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Diversity of Opinion and Financing of New Technologies*

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The objective of this paper is to compare the effectiveness of financial markets and financial intermediaries in financing new industries and technologies in the presence of diversity of opinion. In markets, investors become informed about the details of the new industry or technology and make their own investment decisions. In intermediaries, the investment decision is delegated to a manager, who is the only one who needs to become informed, which saves on information costs, but investors may anticipate disagreement with the manager and be unwilling to provide funds. Financial markets tend to be superior when there is significant diversity of opinion and information is inexpensive. *Journal of Economic Literature* Classification Numbers: G1, G2. © 1999 Academic Press

1. INTRODUCTION

In the long run, the main determinant of economic progress is the degree of technological change. This takes two forms: The introduction of new industries and the development of new technologies in existing industries. We are interested in comparing the performance of markets and intermediaries in the evaluation and financing of new industries and new technologies. We suggest that a key issue

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in this comparison concerns the uniformity of initial beliefs among investors. In standard finance models, such as the CAPM, it is assumed that investors have the same prior probability beliefs. The same assumption is made in the asymmetric information literature and the market microstructure literature.

In an important paper, Aumann (1976) shows that if two individuals assign the same prior probabilities to a given event and their posterior probabilities (conditional on private information) are common knowledge, then the posterior probabilities must be identical. In other words, under the *common prior assumption*, they cannot *agree to disagree*. Geanakoplos and Polemarchakis (1982) demonstrate that if two agents, with different information sets, communicate their posteriors back and forth, they will eventually converge to a common posterior. McKelvey and Page (1986) extend these results to n individuals and show that public announcement of posteriors is not necessary for convergence; the public announcement of aggregate statistics can have the same effect. However, if the information each person observes is sufficiently complex, the number of iterations required to obtain convergence will be large and the amount of information conveyed in each iteration will be small.

As Morris (1995) persuasively argues, there is nothing in Bayesian decision theory or standard theories of rationality that requires agents to have the same priors. There is a long tradition in economics of allowing for differences in prior beliefs. For example, the Arrow–Debreu–Mackenzie (ADM) model and the fundamental theorems of welfare economics allow for different priors. The well-known model of stock market resource allocation developed by Diamond (1967) has this feature. A number of important finance papers such as Lintner (1965) and Ross (1976) have also allowed for differences in prior beliefs. A more recent example is Harris and Raviv (1993). Kandel and Pearson (1995) provide empirical evidence that trading around earnings announcements is due to differences in priors.

The common prior assumption is appropriate when information is plentiful, a large amount of experience has been accumulated, and posterior beliefs have converged. This is the type of situation to which standard finance models apply. However, it can be argued that the common prior assumption is not appropriate when considering new industries such as biotechnology and new technologies such as personal computers. Casual empiricism suggests that there is a wide variation in views on the effectiveness and value of an innovation immediately after the innovation has occurred. Since the amount of data available based on actual experience with new products or technologies are nonexistent or small, such differences in views would appear to be due to differences in priors. In this case, there is *diversity of opinion* and people *agree to disagree*.

Market finance is identified with situations in which investors become informed and then decide individually whether to contribute to the funding of the project. Examples of market finance include IPO's, the private equity market and venture capital firms. Venture capital firms have some of the features of markets and intermediaries, but we include them in market finance because of their size. The number of investors in a single firm is relatively small and there is a large number of firms to choose from, so there is likely to be homogeneity of beliefs among the investors in a single firm. Intermediated finance is identified with large institutions, such as banks, where there is likely to be heterogeneity of beliefs.

When a new industry starts up, there are several types of uncertainty. In addition to uncertainty about the effectiveness of the technology, there is uncertainty about the best management strategies to follow and the consequences of each strategy. We argue below that markets have considerable advantages in such situations. A large number of people participate directly in the investment decision. This is costly because each investor has to acquire the information to make the decision, but it has the great advantage that each investor makes his own decision based on his own information and his own prior. This ability to agree to disagree allows innovative projects to be financed.

The nature of intermediated finance is different. The decision to invest in a project is delegated to a manager. Funds can be allocated to a project even if some of the investors providing the funds think the project is a bad one. The advantage of the intermediary is that it economizes on the acquisition of information, because only the manager needs to become informed (cf. Diamond (1984)). This is fine when investors have homogeneous beliefs. The problem arises when there is diversity of opinion. Even if the manager does his/her best to choose projects he/she honestly believes are profitable (i.e., there is no principal-agent problem in terms of effort), diversity of opinion implies that some providers of finance would disagree with those decisions even if they had the same information as the manager. If the probability of disagreement is sufficiently high, the investors may be unwilling to provide funds in the first place. Thus, intermediated finance may result in underfunding of innovative projects.

Our paper is part of the growing literature analyzing the ways in which different countries' financial systems operate and on the design of financial systems (see Boot and Thakor (1997a,b) and for a survey Thakor (1996)). Allen (1993) contains a general verbal discussion of the differences between markets and intermediaries in the funding of new industries and technologies but does not develop a formal model. Bhattacharya and Chiesa (1995) and Yosha (1995) consider the advantages of financing R&D using bilateral financing (one lender) compared to multilateral financing (many lenders). They do not consider the role of diversity of opinion. Berk, Green, and Naik (1997) analyze how R&D projects should be valued but are concerned with the extent to which risk is systematic rather than differences in views. Our analysis is also related to Manove and Padilla (1998) and DeMarzo, Vayanos, and Zwiebel (1998). Both of these papers consider models where agents have different priors initially and update in a Bayesian manner. However, in both cases agents are irrational in that they do not use all the information available to them in an optimal way. In our analysis all agents are fully rational.

In the rest of the paper, we address the following questions:

- How can diversity of opinion be modeled consistently with a rational, Bayesian approach?

- What is the optimal institution for providing finance, markets or intermediaries, and what factors determine the optimal choice?

In Section 2 we present a model of information acquisition in the presence of diversity of opinion. In Section 3 we compare market and intermediated finance. Section 4 analyzes equilibrium when investors can choose the form of investment and characterizes the efficiency properties of equilibrium. Some concluding remarks are contained in Section 5.

2. A MODEL OF DIVERSITY

In this section, we describe a formal model of information acquisition in the presence of diversity of opinion. A new industry is being established in which there are large numbers of investment opportunities. Because investors have different prior beliefs, they will interpret information differently. Some investors will become pessimistic and refuse to invest when presented with detailed information about a project. Others will interpret the same information as grounds for optimism. Before investors have seen the information, they do not know how they will react and we can simplify the analysis by assuming that investors are ex ante identical, that is, they have the same probability of becoming optimists or pessimists. The importance of assuming heterogeneous priors is not that it implies different beliefs about the profitability of the project ex ante, but rather that it allows investors, after being presented with evidence, to agree to disagree.

We start with the simplest case, a single project which is small relative to the amount of funds available.

- There is a continuum of risk neutral investors with number (measure) MI, each with a single unit of capital to invest.
- There is a single project requiring an input of I units of capital. The project is initially owned by an entrepreneur who has no capital and seeks financing from investors.
- It is assumed $MI > I$ so that the entrepreneur obtains all the surplus from the project and investors obtain their opportunity cost. For simplicity, the investors' best alternative is assumed to be a safe asset with a zero rate of return (one unit of investment yields a gross return of one unit).
- The investors initially have symmetric beliefs about the profitability of the project. They can obtain more information about the profitability of the project before the investment decision by paying a cost $c > 0$. After paying the cost, the investor is either in a state of *optimism* about the project and thinks the expected return per unit of investment is $H > 0$, or he is in a state of *pessimism* and thinks the expected return is $L < 0$ per unit of investment. These returns are net of the original investment. The probability that an informed investor is an optimist is denoted by α. If the investor does not pay the cost c he does not find out whether he is an optimist or pessimist until a later date well after the investment decision has been made.

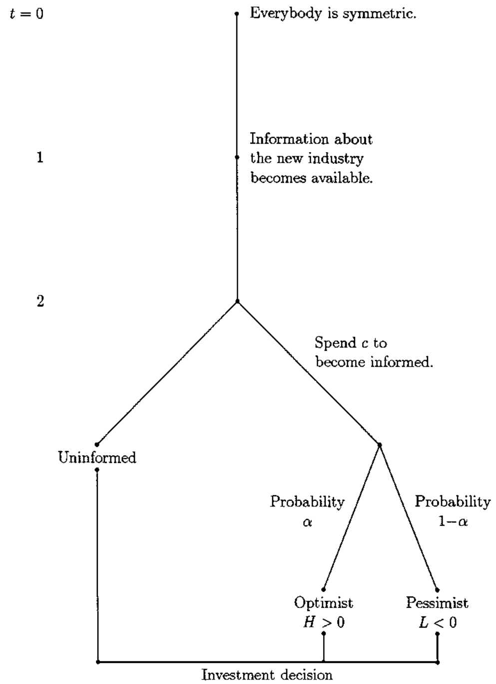

FIG. 1. The time structure of beliefs.

Figure 1 shows the sequence of events. At the initial date, $t = 0$, all investors lack information about the detailed characteristics of the new project. At date $t = 1$ some details of the new project appear. An investor then has two possible courses of action. The first is to remain uninformed about the project. This option is represented by the left hand branch in Fig. 1. The second is to pay a cost c to become informed about the details of the project. This option is represented by the right hand branch. Paying the cost c allows investors to discover whether they are optimists or pessimists before the investment decision. Although the investors receive the same information they interpret it differently. As a result they have different beliefs and agree to disagree. The important point is that, until they pay the cost c and acquire some information, they do not know whether they will react optimistically or pessimistically to the information available. All they can do is to assign probabilities to the expected payoffs H and L. Initially (at date 0), every investor assigns the same probability to becoming an optimist or pessimist because they do not yet know their true "type."

Diversity of opinion implies that informed investors do not necessarily agree. We measure the degree of diversity using the probability that a randomly selected informed investor will disagree with an optimist.

- If a randomly selected, informed investor is an optimist, the probability that another, randomly selected, informed investor agrees with him is denoted by

β. In other words, β is the probability that both investors are optimists, given that the first one is.

The profitability of delegating the investment decision to a manager of an intermediary depends on whether the beliefs of informed investors are correlated ex post. We can think of β as a measure of correlation among the investors' beliefs; alternatively, we can think of $1-\beta$ as a measure of diversity of opinion. To see this, suppose that we select two investors at random from the entire population of investors. Their belief types (optimist or pessimist) can be represented by random variables X and Y that take the value one if the corresponding agent is an optimist and 0 if he is a pessimist. Then it is easy to show that

$$\begin{aligned} cov[X,Y] &= E[XY] - E[X]E[Y] \\ &= \alpha(\beta - \alpha), \end{aligned}$$

where $\alpha \leq \beta \leq 1$; the covariance is zero if and only if $\beta = \alpha$.

The parameter β is important because delegation is profitable if and only if the event "becoming an optimist" is *correlated* across investors. If these events are independent ($\alpha = \beta$), the manager's opinion is uncorrelated with the opinion of the investors in the intermediary. In that case, intermediated finance with delegated decision making is no better than uninformed finance. Conversely, a positive correlation between the manager's opinion and the opinion of the other investors ($\beta > \alpha$) allows for profitable delegation, because the informed manager can make a decision that is more representative of the agents' ex post beliefs than the (uninformed) agents can.

To see the relationship between α and β when they are not equal, it is helpful to develop a concrete example of a stochastic structure. For a given project, suppose that the investors are randomly divided into two groups, one containing a fraction $1/2 \leq \gamma \leq 1$ of the population and the other containing $1-\gamma$. Imagine the population being distributed uniformly on a circle of radius $r = MI/2\pi$, where MI is the measure of investors in the economy and the circumference of the circle. A point x is chosen randomly on the circle (x is uniformly distributed on the circle) and then γMI investors are counted off in a clockwise direction and put into the majority group. The rest are put into the minority group. By symmetry, every investor has the same probability γ of being in the majority.

The beliefs of the majority are the opposite of the minority's. If the majority are optimists, the minority are pessimists, and vice versa. Suppose that the majority is optimistic about the project with probability $0 < \delta < 1$. Then the unconditional probability of any investor being optimistic is

$$\alpha = \gamma\delta + (1-\gamma)(1-\delta).$$

The first term is the probability of being in the majority and the majority being optimistic. The second term is the probability of being in the minority and the minority being optimistic.

For a fixed value of γ, the probability α of being an optimist increases with δ and lies between $(1-\gamma)$ and γ. Intuitively, a lot of diversity (γ close to 1/2 so that the majority and minority are roughly equal) restricts the value of α to lie close to 1/2.

Now suppose that an informed investor is optimistic. What is the probability that he is in the majority? By Bayes' rule, it is equal to the probability that he is optimistic and in the majority, $\gamma\delta$, divided by the probability that he is optimistic, α. Then the probability that a randomly selected investor agrees with an optimist is

$$\beta = \frac{\gamma\delta}{\alpha}\gamma + \left(1 - \frac{\gamma\delta}{\alpha}\right)(1-\gamma),$$

since they agree if they are both in the majority or both in the minority, and the probability of the optimist being in the majority is $\gamma\delta/\alpha$ and the probability of a randomly selected investor being in the majority is γ. Substituting the expression for α we obtain

$$\begin{aligned}\beta &= \frac{\gamma\delta}{\alpha}\gamma + \left(\frac{(1-\gamma)(1-\delta)}{\alpha}\right)(1-\gamma) \\ &= \frac{\gamma^2\delta + (1-\gamma)^2(1-\delta)}{\gamma\delta + (1-\gamma)(1-\delta)}.\end{aligned}$$

For a fixed value of δ, β is a convex function of γ. If γ is equal to 1/2 (resp., 1) then it is easy to see that β is equal to 1/2 (resp., 1). For any value of γ strictly between 1/2 and 1, the numerator is less than $\gamma(\gamma\delta + (1-\gamma)(1-\delta)) = \gamma\alpha$, since $\gamma > (1-\gamma)$, so $\beta < \gamma$. The relationship between β and γ is shown in Fig. 2.

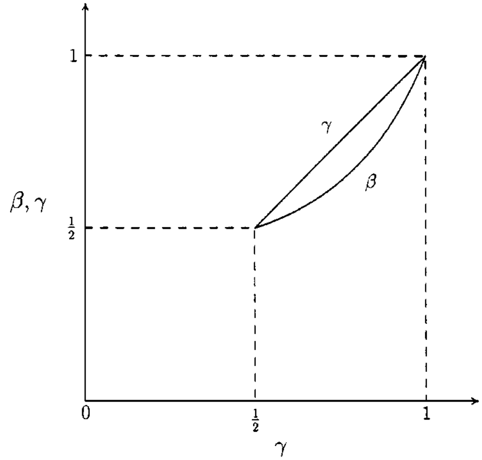

FIG. 2. The relationship between β and γ.

This structure makes clear that if there is a group of people there is a positive correlation between the type of a randomly chosen person and the type of the other people in the group. If the randomly chosen person is an optimist, then it is likely that the majority of the group are optimists. Similarly, if a randomly chosen person is a pessimist it is likely the majority are pessimists. As we shall see in the next section this can lead to intermediated finance with delegation being optimal.

3. MARKET VERSUS INTERMEDIATED FINANCE

Direct or *market finance* is identified as a situation in which investors become informed and then decide individually whether to contribute to the funding of the project.

Intermediated finance is identified with a situation in which I investors form a consortium. One of their number is designated as the *manager*. He or she becomes informed and decides whether to invest in the project on the basis of that information, while the rest of the group remains uninformed. The fact that there is a positive correlation between the manager's type and the types of the other members of the consortium means that, on average, the manager makes a representative decision for the group. If the manager finds out he or she is an optimist, it is likely that a majority of the rest of the consortium are optimists so each uninformed person's expected utility as well as that of the manager is maximized by investing. On the other hand, if the manager finds out he or she is a pessimist, the expected utility of each member of the group is maximized by not investing. The assumption that only one member of the consortium becomes informed is clearly special. There might exist situations in which it would be optimal for any finite number between 1 and I to become informed. Here we simplify the problem by assuming that only one member becomes informed. One possible justification for this assumption is the existence of monitoring costs. The larger the number of managers (informed members of the consortium), the smaller the influence of any one manager's information and the greater the incentive to "free ride" by not acquiring information at all. If managers have to be monitored in order to make sure that they actually become informed and if the marginal costs of monitoring additional managers are increasing, it may be optimal to have a small number of managers. A consortium with a single manager is a limiting case when monitoring costs are high.

Market finance can be thought of as raising money in public stock markets or in private markets. Intermediated finance can be thought of as bank finance. Since the bank provides all the finance and the entrepreneur has no collateral there is no difference between risky debt and equity in the model.

Since there is only one project and a large number of potential investors, competition among investors ensures that the surplus will all go to the entrepreneur.

However, since we are only interested in determining the efficient form of finance there is no loss of generality in assuming that the surplus goes to the entrepreneur.

An investor who does not finance the project receives a net return of 0. An uninformed investor expects the project to earn a net return of

$$V_U \equiv \alpha H + (1-\alpha)L.$$

Even if this return is positive, the investor may be able to do better by becoming informed.

Under market finance, each individual who wishes to become informed must pay the cost c. After becoming informed, an investor will invest in the project if and only if he is optimistic. Thus, the payoff to becoming informed is

$$V_M \equiv \alpha H + (1-\alpha)0 - c = \alpha H - c \tag{1}$$

since with probability α he or she becomes an optimist, has an expected return $H > 0$, and invests in the project, with probability $(1-\alpha)$ he or she becomes a pessimist, has an expected return $L < 0$, and does not invest, and in either case he or she pays the cost c.

Suppose next that a financial intermediary is formed. In order to be able to fund the project, the consortium must contain I members. The formation of an intermediary makes no difference if the intermediary does not become informed, so we always assume without loss of generality that the manager becomes informed.

The typical investor's views on the payoff to the intermediary are determined by considering his or her own possible beliefs if the investor were to become informed and weighting each possibility by the appropriate probability. In particular, the typical investor does not know whether he or she would agree with the manager if the investor were to become informed at this stage, and this must be taken into account in evaluating the payoff to joining the consortium. If the manager is optimistic then the expected return to investment for an uninformed investor is $\beta H + (1-\beta)L$, since the probability that the investor will agree (will be an optimist) is β. On the other hand, if the manager is a pessimist, the expected return to investment for an uninformed investor is $\beta' H + (1-\beta')L$, where β' is the probability of disagreement when the manager is a pessimist. We can calculate the value of β' to be

$$\beta' = \frac{\gamma(1-\delta)}{1-\alpha}(1-\gamma) + \left(1 - \frac{\gamma(1-\delta)}{1-\alpha}\right)\gamma$$

and show that

$$\beta' H + (1-\beta')L < \beta H + (1-\beta)L$$

because $\beta' < \beta$.

Information is valuable to the intermediary only if the investment decision depends on the outcome of obtaining information. We therefore focus on the case where

$$\beta' H + (1 - \beta')L < 0 < \beta H + (1 - \beta)L. \tag{2}$$

Thus, if it is worthwhile forming an intermediary at all, the return conditional on the manager being optimistic (resp., pessimistic) is positive (resp. negative) and everyone agrees to invest in the project if and only if the manager is optimistic. Under this decision rule, the payoff is

$$V_I \equiv \alpha(\beta H + (1 - \beta)L) + (1 - \alpha)0 - \frac{c}{I} \tag{3}$$

$$\equiv \alpha(\beta H + (1 - \beta)L) - \frac{c}{I}, \tag{4}$$

since the manager is optimistic and decides to invest with probability α and, given that the manager is optimistic, the expected return to a randomly selected investor is $\beta H + (1 - \beta)L$. With probability $1 - \alpha$ the manager is pessimistic and does not invest. In every case the investor has to pay his or her share c/I of the information costs.

When (2) is satisfied, the views of the manager and the uninformed investors on whether or not to invest are perfectly aligned. It is the positive correlation between the manager's type and the uninformed investors' types that leads to this unanimity before the investment decision is made. When the investors in the intermediary who did not pay the cost c finally find out whether they are optimists or pessimists, there will be disagreement but this will occur long after the investment decision has been made.

A Comparison

The payoffs from different forms of financing can be summarized as follows:

(i) No investment	0
(ii) Uninformed investment	$V_U = \alpha H + (1 - \alpha)L$
(iii) Market investment	$V_M = \alpha H - c$
(iv) Intermediated investment	$V_I = \alpha(\beta H + (1 - \beta)L) - c/I.$

Obviously, the form of financing with the highest payoff will be chosen. Comparing Eqs. (1) and (4), market finance is preferred to intermediated finance if and only if the following inequality is satisfied:

$$\alpha H - c > \alpha(\beta H + (1 - \beta)L) - \frac{c}{I}. \tag{5}$$

Then we have the following result.

PROPOSITION 1. *Market finance is strictly preferred to intermediated finance if and only if*

$$\alpha(1-\beta)(H-L) > c - \frac{c}{I},$$

and intermediated finance is strictly preferred to market finance if and only if the reverse inequality is satisfied.

The term $\alpha(1-\beta)(H-L)$ on the left-hand side of the inequality in the proposition can be interpreted as the difference in the expected returns under direct and intermediated finance, arising because of misalignment of the investor's preferences under intermediated finance. The term $\alpha(1-\beta)$ is the probability of investment in a project about which the investor is pessimistic. The term $H-L$ is the loss that results from investing in a project the investor is pessimistic about rather than one he or she is optimistic about.

The term $c - c/I$ on the right-hand side is the difference in the information costs of direct and intermediated finance. The inequality makes clear the trade-off involved in the two types of finance. It indicates that the factors that determine which form of finance is preferred are the following.

1. The ex ante degree of optimism, α.
2. The diversity of opinion, $1-\beta$.
3. The difference in the estimated mean returns of optimists and pessimists, $H-L$.
4. The cost of information c and the number of people I.

An increase in the degree of ex ante optimism α, ceteris paribus, makes it more likely that market finance will dominate intermediated finance. An increase in α increases the left-hand side term of (5) $\alpha H - c$ by H but it raises the right-hand side by only $\beta H + (1-\beta)L < H$. The higher the degree of ex ante optimism the greater the expected payoff when an investment is market financed, because everybody who is an investor is optimistic. On the other hand with intermediated finance only a portion of investors agree with the managers' decision and so the increase in the expected payoff to the investors is less.

The higher the degree of diversity of opinion $1-\beta$ (i.e., the lower β), ceteris paribus, the more likely it is that market finance is preferred. The payoff from direct or market finance (the left-hand side of Eq. (5)) is independent of β and the payoff from intermediated finance (the right-hand side of Eq. (5)) is increasing in β, so there will be some critical value β^*, depending on the other parameters, such that market finance is preferred if $\beta < \beta^*$ and intermediated finance is preferred if $\beta > \beta^*$. When people disagree, markets work well because only those people who are optimistic end up investing so the expected payoff of investors is high. With intermediated finance, investors rationally anticipate that there is a significant chance they will disagree with the manager who actually makes the decision. Of course, they do not actually acquire the information before the investment decision because it would be costly, so a disagreement does not actually occur at the time the investment is made.

An increase in the difference in estimated mean returns of optimists and pessimists, $H - L$, ceteris paribus, increases the left-hand side term $\alpha(1-\beta)(H-L)$ in the condition in Proposition 1 but leaves the right-hand side term $c - c/I$ unaffected, so it makes market finance more likely to be preferred. With market finance, only the optimists' estimate matters because only optimists invest. However, with intermediated finance both optimists' and pessimists' estimates matter because the manager may invest even when an investor disagrees with his or her view. As a result, an increase in $H - L$ makes intermediated finance relatively less attractive.

The greater the cost of acquiring information c, and the larger the number of people required to provide finance I, ceteris paribus, the more likely it is that intermediated finance will be preferred. The whole advantage of intermediated finance is that it allows information costs to be shared by delegating the decision to the manager while market finance requires everybody to become informed. The larger c and I are the greater the benefit from sharing the cost. An increase in c increases the right-hand side of the condition in Proposition 1 but leaves the left-hand side unaffected. So there is a critical value c^* such that market finance is preferred if $c < c^*$, and intermediated finance is preferred if $c > c^*$. Of course, if the cost of information is high enough, it may be optimal to invest without information or it may be optimal not to invest at all.

In order to see the operation of the model consider the following numerical example.

EXAMPLE 1.

$$H = 10; \quad L = -10; \quad \delta = 0.5; \quad \alpha = 0.5; \quad I = 3.$$

The trade-off between diversity of opinion β and the cost of information c in the context of this example is illustrated in Fig. 3. Given $\delta = 0.5$, α is independent of γ and remains fixed at 0.5. As γ varies between 0.5 and 1, β also varies between 0.5 and 1. The first thing to note is that

$$V_U = 0.5 \times 10 + 0.5 \times (-10) = 0.$$

Hence there is no uninformed finance in this case. When there is significant diversity of opinion (i.e., β close to 0.5) and the cost of information is high, there will be no finance for the project rather than uninformed finance. This outcome occurs in the bottom right-hand region. Market finance occurs in the bottom left-hand region when diversity of opinion is high and the cost of information is low. Now

$$V_M = 0.5 \times 10 - c = 5 - c$$

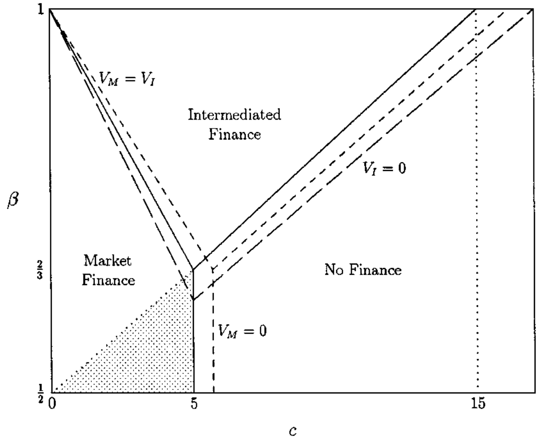

FIG. 3. Example 1. (—), Example 1; (- - -) increase in α or $H - L$; (– – –) increase in I.

so the boundary between the market and no finance regions $V_M = 0$ is

$$c = 5.$$

Also,

$$V_I = 0.5[\beta 10 + (1 - \beta)(-10)] - \frac{c}{3} = 10\beta - 5 - \frac{c}{3}$$

so the boundary between the intermediated finance and no finance regions $V_I = 0$ is

$$\beta = \frac{1}{2} + \frac{c}{30}.$$

Finally, the boundary between intermediated and market finance $V_I = V_M$ is

$$\beta = 1 - \frac{c}{15}.$$

Thus, intermediated finance is optimal in the top region where there is wide agreement and costs are high.

Figure 3 provides a graphic summary of the circumstances in which each type of financing is optimal. Market finance is superior when there is diversity of opinion and costs of information are low. Intermediated finance is best when costs of information are high and there is not much diversity of opinion. The project is not financed if there is diversity of opinion and costs of information are high.

The effect of increasing the ex ante degree of optimism α on Fig. 3 can easily be seen. When α is included explicitly the three boundaries $V_M = 0$; $V_I = 0$; $V_I = V_M$

become, respectively,

$$c = 10\alpha, \quad \beta = \frac{1}{2} + \frac{c}{60\alpha}, \quad \beta = 1 - \frac{c}{30\alpha}.$$

It follows that as α increases the $V_M = 0$ boundary shifts to the right, the $V_I = 0$ boundary rotates downward and the $V_I = V_M$ boundary rotates upward. The intersection of the three boundaries always occurs at $\beta = 2/3$. Hence, the area where market finance is used increases, as does the area where intermediated finance is used. The area where no finance is made available shrinks. This change is illustrated in Fig. 3 with the higher value of α being represented by the short dotted lines.

Next consider what happens if the difference between the optimists' and pessimists' estimates, $H - L$, is increased. The simplest way to do this is to set $L = -H$ and increase H. Returning to the original values of the other parameters, the three boundaries $V_M = 0$, $V_I = 0$, and $V_I = V_M$ now become, respectively,

$$c = 0.5H, \quad \beta = \frac{1}{2} + \frac{c}{3H}, \quad \beta = 1 - \frac{2c}{3H}.$$

It can be seen that the effect of increasing $H - L$ is similar to the effect of increasing α. The changes can again be illustrated by the short dotted lines in Fig. 3. The use of markets and intermediated finance is increased while the circumstances where the project is not financed are reduced.

The remaining parameter is the number of people in the consortium, I. Obviously the $V_M = 0$ boundary is unchanged. The boundaries for $V_I = 0$ and $V_I = V_M$ now become, respectively,

$$\beta = \frac{1}{2} + \frac{c}{10I}, \quad \beta = 1 - \left(1 - \frac{1}{I}\right)\frac{c}{10}.$$

Both boundaries rotate downward as the number of people in the consortium is increased. As might be expected, the use of intermediated finance increases while market finance is used less. The no-finance area is also smaller. The new boundaries are illustrated by the long dotted lines in Fig. 3. As one might expect, increasing the size of the consortium increases the effectiveness of intermediaries.

It has so far been assumed that the optimal type of finance is used, market finance if that is superior and intermediated finance if that is superior. In many countries the institutional settings are such that both systems do not exist side by side. For example, in Germany the possibilities for most companies to access capital markets are nonexistent or very limited. There are a number of possible explanations for the absence of markets, including government regulation or fixed costs that prevent markets from developing. One important implication of the analysis underlying Proposition 1 is that if intermediated finance is used not because it is superior but because market finance has been artificially discouraged, innovative technologies where there is diversity of opinion and a high degree of risk is involved may be underfunded. In the context of Example 1 above, an intermediary-based financial system would not fund projects in the shaded area in Fig. 3. In contrast a market-based financial system would provide finance for these projects. This suggests that ensuring market finance is available can be important for establishing new high technology industries where there is significant diversity of opinion and costs of becoming informed. The welfare properties of the model are discussed further in the context of a more fully developed model below. However, this observation is of interest from a positive perspective.

Example 1 had the special feature that uninformed finance was not worth-while. Consider the following case.

EXAMPLE 2. As in Example 1 except $L = -6$.

$$H = 10; \quad L = -6; \quad \delta = 0.5; \quad \alpha = 0.5; \quad I = 3.$$

In this case

$$V_U = 0.5 \times 10 + 0.5 \times (-6) = 2.$$

The analysis is the same as before except now the best alternative is uninformed finance rather than no finance. The optimality of market and intermediated finance compared to uninformed finance is shown in Fig. 4. The effects of changing the other parameters are similar to those for Example 1. Figure 4 illustrates that the difference between uninformed finance and no finance is not material in this context. It will be seen below that this is not the case when search is introduced.

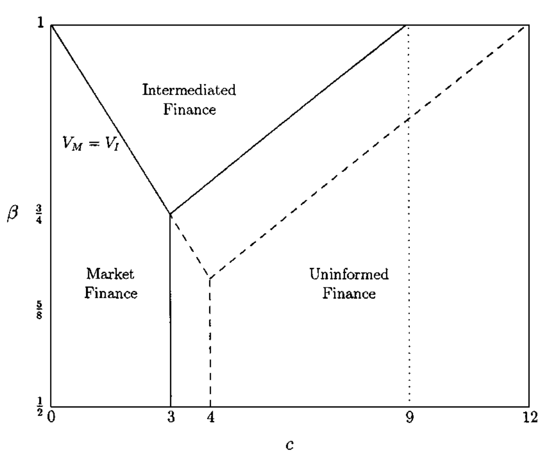

FIG. 4. Example 2. (—) One project, (- - -) equilibrium with search.

4. EQUILIBRIUM WITH MANY PROJECT TYPES

In the previous section, we analyzed the problem of choosing between direct finance and intermediated finance when there was a single project to be funded. In this section, we extend the analysis to a market in which there are many projects of different types to be funded. This raises new questions and requires us to develop an account of search equilibrium where investors and projects are matched. We make the following assumptions to do this.

- There are K different types of projects, $k = 1, \ldots, K$. For each k there is a continuum of ex ante identical projects with the parameters (α_k, β_k, c_k).
- The number (measure) of consumers is MI so that the total number of projects that can be funded is M. There are N_k projects of type k and the number (measure) of projects is $N = \sum N_k > M$.

Because there is an excess supply of projects and the investors who have acquired information have heterogeneous beliefs about their profitability, investors must search in equilibrium to find the project they would like to invest in. To simplify the analysis, we impose assumptions that guarantee that the environment remains stationary over time.

- There is a sequence of dates $t = 1, 2, \ldots$ and at each date there is a continuum of N projects characterized by the parameters (α_k, β_k, c_k) and a continuum of MI identical investors. To keep the population of projects constant, we assume that as soon as a project is funded, it is replaced by an identical project. Similarly, to keep the population of investors constant we assume that as soon as an investor funds a project, he or she is replaced by an identical investor. The total demand for finance in any period remains constant at NI and the total supply remains constant at MI.
- Entrepreneurs are passive. They simply allow investors to investigate the project and fund it when enough willing subscribers have been found.
- An investor can investigate one project per period and continues to search until he or she finds a project that he or she wants to finance. There is no discounting, so investors are indifferent about how long it takes to find a project, but we assume that they do not delay unnecessarily.
- Investors, individually or in consortiums, are randomly matched with projects. Since there are more projects than can be financed with the available capital, every investor who wants to invest can find some project to invest in.
- Some types of project will be more profitable than others, but since the number of each type is limited, the entrepreneurs who own the more profitable types of project are able to collect some rents. Investors first acquire information and then, if they become optimistic and wish to invest, they make a side payment p_k to the owner of a project of type k in addition to the capital needed for the investment. The price of each type of project and the equilibrium payoff to the investors are jointly determined in equilibrium by the marginal type of project that

is just worth financing. The net price p_k is expressed in per capita terms, so the total revenue to an entrepreneur from I investors is $p_k I$. Entrepreneurs of type k will be indifferent about financing their projects if $p_k = 0$. Likewise, investors will be indifferent about supplying finance if the expected net return from the optimal form of finance is zero.

The payoff to no investment is zero, as before, and the payoff to uninformed investment in a type-k project is

$$V_k^U = \alpha_k H + (1 - \alpha_k)L - p_k.$$

Let V^* denote the value of continuing to search in equilibrium. It will also be the equilibrium payoff for the typical investor. Suppose an investor chooses market finance. Each time an investor evaluates a new project of type k a cost of c_k must be paid. Then the payoff will be

$$V_k^M = \alpha_k(H - p_k) + (1 - \alpha_k)V^* - c_k,$$

since with probability α_k the investor becomes optimistic and invests in the current project so the surplus is $H - p_k$, with probability $1 - \alpha_k$ the investor becomes pessimistic and continues to search. In either case the investor pays the cost c_k. Market finance is optimal if and only if $V^* = V_k^M$, that is,

$$V_k^M = H - p_k - \frac{c_k}{\alpha_k}. \tag{6}$$

Comparing this with the value of the project with market finance in the previous section in (1) and taking $p_k = 0$ as it was there, it can be seen that the value is higher (provided it is positive). The reason is that every investor undertaking search will inevitably find a project which they are optimistic about. The expected payoff therefore rises from αH to H. In addition, costs are higher because on average information will have to be acquired $1/\alpha$ times but this effect is less than the increase in expected revenue provided the project has positive value.

Similarly, intermediated financing of a type-k project yields

$$V_k^I = \alpha_k(\beta_k H + (1 - \beta_k)L - p_k) + (1 - \alpha_k)V^* - \frac{c_k}{I},$$

since with probability α_k the manager is optimistic and finances the project, given he or she finances the project the typical investor's expected return is $\beta_k H + (1 - \beta_k)L - p_k$, and with probability $(1 - \alpha_k)$ the manager is pessimistic and continues searching, and in any case the investor has to pay a share c_k/I of the cost of information. Intermediated financing is optimal if and only if $V^* = V_k^I$, that is,

$$V_k^I = \beta_k H + (1 - \beta_k)L - p_k - \frac{c_k}{\alpha_k I}.$$

Again this is higher than the value in (3) because the investor knows the intermediary will fund a project for sure and will incur total expected costs of c_k/α_k so the investor's share is $c_k/\alpha_k I$.

For any project type that does receive funding, we must have $p_k \geq 0$ and $V^* = \max\{V_k^U, V_k^M, V_k^I\}$. Let $\hat{V}_k^U = V_k^U + p_k$, $\hat{V}_k^M = V_k^M + p_k$ and $\hat{V}_k^I = V_k^I + p_k$. Then from the expressions above, it is clear that

$$p_k = \max\left\{\hat{V}_k^U, \hat{V}_k^M, \hat{V}_k^I\right\} - V^*.$$

To determine the equilibrium prices and the allocation of investments, we need only determine the equilibrium payoff for the investors V^*, since this immediately determines p_k and that in turn tells us which projects are financed and the form of financing adopted in equilibrium.

For any value of V^*, there is a set of projects K^+ that are strictly profitable ($p_k > 0$) and a set of projects K^0 that are weakly profitable ($p_k = 0$). In order to have equilibrium in the market for firms, the number of investors searching must equal the number of profitable financing slots. This will be true if

$$\sum_{k\in K^+} N_k \leq M \leq \sum_{k\in K^+} N_k + \sum_{k\in K^0} N_k,$$

since the projects of type $k \in K^+$ must be financed and the projects of type $k \in K^0$ may or may not be financed in equilibrium. Since the price p_k is continuous and decreasing in V^*, we can find a unique value V^* such that the market-clearing inequality is satisfied if a weak profitability condition is satisfied, for example,

$$0 < \max\left\{V_k^U, \alpha_k \hat{V}_k^M, \alpha_k \hat{V}_k^I\right\}$$

for each k, or at least for enough types to provide more than M strictly profitable projects. Technically, one needs $\sum_{k\in K^+} N_k > M$ for $V^* = 0$, since individual rationality requires $V^* \geq 0$ in any equilibrium.

We can extend Examples 1 and 2 to illustrate the structure of this kind of equilibrium. Initially, consider the case where $K = 1$ so there is only one type of project. Since the number of projects is larger than the number that can possibly be financed, the investors will receive the surplus. The entrepreneurs will receive their opportunity cost of zero for their projects and $p_1 = 0$. The expressions for the values of the projects with the different types of finance are then the same as in Section 3 except that they are divided through by α. The boundaries are identical to those in Fig. 3. To see this, note that the boundary between market finance and intermediated finance is defined by the condition that $V_1^M = V_1^I$, which is equivalent to $\alpha V_1^M = \alpha V_1^I$, the boundary condition in the single-project case. The boundary between market finance and no finance is defined by $V_1^M = 0$, which again is equivalent to $\alpha V_1^M = 0$, and the boundary between intermediated finance and no finance is defined by $V_1^I = 0$, which again is equivalent $\alpha V_1^I = 0$, the boundary condition in the single-project case.

The comparative statics of changing the other parameters are also similar to the previous section. When the best alternative is uninformed finance as in Example 2 there is a difference. Here the comparison of market and intermediated finance is with uninformed finance, which has a payoff of $V_1^U = 2$. Now the fact that the expressions are divided by α is significant and the boundaries are marked by the dotted lines rather than the solid lines shown in Fig. 4.

Next consider the case where $K > 1$. Suppose that projects are identical except they possibly have different values of β_k and c_k. This means that the optimal type of finance is shown in Fig. 3. Consider first a situation with two types of project which are both optimally financed by markets and which simply differ with regard to the degree of diversity of opinion.

EXAMPLE 3. As in Example 1 except that there are two types of projects, with parameters (β_1, c_1) and (β_2, c_2) respectively.

$$H = 10; \quad L = -10; \quad \delta = 0.5; \quad \alpha = 0.5; \quad I = 3;$$
$$\beta_1 = 0.5; \quad c_1 = 4; \quad \beta_2 = 0.5; \quad c_2 = 3.$$

It can be seen from Fig. 3 that both projects will use market finance. Moreover $\hat{V}_1^M = 10 - 4/0.5 = 2$ and $\hat{V}_2^M = 10 - 3/0.5 = 4$. Here the initial owners of Project 2 will earn a rent. The payments received by owners of Project 1 are $p_1 = 0$ since they are the marginal project. The owners of Project 2 are able to charge $p_2 = \hat{V}_2^M - \hat{V}_1^M = 4 - 2 = 2$. The investors receive a net return of $V^* = \hat{V}_1^M = 2$ from both projects.

There are of course many other possibilities even with only two types of projects. In addition to having both types use the same method of finance, it would be possible to have one using intermediated finance and the other market finance, with the rents earned by entrepreneurs depending on which is the marginal project. The next example illustrates these possibilities.

EXAMPLE 4. As in Example 3 except that there are two types of projects, with parameters (β_3, c_3) and (β_4, c_4), respectively.

$$H = 10; \quad L = -10; \quad \delta = 0.5; \quad \alpha = 0.5; \quad I = 3;$$
$$\beta_3 = 2/3; \quad c_3 = 4; \quad \beta_4 = 3/4; \quad c_4 = 3.$$

For Project 3, $\hat{V}_3^M = 10 - 4/0.5 = 2$ and $\hat{V}_3^I = (2/3)10 + (1/3)(-10) - 4/(0.5 \times 3) = 2/3$ so market finance will be used. For Project 4, $\hat{V}_4^M = 10 - 5/0.5 = 0$ and $\hat{V}_4^I = (3/4)10 + (1/4)(-10) - 5/(0.5 \times 3) = 5/3$ so intermediated finance will be used. It can be seen that Project 4 is the marginal project so $p_4 = 0$. The owners of Project 3 are able to charge $p_3 = 2 - 5/3 = 1/3$ and the investors receive $V^* = 5/3$.

Examples 3 and 4 illustrate two possible equilibria when there are many types of project. There are, of course, many other examples that could be developed. However, these two illustrate the main features of this type of equilibrium, which were not present in previous sections. These are the determination of the rents p_k received by the owners of the different types of project and the return received by investors V^*.

Finally, consider the efficiency of equilibrium. At the initial date all investors hold the same beliefs concerning their type. After the new industry technology has been discovered and after they have expended a cost acquiring information they discover whether they are optimistic or pessimistic. This structure simplifies the welfare analysis of the model since ex ante every-body has the same expected utility. It is sufficient therefore to focus on the representative investor at the initial date.

Since all investors are risk neutral, an equilibrium is *efficient* if the method of financing each type of project in equilibrium maximizes the surplus. The surplus is the sum of the price paid to the entrepreneur p_k and the payoff to the typical investor. Since

$$V^* = \max\{\hat{V}_k^U, \hat{V}_k^M, \hat{V}_k^I\} - p_k,$$

the surplus from financing the project is

$$V^* + p_k = \max\{\hat{V}_k^U, \hat{V}_k^M, \hat{V}_k^I\},$$

so the method of financing is clearly chosen efficiently in equilibrium.

Efficiency depends on a number of special features of the model, and may not be robust to plausible extensions of the model. In particular, the linearity of the financing technology and the risk neutrality of investors are critical to the efficiency of equilibirium.

5. CONCLUDING REMARKS

There is no reason to think that one method of financing will be optimal for all projects. On the contrary, different parameters (α_k, β_k, c_k) will make different types of finance optimal, as Example 4 in the previous section illustrated. So a predominance of one type of financing, market or intermediated, throughout the economy, is unlikely to be efficient, at least in the context of the current model. In some countries, such as Germany, there appears to be a predominance of intermediated finance. In other countries, such as the United States, markets play a more prominent role. One possible explanation is that restrictive regulations may have prevented the development of markets in Germany. Another is that fixed costs of setting up markets may result in multiple equilibria, one in which market finance predominates and another in which intermediated finance predominates (see

Pagano (1993) and Subrahmanyam and Titman (1999)). Once one institutional form has been established, perhaps as a result of historical accident, increasing returns to scale give it an advantage that may prevent the establishment of a competing form. In this kind of situation, there is no reason to think that the observed predominance of one form of finance is optimal. If the German financial system developed in this way, the absence of markets may represent a loss of welfare. In the context of Example 1 it was pointed out that, under certain conditions, innovative new projects will not be financed by intermediaries, but will be financed by markets. If each generation is weighted equally then in the long run the system with markets will predominate because of technological progress.

The model developed has a number of testable implications. In particular, in financial systems where bank and market finance coexist there should be systematic differences in the types of new technology that are financed through each. The model implies market-financed projects will be characterized by considerable diversity of opinion about their likely commercial success and the technologies they are based on will be relatively cheap to assess. On the other hand, bank-financed projects will be characterized by uniformity of opinion and the technologies they use will be relatively expensive to assess.

The polar case where entrepreneurs have no funds of their own and all funds are provided externally was considered above. In this situation there is no distinction between risky debt and equity, and contract form is not an important issue. If entrepreneurs have some funds of their own but need some external finance in addition, then the contract form will matter. In this case risk free debt can be used at least partially and this will not be affected by diversity of opinion. As a result debt or a combination of debt and equity may be superior to equity alone. When entrepreneurs can entirely self-finance, everybody will be able to back their own views and diversity of opinion will not matter.

The delegation model of intermediation developed above is essentially a form of principal-agent model. This observation suggests that the techniques used in this paper may be applicable in a wide range of principal–agent relationships. The basic assumption of the standard approach is that priors are common. However, in many of the standard applications it is not at all clear that this is valid. For example, in many of the classic principal–agent relationships, such as those between doctors and patients, lawyers and clients and managers and shareholders, there may well be diversity of opinion between different parties because of a lack of actual data. We believe that incorporating the possibility for differences in beliefs into the standard principal–agent model and its many applications is an important area for future research.

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