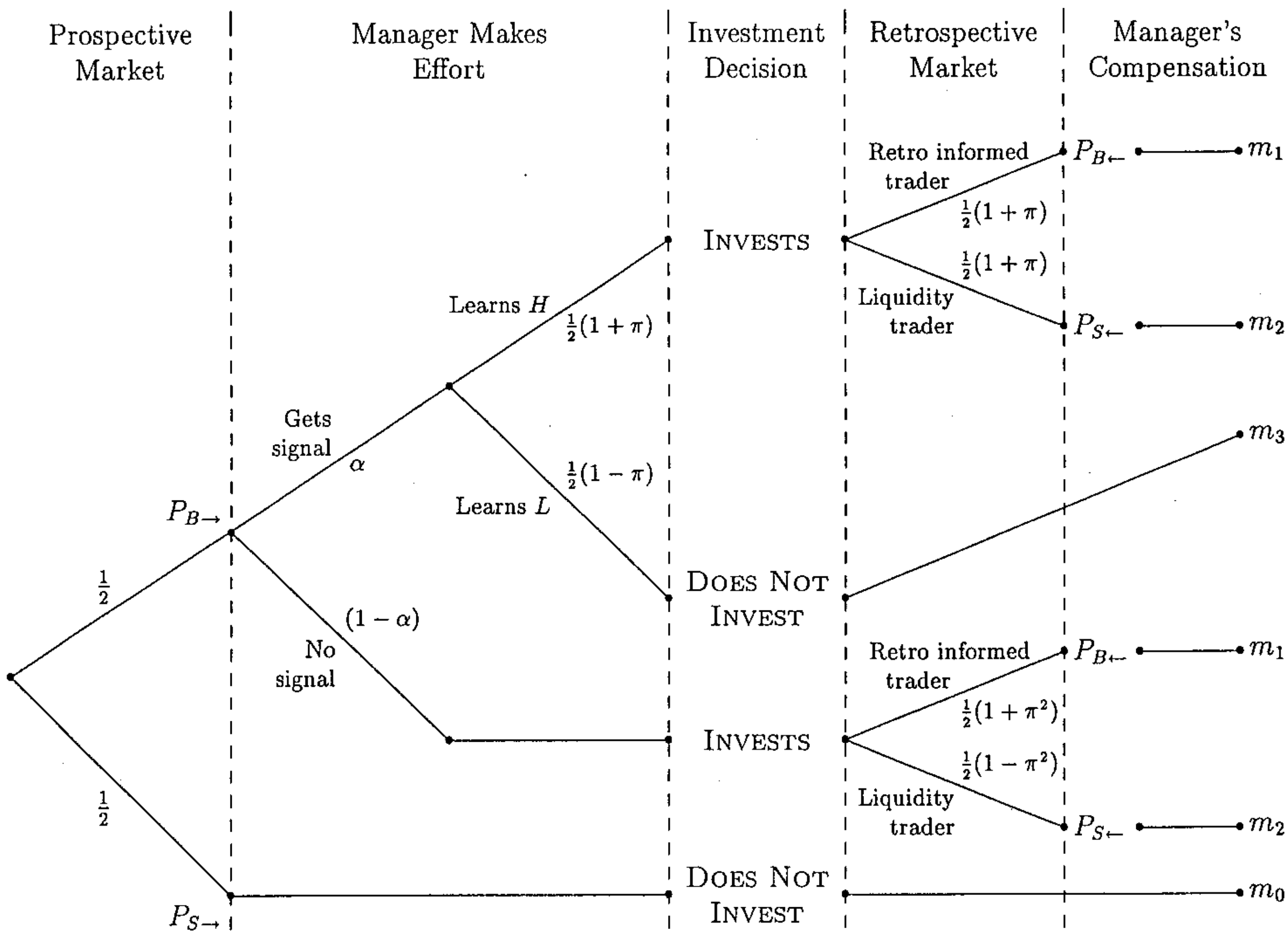
Lucas, Deborah J. and Robert L. McDonald (1990), "Equity Issues and Stock Price Dynamics," *Journal of Finance* 45: 1019-1043.

Stiglitz, Joseph E. (1981), "The Allocation Role of the Stock Market," *Journal of Finance* 36: 235-251.

Tobin, James (1969), "A General Equilibrium Approach to Monetary Theory," *Journal of Money, Credit and Banking* 1: 15-29.

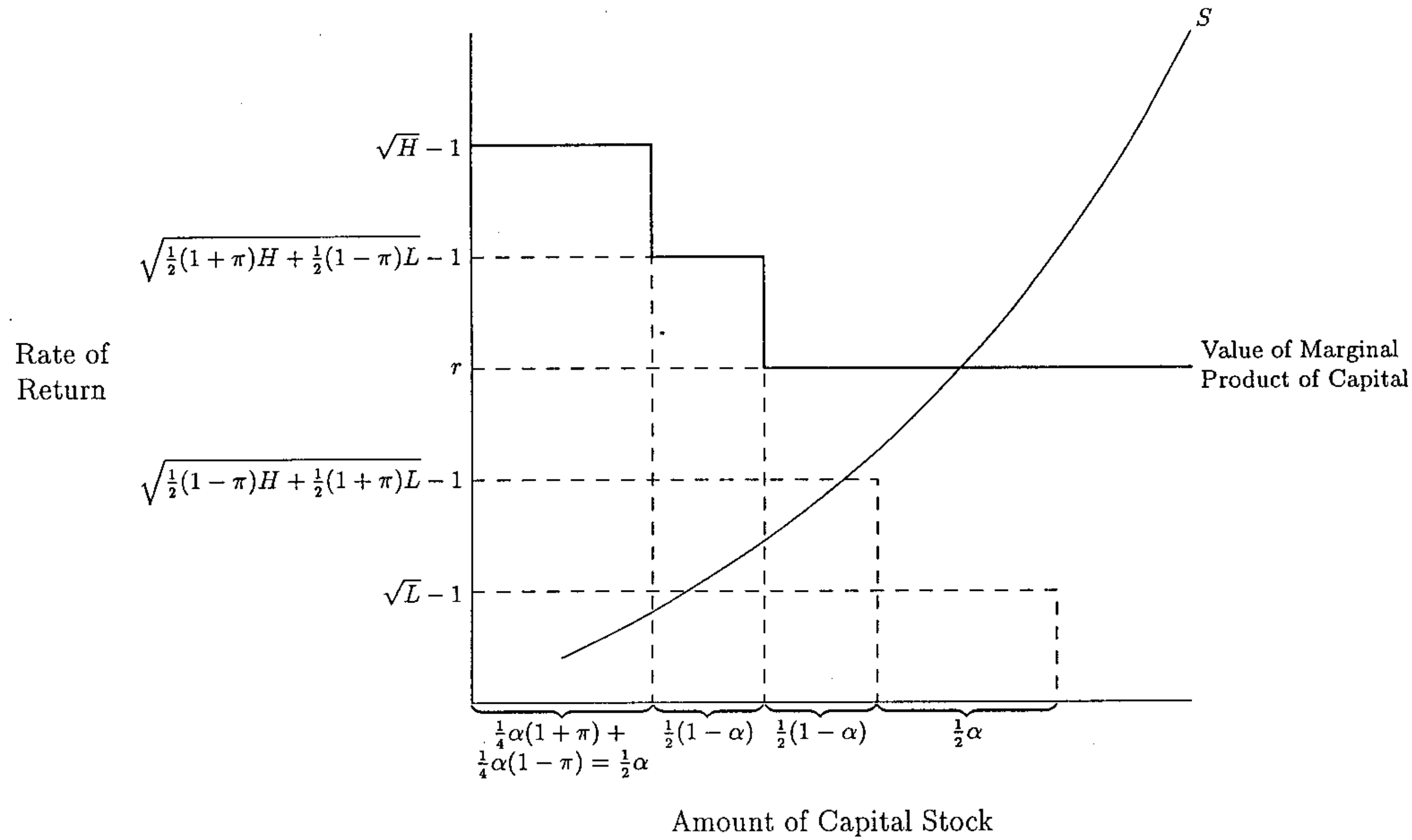
Welch, Ivo (1994), "The Cross-Sectional Determinants of Corporate Capital Expenditures: a Multinational Comparison," UCLA working paper.

Figure 1



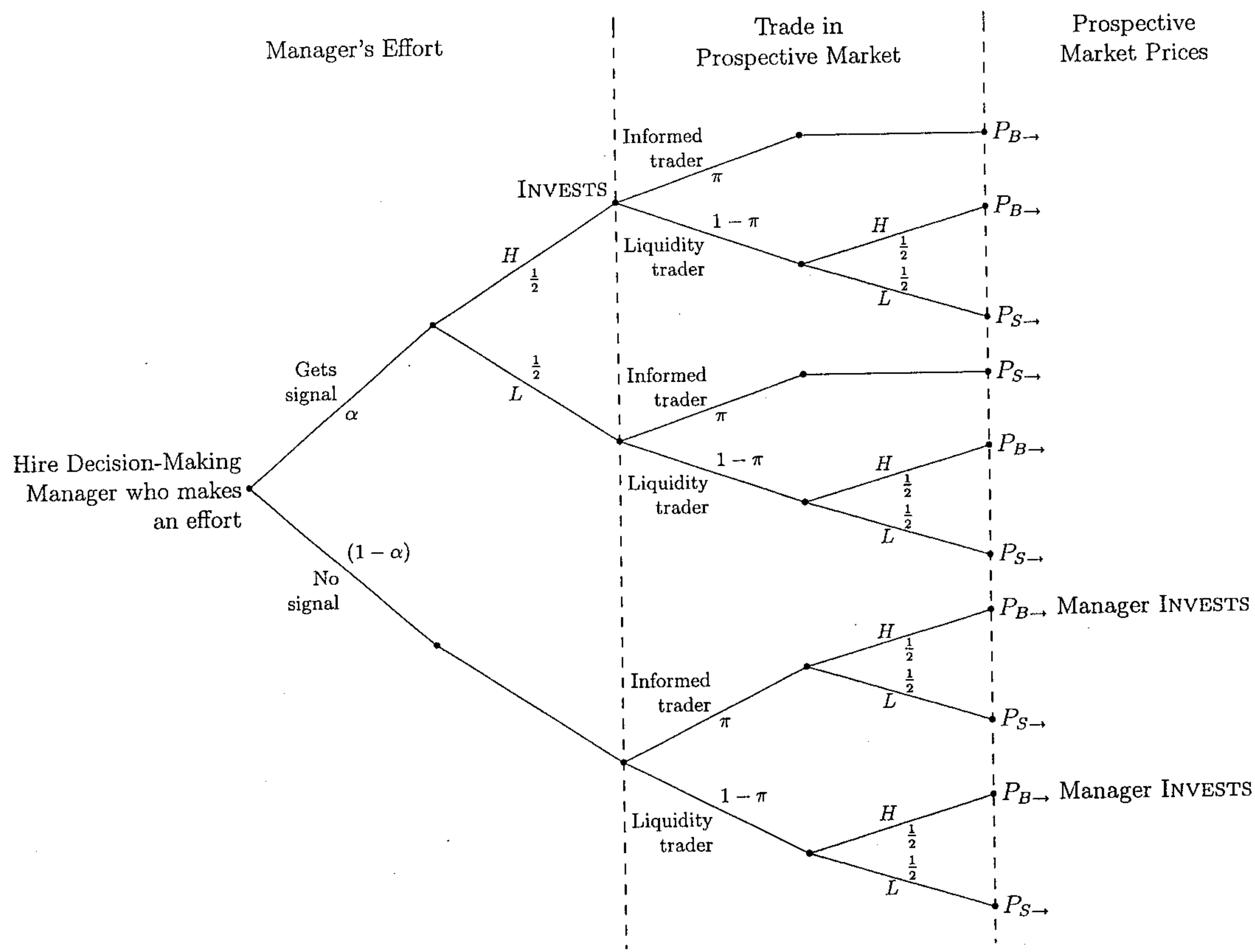
Prospective Market
Manager Makes Effort
Investment Decision
Retrospective Market
Manager's Compensation
1/2
1/2
$P_{B\rightarrow}$
$P_{S\rightarrow}$
Gets signal
α
No signal
$(1-\alpha)$
Learns H
$\frac{1}{2}(1+\pi)$
Learns L
$\frac{1}{2}(1-\pi)$
INVESTS
DOES NOT INVEST
INVESTS
DOES NOT INVEST
Retro informed trader
$\frac{1}{2}(1+\pi)$
$\frac{1}{2}(1+\pi)$
Liquidity trader
Retro informed trader
$\frac{1}{2}(1+\pi^2)$
$\frac{1}{2}(1-\pi^2)$
Liquidity trader
$P_{B\leftarrow}$
$P_{S\leftarrow}$
$P_{B\leftarrow}$
$P_{S\leftarrow}$
m_1
m_2
m_3
m_1
m_2
m_0

Figure 2



Rate of Return
$\sqrt{H} - 1$
$\sqrt{\frac{1}{2}(1+\pi)H + \frac{1}{2}(1-\pi)L} - 1$
r
$\sqrt{\frac{1}{2}(1-\pi)H + \frac{1}{2}(1+\pi)L} - 1$
$\sqrt{L} - 1$
S
Value of Marginal Product of Capital
$\frac{1}{4}\alpha(1+\pi) + \frac{1}{4}\alpha(1-\pi) = \frac{1}{2}\alpha$
$\frac{1}{2}(1-\alpha)$
$\frac{1}{2}(1-\alpha)$
$\frac{1}{2}\alpha$
Amount of Capital Stock

Figure 3



Manager's Effort
Trade in Prospective Market
Prospective Market Prices
Hire Decision-Making Manager who makes an effort
Gets signal
α
No signal
(1 − α)
H
L
1/2
INVESTS
Informed trader
Liquidity trader
π
1 − π
$P_{B\to}$
$P_{S\to}$
Manager INVESTS