JOURNAL OF FINANCIAL INTERMEDIATION 3, 188–203 (1994)

Asymmetric Information: A Rationale for Corporate Speculation[1]

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Received July 15, 1992

This paper demonstrates how managers with private information about firms' exposure to risk may, in the best interest of shareholders, engage in speculation instead of hedging as the conventional wisdom tells us. The reason is that when profits serve as a signal of firms' values, speculative trades can be used to distort profits and hence manipulate stock prices to the shareholders' advantage. A consequence of such corporate speculation is that stock prices become less informative about firms' true worth. *Journal of Economic Literature* Classification Numbers: D82, G14, G32.

1. INTRODUCTION

This paper explores the motivation for firms to engage in speculative transactions. It demonstrates the existence of such a motive when managers have private information regarding the value of the firm and seek to increase the stock price on behalf of shareholders. Since profits serve as a signal of firms' values, speculative trades can be used to distort profits and hence manipulate stock prices. In other words, managers try to exploit the economy's mapping from profits to share prices. In equilibrium, share prices adjust to reflect the ongoing speculation, but a remaining

[1] I received many helpful comments on an earlier version of this paper from Edward Prescott, George Mailath, David Hirshleifer, and in a presentation at the American Economic Association Annual Meeting in 1992. The final exposition of my work has benefited from suggestions made by an anonymous referee and a processing editor of this Journal. I am also grateful to the Institute for International Economic Studies at Stockholm University and the Stockholm School of Economics for their generous hospitality while I stayed there as a visiting research fellow. Any errors in this paper remain, of course, my sole responsibility.

1042-9573/94 $6.00

effect of such corporate speculation is that profits and, therefore, share prices become less informative about firms' true worth.

A classical rationale for corporate speculation has been the so-called "asset substitution problem" discussed by Fama and Miller (1972) and Jensen and Meckling (1976). The idea is that equity holders (shareholders) may be in favor of the firm investing in excessively risky projects since a successful gamble will solely benefit the shareholders while the consequences of a failure are, because of limited liability, borne by the debt holders. Such a conflict of interest is not the underlying force in my model since firms can as well be financed solely with equity. The focus is instead on information asymmetries, as in Myers and Majluf (1984). They analyze a model where managers are better informed about investment opportunities, which may cause a firm's equity to be underpriced. Managers of underpriced firms would then be reluctant to issue equity when financing new investments because that would dilute the wealth of existing shareholders. My paper brings together the asymmetric information aspect and the motive for corporate speculation by asking the question: Can purely speculative transactions, meaning fair gambles in profits, be in the best interest of shareholders when managers have private information about firms' values? The answer may seem to be "no" when looking at the work by DeMarzo and Duffie (1991) where abstaining from such speculative transactions is the optimal hedging strategy given that shareholders care only about profits. However, my model demonstrates how corporate speculation can be in the best interest of shareholders when they are concerned about both profits and stock prices, which would be the case if shares are traded over time.

My paper considers an economy where the market makes inferences about firms' productivities from their profits. Since higher profits are more likely to have been generated by firms with higher productivity, equilibrium stock prices will be an increasing function of profits. Managers acting on behalf of shareholders must take this positive relationship into account when deciding whether or not to engage in speculation in the form of fair gambles in profits. A successful gamble would increase a firm's reported profit and therefore its stock price, while an unsuccessful gamble would do the opposite. Even though such speculative transactions cannot affect the expected profit of a firm, the manager may be able to increase the expected stock price through a fair gamble in profits. The expected outcome of such a gamble depends on the shape of the equilibrium mapping from profits to stock prices. If stock prices are concave in profits, speculation will necessarily decrease a firm's expected stock price. But any firm finding itself in a nonconcave segment of this mapping can increase its expected market value by exposing its profit to a fair gamble. For example, a firm facing bankruptcy with a zero stock price could undertake such a speculative gamble without any downward risk in the hopes of mimicking a higher productivity firm and obtaining a positive stock price. In general, there are no fundamental reasons why the equilibrium mapping from profits to stock prices should be either convex or concave. In the presence of nonconcavities (without restricting the analysis to bankruptcy cases), my model demonstrates that speculation can be in the best interest of shareholders who are concerned about stock prices.

It should be noted that my model is not a signaling model in the traditional sense of Spence (1973). In contrast to the research initiated by Ross (1977) and Leland and Pyle (1977), where a firm's choice of capital structure acts as a signal to investors, my critical assumption is that speculative transactions cannot be observed by the market. Speculation in my model is therefore an example of "signal-jamming" as discussed by Holmstrom (1982), Fudenberg and Tirole (1986), and Stein (1989). The general idea is that agents (managers) undertake unobservable actions to influence other agents' learning about them or their firms. Stein (1989) examines a model where managers are trying to affect their firms' share prices. He assumes that firms can increase current earnings by "borrowing" against future earnings at an unfavorable implicit rate of interest. In equilibrium, the market is not misled about firms' worth, and stock prices adjust for the costly earnings inflation. In contrast, the speculative transactions in my model are costless to firms *and* they fool the market with respect to some firms' true values. Corporate speculation introduces noise in reported profits, which creates an informational externality by making share prices less informative.

The basic framework with four critical assumptions is spelled out in the next section. The rationale for corporate speculation is illustrated in Fig. 1, depicting a mapping from profits to stock prices. The optimal speculation strategy depends on the shape of this mapping, which is in turn affected by those decisions on speculation. To fully appreciate this interdependence, a simple two-period model is presented in Section 3. In the case of only two possible productivity levels, it is shown that an equilibrium cannot exist without corporate speculation. Instead, there are a multitude of equilibria with different levels of speculation. The existence of such equilibria demonstrates how corporate speculation can be an optimal strategy for managers acting in the best interest of shareholders. Section 4 concludes with a discussion of the findings.

2. THE BASIC FRAMEWORK

This section focuses on the general implications of the following four assumptions generating a motive for corporate speculation. The basic

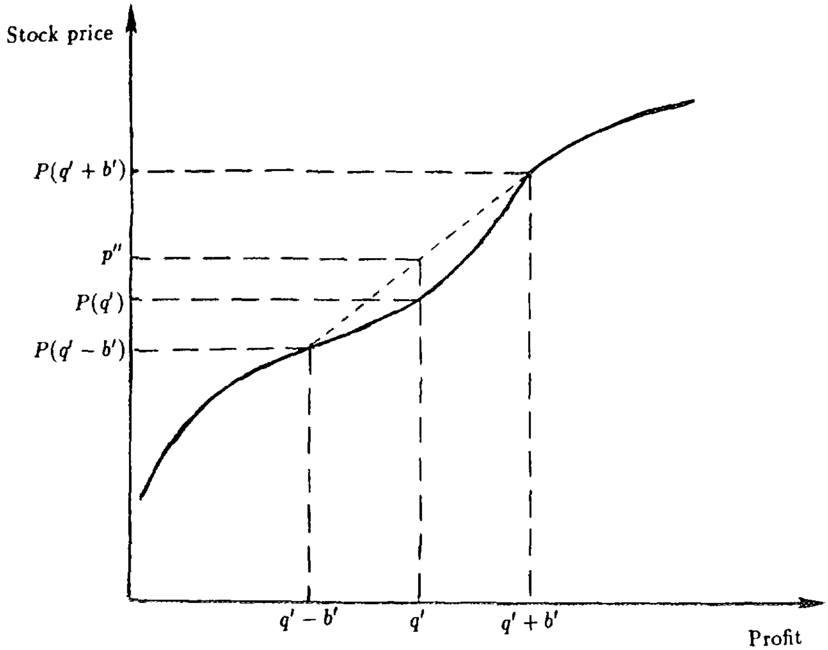

FIG. 1. An example of a mapping from profits to stock prices where a fair gamble in profits increases the expected stock price.

idea is illustrated in Fig. 1, depicting a mapping from profits to stock prices. However, the formal derivation of such an equilibrium mapping is deferred to the next section.

1. A firm's productivity is positively correlated over time; i.e., good production results today are more likely to be followed by good future production results than bad production results today would be.
2. Managers can choose to engage in speculative transactions which amount to fair gambles in production results.
3. A firm's production result and its speculative transactions are private information to the managers, while the final profit, i.e., the sum of the production result and the outcome of any speculation, is public information.
4. Managers act in the best interest of their shareholders, who are assumed to be risk neutral. Shareholders would like to see expected profits maximized and to get the highest possible expected stock price when selling shares.

The first critical assumption is that a firm's productivity displays positive serial correlation. Rational investors in stock markets will therefore use current profits as signals of firms' future profitabilities. In particular, high profits today are more likely to be followed by high profits tomorrow compared to the realization of low profits today. As a result, the profit level will affect the stock prices today. Higher profits will be associated with higher stock prices. One example of such a mapping is depicted in Fig. 1.

The second assumption says that managers can engage in speculation. It can be thought to capture the idea that financial markets are so well developed that any bets can be arranged. Moreover, the transaction costs are usually negligible, so these financial transactions are assumed to be costless. This means that managers are free to choose any fair gamble in profits; i.e., the expected return is zero. Let b denote the size of the bet and the probability of winning be π. That is, with probability $1 - \pi$, the firms loses its bet, and with probability π, it wins back the amount ϕb. The odds ϕ are obtained by imposing the condition of zero expected profits, or, equivalently, the expected payoff is just the original bet b:

$$(1 - \pi) \cdot 0 + \pi \cdot \phi b = b \quad \Rightarrow \quad \phi = \pi^{-1}. \tag{1}$$

If firms do not engage in speculation, the mapping in Fig. 1 can be used to read off the firm's stock price as a function of its net production result. However, given the informational asymmetry in the third assumption, a firm may be able to affect its expected stock price by taking a fair bet in profits. Whether or not such gambling is beneficial to the firm's shareholders depends on the shape of the equilibrium mapping from profits to stock prices. Suppose the firm's production result is q', which is associated with a stock price $P(q')$ as shown in Fig. 1. Since the equilibrium mapping is convex in the neighborhood around q', it follows that there exist fair gambles in profits that would increase the firm's expected stock price. For example, the bet b' with a fifty–fifty chance of winning in Fig. 1 would result in the expected stock price $p'' = .5P(q' - b') + .5P(q' + b')$ which is greater than $P(q')$.

Corporate speculation in Fig. 1 attains a higher expected stock price without affecting the expected profit of the firm. If shareholders are risk neutral, as stated in the fourth assumption, it follows that the expected welfare of shareholders who would like to sell their shares is increased while the welfare of other shareholders is kept unchanged. Managers acting in the best interest of shareholders would therefore engage in speculation. Leaving a discussion of risk aversion to the conclusion of my paper, it is also straightforward to characterize the optimal speculation strategy under risk neutrality. Formally, a manager of a firm with production result q should choose a bet b and a probability of winning π such that the expected stock price is maximized:

$$\max_{b,\pi} \; (1 - \pi)P(q - b) + \pi P(q - b + \pi^{-1}b) \tag{2}$$

$$\text{subject to} \quad b \in [0, q] \quad \text{and} \quad \pi \in (0, 1).$$

The argument thus far has avoided a major complication, which is that corporate speculation will of course affect the equilibrium mapping from profits to stock prices. For example, consider the firm with production result q' in Fig. 1 which undertakes the bet b' with a fifty–fifty chance of winning. If the gamble is successful, the firm reports the profit $q' + b'$. The market is then unable to distinguish this firm from other firms reporting the same profit but with greater production results. It follows that any firm successful in its gamble will reduce the average quality of firms at that higher profit level. As a consequence, the stock price of firms reporting that profit level must decline to reflect their lower average quality. On the other hand, firms that lose their gambles will tend to increase the stock prices at lower profit levels. An equilibrium is obtained when the mapping from profits to stock prices satisfies the following conditions:

(a) given the mapping, no firm can increase its expected stock price by changing its decision on corporate speculation;

(b) the stock price at each profit level reflects accurately the average quality of the firms reporting that profit, i.e., the market is not fooled on the average.

Such an equilibrium mapping is explicitly solved for in a two-period model in the following section.

3. A SIMPLE TWO-PERIOD MODEL

The four assumptions in the previous section are now embedded in a simple two-period model, where we can explicitly solve for the equilibrium mapping from profits to stock prices. Suppose there is a continuum of firms, which are of two types, low-output firms and high-output firms. Let the fractions of low-output firms and high-output firms be α and $1 - \alpha$, respectively, where $\alpha \in (0, 1)$. The net output of a high-output firm is q_H in both periods, while the net output of a low-output firm is q_L, where $q_H > q_L > 0$. Managers know the type of their firms, while others must learn from reported profits. The timing is as follows. At the beginning of each period, firms produce outputs and then decide on corporate speculation, which can be any fair gamble in profits. Thereafter, the final profits from production and any speculation are reported and paid out to the shareholders. At the end of the first period, there is also a stock market or, equivalently, a market for claims to second period output.

Besides a given number of firms, the economy has access to a storage technology where the gross rate of return on any amount stored between periods is $1 + r$. It is assumed that the economy's aggregate savings at the interest rate $1 + r$ are sufficiently large for the storage technology to be in operation between the two periods. Stock prices in the first period are then determined by the arbitrage condition that the expected rate of return on firm ownership is also equal to $1 + r$. The price $P(\gamma)$ of a firm reporting a profit γ in the first period is therefore given by

$$P(\gamma) = \frac{\text{Expected second period output, given current profit } \gamma}{1 + r}. \quad (3)$$

The equilibrium mapping $P(\gamma)$ that assigns a stock price to each profit level γ is now studied in three propositions. The first proposition shows that an equilibrium without corporate speculation cannot exist. The reason is that low-output firms would then have an incentive to engage in speculation such that successful bets would make them indistinguishable from high-output firms.

PROPOSITION 1. *There cannot exist an equilibrium without corporate speculation.*

Proof. See Appendix.

While Proposition 1 firmly rules out the existence of any equilibrium without corporate speculation, there exist a multitude of equilibria with corporate speculation. In these equilibria, speculation increases the variance of reported profits but decreases the dispersion of stock prices. The reason for the latter is that some firms of both types, low-output and high-output firms, will end up reporting the same profits and therefore demand the same stock price, which reflects their average quality. Such equilibria, exhibiting pooling of firms, are illustrated in Propositions 2 and 3. Specifically, Proposition 2 establishes a continuum of equilibria with corporate speculation, where the equilibrium mapping $P(\gamma)$ is an increasing step function with two stock prices. The intuition is as follows. Let γ_H be the profit level at which the stock price jumps, as shown in Fig. 2. All firms will then choose speculative transactions such that they report the profit γ_H when winning. No firm will choose a speculative transaction generating a profit higher than γ_H when winning, since that would only reduce the probability of winning, without affecting the stock price that can be attained. In order to maximize the probability of winning, all firms will also choose to bet their whole production results. Thus, high-output firms are more likely to win, explaining why there is a higher stock price $\bar{p}_H$ at reported profits greater than or equal to γ_H. The lower stock price $\bar{p}_L(\gamma_H)$ can be shown to depend on the level of γ_H. As stated in the proposition,

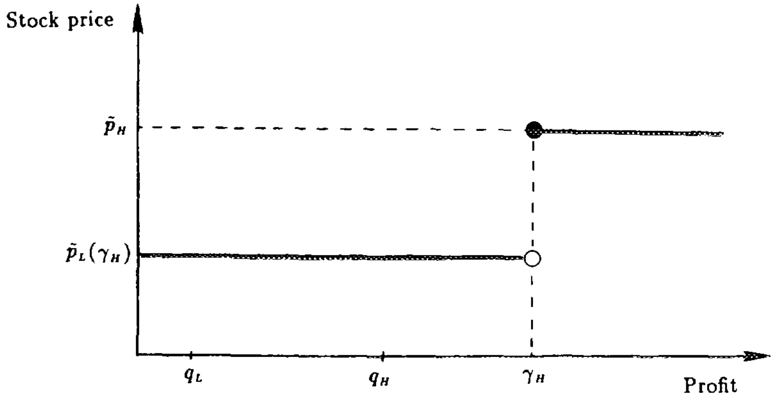

FIG. 2. An equilibrium with corporate speculation as in Proposition 2.

for each $\gamma_H > q_H$, there is an equilibrium with an associated step function where the lower stock price is increasing in γ_H. The intuition for the positive relationship between the lower stock price and γ_H is best understood by considering the limit. When γ_H approaches infinity, hardly any firm will be able to reach the higher stock price. It follows that the lower stock price will increase asymptotically toward the average quality of all firms in the economy.

PROPOSITION 2. *For any $\gamma_H > q_H$, there exists an equilibrium with corporation speculation. In this equilibrium, stock prices are given by a step function with two values:*

(*i*) *firms reporting a profit $\gamma < \gamma_H$ are traded for $\tilde{p}_L(\gamma_H)$,*
(*ii*) *firms reporting a profit $\gamma \geq \gamma_H$ are traded for $\tilde{p}_H > \tilde{p}_L(\gamma_H)$.*

For different equilibria, $\tilde{p}_L(\gamma_H)$ is increasing in γ_H, while $\tilde{p}_H$ is a constant. Corporate speculation in these equilibria is such that all firms report zero profits when losing and the profit γ_H when winning.

Proof. See Appendix.

Still another class of equilibria with corporate speculation is established in Proposition 3 below. Once again, the equilibrium mapping $P(\gamma)$ is given by an increasing step function, but this time with three stock prices. Let γ_M and γ_H be the two profit levels at which the stock price jumps, as shown in Fig. 3. In an equilibrium, only low-output firms will report profits less than γ_M, while only high-output firms will ever generate a profit greater than or equal to γ_H. But the medium range of profits will consist of both types of firms, i.e., low-output firms that have been successful in their speculation and high-output firms that have been unsuc-

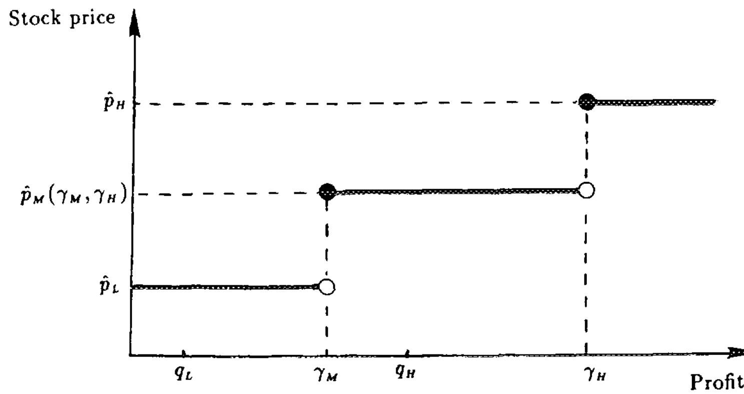

FIG. 3. An equilibrium with corporate speculation as in Proposition 3.

cessful. The stock price in this profit category, $\hat{p}_M(\gamma_M, \gamma_H)$, is therefore a weighted average of the two firms' qualities. For different equilibria, the stock price in the medium-profit category is increasing in both γ_M and γ_H. Some intuition for this is as follows. A higher γ_M reduces the probability of low-output firms winning their bets, which increases the average quality of firms in the medium-profit category. Analogously, a higher γ_H reduces the probability of high-output firms winning their bets and their higher representation in the medium-profit category drives up the stock price. Finally, while γ_M is only restricted to be in the open interval (q_L, q_H), the lower bound on γ_H is of a more complicated nature. This latter restriction is a necessary and sufficient condition to ensure that no firm would like to change its speculation strategy. A large enough γ_H makes it too costly for low-output firms to speculate for the highest stock price. It is also needed to deter high-output firms from raising their bets in order to increase the probability of getting the highest stock price (but at the risk of ending up with the lowest stock price).

PROPOSITION 3. *For any* $\gamma_M \in (q_L, q_H)$ *and* $\gamma_H \geq q_H + \alpha(1-\alpha)^{-1}q_L$, *there exists an equilibrium with corporate speculation. In this equilibrium, stock prices are given by a step function with three values:*

(*i*) *firms reporting a profit* $\gamma < \gamma_M$ *are traded for* $\hat{p}_L$,

(*ii*) *firms reporting a profit* $\gamma \in [\gamma_M, \gamma_H)$ *are traded for* $\hat{p}_M(\gamma_M, \gamma_H) > \hat{p}_L$,

(*iii*) *firms reporting a profit* $\gamma \geq \gamma_H$ *are traded for* $\hat{p}_H > \hat{p}_M(\gamma_M, \gamma_H)$.

For different equilibria, $\hat{p}_M(\gamma_M, \gamma_H)$ *is increasing in* γ_M *and* γ_H, *while* $\hat{p}_L$ *and* $\hat{p}_H$ *are constants. Corporate speculation in these equilibria is such that low-output firms report zero profits when losing and the profit* γ_M

when winning, and high-output firms report the profit γ_M *when losing and* γ_H *when winning.*

Proof. See Appendix.

4. CONCLUDING DISCUSSION

This paper has questioned the conventional wisdom that managers with private information about firms' exposure to risk, who act in the best interest of shareholders, should engage in hedging. Instead, it is shown that benevolent managers may speculate on behalf of shareholders. The reason is that when profits serve as a signal of firms' values, speculative trades can be used to distort profits and hence manipulate stock prices to the shareholders' advantage. Corporate speculation as an equilibrium phenomenon is demonstrated in a simple two-period model, but it should be clear that the economic forces underlying the result would also be present in a more complicated model. In particular, while it can be argued that stock prices should be positively related to firms' production results, there is no apparent reason why this mapping should be a concave one. And any firm finding itself in a nonconcave segment of this mapping can increase its expected market value by exposing its profit to a fair gamble. This rationale for corporate speculation does not arise from any conflict of interest between owners and managers, but it is the optimal financial policy when the stock market evaluates firms on the basis of their reported profits.

When shareholders are risk neutral, it is optimal for managers acting in their interest to choose corporate speculation so that the expected stock price is maximized. This benefits shareholders who would like to sell stocks, while leaving the welfare of other shareholders unchanged, since expected profits are unaffected. In the case of risk aversion, the objective for managers acting in the best interest of shareholders becomes more complicated when shareholders have different horizons. Risk averse shareholders who would like to sell stocks are willing to accept some additional variance in exchange for a higher expected stock price. But if managers act accordingly, risk averse shareholders who choose to hold on to their stocks will lose, due to the increased variability in profits without any change in the expected profit level. Managers trying to reconcile these different interests may end up with an objective function similar to the one in Stein (1989), where separate weights are attached to both profits and stock price. Another solution to this dilemma would be if shareholders avoid risk exposure with respect to profits by holding a well-diversified portfolio. This argument rests on the fact that the net supply of speculative transactions is zero in an equilibrium. That is, one firm's loss is another firm's gain, so there would be no risk with respect to profits for investors holding a well-diversified portfolio. Managers could then concentrate on using speculation as a way to increase stock prices on behalf of shareholders who would like to sell stocks. Of course, this strategy would fail if shareholders were unable to diversify because of transaction costs or some other reason.

Under the assumptions of risk neutrality and fair gambles, there are no welfare costs associated with speculation in my model. Risk neutral investors are indifferent to the noise in stock markets created by corporate speculation. Equilibrium stock prices will adjust to reflect the average quality of firms in any profit category. The purchase of a firm with a given profit level will then constitute a fair gamble among the firms falling in that profit category. However, suppose the assumption of fair gambles is replaced by speculative transactions being costly to firms. As long as the cost is not prohibitively large and stock prices are deemed important, managers will continue to speculate, resulting in a social waste of resources. Thus, welfare will be adversely affected by speculation. In fact, such speculative transactions would be tantamount to investments with a negative expected net present value (NPV). The idea that asymmetric information can lead firms to undertake negative NPV projects has also been explored by Narayanan (1988) and Heinkel and Zechner (1990). In their models, a firm's decision to accept a project is public information and new equity is issued before the market observes the quality of a project. Firms with poor investment opportunities may therefore wish to disguise themselves as firms with good prospects by accepting projects with negative NPV if the proceeds from selling overpriced equity can compensate for the poor investment. This conflict between current shareholders and future investors is also the driving force in my framework, which uses profits as a signal to the stock market instead of investment decisions. In either case, current shareholders are interested in high stock prices to enhance their wealth while future investors would like to see informative price signals in the stock market.

Corporate speculation in my model causes a delay in the resolution of uncertainty about firms. This is similar to the results of work done by DeMarzo and Duffie (1992), and Hirshleifer and Chordia (1992). While DeMarzo and Duffie show that managers uncertain about their own abilities may wish to increase the risk of investments in order to delay resolution regarding their managerial qualities, Hirshleifer and Chordia demonstrate how managers who know they are of high (low) ability use investment decisions to advance (defer) resolution of shareholders' uncertainty about them. Similarly, high-output firms in my model prefer a complete revelation of productivities which would guarantee them the highest stock price. If possible, they would therefore like to commit themselves not to speculate at all. However, it is in the interest of low-output firms to try to delay this resolution through corporate speculation. Since they have nothing to lose from a fair gamble in profits, they would make the same announcements not to speculate as the high-output firms but then go ahead with *unobservable* speculation. In equilibrium, investors ignore all announcements about speculation and make inferences about firms' productivities from reported profits assuming that optimal speculation strategies have been followed. The ensuing speculation will then increase the variance of reported profits but decrease the dispersion of stock prices. The reason for the latter is that some firms of both types, low-output and high-output firms, will end up reporting the same profits and therefore demand the same stock price which reflects their average quality. This pooling of firms with a lower dispersion of stock prices is just another way of saying that corporate speculation makes stock prices less informative about firms' true worth.

APPENDIX

Proof of Proposition 1. The proof will be by contradiction. Suppose there exists an equilibrium without corporate speculation. This means that only two profit levels will be observed in the economy, q_L and q_H. Any reasonable out-of-equilibrium belief must be that all other profit levels are associated with a stock price which is at least as high as the stock price of the worst possible firms, i.e., low-output firms which produce q_L in the two periods. It follows that low-output firms cannot reduce their stock prices if engaging in corporate speculation. Instead, their expected stock prices can be increased through speculative transactions such that they are sometimes mistaken to be high-output firms. For example, consider a low-output firm choosing the bet $b = q_L$ with probability of winning $\pi = q_L/q_H$. If that firm is successful in its gambling, it will report a profit equal to q_H and be indistinguishable from high-output firms. We can therefore conclude that an equilibrium without corporate speculation cannot be sustained with reasonable out-of-equilibrium beliefs.

Proof of Proposition 2. A firm that abstains from corporate speculation will with certainty face the lowest stock price $\bar{p}_L(\gamma_H)$. Since speculation cannot result in a lower stock price than $\bar{p}_L(\gamma_H)$ and risk neutral shareholders are indifferent to any fair gambles in profits, it follows that managers acting on behalf of shareholders would like to speculate in an attempt to attain the higher stock price $\bar{p}_H$. This can be done through a successful gamble that results in a profit greater than or equal to γ_H. The probability of attaining this higher stock price is maximized by betting the firm's whole production result and choosing a gamble that generates exactly the profit γ_H when it wins. That is, the optimal strategy for a firm with production result q_i is to bet q_i and select a probability of winning equal to q_i/γ_H. According to (1), a successful gamble will then generate exactly the profit γ_H. The probabilities of winning for low-output firms and high-output firms are therefore

$$\tilde{\pi}_L = \frac{q_L}{\gamma_H} \quad \text{and} \quad \tilde{\pi}_H = \frac{q_H}{\gamma_H}, \tag{A1}$$

respectively. Since there is a continuum of firms, the probabilities of winning stand also for the fractions of firms that will be successful in their gambles. Thus, a fraction $\tilde{\pi}_L$ of all low-output firms and a fraction $\tilde{\pi}_H$ of all high-output firms will win their gambles and report the profit γ_H. The average second period's output of these firms is therefore

$$\frac{\tilde{\pi}_L \alpha q_L + \tilde{\pi}_H(1-\alpha)q_H}{\tilde{\pi}_L \alpha + \tilde{\pi}_H(1-\alpha)}. \tag{A2.a}$$

(Recall that the fractions of low-output firms and high-output firms are α and $1-\alpha$, respectively.) Analogously, the average second period's output of firms which lost their gambles (and report a zero profit in the first period) is

$$\frac{(1-\tilde{\pi}_L)\alpha q_L + (1-\tilde{\pi}_H)(1-\alpha)q_H}{(1-\tilde{\pi}_L)\alpha + (1-\tilde{\pi}_H)(1-\alpha)}. \tag{A2.b}$$

The two stock prices in an equilibrium are then obtained by discounting these expected output levels as shown in (3). Since high-output firms have a higher chance of winning their gambles, as can be seen in (A1), it follows immediately that $\tilde{p}_H$ exceeds $\tilde{p}_L(\gamma_H)$. Using the probabilities in (A1) and after some rearranging, the equilibrium stock prices can also be written in terms of primitives,

$$\tilde{p}_H = \frac{\alpha q_L^2 + (1-\alpha)q_H^2}{(1+r)[\alpha q_L + (1-\alpha)q_H]}, \tag{A3.a}$$

$$\tilde{p}_L(\gamma_H) = \frac{(\gamma_H - q_L)\alpha q_L + (\gamma_H - q_H)(1-\alpha)q_H}{(1+r)[(\gamma_H - q_L)\alpha + (\gamma_H - q_H)(1-\alpha)]}. \tag{A3.b}$$

While the higher stock price $\tilde{p}_H$ does not depend on γ_H, the lower stock price $\tilde{p}_L(\gamma_H)$ can be shown after some algebra to be an increasing function in that parameter,

$$\frac{d\tilde{p}_L(\gamma_H)}{d\gamma_H} = \frac{\alpha(1-\alpha)(q_H - q_L)^2}{(1+r)^2[(\gamma_H - q_L)\alpha + (\gamma_H - q_H)(1-\alpha)]^2} > 0. \tag{A4}$$

Proof of Proposition 3. Consider the firms' decisions on corporate speculation in an equilibrium with three stock prices as described in the proposition. In the case of low-output firms, they strictly prefer to speculate, since they would otherwise face the lowest stock price $\hat{p}_L$ with certainty. However, depending on the distribution of stock prices, they may choose to gamble for the medium stock price $\hat{p}_M(\gamma_M, \gamma_H)$ or for the highest stock price $\hat{p}_H$. Analogously to the discussion in the proof of Proposition 2, it will in either case be optimal for a low-output firm to bet the whole production result and to choose a gamble that results in the lowest possible profit associated with the targeted stock price. The medium stock price $\hat{p}_M(\gamma_M, \gamma_H)$ is optimally targeted by gambling for the profit γ_M, while the highest stock price $\hat{p}_H$ is optimally targeted by gambling for the profit γ_H. The two speculation strategies can then be indexed by the probabilities of winning the gambles. Let $\hat{\pi}_L$ and $\hat{\pi}'_L$ denote the probability of winning when the targeted stock price is $\hat{p}_M(\gamma_M, \gamma_H)$ and $\hat{p}_H$, respectively. Following the proof of Proposition 2, these probabilities are given by

$$\hat{\pi}_L = \frac{q_L}{\gamma_M} \qquad \text{and} \qquad \hat{\pi}'_L = \frac{q_L}{\gamma_H}. \tag{A5.a}$$

In the case of high-output firms, these firms can bet any amount less than or equal to $(q_H - \gamma_M)$ without facing any downward risk from speculation. Such a limited gamble guarantees them at least the medium stock price $\hat{p}_M(\gamma_M, \gamma_H)$, and they may be successful in attaining the highest stock price $\hat{p}_H$. Depending on the distribution of stock prices, they may even want to bet the whole production result in order to maximize the probability of attaining the highest stock price but at the risk of ending up with the lowest stock price. These two different strategies can be summarized in terms of their probabilities of winning. First, let $\hat{\pi}_H$ denote the probability of winning when a high-output firm avoids the risk of facing the lowest stock price. The optimal strategy is then to bet exactly $(q_H - \gamma_M)$. Second, let $\hat{\pi}'_H$ denote the probability of winning when a high-output firm takes the risk of facing the lowest stock price, and therefore bets its whole production result. In either case, the firm will choose a gamble that results in exactly the profit γ_H when winning. The probabilities are then, by using (1),

$$\hat{\pi}_H = \frac{q_H - \gamma_M}{\gamma_H - \gamma_M} \qquad \text{and} \qquad \hat{\pi}'_H = \frac{q_H}{\gamma_H}. \tag{A5.b}$$

Suppose the firms choose the speculation strategies in the proposition, i.e., the ones associated with the probabilities $\hat{\pi}_L$ and $\hat{\pi}_H$ in (A5). From the discussion above, only high-output firms will then ever generate the profit γ_H and only low-output firms can end up with zero profits. The second period's output for firms reporting these two profit levels is therefore q_H and q_L, respectively. However, there will be both low-output firms and high-output firms reporting the medium profit γ_M. A fraction $\hat{\pi}_L$ of low-output firms are successful in their gambles, generating the profit γ_M, while a fraction $(1 - \hat{\pi}_H)$ of high-output firms lose their bets and end up with the same profit γ_M. The average second period's output of these firms reporting the profit γ_M is therefore

$$\frac{\hat{\pi}_L \alpha q_L + (1 - \hat{\pi}_H)(1 - \alpha) q_H}{\hat{\pi}_L \alpha + (1 - \hat{\pi}_H)(1 - \alpha)}. \tag{A6}$$

(Recall that the fractions of low-output firms and high-output firms are α and $1 - \alpha$, respectively.) The equilibrium stock prices are obtained by discounting the expected output level in each profit category, as shown in (3), and by using the probabilities in (A5):

$$\hat{p}_H = \frac{q_H}{1 + r}, \tag{A7.a}$$

$$\hat{p}_M(\gamma_M, \gamma_H) = \frac{(\gamma_H - \gamma_M)\alpha q_L^2 + (\gamma_H - q_H)(1 - \alpha)\gamma_M q_H}{(1 + r)[(\gamma_H - \gamma_M)\alpha q_L + (\gamma_H - q_H)(1 - \alpha)\gamma_M]}, \tag{A7.b}$$

$$\hat{p}_L = \frac{q_L}{1 + r}. \tag{A7.c}$$

While the stock prices $\hat{p}_H$ and $\hat{p}_L$ do not depend on γ_M and γ_H, the medium stock price $\hat{p}_M(\gamma_M, \gamma_H)$ can be shown after some algebra to be an increasing function in those two parameters,

$$\frac{d\hat{p}_M(\gamma_M, \gamma_H)}{d\gamma_M} = \frac{\alpha(1 - \alpha)(\gamma_H - q_H)(q_H - q_L)\gamma_M q_L}{(1 + r)^2[(\gamma_H - \gamma_M)\alpha q_L + (\gamma_H - q_H)(1 - \alpha)\gamma_M]^2} > 0, \tag{A8.a}$$

$$\frac{d\hat{p}_M(\gamma_M, \gamma_H)}{d\gamma_H} = \frac{\alpha(1 - \alpha)(q_H - \gamma_M)(q_H - q_L)\gamma_M q_L}{(1 + r)^2[(\gamma_H - \gamma_M)\alpha q_L + (\gamma_H - q_H)(1 - \alpha)\gamma_M]^2} > 0. \tag{A8.b}$$

Finally, the conjectured equilibrium with three stock prices will only exist if the postulated speculation strategies are not dominated by the alternative strategies associated with the probabilities $\hat{\pi}_L'$ and $\hat{\pi}_H'$ in (A5). It must therefore be shown that low-output firms and high-output firms cannot reach a higher expected stock price under those alternative strategies; i.e.,

$$(1 - \hat{\pi}_L)\hat{p}_L + \hat{\pi}_L \hat{p}_M(\gamma_M, \gamma_H) \geq (1 - \hat{\pi}'_L)\hat{p}_L + \hat{\pi}'_L \hat{p}_H, \qquad \text{(A9.a)}$$

$$(1 - \hat{\pi}_H)\hat{p}_M(\gamma_M, \gamma_H) + \hat{\pi}_H \hat{p}_H \geq (1 - \hat{\pi}'_H)\hat{p}_L + \hat{\pi}'_H \hat{p}_H. \qquad \text{(A9.b)}$$

After (A5) and (A7) are substituted into these expressions, both (A9.a) and (A9.b) can be rearranged to read

$$\gamma_H \geq q_H + \alpha(1 - \alpha)^{-1} q_L. \qquad \text{(A10)}$$

This restriction is therefore both a necessary and a sufficient condition to ensure that no firm would like to change its speculation strategy.

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