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ABSTRACT

This paper advances the hypothesis that some of the volatility of stock prices in excess of fundamentals is caused by fluctuations in the amount of public information over time. The model assumes that dividends and consumption are constant in the aggregate but that there are good firms and bad firms whose identity may be unknown to the public, as in Akerlof's "lemons" problem. The paper then shows that the collective valuation of the constant dividend stream will depend on the amount of information in the economy: The better the information, the better the allocation of firms' shares over savers.

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1. Introduction

We propose an explanation of fluctuations in stock prices which does not require fluctuations in aggregate dividends or aggregate consumption. Our explanation is based on changes in the amount of publicly available information about the distribution of future output across sectors. We assume that some insiders always know the correct distribution of output. Therefore fluctuations in public knowledge lead in our model to fluctuations in the degree of informational asymmetry and hence in the degree in which the market suffers from Akerlof's lemons problem.

Shiller, LeRoy and Porter present evidence that the variability of stock price indices cannot be accounted for by information regarding future dividends, since dividends just do not seem to vary enough to justify the price movement. They assume a constant discount factor. Grossman and Shiller (1981) argue that fluctuations in discount factors must be related to fluctuations in aggregate consumption. They conclude that even under perfect foresight the large fluctuations in stock prices in the thirty years between 1949 and 1979 cannot be explained by the fluctuations in aggregate consumption and dividends[1].

A number of arguments have been advanced to explain the phenomenon of excess volatility. It has been argued (by analogy to the "Peso problem") that the time series does not include events of possibly catastrophic proportions, and the market's assessment of the likelihood that such events will occur fluctuates in response to variables not observed by the analyst. A proper test of this hypothesis would seem to require too long a time series of observations to be feasible at present. Kleidon(1986) points out that the excess volatility literature assumes stationarity in the relevant time series and develop tests which do not require this assumption.

In an overlapping generations model one can get "sunspot" equilibria that involve excess movements in prices relative to fluctuations in dividends (Cass and Shell, 1981). To get such equilibria one must assume that the income effect dominates the substitution effect, and the equilibrium interest rate must fluctuate. Our explanation does not require that income effect dominate the substitution effect, and nor does it require fluctuations in the average interest rate , where the average is across individuals who are asymmetrically informed. Furthermore, overlapping generations models typically possess an equilibrium in which sunspots do not play a role and in which no excess volatility arises: It is unclear why, if at all, the sunspot equilibria deserve special attention.

Our explanation is based on changes in the amount of publicly available information about the distribution of future output across sectors. Predicting the distribution of future output is harder than predicting the aggregate level of future output. It is also likely that our ability to predict the distribution of future output fluctuates over time: In the eighties we seem to have a better idea of where the economy is going relative to the seventies.

Generally speaking, our ability to forecast the distribution of future output may be described as the outcome of a tug of war between the extent of our prior ignorance on the one hand, and the quality of the evidence available to us on the other. Because technological developments lead to a bewildering array of new investment opportunities, our prior ignorance is, in the relevant sense, always growing. At the same time, improvements in information technology lead to growth in the amount of evidence collected and stored. The net result is that our ability to forecast the distribution of output can well be viewed as fluctuating randomly from one period to the next.

The next section describes the intuition behind our argument, while section 3 lays out the formal details. For the sake of completeness, section 4 presents a model in which fluctuations in information are endogenous. This arises as part of a mixed strategy equilibrium in which each agent decides randomly whether to buy information about a firm. If purchased, this information is then revealed to other traders because the rational expectations equilibrium is fully revealing. We show that the amount of public information is random, and that its distribution remains nondegenerate even as the number of traders gets large.

2. Heuristics

This section will show that shocks to the amount of public information about the distribution of output can cause stock prices to move more than is warranted by changes in the joint distribution of aggregate dividend and aggregate consumption. We assume that some agents are always informed and that fluctuations in the amount of public information lead to fluctuations in the degree of asymmetry in information. To understand why we use this construct rather than a possibly simpler one which focuses on changes in the amount of **symmetric** information with respect to the aggregate, it helps to begin with the following model.

Consider a one-period security which pays a gross return of r, a random variable for which investors observe the signal $s = r + \varepsilon$. Risk neutral investors with a discount factor of β would value the security at $\beta E(r \mid s)$. Assuming that $r \sim N(\bar{r}, \sigma^2)$ and $\varepsilon \sim N(o, v^2)$, so that v is an index of how accurate the information is, the equilibrium price of the security is

$$p(s,v) = \beta\,[\bar{r} + \{\sigma^2/(\sigma^2 + v^2)\}\,(s - \bar{r})],$$

and the variance of p conditional on v is

$$(1)\quad \sigma^2_p(v) = \beta^2\sigma^2/(1 + [v^2/\sigma^2]) < \beta^2\,\sigma^2 .$$

Therefore, the variance of p is less than the variance of the discounted dividends, so long as $v^2 > 0$.

The next question is, can the inequality be reversed if v itself is random? That is, what if the accuracy of information, v, fluctuated randomly from period to period? Suppose that v is i.i.d., with distribution G(v), and let $F(s \mid v)$ denote the distribution of the signal given v. The unconditional variance of the price is then

$$\sigma^2_p = \int [\, p(s,v) - E_{s,v}\, p]^2 \, dF(s \mid v)\, dG(v) \; .$$

But $E_s\, p = \bar{r}$ for all v and therefore the unconditional mean is also $\bar{r}$. Therefore,

$$\sigma^2_p = \int \sigma^2_p\, (v)\, dG(v) < \beta^2 \sigma^2 \;\; ,$$

using equation (1). We conclude that in this setup, fluctuations in the accuracy of information about aggregate dividends cannot cause excess volatility of stock prices.

We focus on fluctuations in the public's ability to predict the distribution of dividends across sectors relative to the ability of insiders to do that. We use Akerlof's (1970) intuition that when buyers and sellers of a good are asymmetrically informed about it, the good may end up "in the wrong hands", and the market value of all goods may differ from their market value under full information. In other words, the market value of Akerlof's used cars depends on the amount of publicly available information. This represents volatility of the value of all used cars in excess of fundamentals which, if the distribution of the qualities of the cars is fixed, do not change.

This, in a nutshell, is the intuition we wish to exploit, with firms' securities replacing used cars. But one hurdle immediately crops up: firms last a lot longer than used cars, and the question is, can there be uncertainty about the "quality" of firms, period after period, that does not disappear so quickly as to be uninteresting for present purposes? The answer to this is twofold. First, while the birth and death rate of firms is lower than that of new cars, it is still positive and significant. And second, existing firms are constantly faced with new risks, risks that call for an ongoing reevaluation of the firms as investment prospects. For both reasons, an investor will find it hard to differentiate the good firms from the lemons, unless he can become better informed about their investment opportunities.

Before presenting the details of the model, let us describe its logic in general terms.

We model an exchange economy in which the net return to owning a firm is exogenous, and in which owning firm's shares is the only means by which a person can save. In this respect, the model is the same as Lucas (1978). We depart from his model, however, in that here the distributional properties of the earnings stream of each firm are unknown to a subset of traders: a firm is either good or bad, but only the firm's owner knows for sure which.

To isolate our hypothesis from other possible explanations of excess volatility, we rig things so in the aggregate the sequence of dividends is constant over time.[2] The economy is divided into two sectors--say north and south. Half the firms are in the north, half in the south. Firms' technologies get hit by an aggregate shock that is purely distributive in the sense that collectively, the firms are equally productive in each period--when it rains in the north, it is sunny in the south, and vice versa, so that the aggregate amount of rain is always the same. This ensures that in the aggregate, dividends paid out are the same in each period--all firms produce the same good, and the total amount produced does not change over time.

Owners of firms (insiders) always know which sector is productive. The information of buyers fluctuates: sometimes they know the identity of the productive sector and sometimes they do not. It is assumed that in the absence of complete information, owners of bad firms realize that they are "informationally large" and take this fact into account: they choose to trade in a way that will not reveal the identity of the bad sector. Let us start with the assumption that the bad sellers' will not be found out if they behave like good sellers in selling ownership in their own firm, and if they behave like uninformed buyers in buying shares in other firms. We shall later discuss the robustness of our result to changes in this assumption.

In equilibrium, a buyer always knows with certainty the amount of his future consumption. When information is perfect this is obvious, since then he will buy shares in good firms only. When information is incomplete, the buyer will hold the market portfolio and since we do not have aggregate risk, he again knows how much future consumption he will get. It is therefore useful to talk about the buyer's demand for future consumption. Under the assumption that bad sellers behave as uninformed buyers on the demand side, it is simple to aggregate the demand curves of the uninformed buyers and the bad sellers. Assuming no income effect, this aggregate demand curve does not change with the state of public information. It is depicted by the curve D in Figure 1. The excess supply for future consumption is positive only for the good sellers and is depicted by the curve S.

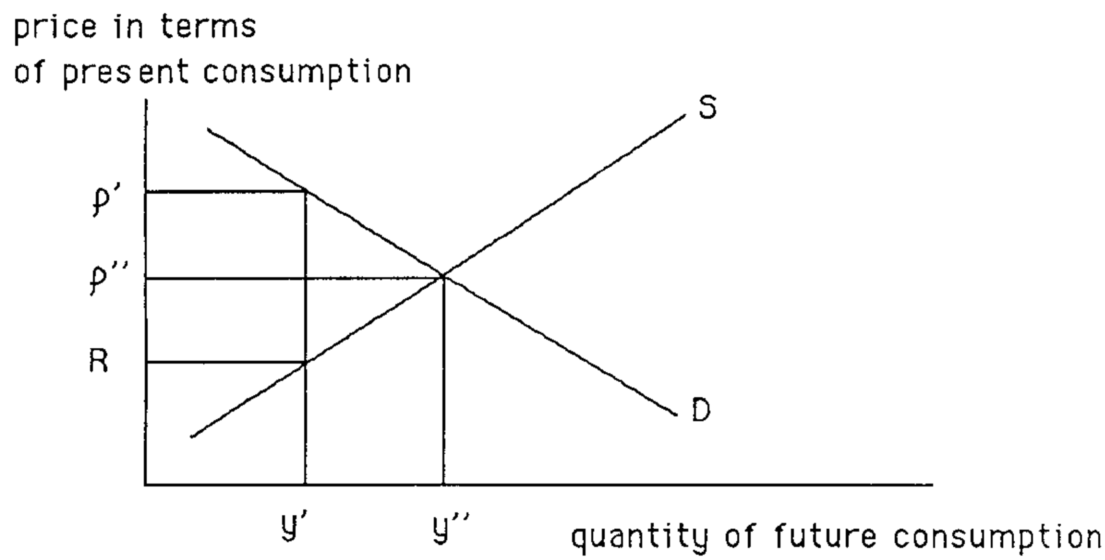

Figure 1

In the full information case we get an equilibrium in which the price of future consumption in terms of present consumption is ρ'' (= 1/[1 + r''], where r'' is the real interest rate in this case). When buyers are uninformed, they must buy a portfolio of firms in both sectors to secure a given quantity of future consumption. They will therefore spend more current consumption per unit of future consumption than the sellers of firms in the good sector who know where to invest. This divergence between the price to the informed and the uninformed agents leads to an equilibrium in which the quantity of future consumption traded is less than in the complete information case. The uninformed see the price $\rho' > \rho''$ and the informed see the price $R < \rho''$. (Note that this is a unique equilibrium: if the quantity traded were larger, the price to buyers would be less than the price to good sellers which contradicts the information advantage of the good sellers).

Since firms are the only source of future consumption and since only uninformed buyers value bad firms, the value of the stock exchange must be equal to the value of aggregate future consumption from the uninformed buyers' point of view. If aggregate output is Y, then its value in the informed case is $\rho''Y$ and its value in the uninformed case is $\rho'Y > \rho''Y$, since $\rho' > \rho''$. Thus the value of the stock exchange is higher in the uninformed state.

We did not expect this result, but on second thoughts it is rather intuitive. The value of all used cars from the uninformed buyers point of view is higher in the presence of asymmetric information because in this case they end up with a smaller amount of quality adjusted units of cars.

According to Figure 1, the quantity traded is inversely related to the price of future consumption as perceived by the buyers. This implies a positive correlation between the rate of return on holding the market portfolio, $r = (1/\rho) - 1$, and the fraction of the market portfolio that changed hands during trade, y / Y. This implication is consistent with the findings in the finance literature regarding the relationship between price changes and trading volume. See Karpoff (1987) for a recent survey of the literature on this topic.

3. The Model

We consider an economy that lasts for two periods, (or more accurately, a sequence of non-overlapping, unconnected two-period economies). Agents have preferences over a single consumption good, given by $C_1 + U(C_2)$, where C_i is the agent's consumption in period i and U is differentiable, monotone and strictly concave. Each agent is endowed with a unit of the first period consumption good, but with none of the second period consumption good. In addition, some of the agents are endowed with firms. There are two kinds of firms, good and bad. A good firm yields α units of C_2 and none of C_1. A bad firm yields nothing in either period. There are m agents who own good firms, m agents who own bad firms and n agents who own no firms at all. Thus there are a total of m good firms, and m bad firms, and a total of n + 2m agents.

As there is no storage, the only way to get any C_2 is to own a fraction of a good firm. Owners sell shares of their firms to the public and to each other. We assume throughout that the owner of a firm knows whether his firm is good or bad. In this section we shall analyze price-taking equilibrium for two different cases: (A) when all buyers have complete information about the identity of the good and bad firms, and (B) when the n buyers have no information whatsoever about the identity of the good and bad firms.

(A) Buyers have complete information. Since everyone knows the identity of the good firms, the bad firms will have shares that fetch a zero price. Only shares of good firms will be traded. Since the utility function we assume implies no income effects, each agent will demand the same amount of future consumption. A person holding s shares of a good firm gets $s\alpha$ units of C_2. If p is the price per share in units of

C_1, each agent's demand for shares is

$$s(p,\alpha) \equiv \text{argmax}_s \{U(s\alpha) - ps\} .$$

To guarantee an interior solution we assume that the endowment of C_1 is large enough, U'(0) is large and U' goes to zero as C_2 gets large.

The current consumption of a good seller is 1 + p(1-s), while a bad seller and a buyer each has C_1 equal to 1 - ps. All markets clear if and only if

(2) $s(p,\alpha) = m/(2m + n)$.

(B) Buyers have no information. An uninformed buyer can assure himself of a riskless return of $\alpha/2$ per share by buying the market portfolio made up of an equal fraction of the firms in the two sectors. His demand will be $s(p,\alpha/2)$. The owner of a good firm can assure himself of a return of α by holding on to s shares of his own firm, and at a price p, he will hold $s(p,\alpha)$ shares. Here we assume that all the transactions can be directly observed and therefore a bad seller can mask the identity of his sector only if he completely mimic the behavior of a good seller. This is different from the assumption used in the previous section[3]. If the utility from future consumption is not too large[4], a bad seller will hold $s(p,\alpha)$ units of his firm and no shares in other firms, in order not to be found out. (Of course, he would prefer to sell off his entire firm, since he knows that it is worthless, but that would give him away). Markets will clear if and only if

(3) $\overline{s}(p) \equiv \{2m/(2m+n)\} \cdot s(p,\alpha) \quad + \quad \{n/(2m+n)\} \cdot s(p,\alpha/2)$
$\quad\quad = 2m/(2m+n)$.

The function $\bar{s}(p)$ is the weighted average demand for shares per agent. The right hand side of (3) is the supply of shares per agent.

Let p^* solve equation (2) and let p' solve equation (3). When buyers are informed, the value of the market portfolio is mp^*, while, when they are uninformed, the value of the market portfolio is $2mp'$. One would expect that $p' < p^*$, since when buyers are uninformed the return per share is half of that when they are informed. But to prove that the aggregate value fluctuates we must show that $p^* \neq 2p'$. We shall now show that

(4) $p' < p^* < 2p'$.

Since U is strictly concave, the demand for shares must be downward sloping--there is no income effect. Also, for any p, and any $\lambda > 0$, $s(p,\alpha) = \lambda s(\lambda p, \lambda\alpha)$. This homogeneity of degree -1, follows directly from the solution $s(p,\alpha) = U'^{-1}(p/\alpha)/\alpha$. It says that the demand for future consumption, $s(p,\alpha)\alpha$, must remain the same if the price of a firm and its output are increasing by the same proportion, λ. Applying this in eq. (2) yields $\lambda s(\lambda p^*, \lambda\alpha) = m/(2m+n)$, or, at $\lambda = 1/2$,

$s(p^*/2, \alpha/2) = 2m/(2m+n)$, as in Figure 2.

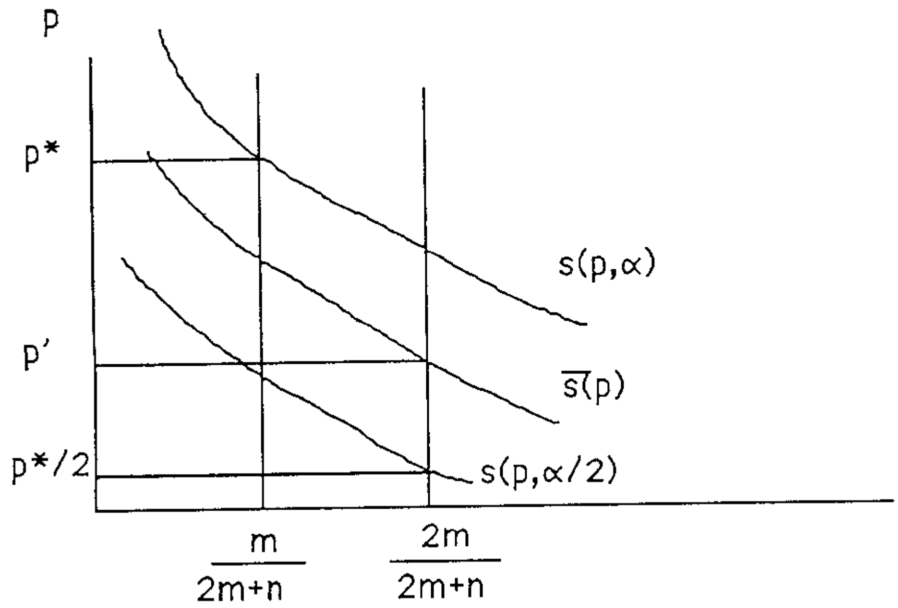

Figure 2

Since $\bar{s}(\cdot)$ is a convex combination of $s(\cdot, \alpha)$ and $s(\cdot,\alpha/2)$, $\bar{s}(\cdot)$ lies between these two functions, as in the figure. And since p' solves (3), it must obey (4).

Thus the total value of shares is higher in the uninformed state, 2mp', than in the informed state mp*. We have shown that if publicly available information fluctuates over time, the value of firms will also fluctuate even though aggregate dividends and aggregate consumption are both constant.

4. Endogenous fluctuations in information

The introduction section argued that the quality of information may reasonably be expected to fluctuate over time, therby causing excess volatility of stock prices. For the sake of completeness we present a model in which public information fluctuates endogenously because of its public good aspect. The approach that follows yields a distribution of information, and the parameters of this distribution depend on the fundamentals of the model. We begin with a general result for games involving a public good.

In an economy with n agents, agent i can take action: $x_i \in \{0,1\}$. The technology for producing a public good, y, is

$$(5) \qquad y = \begin{cases} \lambda & \text{if } x_i = 1 \text{ for some } i, \\ 0 & \text{otherwise.} \end{cases}$$

Player's i's payoff is $y - kx_i$, where $k \in (0,\lambda)$ is the cost of providing the public good. The only symmetric equilibrium is in mixed strategies.[5] Let q be the probability that $x_i = 1$, for all i. If $x_i = 1$, player i collects $\lambda - k$. If $x_i = 0$, he collects zero unless someone else plays $x_j = 1$ (which happens with probability $1-(1-q)^{n-1}$), in which case he collects λ. For q to be strictly between zero and one, the player must be indifferent between his two options: $\lambda - k = [1 - (1-q)^{n-1}]\lambda$, so that

$$(6) \qquad (1-q)^{n-1} = k/\lambda.$$

Let Q be the probability that $y = \lambda$. Since this is the probability that $x_i = 1$ for some i,

$$(7) \qquad Q = 1 - (1-q)^n = 1 - (k/\lambda)^{n/(n-1)}.$$

Taking the limit in (6) and (7) as $n \to \infty$ yields:

$$(8) \qquad \lim q = 0, \text{ and } \lim Q = 1 - k/\lambda.$$

Therefore, while the probability that any one player will provide the public good, q, converges to zero, the probability that someone will provide it, Q, converges to a number strictly between zero and one.

In section 3, the state of information was taken as exogenous. Let us now allow the n buyers the possibility of buying information about a particular firm. This information consists of a perfect signal of a firm's return.[6] But because uncertainty is sector-specific, we shall now show that if a buyer acts on the information that he has bought, prices will reveal it to the other demanders.

Assume that the Walrasian auctioneer announces the price p' when some buyers are informed about the identity of a good firm, and hence they know which the good sector is. In this case the demand for shares in the good sector is greater than $\overline{s}(p')$ per agent and the demand for shares in the bad sector is less than $\overline{s}(p')$ per agent. As a result (3) is violated: there is an excess demand for shares in good firms and excess supply for shares in bad firms. The Walrasian auctioneer will therefore increase the price of good firms and reduce the price of bad firms. Rational agents who understand the rules of the tatonnement process will conclude that firms whose price went up are good firms and firms whose price went down are bad firms. This will lead to a further increase in the demand for shares in the good firms and to the elimination of demand for shares in bad firms. We will reach the full information equilibrium in which the price of good firms is p^* and the price of bad firms is zero.[7]

Although in this example prices are fully revealing, our argument does not require this. All we need is that <u>some</u> piece of information that can be acquired at a cost will be perfectly revealed by prices: this is much weaker than the assumption that prices reveal everything. In this case where revelation is perfect, the second inequality in (4) implies that in the informed state, buyers are strictly better off, because C_2 is cheaper. Therefore, if information is cheap enough, it will pay some buyers to obtain it, even though the information is revealed to other traders through prices. To show this formally, in eq. (5) take λ to be the strictly positive difference in utility that a buyer gets in the informed state and let k be the cost of buying information. As the number of buyers, n, gets large, eq. (8) tells us that p will approach the random variable

$$p = \begin{cases} p^* & \text{with probability } 1-k/\lambda \\ p' & \text{with probability } k/\lambda \end{cases}$$

The value of all share in the economy approaches

$$v = \begin{cases} mp^* & \text{with probability } 1-k/\lambda \\ 2mp' & \text{with probability } k/\lambda \end{cases}$$

From the second inequality in (4), v is a nondegenerate random variable, taking on a larger value in the uninformed state. This requires, of course, that $k < \lambda$, that is, that information be cheap enough relative to the gains that can be expected from it.

5. Conclusions

We have shown that endogenously generated fluctuations in the amount of public information can lead to fluctuations in the stock market value of all firms even though aggregate dividends and aggregate consumption are constant. In our model market value is equal to the value that buyers place on aggregate future consumption. Market value is higher , and the rate of return is lower, when information is less precise, because in this case the uninformed buyers get a smaller quantity of future consumption and at the margin they value future consumption more. The implied positive correlation between the turnover rate and the rate of return on holding the market portfolio is supported by the findings in the finance literature.

Footnotes

[1] In general, one needs fluctuations in expectations about the joint distribution of aggregate consumption and dividends to generate fluctuations in stock prices. If agents are uncertain about how aggregate consumption and dividends evolve, the assumption of perfect foresight tends to exaggerate the fluctuations in the ex ante joint distribution, since different realizations of the joint distribution are taken to imply changes in the distribution itself.

[2]This corresponds to an unchanging distribution of quality among Akerlof's used cars.

[3] The assumption made is on what can be directly observed. Another approach is to ask what will be revealed by prices. It is fairly straightforward to show that in a rational equilibrium framework there is a pooling equilibrium with non-revealing prices if all the bad sellers in our model behave like good sellers on the supply side and like uninformed buyers on the demand side. Another pooling equilibrium exists if all the bad sellers behave entirely like good sellers. But there are no other symmetric pooling equilibria. Thus if all the bad sellers behave in any other way prices will reveal their information. Our results do not depend on which of the two possible assumption is chosen.

[4]The bad seller will try to mask the identity of the bad sector only if he prefers the outcome in the uninformed state to the full information outcome. His utility in the full information case is : (a) $U\{s(p^*,\alpha)\alpha = \alpha m/(2m+n)\} + 1 - p^*s$, where p^* is the equilibrium price in the full information case. His utility in the incomplete information case is (b) $1 + p'\{1 - s(p',\alpha)\}$. A choice of $U\{\alpha m/(2m+n)\}$ which is not too large guarantees that (b) is larger

than (a).

[5]The game also has n asymmetric Nash equilibria in pure strategies: Player i plays $x_i = 1$ and collects $\lambda - k > 0$ as his payoff; the remaining players choose $x_j = 0$ and each collects λ.

[6]The signal could be imperfect as well, with no change in the analysis.

[7]Formally there can be $J=2^{2m}$ different states of the economy, where a state is defined by the identity of the good firms. Let $p^j \varepsilon R^n_+$ be a vector of prices of the n firms' shares in state j. Let $p \varepsilon R^{2mJ}_+$ be a vector of prices for all firms in all states. Then p is a rational expectations equilibrium if (a) every buyer expects p^j to be the market price in state j; (b) when each buyer maximizes his expected utility conditioned on both his own initial information and the information contained in the market price, and when sellers maximize their utility, then excess demand for the shares of each firm is zero in each state; (c) prices do not reveal more information than the information that buyers collectively have.

Clearly, a price vector which assigns p^* to good firms and zero to bad firms is a rational expectations price vector. To show that this is a unique equilibrium, assume that a bad firm is assigned a strictly positive price. In this case informed buyers will choose short positions in this firm (i.e., $s < 0$ and large in absolute value) and will disturb market clearing.

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