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ABSTRACT

This paper argues that some of the volatility of stock prices in excess of fundamentals results from 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 depends on the degree of informational asymmetry.

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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 indexes cannot be accounted for by information regarding future dividends, since dividends just do not seem to vary enough to justify the price movement. The literature has pretty much solved the statistical controversies surrounding the original tests (Kleidon 1986, for example) and made the connection between the excess volatitlity paradox and the Fama and French's findings that long horizon (2 to 10 years) returns have a large forecastable component. (For surveys of this literature see Campbell Lo and Craig, n.d., Cochrane 1991, LeRoy 1989, and Fama 1991). Shiller (1981, 1984) and Summers (1986) summarize the empirical evidence by a model in which stock prices follow a random walk plus a fad variable, where the latter is modeled as a slowly mean reverting stationary series.

The original test assumed 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

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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 dividend.

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 seems to require too long a time series of observations to be feasible at present.

In an overlapping generations model one can get "sunspot" equilibria that can play the role of a fad variable in the Shiller-Summers formulation (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 the 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). More importantly, overlapping generations models typically have 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.

We will show that the degree of asymmetric information can also play the role of a fad variable but in contrast to the sunspot model, ours does not require multiplicity of equilibria. We should emphasize that our agents are rational: they do the best given the available information. In this sense the degree of asymmetry is not a fad variable: it is just an additional factor that effects stock prices.

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The way in which we endogenize the fluctuations in informational asymmetry also solves the Grossman-Stiglitz paradox on the incentives to gather information. This paradox arises from the public good aspects of information: If prices are sufficient statistics for all relevant information then there is no incentive to gather information. But if no one gathers it, market prices cannot be informative and in this case there will in general be an incentive to collect information. One way to solve this public good problem is to assume that agents adopt a mixed strategy with respect to gathering information. To keep an incentive to collect information, the probability that no one will buy information is strictly positive. If some agents (insiders) are always informed and other agents (outsiders) adopt a mixed strategy with respect to gathering information, we will have some periods in which everyone is symmetrically informed and some periods in which only the insiders are informed.

We consider two examples. In the first uninformed agents know a lot about the market structure and observe and interpret every transaction. In the second uninformed agents know only the return on a randomly selected stock out of all the stocks that are for sale.

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2. EXAMPLE 1: THE UNINFORMED SEE ALL TRANSACTIONS AND PRICES

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

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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

$$(1) \qquad s(p, \alpha) \equiv \text{argmax}_s \{U(s\alpha) - ps\} .$$

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

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

The assumptions on U guarantee that a unique equilibrium exists.

(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. If the utility from future consumption is not too large[1], a bad seller will hold $s(p, \alpha)$ units of <u>his</u> 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

$$(3) \qquad \bar{s}(p) \equiv \{2m/(2m+n)\}s(p, \alpha) + \{n/(2m+n)\}s(p, \alpha/2) = 2m/(2m+n) \ .$$

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. As p increases, $\bar{s}(p)$ declines continuosly from infinity to zero, so that a unique equilibrium exists.

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 $p^* \neq 2p'$. Indeed, the total value of shares in the uninformed state is higher than in the informed state.

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[1] 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).

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Proposition 1:

$$2mp' > mp^* . \quad (4)$$

Proof: From (1), $p = \alpha U'$, so that $mp^* = m\alpha U'[s(p^*,\alpha)\alpha]$ in the full information case, and $2mp' = 2m(\alpha/2)U'[2s(p',\alpha/2)(\alpha/2)] = m\alpha U'[s(p',\alpha/2)\alpha]$ in the asymmetric information case. So, we can think of the total value of the market as the valuation of aggregate future consumption from the uninformed point of view. The valuation is higher in the asymmetric case because the uninformed consume less in this state. Their share in aggregate future consumption is smaller in the asymmetric case, because in this state there is a price difference: they pay $2p'$ to get α units while the informed pay only p'. And since there is no income effect the demand for future consumption is lower when its price is higher. □

We showed 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. We now turn to discuss how the fluctuations in information may come about.

Fluctuations in information: We argued in the introduction that fluctuations in information are one way to solve the Grossman-Stiglitz paradox. We now illustrate this point and present a model in which information fluctuates endogenously because of its public good aspect. The approach that follows yields a distribution of information, and the

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parameters of this distribution depend on the fundamentals of the model. We begin with a general result for games involving a public good.[2]

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

$$y = \{\lambda \text{ if } x_i = 1 \text{ for some } i;\ 0 \text{ otherwise}\} \tag{5}$$

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.[3] 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

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

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

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

Taking the limit in (6) and (7) as n goes to infinity yields:

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[2] See for example, Eden (1981).

[3] 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.

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

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.

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.[4] 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 $\bar{s}(p')$ per agent and the demand for shares in the bad sector is less than $\bar{s}(p')$ 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

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

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information equilibrium in which the price of good firms is p* and the price of bad firms is zero.[5]

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 inequality (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

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[5] 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 $p^j \in R^n_+$ be a vector of prices of the n firms' shares in state j. Let $p \in R^{2mJ}_+$ 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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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 shares in the economy approaches

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

From (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.

3. EXAMPLE 2: THE UNINFORMED KNOW THE RETURN ON INVESTING A DOLLAR IN ALL STOCKS

In the first example, agents see and interpret all transactions. In the real world, firm size differs and it is hard to know whether the price of a firm is low because it is small and productive, or large and unproductive. We now consider the other extreme, and assume that in periods of asymmetric information, agents cannot interpret prices and follow a policy that requires minimal judgement: They invest the same

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dollar amount in all stocks.[6] This policy yields a non-random return and the uninformed are aware of it and use it to calculate their demand for future consumption.

In equilibrium marginal utilities from future consumption fluctuate with the state of information: In the asymmetric case, informed agents' marginal utility goes down and uninformed agents' marginal utility goes up. We use Jensen's inequality to show that when U' is not linear, these fluctuations in marginal utilities lead to fluctuations in the value of the market.

Each period there are M good firms and m bad firms. As before, a good firm will produce α units next period and a bad firm will produce none. There are N + n agents. In periods of asymmetric information, N are informed and n are uninformed. In a period of complete information only the market for good firms must clear:

$$(n + N)s(p,\alpha) = M \quad (9)$$

From the first order condition to (1), the solution to (9) satisfies: $P = \alpha U'(s(P,\alpha)\alpha)$. Therefore, the value of stocks in periods of full information equals the value of future consumption:

$$MP = M\alpha U'(s(P,\alpha)\alpha) \quad (10)$$

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[6] The main result will not change if each uninformed agent randomly chooses a single stock out of all stocks that are for sale. This may be closer to reality: There are actually many people who hold a single stock rather than a portfolio of stocks.

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We now turn to periods of asymmetric information. Let p' be the price of a good firm and p'' be the price of a bad firm. Informed agents face the price of p' per α units of future consumption and at this price they demand $s(p',\alpha)\alpha$ units. To compute the return on a dollar investment in all stocks, which is the

price of future consumption that the uninformed face, note that a dollar in each of the $M + m$ firms yields $M\alpha/p'$ units of future consumption. The price per unit is therefore $p'(M + m)/M\alpha$ and the price per α units is:

$$(11) \qquad p^* = p'(M + m)/M .$$

At this price, uninformed agents demand $s(p^*,\alpha)\alpha$ units of future consumption. Note that the uninformed pay a premium for future consumption the size of which is proportional to the fraction of bad firms in the economy.

Equilibrium prices are a vector (P' , P'' , P^*) that satisfy (11) and the market clearing conditions:

$$(12) \qquad ns(p^*,\alpha)p^*(m/M+m) = mp'';$$

$$(13) \qquad ns(p^*,\alpha)p^*(M/M+m) + Ns(p',\alpha)p' = Mp'.$$

The requirement (12) says that the amount of money that uninformed agents spend on bad firms must equal their total value. We may think of it in the following way. The uninformed demand for future consumption implies a derived demand for shares in bad firms. This derived demand is

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$ns(p^*,\alpha)p^*(m/M+m)/p''$. Equation (12) says that derived demand equals supply. Requirement (13) says that the total amount spent on good firms by both uninformed and informed agents must equal their total value. Dividing both sides of (13) by p' and using (11) leads to the condition that (derived) demand for good firms equals supply:

$$ns(p^*,\alpha) + Ns(p',\alpha) = M .$$

A unique equilibrium exists: After (11) is used to substitute for p^* into (13), the latter becomes an equation in p' alone which has a unique solution for the same reason that (3) does; inserting this value into (12) yields the equilibrium value of p''. We now turn to the equivalent of proposition 1.

Proposition 2: If $U''' > 0$ everywhere, then $MP' + mP'' > MP$,
while if $U''' < 0$ everywhere, then $MP' + mP'' < MP$.

Proof: Since, $P^* > P'$, $s(P^*, \alpha) < s(P',\alpha)$. And since $Ns(P',\alpha)\alpha + ns(P^*, \alpha)\alpha = M\alpha$, Jensen's inequality implies:

$$(14) \quad \{Ns(P',\alpha)\alpha U'[s(P',\alpha)\alpha] + ns(P^*, \alpha)\alpha U'[s(P^*, \alpha)\alpha]\}/M\alpha > U'(M\alpha/[N+n]) .$$

Using first order conditions,

$$(15) \quad MP' + mP'' = Ns(P',\alpha)\alpha U'[s(P', \alpha)\alpha] + ns(P^*, \alpha)\alpha U'[s(P^*, \alpha)\alpha] .$$

Using (14), (15) and (10) leads to:

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$$(16)\quad MP' + mP'' = \{Ns(P',\alpha)\alpha U'[s(P',\alpha)\alpha] + ns(P^*, \alpha)\alpha U'[s(P^*, \alpha)\alpha]\}$$
$$> M\alpha U'(M\alpha/[N+n]) = MP ,$$

which proves the first part of the proposition. The second part follows analogously. □

The fraction of bad firms is one measure of the degree of informational asymmetry. In the full information case this fraction is zero. In the other case this fraction is $m/(M + m)$. In general, it can vary over time. A fad variable story may go as follows. At some point there is a new invention and M + m firms try to implement it. Later on, it becomes clear to insiders who the successful M implementors will be, but this information spreads slowly to the public, as some of the m bad firms exit. As the fraction of bad firms declines, so does the premium paid by the uninformed (11), and with it the market value (assuming here the more plausible case: $U''' > 0$).

4. CONCLUSIONS

In the first example we showed that endogenous fluctuations in public information can lead to fluctuations in the stock market value of all firms even though aggregate dividends and aggregate consumption are constant. The market value equals 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 uninformed buyers get less future consumption and at the margin they value it more.

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It is hard to extend the first example to a dynamic setting because it assumes a strong correlation between endowments and information: the set of informed agents coincides with the set of firm owners. The second example does not require any special relationship between endowments and information but it assumes less sophistication on the part of the uninformed.

Overall, the examples do illustrate that the degree of asymmetry in information is a variable that can influence stock prices.

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