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2 Market Structure, Information, Futures Markets, and Price Formation

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INTRODUCTION

The futures markets for agricultural and other commodities are easy to single out as being those capitalist institutions which come closest to satisfying the textbook definition of perfect competition. Indeed, the large open interest, heavy trading volume, and great liquidity of the active futures markets for soybeans, corn, and a variety of other commodities seem to make the assumption of perfect competition a reasonable one. This assumption gains further plausibility when one considers that the market clearing price is determined by the non-cooperative actions of hundreds of floor traders and thousands of speculators and hedgers off the floor of the commodity exchanges.

Two facts about futures trading suggest, however, that futures markets are not as competitive as they seem at first glance. First, seats on commodity exchanges are quite valuable and that much of their value is derived from the floor trading privileges attached to their ownership. The barrier to entry created by the requirement that floor traders own seats may well increase the returns to floor traders by making floor trading less competitive.1 Second, open interest in futures markets is often concentrated in the hands of a small number of traders. This suggests that traders with large positions will consider the effect of their trading actions on price and thus behave in a strategic or, equivalently, non-competitive manner.

In this paper, a simple model of the trading process is constructed which incorporates the

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assumption that commodity futures markets are non-competitive in a manner consistent with the above facts. The model is used to analyze the effectiveness of policies designed to improve the performance of agricultural commodity markets by increasing the informativeness of prices. In particular, the following questions are addressed:

1. How does the publication of information, such as crop forecasts and export data by the USDA, affect the informativeness of prices?
2. How does a policy of excluding from trading in commodity futures markets "shippers" who have no economic need to trade in the market and no non-public information about demand or supply for the commodity tend to affect the amount of noise in prices and therefore the informativeness of prices?

These questions concerning the informativeness of speculative prices are clearly important ones. The USDA currently spends millions of dollars each year collecting and publicizing information about agricultural commodities; yet economists have not been able to come to grips with the question of what would happen if the production of information was left to "market forces", especially if these market forces are not competitive. Concerning trading by uninformed retail speculators, the Commodity Futures Trading Commission, which regulates organized trading in agricultural and other commodities on commodity exchanges, has a policy of allowing essentially anyone who wants to trade futures contracts to do so as long as he has a sufficiently large amount of money to lose. While there are virtually no suitability rules to weed out uninformed or emotionally ill-equipped traders, it has been proposed that such rules would not only be desirable on paternalistic grounds but would also tend to stabilize prices by eliminating uninformed noise trading. This problem is also one which economists have a hard time addressing, especially with imperfectly competitive markets.

The model of imperfectly competitive speculative markets discussed in this paper has properties quite different from models based on the assumption of perfect competition. The assumption that floor traders, who provide a market making service, behave as imperfect competitors leads to negative serial correlation in price movements. This negative serial correlation allows market makers to make supernormal profits by buying when other traders are selling (and prices are falling) and selling when other traders are buying (and prices are rising). In addition to imperfectly competitive market makers, the model has large imperfectly competitive speculators who trade on the basis of private information. Since these large speculators trade strategically, taking into account the effect that their buying and selling has on market prices, they find it optimal to trade smaller quantities than might otherwise be optimal in order to obtain better prices. This restricted trading means that large speculators in effect withhold some of their private information from prices. In equilibrium, prices do not reveal all of the private information of large speculators but large speculators earn positive profits on the basis of their private information.

In competitive models, the analogous features the equilibrium depend very heavily upon the assumption of risk aversion. In our model of imperfectly competitive speculative markets, both market makers and speculators are risk neutral. In competitive markets, however, risk aversion is necessary if market makers or speculators are to earn positive returns. With perfectly competitive risk averse market makers, prices have negative serial correlation due to the fact that when prices are falling (because other traders are selling) market makers are unwilling to buy at actuarially fair prices because of risk aversion; a similar argument holds when prices are rising. When competitive speculators with private information are risk averse, they are unwilling to trade large quantities at the statistically unbiased prices which reveal all of their private information because these prices offer no return for bearing risk. In equilibrium, the risk premium speculators demand prevents prices from revealing all of the private information of speculators.

The assumption that speculative markets are imperfectly competitive has policy implications which differ from those of standard competitive models. Consider first the effect of the public production of new information which is an imperfect substitute for speculators' private information. We show below that an increase in public information tends to make the atmosphere for speculators more competitive and thus induces them to incorporate more of their private information into prices. This lowers the returns to speculators and leads to an exit of speculators from the market, but prices in the new equilibrium are more informative than prices were before the increase in public information.

The greatest difference between imperfectly competitive models and competitive models concerns the effect of noise trading on the informativeness of prices. In competitive models, increases in noise trading lead to increases in the size of risky positions that must be carried by speculators and market makers. The
increased risk premiums demanded by speculators and
market makers to carry these positions make prices
noisier and therefore less informative. While returns
to speculators and market makers increase and new entry
occurs, prices in the new equilibrium which emerges
are more informative than in the old. In this sense,
informed noise trading is destabilizing.
In our model of imperfectly competitive markets,
by contrast, increased noise trading tends to make
prices more informative. This surprising result is due
to the tendency for increased noise trading to increase
the liquidity of the market, where "liquidity" is
proportional to the quantity of trade it takes to cause
prices to change by one dollar. When noise trading
increases, market liquidity increases and speculators
and market makers, acting similarly to monopolists who
suddenly face a more elastic demand curve, are willing
to trade the larger quantities necessary to sustain the
greater degree of liquidity, with prices equally as
informative as before. In this situation the rewards
to speculators are increased, new entry occurs, and in
the new equilibrium which emerges, prices are more
informative because more information is produced and
more of the information which is produced is
incorporated into prices.
The obvious policy implication of this result is
that it is not clear that uninform noise trading is
bad for anyone other than the noise traders themselves.
The case for suitability rules must be based upon
specific assumptions about the structure of speculative
markets or upon paternalistic arguments.

HOLBROOK WORKING'S IDEAS AND THE RECENT LITERATURE

This paper draws upon ideas from four strands of
literature in finance and economics: the pioneering
work of Holbrook Working on futures markets, the
theoretical and empirical work on the Efficient Markets
Hypothesis, the rational expectations literature, and
the industrial organization literature.

Many modern ideas about the informational role of
prices were formulated quite early by Working (1953).
Working observed if prices reflect expectations
accurately, then price fluctuations in an "ideal"
market are unpredictable, reflecting always the arrival
of new information. He also formulated clearly the
notion that future prices were always the best
possible estimate of prices at a later date, then
returns to speculators would be driven to zero and "the
speculation necessary to maintain even an approximation
to ideal price behavior would tend to vanish." He
proposed that economists investigate price fluctuations
empirically in an effort to isolate the "imperfections" which enable professional traders to make profits
consistently. On the basis of his own rudimentary
empirical work (1953, 1960, 1967) Working observed that
futures prices tend to jiggie back and forth on an
intra-day, tick-by-tick basis, and the resulting
negative autocorrelation in price changes enables floor
traders who make markets (scalpers or day traders) to
earn positive profits consistently; he also observed
that it is very difficult to construct, on the basis
of current public information, better estimates of the
future prices of their current crop.

In the efficient markets literature of the 1960s
and 1970s we find a more sophisticated approach to the
theoretical assumptions underlying the Efficient
Markets Hypothesis and a great deal of empirical work
of the kind advocated by Working (much of the empirical
work being done on stock market data rather than
futures market data). Fama (1970) provides a well-
known summary of the earlier empirical work in the area,
together with a treatment of three distinct forms of
the Efficient Markets Hypothesis: the weak form, the
semi-strong form, and the strong form. Fama's
conclusions about the efficiency of stock market prices
are very similar to Working's conclusions about futures
market data. It is difficult to beat the market on the
basis of public information. (The stock market is semi-
strong form efficient.) Only two glaring
inefficiencies stand out: a tendency towards too many
revisions of tick-by-tick prices, documented by
Niederhoffer and Osborne (1966), reflecting the
supernormal profits earned by specialists due to their
monopolistic access to the order flow (consistent with
Working's evidence on day trading); and an ability of
corporate insiders to earn supernormal profits on the
basis of inside information which is not
instantaneously incorporated into prices.

The theoretical model discussed in this paper
captures exactly these kinds of informational
imperfections while preserving the assumptions that it
is impossible to make profits consistently on the
basis of public information. Furthermore, Fama's
assertion that the profit opportunities are due to
monopolistic access to information is exactly the idea
designed to be captured by our model. Thus, our model
fits well empirical evidence from the efficient markets
literature, assuming of course that futures markets for
agricultural commodities behave somewhat like markets
for common stocks.

A theoretical tool useful in our model is the
concept of a rational expectations equilibrium, due to
Muth (1961), in which a sharp distinction is made
between changes in structure and changes in outcomes.
As in a rational expectations equilibrium, our traders
are assumed to know the structure of the model when
making trading decisions but not the outcome of all
random variables they would like to know. Our result
that uninformd trading is stabilizing is a structural
result. That is an increase in the variance of the
quantity of noise trading leads to an increase in the
statistical precision of prices. At the same time,
large outcome of the quantity of noise trading, which
traders do not observe is associated with a noisier,
less precise price.

Our model also deals with the role of noise
trading in sustaining a rational expectations
equilibrium, an issue discussed for example by Grossman
and Stiglitz (1980). In the context of a formal model
of a competitive market with informed and uninformed
traders, Grossman and Stiglitz show that as trading
noise vanishes, prices become perfectly informative.
In the limit, equilibrium breaks down because informed
traders cannot earn a positive return on their private
information. In our model (without entry and exit of
speculators) the informativeness of prices is not
affected by changes in the amount of noise trading.
When entry and exit of speculators occurs, a reduction
in noise trading leads to exit of speculators until
eventually only one monopolistic speculator is left;
even he eventually leaves as well. Prices become less
(not more) informative with fewer speculators and
although eventually there are no speculators and
therefore, no private information incorporated into
price, equilibrium does not break down. The
introduction of non-competitive behavior on the part
of informed traders thus eliminates the tendency for
equilibrium to break down (with endogenous entry), as
it does in the Grossman and Stiglitz model.

Our concept of imperfect competition is similar
to concepts in the industrial organization literature.
We use a Nash equilibrium in trading strategies for
both market makers and speculators, with similar
restrictions to capture the informational structure of
the market discussed below.

Our "paradoxical" result that noise trading is
stabilizing is similar to the result that an increase
in demand may lower price in a model of Cournot
competition. Consider a market with a linear demand
curve and firms characterized by a fixed cost and a
constant marginal cost the same for all firms. There
is no competitive equilibrium because marginal cost
pricing does not cover fixed costs, but with freedom
of entry, quantity Cournot pricing leads to an
equilibrium price above marginal cost. We suppose
that demand doubles. It can be shown that this leads
to additional entry and a lower price because the
market becomes more competitive. This result is
similar to our result that more noise leads to more
entry and a more competitive, informative price. The
similarity is not a perfect analogy, however.

AN ECONOMIC FRAMEWORK

In this section we outline a simple economic
framework in which the informativeness of prices
can be discussed and from which implications about
efficiency of resource allocation can be drawn.
The model is a very simple one designed to make a simple
economic point, but the idea can be generalized.
Consider a seasonal agricultural commodity which
can be stored costlessly for two periods after the
harvest but which perishes before the next harvest.
The harvest, denoted z, becomes an "exhaustible
resource" which is consumed over two periods. Letting
c1 and c2 denote consumption in the two periods, we
have the resource constraint z = c1 + c2, 2/
Demand for the commodity is generated by a
representative consumer's quadratic utility function:

\[ u(x,c_1,c_2) = x - \frac{1}{2} (A - c_1)^2 - \frac{1}{2} (A + \hat{d} - c_2)^2 \]

(1)

where x denotes consumption of the numeraire good, A is
a parameter defining the utility function, and \( \hat{d} \) is a
random demand shock with zero mean affecting demand in
period two.

Demand functions for the good in the two periods
are given by:

\[ c_1 = A - p_1 \]

(2)

\[ c_2 = A + \hat{d} - p_2 \]

and

where \( p_1 \) and \( p_2 \) denote prices in periods one and two
respectively. To abstract away from unnecessary
complications, we assume that storage costs and
interest rates are zero. This allows us to interpret
\( p_1 \) as a futures price for delivery in period two as
well as a spot price.

If the outcome of \( \hat{d} \) is observed before the
consumption decision must be made in period one, then
storage arbitrage equates prices across periods, and
equilibrium prices and quantities are given by:

\[ p_1 = p_2 = A + \frac{1}{2} \hat{d} - \frac{1}{2} z, \]

(3)

\[ x_1 = \frac{1}{2} (z - \hat{d}), \]

and

\[ x_2 = \frac{1}{2} (z + \hat{d}). \]
This allocation maximizes social welfare defined using the standard consumer surplus concept. We shall assume, however, that the outcome of \( \hat{d} \) is not observed with perfect accuracy in period one but that some information about the outcome of \( \hat{d} \) is incorporated into prices in period one. In this case actual social surplus will be lower by the amount \( \frac{1}{2} (p_2 - p_1)^2 \), where \( p_2 \), obtained from the demand function and the resource constraint, is given by:

\[
p_2 = 2A + \hat{d} - z - p_1. \tag{4}
\]

We wish to develop the intuitive idea that an accurate price \( p_1 \) implies that \( p_2 - p_1 \) is small, thus establishing a positive relationship between the informativeness of prices, the stability of prices, and social welfare. To do so, assume that there exist risk neutral traders and that an ex ante market is held in which there is no information available about the outcome of \( \hat{d} \). Letting \( p_0 \) denote the ex ante price, it is easy to show that a policy of buying two units ex ante and selling one unit in periods one and two respectively yields profits \( 2p_0 - 2A + z + \hat{d} \), an expression which does not depend on the particular prices \( p_1 \) and \( p_2 \) which are realized. Then the assumptions of risk neutrality (implying zero expected profits) and no information about \( \hat{d} \) (which has a zero "prior" mean) guarantee that \( p_0 = A - \frac{z}{2} \).

Consider the price fluctuations \( \Delta p_1 \) and \( \Delta p_2 \) defined by

\[
\Delta p_1 = p_1 - p_0, \quad \Delta p_2 = p_2 - p_1,
\]

where we now think of \( p_1 \) and \( p_2 \) as random variables. From equation (4), it is easy to show that:

\[
\hat{d} = 2\Delta p_1 + \Delta p_2. \tag{5}
\]

Now make the Martingale assumption that \( E(\Delta p_j | \Delta p_1) = 0 \). This allows us to interpret \( 2\Delta p_1 \) as an unbiased forecast of \( \hat{d} \) with error \( \Delta p_2 \). The overall volatility of prices, measured by \( \text{var}(p_2) = \text{var}(\Delta p_1) + \text{var}(\Delta p_2) \), can be shown to be given by:

\[
\text{var}(\Delta p_2) = \text{var}(\hat{d}) - 3\text{var}(\Delta p_1). \tag{6}
\]

Improving the informativeness of the price \( p_1 \) increases the variance of \( \Delta p_1 \), but reduces the variance of \( \Delta p_2 \) four times as much; it thus reduces the overall volatility of prices. Note that it also reduces the expected welfare loss due to not having perfect information, which is given by \( \frac{1}{4} \text{var}(\Delta p_2) \).

The idea that more informative prices are less volatile overall and result in expected welfare gains is contained in Working's onion study (1960). He observed in that study that an increase in the informativeness of prices should increase volatility early in the season but reduce it by even more later on. His study sought to document this fact empirically using the historical experience of onion futures trading.

INFORMATION STRUCTURE AND TRADING STRATEGIES

While a framework for discussing the implications of prices is contained in the previous section, that section does not contain a model of the price formation process itself. In principle, a large number of specific models of price formation, both competitive and non-competitive, can be developed within this framework. In this section we outline one such model of market structure and price formation.

Of the three prices \( p_0 \), \( p_1 \), and \( p_2 \), clearly \( p_1 \) is the only one which is determined in a non-trivial manner. The price \( p_0 \) is merely an ex ante expectation, and \( p_2 \) is determined mechanically from \( p_1 \) by equation (4). In our model of price formation, the price \( p_1 \) is the outcome of a game played by several different classes of traders. The rules of this game determine the institutional structure of the market. In the rest of this section we discuss "the rules of the game" by defining the trading strategies each trader can use, paying particular attention to the information each trader utilizes in his trading strategy.

There are three kinds of traders in the market: an undetermined number of uninformed noise traders, \( M \) market makers, and \( N \) informed speculators. These traders trade on the basis of public and private information about the demand shock \( d \).

The public information, which can be interpreted as a government statistic published to all traders in advance of trading in period one, is a noisy observation of \( d \) given by \( \hat{d} + \hat{g} \), where \( \hat{g} \) is a random noise term. In addition to this public information, each of the \( N \) informed speculators, indexed \( n = 1, \ldots, N \), has a private observation given by \( \hat{d} + \hat{e}_n \), where \( \hat{e}_n \) is a random noise term. We assume that the \( N + 2 \) random variables \( \hat{d} \), \( \hat{g} \), \( \hat{e}_1 \), \ldots, \( \hat{e}_N \) are normally and independently distributed with zero means and variances given by:

\[
\text{var}(\hat{d}) = 1/\tau_0, \quad \text{var}(\hat{g}) = 1/\tau_1, \quad \text{var}(\hat{e}_n) = 1/\tau_n, \quad n = 1, \ldots, N, \]
The uninform noise traders trade "exogenously," purchasing a random quantity denoted \( \delta \) in period one. The random variable \( \delta \) is normally distributed with zero mean and variance \( \tau_\delta^2 \); it is exogenous in that it is assumed to be distributed independently of \( \tilde{g}, \tilde{e}_1, \ldots, \tilde{e}_n \). Noise trading thus contains no information about "the fundamentals" of supply and demand.

Some discussion of the trading strategies of market makers and informed speculators is in order at this point. It is useful to think of the trading strategies as functions of the informational and price variables \( \tilde{d} + \tilde{g}, \tilde{d} + \tilde{e}_n \), and \( p_1 \). Under this interpretation, the parameters \( \gamma_m \) and \( \beta_n \) represent particular linear functions of subsets of these variables. Using the concept of equilibrium described above, it can be shown that linear strategies of the particular form specified by equations (11) and (12) are equilibrium strategies when market makers and informed traders choose from the following broader sets of strategies:

1. The mth market chooses the quantity he trades \( x_{Mm} \) as any measurable function of \( \tilde{d} + \tilde{g} \) and \( p_1 \) (but not of private observations \( \tilde{d} + \tilde{e}_n \));
2. The nth informed trader chooses the quantity he trades \( x_{In} \) as any measurable function of \( \tilde{d} + \tilde{g} \) and \( \tilde{d} + \tilde{e}_n \) (but not of the market price \( p_1 \)). Proving this result is somewhat tedious and takes us beyond the scope of this paper. Hence, we have begun by assuming that the trading strategies have this particular linear form.

These trading strategies do, however, embody one restrictive assumption. While informed speculators can choose the quantities they wish to trade on the basis of public and private information, they must choose this quantity before they observe the market clearing price \( p_1 \). It is as if they are forced by the rules of the game to trade by placing a market order for a specific quantity. This assumption confers an informational advantage upon market makers by giving them a chance to react to the incoming order flow before informed speculators are given a chance to react. If we think of market makers as floor traders and informed speculators (and noise traders) as traders off the floor, then this assumption captures in a rough way an informational division of labor, which casual observation suggests is a characteristic of organized commodity trading. Floor traders concern themselves a great deal with the order flow but are often quite ignorant of information about the fundamentals of demand and supply; at the same time, even large
informed speculators off the floor find it impossible to beat floor traders at their game. We have tried to capture this institutional feature of commodity trading with the assumption that market makers set quantities traded as functions of prices but speculators do not. 4

THE DEFINITION OF EQUILIBRIUM AND ITS EXISTENCE

We now turn to the definition of equilibrium. Roughly speaking, our equilibrium is a Nash equilibrium in the parameters \( y_m \) and \( \beta_n \), calculated under the assumption that market makers and informed speculators are risk neutral. According to the Nash equilibrium concept, each market maker and each informed trader maximize expected profits taking into account his effect on prices.

From the market clearing condition:

\[
M \sum_{m=1}^{N} x_{Mm} + \sum_{n=1}^{N} x_{In} + \tilde{u} = 0, \quad (14)
\]

and from equations (11) and (12), the price in period one is given by:

\[
P_1 = p_0^* + \left( \sum_{m=1}^{M} \gamma_m \right)^{-1} \left( \sum_{n=1}^{N} \beta_n \hat{X}_n + \tilde{u} \right), \quad (15)
\]

and from equation (4) the price in period two is given by:

\[
\hat{p}_2 = \hat{p}_0^* + \tilde{d} - E(\tilde{d} + \hat{g}) - \left( \sum_{m=1}^{M} \gamma_m \right)^{-1} \left( \sum_{n=1}^{N} \beta_n \hat{X}_n + \tilde{u} \right). \quad (16)
\]

Note that the unexpected fluctuation in prices \( p_1 - \hat{p}_0^* \) is a linear function of the order flow, \( \hat{X}_n + \tilde{u} \), and that this order flow term consists of "information plus noise." In taking into account the effect that their trading has on "prices," market makers and speculators must consider their effect on both \( p_1 \) and \( \hat{p}_2 \). Buying more today raises \( p_1 \) but increases stocks and thus lowers \( \hat{p}_2 \). Tomorrow, from equations (15) and (16), \( \Delta \hat{p}_2 \) which represents profits per unit traded under the assumption that positions are liquidated in period two, is given by:

\[
\Delta \hat{p}_2 = \hat{p}_2 - \hat{p}_1 = \tilde{d} - E(\tilde{d} + \hat{g}) - 2 \left( \sum_{m=1}^{M} \gamma_m \right)^{-1} \left( \sum_{n=1}^{N} \beta_n \hat{X}_n + \tilde{u} \right). \quad (17)
\]

The expected profits of market makers and the expected profits of informed traders, denoted \( \pi_m \) and \( \pi_n \), are given as functions of the strategy parameters \( \gamma_1, \ldots, \gamma_M, \beta_1, \ldots, \beta_N \) by:

\[
\pi_m^*(\gamma_1, \ldots, \gamma_M, \beta_1, \ldots, \beta_N) = E(\gamma_m (\hat{p}_1 - \hat{p}_0^*) \Delta \hat{p}_2), \quad m = 1, \ldots, M, \quad (18)
\]

\[
\pi_n^*(\gamma_1, \ldots, \gamma_M, \beta_1, \ldots, \beta_N) = E(\beta_n \hat{p}_2), \quad n = 1, \ldots, N, \quad (19)
\]

where \( \Delta \hat{p}_2 \) and \( \hat{p}_1 \) are understood to depend upon \( \gamma_1, \ldots, \gamma_M, \beta_1, \ldots, \beta_N \) according to equations (15) and (17).

An equilibrium is defined as a vector of strategy parameters \( \gamma_1, \ldots, \gamma_M, \beta_1, \ldots, \beta_N \) such that \( \gamma_m \) maximizes \( \pi_m^*(\gamma_1, \ldots, \gamma_M, \beta_1, \ldots, \beta_N) \) holding constant the other \( N + M - 1 \) parameters and \( \beta_n \) maximizes \( \pi_n^*(\gamma_1, \ldots, \gamma_M, \beta_1, \ldots, \beta_N) \) holding constant the other \( N + M - 1 \) parameters.

It can be shown that a unique equilibrium exists. The actual proof is tedious and takes us beyond the scope of this paper, but it goes as follows: By substituting specific expressions for \( \Delta \hat{p}_2 \) and \( \hat{p}_1 \) into the expressions for \( \pi_m^*(\ldots) \) and \( \pi_n^*(\ldots) \) and evaluating the resulting expectations, specific expressions for \( \pi_m^*(\ldots) \) and \( \pi_n^*(\ldots) \) are calculated in terms of the strategy parameters and the six exogenous parameters \( M, N, \gamma_0, \gamma_1, \beta_0, \beta_1 \). These expressions are then differentiated with respect to the appropriate strategy parameters to obtain \( N + M \) first order conditions characterizing the \( N + M \) equilibrium strategy parameters in terms of the six exogenous parameters. A symmetry argument is used to show that all market makers choose the same strategy parameter and all informed speculators choose the same strategy parameters. Call these parameters \( \gamma \) and \( \beta \) respectively. This reduces the \( N + M \) first order conditions in \( N + M \) unknowns to two equations in two unknowns. These two equations are then solved for \( \gamma \) and \( \beta \) explicitly. The results of these calculations are the following messy-looking expressions:

\[
2 (M-2) (N+1) \left( \begin{array}{c} 2 i \frac{1}{M} - \frac{1}{N} \frac{1}{0^+ G} \end{array} \right) - \frac{2 i}{\sqrt{0^+ G}} \frac{1}{0^+ G} \frac{1}{i}, \quad (20)
\]

and:

\[
M (M-1) \frac{N^2}{2} \left( i \frac{1}{M} - \frac{1}{N^2} \frac{1}{0^+ G} + \frac{1}{i} \right) \frac{1}{i}, \quad (20)
\]
\[ \beta = \frac{(\sigma_u^2)^{1/2}}{N^{1/2} \left( \frac{1}{\tau_0^G + \frac{1}{\tau}} \right)^{1/2}} \]  

(21)

Now define \( \lambda \) by:

\[ \lambda = \frac{1}{N} \]  

(22)

and let \( \tilde{x} \) denote the combined quantity bought by speculators and uninformed traders:

\[ \tilde{x} = \frac{N}{n=1} \left( \beta \tilde{t} \tilde{E}_n + \tilde{u} \right) \]  

(23)

Then \( p_1 \) is given by:

\[ \tilde{p}_1 = \tilde{p}_0 + \lambda \tilde{x} \]  

(24)

The quantity \( \lambda \), which converts order flow into price fluctuations, is a good index for the liquidity of the market, with small values of \( \lambda \) corresponding to great liquidity. It is not too misleading to refer to \( \lambda \) as the equilibrium bid-asked spread. The total price fluctuation \( p_1 - p_0 \) can be written:

\[ \tilde{p}_1 - \tilde{p}_0 = (\tilde{p}_0 - p_0) + \lambda \tilde{x} \]  

(25)

The term \( \tilde{p}_0 - p_0 = \frac{1}{N} \sum_{n=1}^{N} \left( \beta \tilde{t} \tilde{E}_n + \tilde{u} \right) \) is an announcement effect and the term \( \lambda \tilde{x} \) is an order flow effect.

**Properties of the Equilibrium with Large Numbers of Market Makers**

In equilibrium, both market makers and informed speculators earn positive expected profits. Market makers earn positive profits due to their oligopolistic access to the order flow, i.e., their ability to trade on the basis of current prices. Informed speculators earn profits due to their monopolistic access to information. It is clear from equation (17) that \( E(\Delta p_2 | \tilde{d} + \tilde{g}) = 0 \). Thus, it is impossible for a trader who is not a market maker and who has no private information to construct a consistently profitable trading strategy based on public information alone. \( \beta \) / At the same time, however, the fact that market makers make positive profits implies that prices do not follow a Martingale, i.e., it is not generally true that \( E(p_2 | p_1) = p_1 \). In fact, prices overreact in period one, rising too much (for a Martingale) when the order flow is positive and falling too much when the order flow is negative. 

Thus allowing market makers, who face the order flow, to liquidate positions later at a profit on average. As the number of market makers increases, the market power of each market maker is reduced toward zero, the profits of each market maker (indeed, of market makers as a whole) tend to vanish, and the Martingale property holds in the limit as \( N \rightarrow \infty \).

In the rest of this paper we assume that \( N \) is approximately infinite, so that the Martingale property holds.

Defining \( \lambda^* \) as the limit of \( \lambda \) as \( N \rightarrow \infty \), we have:

\[ \lambda^* = \frac{1}{N} \left( \frac{2}{\tau_0^G} \right)^{1/2} \]  

(26)

\[ \beta = \frac{N^{1/2} \left( \frac{1}{\tau_0^G + \frac{1}{\tau}} \right)^{1/2}}{(\sigma_u^2)^{1/2}} \]  

(27)

The equilibrium price in period one is given explicitly by:

\[ p_1 = \tilde{p}_0 + \lambda^* \left( \sum_{n=1}^{N} \tilde{E}_n \right) + \tilde{u} \]  

(28)

\[ = \tilde{p}_0 + \left( \frac{1}{2 \tau} \right)^{1/2} \]  

(29)

\[ + \frac{1}{2 \left( \tau_0^G + \frac{1}{\tau} \right)^{1/2}} \left( \frac{\sigma_u^2}{N^{1/2}} \right)^{1/2} \left( \frac{1}{\tau_0^G} \right)^{1/2} \left( \frac{1}{\tau} \right)^{1/2} \left( \sum_{n=1}^{N} \tilde{E}_n \right) + \tilde{u} \]

How informative are prices in this equilibrium? Define \( \tau(p_1) \), the precision of prices by \( \tau(p_1) = \text{var}^{-1}(\tilde{d} | p_1) \). It is a tedious but straightforward exercise to show that:

\[ \tau(p_1) = \tau_0^G + \tau_G + \left( \frac{\tau_0^G + \frac{1}{\tau}}{\tau_0^G + \frac{1}{\tau} + \frac{1}{\tau}} \right) \sum_{n=1}^{N} \tilde{E}_n \]

\[ = \tau_0^G + \tau_G + \left( \frac{\sigma_u^2}{N^{1/2}} \right)^{1/2} \left( \frac{1}{\tau_0^G} \right)^{1/2} \tau_G \]

This formula for \( \tau(p_1) \) is quite useful. For the sake of comparison, define \( \tau^* \) as the precision of the best estimate of \( \Delta \) which could be made on the basis of all public and private information. It is easy to show that:

\[ \tau(p_1) = \tau_0^G + \tau_G + \left( \frac{\tau_0^G + \frac{1}{\tau}}{\tau_0^G + \frac{1}{\tau} + \frac{1}{\tau}} \right) \sum_{n=1}^{N} \tilde{E}_n \]

This formula for \( \tau(p_1) \) is quite useful. For the sake of comparison, define \( \tau^* \) as the precision of the best estimate of \( \Delta \) which could be made on the basis of all public and private information. It is easy to show that:

\[ \tau(p_1) = \tau_0^G + \tau_G + \left( \frac{\sigma_u^2}{N^{1/2}} \right)^{1/2} \left( \frac{1}{\tau_0^G} \right)^{1/2} \tau_G \]
\[ \tau^* = \text{var}^{-1}(\bar{d} + \bar{\sigma}_d, \bar{\epsilon}_d, \ldots, \bar{\epsilon}_N) \]  

(31)

By comparing the formulas for \( \tau(p_1) \) and \( \tau^* \) in the two above equations, we see that the price \( p_1 \) does not reflect all socially available information: intuitively, we can say that to the prior precision \( \tau_0 \), the price adds all of the public precision \( \tau_G \) but only a fraction of the private precision \( \tau_I \). This fraction which is less than 1/2, is given by \((\tau_0 + \tau_G)/(2\tau_0 + 2\tau_G + \tau_I)\).

Clearly, it is by withholding some of their private information from the market that informed speculators are able to make profits on average. It can be shown that the expected profits of each informed trader, which we denote \( \pi \), are given by:

\[ \pi = \frac{(\tau_0 + \tau_G + \tau_I)^2 \tau_0^2}{4N[2(\tau_0 + \tau_G) + (N+1)\tau_I](\tau_0 + \tau_G)} \]  

(32)

We can make the number of informed speculators endogenous by assuming that each informed speculator must pay a cost \( c \) to acquire this private information before random variables are realized. Then the number of informed speculators will be approximately the number \( N \) which makes \( \pi = c \). In this equilibrium, the losses of noise traders, which are equal to the trading profits of informed speculators, are translated dollar for dollar into resources spent acquiring private information, no more than half of which is incorporated into prices.

THE EFFECT OF PUBLIC INFORMATION ON THE INFORMATIVENESS OF PRICES

How does a change in the amount of public information affect the informativeness of prices? In our model, answering this question is a comparative statics exercise concerning the effect of increasing \( \tau_G \).

If the number of speculators is held constant, the answer to the question can be obtained by inspecting equation (30). Clearly, an increase in \( \tau_G \) not only increases prices directly via the announcement effect but also indirectly by increasing the percentage of informed traders information which is incorporated into prices. Additional public information tends to increase the efficiency with which private information is incorporated into prices.

The number of speculators is endogenous, we can see from equation (32) that an increase in \( \tau_G \) tends to reduce \( \pi \) and thus leads to an exit of speculators.

We wish to know whether the increase in \( \tau_G \) can reduce the number of speculators so much that the informativeness of prices is reduced as a result of providing more information publicly. The expression for \( \tau(p_1) \) in equation (30) can be written:

\[ \tau(p_1) = \frac{2(\tau_0 + \tau_G) + (N+1)\tau_I}{2(\tau_0 + \tau_G) + \tau_I} \]  

(33)

Combining this expression with the equilibrium condition \( \pi = c \) and equation (32), we obtain:

\[ \tau(p_1) = \frac{1}{4} \left[ \left( \frac{(\tau_0 + \tau_G + \tau_I)^2 \tau_0^2}{(2\tau_0 + 2\tau_G + \tau_I)^2} \right)^{\frac{1}{2}} \right] \]  

(34)

Since an increase in \( \tau_G \) reduces \( N \) and since the partial derivative of the right-hand-side of the above equation with respect to \( \tau_G \) is positive, while the partial derivative with respect to \( N \) is negative, it is clear that an increase in \( \tau_G \) increases the informativeness of prices \( \tau(p_1) \), even though it reduces the amount of information produced privately.

This result provides a justification for the government to produce information and to release it publicly to all traders simultaneously. If the government produces information at the same cost as private speculators, there are clear advantages to having public production of information. Even if the government is a higher cost producer of information than private speculators, there may be advantages to having the government produce private information because of the better efficiency with which it is incorporated into prices and its effect on the incentives of private speculators.

THE EFFECT OF UNINFORMED NOISE TRADING ON THE INFORMATIVENESS OF PRICES

An increase in uninformed noise trading can be modeled in comparative statics terms as an increase in \( \sigma_n^2 \). With a fixed number of informed speculators, it is clear from equation (30) that an increase in noise trading has no effect on the informativeness of prices at all.

The reason that \( \sigma_n^2 \) does not affect the informativeness of prices is that market makers and informed speculators scale up their activities proportionately as \( \sigma_n \) increases. That is, if the standard deviation \( \sigma_n \) doubles, then each informed speculator doubles the quantity he trades in the new equilibrium. He does this because the quantity he trades is not limited by risk aversion but rather by
the quantity the market will bear. When \( \sigma_u \) doubles, the market will bear twice as much because \( \lambda^* \) is halved. This occurs because market makers also double the quantities they trade. Note that the role of noise trading and liquidity here is completely different from the competitive model of Grossman and Stiglitz (1981), where increases in noise trading and risk aversion interact to make prices less informative.

With endogenous speculators, it can be seen from equation (32) that an increase in uninformed noise trading tends to increase the profits of informed speculators and thus induce entry of new speculators. From equation (30), it can be seen that this increase in \( N \) leads to an increase in the informativeness of prices. From the result in Section 3, we conclude that increases in noise trading tend to stabilize prices overall by shifting less volatility into the present than is shifted out of the future and increases the efficiency with which resources are allocated to consumption. The increased efficiency with which resources are allocated to consumption is bought at a cost. That is, society as a whole spends more resources acquiring information than before. These real resources are provided through the trading losses of uninformed noise traders. Within the framework of this model, it thus appears that the consumers of the commodity have no incentive to discourage unprofitable speculation (except perhaps on paternalistic grounds) and may even have an incentive to encourage it.

CONCLUSION

In this paper we have examined a three period model of a speculative market which focuses on the informational effects of speculation. We have shown that in a model where the ability to speculate successfully is based on the possession of private information, and the willingness to hold risky positions does not depend on risk aversion but rather on the ability of the market to supply positions, then an aggregate economy-of-scale property emerges in which uninformed speculation has a stabilizing rather than a destabilizing effect. We have also shown that when information is costly, public generation of information tends to add informativeness to prices. A key feature of the model is the idea that uninformed speculation and hedging to the extent that both are random, should be seen as having the same kind of effect on prices. Furthermore, the uninformed participants who lose money consistently pay for the information which is privately produced and incorporated into prices through speculation. If a willingness on the part of some participants to make expected losses is not present, then there is no reason for the market to exist.

There are a large number of questions about speculative markets which this paper does not address. Examples are the following:

1. Why are hedgers and speculators willing to lose money consistently?
2. What is the optimal size of a speculative firm?
3. What properties does an over-the-counter market without market makers have?
4. What happens when some speculators acquire information about what uninformed traders are doing rather than about the "fundamentals" of demand and supply?
5. Do commodities exchanges maximize seat values by limiting the number of market makers?
6. What happens when the participation of uninformed traders in the market is influenced by the "cost" of trading?
7. Can the model be made dynamic by having non-degenerate trading take place in more than one period?

It seems likely that questions such as these can be effectively discussed within the framework of models similar to the one developed in this paper.

NOTES

1. The alternative view, that the entry barrier raises returns by restricting the flow of floor trading resources onto the floors of commodity exchanges, is not considered here.
2. This resource constraint rules out storage of the commodity between seasons. It also rules out attempts to manipulate prices by destroying stocks of the commodity.
3. See Kyle (1981a) for proofs.
4. For a model in which informed speculators have price contingent trading, see Kyle (1982).
5. See Kyle (1982) for details.
6. A role for such traders does occur if we assume that \( E(\tilde{u}) \neq 0 \). Then if there is a competitive fringe of traders who are not market makers and have no private information, it can be shown that this fringe will face the predictable component of the noise trading by trading the quantity \( -E(\tilde{u}) \) and make zero profits in equilibrium. Aggregating this fringe together with the noise traders gives us the zero mean noise term of our model.
7. This model provides another approach to a
problem raised by Friedman (1969).

REFERENCES


3 Speculative Storage, Futures Markets, and the Stability of Agricultural Prices

Alexander H. Sarris

INTRODUCTION

Most analyses of the welfare effects of commodity market stabilization focus on the benefits to producers and consumers of eliminating price fluctuations. Early literature on the subject that started with the pathbreaking articles of Waugh (1944) and Ol (1961) and was followed by several articles—notable among which are those of Massell (1969), Huen and Schmitz (1972), and Turnovsky (1974)—used very simple linear theoretical models of price fluctuations with additive disturbances to show that elimination of fluctuations is generally beneficial to society but the distribution of benefits is a function of the slopes of the demand and supply curves and the sources of the fluctuations.

Recent literature has relaxed several of the early assumptions by incorporating nonlinear supply and demand curves, multiplicative disturbances, alternative expectation assumptions and different models of producer and consumer behavior, but the overall conclusion that elimination of price fluctuations by a costless public buffer stock is beneficial to society has stayed remarkably intact. The recent article by Newberry and Stiglitz (1979) seems to be the only place where this basic conclusion has been questioned. The real contribution of these recent writings has been to provide increasingly sophisticated models for the allocation of the total benefits from stabilization to different groups.

Prominently absent from all this literature are the explicit incorporation of a public buffer stock rule with its expected costs, the consideration of private stockholding behavior, and the incorporation of futures markets. Turnovsky (1978b) considered explicit stabilization rules to show that they indeed stabilized