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PRICING EFFICIENCY AND INFORMATION USE

IN RISKY MARKETS

by

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Prices

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Information has economic value if it helps estimate the value of something. Both individuals and society at large are interested in the extent to which information about an object's value is contained in its market price. Conformance of price to value affects optimal strategies not only of market participants, but of others tangentially related to a market. Individuals trading by private treaty, for example, often use prices on more organized exchanges as an indicator of worth. And vertically integrated firms may employ market prices to set transfer prices between integrated units. Apart from distributional issues, society's interest is that price guide resource allocation so as to maximize value-weighted production. Prices that would induce such efficient resource use are themselves efficient.

There is reason to worry about a price's efficiency if traders are few, goods heterogeneous, resources somewhat immobile, or information incomplete (Tomek and Robinson, pp. 79-80). The primary concern of the present paper is incomplete information. My purposes are threefold: to distinguish various notions of an efficient price and relate these notions to the kinds of data analysts possess; to outline hypotheses about pricing efficiency in certain types of agricultural markets; and to discuss difficulties in efficiency assessment. Emphasis is placed throughout on the information content of prices and on the importance of information supply in price discovery and efficiency.

Pricing or Market Efficiency

We should distinguish first between the class of efficiencies associated with an industry and that associated with a market. As examples of the former, Bain (pp. 340-405) and Jesse analyze an industry's allocative efficiency, its productive or cost efficiency, and other performance dimensions such as resource conservation. These concepts might, of course, be applied to market-making industries, that is to the collections of entities which set pricing rules, facilitate trade, or speculate in goods or obligations. Thus, Sosnick (1964, pp. 112-116) includes in his criteria for "exchange efficiency" the elimination of needless costs of handling, transportation, information gathering, and price discovery. Yet market-makers should be judged also by the quality of prices they discover. It is in this latter sense that "market" or "pricing" efficiency is most strictly used, and in which it is used in the present paper.[1/] [2/]

Full Notions of Efficiency

Burns (pp. 7-25) argues that pricing efficiency is determined by a market's liquidity and "orderliness." Liquidity, he says, rises in proportion to the predictability of a good's "underlying value" and the "expected ease" with which the value can be accessed in trade. Ease of access is a negative function of the bid-ask price spread and other transfer costs. A market becomes more orderly insofar as it is freed of monopoloid elements, deliberately false rumors, or "artificial" (presumably noncost-based) restrictions to market use. Liquidity and orderliness in this framework are positively related: monopoly power or false rumor tends to draw average price away from competitive equilibrium, reducing traders' information about underlying value. Further, increased price risk not only reduces predictability of underlying value but also increases the bid-ask price spread, thereby discouraging market access (Copeland and Galai).

The underlying theme in Burns (and in many other discussions of liquidity and orderliness) is that price becomes more efficient insofar as it more closely approximates competitive equilibrium. But if competitive equilibrium is a reasonable efficiency standard, it is reasonable to consider also how quickly and surely price would reach such equilibrium once it is shocked by value-relevant information. Suppose, for example, that the advent of information is followed by a quiescent period in which no additional messages arrive from sources external to the market. Unsure of the new equilibrium price, each trader will offer or entertain price bids in an attempt to promote his self-interest. Bids refused and accepted, which collectively we may call the market's internal information, guide traders in a sequential search for what the market will bear, that is, for the price's new equilibrium.

The time path of market prices (i.e., accepted bids) during this quiescent state will not necessarily be smooth. Besides differing in risk aversion and bargaining skills, traders generally differ also in their estimates of which way price is heading. This naturally results in fluctuating prices as optimistic trades are followed by pessimistic ones. It is possible to identify, in such a context, several efficiency measures:

(a) the rate at which an expected (e.g. "smoothed") price series approaches an asymptote (if any);

(b) difference between this asymptote and the competitive equilibrium (supply-demand intersection) price;

(c) difference between overall mean price and competitive equilibrium;

(d) rate of change in price variability around the expected series; and

(e) overall variability around overall mean price.

Measures (a), (b), and (c) refer to price bias or its rate of change while (d) and (e) reflect price risk or its rate of change.[3/] Bias and risk components may be combined into mean square error (MSE) estimates. Assuming quadratic loss and zero information cost, optimal efficiency is achieved if MSE is zero in every period, that is if market price adjusts immediately to the competitive equilibrium implied by the external information.

Partial Notions of Efficiency

When market trading is observed in a laboratory environment, all the above measures may be employed because competitive equilibrium is controlled and known (Smith 1980). Outside laboratories, competitive equilibrium usually is unknown and subject to continual change as new external information arrives. Analysts therefore have adopted a number of partial efficiency measures to suit the data available. Tomek, for example, assumed observed prices at the Denver terminal cattle market were unbiased estimates of a (continually changing) competitive equilibrium. He gauged the Denver market's pricing efficiency by its price variability relative to a larger market. This is equivalent to relying only on measure (e) above, where mean prices are serially adjusted for estimated changes in equilibrium.

An opposite tack is taken by the "efficient markets" or "fair game" literature. Let P_t, P_{t+1}, ..., P_{t+k} be successive prices, Φ_t, Φ_{t+1}, ..., Φ_{t+k} be successive information sets, and

$$(1) \qquad \begin{aligned} e_t &= P_t - E(P_t \mid \Phi_{t-1}) \\ e_{t+1} &= P_{t+1} - E(P_{t+1} \mid \Phi_t) \\ e_{t+k} &= P_{t+k} - E(P_{t+k} \mid \Phi_{t+k-1}) \end{aligned}$$

be successive forecast errors incurred when one-period-ahead prices are projected on the basis of current Φ. Sequence e_t, e_{t+1}, ..., e_{t+k} is a fair game with respect to information Φ if

$$(2) \qquad E(e_{t+k} \mid e_t) = E(e_{t+k}) = 0, \qquad \text{all } t \text{ and } k.$$

Equations (2) hold only if conditional price forecasts $E(P_{t+1} \mid \Phi_t)$ are unbiased in each time period and if forecast errors are serially independent.[4/] As is well known, the "strong" form of fair game includes in Φ any relevant information, the "semi-strong" form selected nonprice information, and the "weak" form only the sequence of past prices (Fama, p. 388).

Price changes themselves are a fair game, and hence "efficient," with respect to Φ if each conditional price forecast in (1) is taken to be the most recent market price. Assuming in this spirit that

$$(3) \qquad E(P_{t+1} \mid \Phi_t) = P_t, \qquad \text{all } t,$$

a typical element of (1) becomes

(4) $$e_{t+1} = P_{t+1} - P_t.$$

Efficiency criterion (2) then requires that

(5) $$E[(P_{t+k} - P_{t+k-1}) | (P_t - P_{t-1})] = E(P_{t+k} - P_{t+k-1}) = 0 \qquad \text{all } t \text{ and } k,$$

that is, that successive price changes follow a martingale.

Of course, like the strong fair game, this weaker form makes no explicit reference to a competitive equilibrium. Prices are thought to be efficient only insofar as they are unbiased and (given the information available) minimum-variance forecasts of future prices. Immediate reference to efficiency standard (b) or (c) in the previous section is ruled out. Further, weak-form criterion (5) does not provide for an optimal price change variance nor prescribe how the variance should change from one period to the next. Standards (d) and (e), therefore, also are ignored by the weak fair game.

In strong or weak form, fair game efficiency does imply that expected price follow no recognizable pattern over time: rate of adjustment of expectation to an equilibrium is immediate (standard a). Put differently, the criterion implies that expected price immediately and fully reflect any change in information set Φ. New information is immediately appropriated in the market's mean accepted price bid. Whether such mean equals the competitive equilibrium price could only be determined on the basis of additional argument, for example, that buyers and sellers have equal bargaining power.

Conditions for Fair-Game Efficiency

Under what conditions might we expect a market to be fair-game efficient with respect to an information set Φ? Two assertions would be jointly sufficient for arguing that (5), at least, is true: (i) each trader's conditional price forecast $E(P_{t+1} | \Phi_t)$ is unbiased and efficient, permitting us to write equation (2); (ii) market prices are "bid up" to equal traders' weighted mean price forecast $E_a(P_{t+1} | \Phi_t)$, justifying equation (3).[5/] Taking (1) into account, (2) and (3) together give us (5), implying that P_t "fully reflects" Φ_t. Validity of (i) and (ii) depends, among other factors, on the type of good or contract considered, length of the trading period, and traders' sophistication, number, and market conduct.

Specifying the Fair Game: "Storage" Costs

It is clear immediately that (ii) is unlikely to hold when there are positive costs of transferring the item from one period to another. Let S_t represent such "storage" costs, including storage and processing expenses, interest, brokerage charges, and any pure profit. If traders have linear utility, they will bid up current price so that the sum of price and expected storage cost $E_a(S_t)$ equals the weighted mean price forecast among all traders:

$$(6) \qquad E_a(P_{t+1} | \Phi_t) = P_t + E_a(S_t), \qquad \text{all } t.$$ [6/]

Substituting (6) into (1) gives the difference between eventual future price and the sum of current price and expected storage cost:

(7) $$u_{t+1} = P_{t+1} - [P_t + E_a(S_t)]$$
$$= e_{t+1} - E_a(S_t).$$

If indeed $E_a(P_{t+1} \mid \Phi_t)$ is unbiased and efficient and $E_a(S_t)$ known, then it is u_{t+1} and not e_{t+1} that follows a martingale. Price difference $e_{t+1} = P_{t+1} - P_t$ would follow a martingale with drift factor $E_a(S_t)$ (Granger and Newbold, pp. 38-9).

One way of accounting for the drift is to "detrend" or "deseasonalize" prices before testing for a martingale in first differences. This is equivalent to replacing (6) with the cautious assertion that $E_a(P_{t+1} \mid \Phi_t) \geq P_t$, the so-called submartingale (Fama, p. 386). Unfortunately, it implies an overly lax market efficiency standard. The detrending process may correct not only for storage cost, but also for persistent bias or inefficiency in traders' price forecasting models. Portions of such inefficiency would in effect be explained away by appeals to unobserved and unanalyzed variations in storage expenses.

If we believe (6), the only adequate procedure is to estimate $E_a(S_t)$ from information additional to the price series in question. With some types of cost this will be straightforward; for example, currency depreciation applies to a broad range of individuals and can be accommodated by price deflation. But other costs differ among traders depending upon their productive efficiency or the prices they pay for added inputs. Cash market buyers, for instance, often differ in reprocessing costs, while speculators' interest rates may vary with margin volume. The criteria of productive efficiency imply using minimum feasible costs for adjusting price differences; yet this precisely would be to confuse price efficiency with productive efficiency. A rational bidder takes into account, not the minimum or even his own storage cost, but his expectation of the costs that others expect to incur. The optimal cost forecast, then, is an average and is fully as endogenous as an optimal price forecast. If the researcher's cost estimate differs in a regular manner from traders' optimal cost forecasts, the researcher's estimate of (7) will depart from a martingale even when no price inefficiency is present.

Specifying the Fair Game: Risk Premia

Consider now the added complication that traders may not all have linear utility. Risk averse traders will bid up current price so that the sum of price, expected storage cost, and expected risk premium $E_a(R_t)$ equals the weighted mean price forecast among all traders (Hanson and Menezes):

$$(8) \qquad E_a(P_{t+1} \mid \phi_t) = P_t + E_a(S_t) + E_a(R_t).$$

Substituting (8) into (1) gives the difference between eventual future price and the sum of current price, expected storage cost, and expected risk premium:

$$(9) \qquad \begin{aligned} v_{t+1} &= P_{t+1} - [P_t + E_a(S_t) + E_a(R_t)] \\ &= u_{t+1} - E_a(R_t). \end{aligned}$$

Risk premium $E_a(R_t)$ provides another source of price drift, which has been termed "normal backwardation" (Cootner). The context of this phrase usually is a futures market, in which "storage" costs involve only interest and brokerage charges and in which, therefore, risk premia may be the major source of drift.

As with storage costs, the task of estimating risk premia from a single price series involves an identification problem. Technical "smoothing" procedures may eliminate not only risk cost but persistent error patterns in traders' price forecasts. This would produce an unjustifiably sanguine view of a market's efficiency. Also like storage costs, risk premia generally differ among traders and each trader rationally would bid according to his estimate of the mean risk premium assumption implicit in the market. "Risk adjusting" price differences for this purpose, by filtering them through a "likely" or "conservative" utility model, is merely _ad hoc_. It does not address the essentially endogenous nature of a market's self-estimate of its average risk premium. Regular discrepancies between a market's true risk premium and that assumed by the analyst will result in underadjustment for drift in u_{t+1} and induce in v_{t+1} a false serial dependence.

Risk-induced price drift was assumed in the early literature to be positive (Cootner). For futures markets in which most hedgers are producers, and in which, therefore, sellers early in a contract's lifetime primarily are hedgers, this may be a reasonable hypothesis. Speculators' price risk typically is greater than hedgers' basis risk, meaning speculators' risk premia may be greater than hedgers' even if speculators are the less risk averse (Pratt, p. 125). Presence of a relatively greater risk premium on the buyer side in a contract's early life would result in an updrift in prices as the contract matures. However, this result would not necessarily apply to futures markets where many place long hedges.[7/] Nor would it apply to forward deliverable contracts, where sellers could face greater risks than buyers. In the latter markets, price will depend partly on the relative risk premia of sellers and buyers, so an updrift in cost-adjusted prices can't be presumed (Buccola 1981).

There are, perhaps, sources of drift other than storage or risk cost that might be consistent with a fair-game efficient market. The spirit of fair game analysis is to identify all costs a "rational" buyer would consider, then determine whether price differences follow a martingale with drift defined precisely by such costs. One's definition of rationality clearly affects conclusions derived from this sort of procedure.

Rational Expectations and Informational Equilibrium

As noted earlier, the fact that market prices are bid up to equal (cost adjusted) price forecasts is not sufficient for fair-game efficiency. It is also required that traders' conditional price forecasting models $E(P_{t+1} \mid \Phi_t)$ be unbiased and have minimum variance.[8/] To the extent forecasts are best unbiased, we may use (9) to write the fully cost-adjusted form of (2):

$$(10) \qquad E(v_{t+k} \mid v_t) = E(v_{t+k}) = 0, \qquad \text{all } t \text{ and } k.$$

Forecast unbiasedness would ensure the second equality in (10) while minimum variance would imply the first equality. A trader would be assumed to perceive any persistent bias or serial dependence in his forecast residuals and immediately use this information to form corrected, efficient parameter estimates.

Arguing that traders can or do behave in this manner is the same as saying they have rational expectations. Regardless of its literal truth, the rational expectations assumption permits analysis of market efficiency in a continuous equilibrium state and so it has intellectual value. For example, the assumption has been used to characterize relations between more informed and less informed traders in a competitive market. Informed traders are those with access to a relatively large set of forecasting information (Φ_{ti}); the uninformed are those with a smaller set Φ_{tu} such that $\Phi_{tu} \varepsilon \Phi_{ti}$. Since all rationally expectant traders are assumed to employ unbiased estimates, the only advantage of being informed is to improve profitability through reduction in forecast variance (Grossman). An informational equilibrium is achieved when for each trader the expected utility of the cost of acquiring additional information equals the expected utility of increased profits such new information would provide (Grossman and Stiglitz 1976).

Implications of Rationally Expectant Trading

A market in informational equilibrium does not necessarily reveal all price-relevant information, nor even the entire set of information Φ_{ti} known by informed traders. Radner has shown price to be fully reflective of all information if the number of sources of information is small relative to the number of markets reflecting it. Grossman and Stiglitz (1980) and Grossman add that, even if information sources are infinite, price is fully revealing provided: information signals and prices are jointly Gaussian, utilities are constantly risk averse, information and model noise are uncorrelated, and information is free. However, as Grossman and Stiglitz (1976) and Jordan demonstrate, costless information (or a complete market regime) is necessary as well as sufficient for a strong fair game, and these conditions are unrealistic. In the real world of costly information and incomplete market development, price is not a sufficient statistic and cannot be used to solve for all information held by informed traders.

Besides being incompatible with strongly efficient markets, rational expectations has another and more visible significance: it implies markets must be weakly efficient. Intuitively, the reason is that information about past prices is considered freely available. Every trader will, therefore, employ all such information in his price forecasts and by doing so erase any regularity in cost-adjusted price changes. More formally, suppose cost-adjusted price first difference v_{t+1} is periodically shocked by a random information variable I_t. Factor I_t is observed only by informed traders and has generally nonzero mean $E(I_t)$. Let the relation between v_{t+1} and I_t be

(11) $$v_{t+1} = bI_t + z_t$$

where b is a constant and z_t a (possibly serially dependent) residual with zero mean. The uninformed observe only v_{t+1} and, taking its expectation

(12) $$E(v_{t+1}) = bE(I_t),$$

find it generally nonzero. Under competitive conditions they will bid up P_t by this amount, so that a new cost-adjusted price change series

(13) $$w_{t+1} = v_{t+1} - bE(I_t) + z_t$$

will result with zero mean. Since the uninformed freely observe z_t they can regress it on itself to minimize forecast error variance. Thus, although the uninformed cannot observe I_t, they can impound its mean effect, and any serial dependence in the associated residual, into price.

It is immediately clear that if traders have rational expectations, cost-adjusted price changes cannot follow an ARMA process. The changes cannot be autoregressive since traders would have corrected the persistent forecast bias such models imply. The changes cannot be a moving average since any error variance improvements a moving average would offer would already have been made. It might be imagined that at least uninformed traders with rational expectations would use ARMA models in developing bidding strategies. Yet if there are rational expectations, the effects of such use already are incorporated into price and ARMA forecasts offer no advantage.[9/]

The same generally cannot be said for informed traders' use of an econometric price forecasting model. Provided the cost of observing the econometric information is sufficiently high, those using it will be sufficiently few that resulting forecasts will not be fully impounded into price. That is, informed traders will continue to have smaller mean square forecast errors than the uninformed, and informed forecasts will not be completely self-defeating. The econometrician's newly estimated model will be of no interest to the informed, who are assumed already to know the relationships involved. But the model's presence on the information market may reduce marginal information cost, increasing the number of informed traders and hence the information content of prices.[10/]

Fair-Game and Full Efficiency

As suggested at the beginning of this paper, a market free of information cost might be considered "fully" efficient if price were always at competitive equilibrium, the intersection of supply and demand. Barring externalities or other sources of market failure, this would provide Pareto optimal resource use, maximizing aggregate wealth. Fair-game analysis makes no explicit reference to competitive equilibrium or, therefore, to Pareto optimal resource allocation. Under "competitive" conditions, however, the average of traders' cost-adjusted price forecasts might be assumed to lie at the supply-demand intersection, permitting comparisons between fair games and Pareto optimality. "Competitive" conditions would include equality of information and bargaining power between buyers and sellers and absence of collusive behavior.[11/]

Given such assumptions, a strong fair game is completely Pareto efficient. That is, if price adjusts immediately to all relevant information and there are no barriers to competitive trade, then price must always be at competitive equilibrium. Weak (or semi-strong) fair-game prices are not so informationally reflective. Yet even in a weak fair game, competitive conditions would ensure that price changes fluctuate in a serially independent manner around competitive equilibrium. This suggests adding to criterion (10) the requirement that

$$(14) \qquad E(P_{t+1}) = P_c$$

where P_c is the competitive equilibrium price. It is reasonable to call a market satisfying (10) and (14) efficient if, in addition, traders' marginal expected utility of nonprice information use is zero. In this limited sense, any market in informational equilibrium is efficient provided competitive conditions exist (Just, p. 877). A strong fair game is not, with positive information costs, the most desirable game, despite its reflection of long-run efficiency gains achievable through reduction in the cost of information.

Existence of Rational Expectations

In the short run, can we reasonably expect markets to be efficient in the limited sense just described? The first requirement, that "competitive" conditions prevail, has been discussed adequately elsewhere (Sosnick 1968). The second requirement, that an informational equilibrium be achieved, is equivalent to the assertion that traders have rational expectations. This assertion deserves scrutiny.

Like the actor in an Arrow-Debreu tatonnement process, a rationally expectant trader is assumed to think through his bidding strategy under the assumption others are thinking it through in similar fashion. If each trader makes correct suppositions about the others, each will have a price forecasting equation whose mean forecast is the equilibrium mean. The difficulty is that it is unclear how each would learn the parameters of an equilibrium price forecasting equation. A "fully rational" effort to learn such parameters faces the following conundrum: the parameters depend upon the market's average opinion of what they should be; but information about this general opinion is incomplete until it includes the opinion of each agent attempting to learn it.[12/] Put differently, the average opinion momentarily observed is (if the system is out of equilibrium) already obsolete, since others too will react to the information and change their opinions (Frydman; DeCanio). Each agent therefore has momentarily biased parameter estimates if he attempts to learn them by using current information on the average opinion. The goal of immediately arriving at unbiased parameter estimates is not generally achievable and in the short run the market usually will forecast itself in a biased manner.

Because average opinion in the short run is fundamentally indeterminate, there is no short-run basis for a fully rational forecast in the rational expectations sense. Ignorant of the parameters he faces, a bidder can operate only on the basis of an ad hoc decision rule with the hope that over time he can improve the rule's rationality. Models that permit learning in a fundamental way (as opposed to merely allowing for a reduction in error variance) inevitably begin with an ad hoc bidding rule, then show under what conditions the rule reduces to an autoregressive system converging to equilibrium in finite time (Rothschild). Frydman, for example, shows that consistent price forecasting parameters may be found through iterative application of informed "guesses" about the average opinion. The lesson of such models is that a self-fulfilling rational equilibrium eventually can result from arational groping. Rational expectations well reflects this long-run equilibrium once it is achieved, but there is a time frame short enough in which its prediction of weak-form efficiency must be violated.

Likely Efficiency in Agricultural Markets

For reasons of both structure and conduct, agricultural markets differ widely in competitiveness. Markets also differ in traders' price forecasting ability, the number of factors to forecast, and the quantity and quality of information available for these purposes. Thus, we would expect considerable efficiency differences across market types.

Commodity Futures Markets. Hypotheses that futures markets are efficient rely often on Samuelson's proof that, under competition, cost-corrected futures price changes are serially uncorrelated regardless of cash market efficiency. The proof assumes the true probability distribution of cash prices is known, which presumably would be the case only under rational expectations. Leroy shows, too, that Samuelson's proof holds only if the costs used to correct prices are exogenously given. Still, commodity futures markets are likely to be relatively efficient. They involve numerous traders, many of whom are willing to switch roles as buyers or sellers; "storage" costs are few and thus (relatively) easily computed; prices are discovered by double auction, thereby centralizing the market's internal bidding information; and much nonbid or external information is readily available.

Centralized Commodity Spot Markets. Although many cash market exchanges employ double-auction pricing, they usually are less heavily attended than futures markets. Further, cash exchange traders often are unwilling to switch buyer-seller roles since many are producers or handlers only. (See, for example, Gould's description of the National Cheese Exchange.) More importantly, cash traders are burdened with forecasting seasonal price movements, which in turn are affected by the future supply and demand for storage and for reprocessing inputs. Such forecasts may be biased, possibly compounding any bias in deseasonalized price forecasts. Hence, cash exchanges are likely to be less price efficient than futures exchanges.

Other Agricultural Cash Markets. The variety of competitive conditions in noncentralized cash markets has been extensively documented (e.g., National Commission on Food Marketing). Many markets are quite competitive. Others are monopsonoid with implicitly collusive behavior, or employ pricing rules that convey more bid information to one side of the market than to the other (Smith 1964). In the latter types of markets, even rational expectations would be insufficient for mean price to be the competitive equilibrium. Cash market efficiency also is affected by product perishability. The less storable the product, the greater is the effect of storage cost forecast errors on current price discovery, and hence the less likely cost-corrected price changes are to follow a martingale.[13/] Like increases in information supply, therefore, reductions in storage or reprocessing cost should improve pricing efficiency.

Assessing Pricing Efficiency

Economists do not seem even to have attempted to isolate a single measure of price efficiency that would vary, say, on a percentage scale. The number of dimensions that would have to be considered, and the problem of identifying an index optimum, are good reasons we do not have an index. Forecast mean square error, for example, would be a poor index basis because its optimal level is difficult to know *a priori*.

Mean square error depends not only on the forecaster's ability and information supply, but also on price's sensitivity to unknown random effects. The latter may vary over time even in a given market (Samuelson, pp. 46-7).[14/] It is for such reason we have not discussed efficiency in terms of random walks, white noise, or any other implication that price changes should be identically distributed over time (Fama, pp. 386-7).

Methods Used

For assessing price efficiency in nonlaboratory markets, analysts usually are content to test the market's ability to respond to selected categories of information. This involves testing directly for serial dependence in (perhaps adjusted) price changes or trying to devise trading rules that yield "substantial" risk-adjusted profits. The latter is more suitable for discerning complex nonlinear forms of dependence but is not as amenable to rigorous hypothesis testing (Cargill and Rausser). Recent literature on serial dependence tests has emphasized use of specific alternatives to the null hypothesis of serial independence. An appropriate specific alternative has greater power than the general alternative. Not surprisingly, application of more powerful tests is providing increased evidence of weak-form inefficiency even in competitive markets (Taylor; Hsieh and Kulatilaka).

Economist and Trader

Regardless of advances in statistical tests, use of actual market data to assess efficiency is a daunting task. The principal difficulty is accurate estimation of expected carrying costs and risk premia which, along with price forecasts, are assumed to be impounded into current price. Direct, unbiased estimates of storage costs and risk premia are hard to come by because they require information about other traders' characteristics and assumptions (Figlewski; Buccola 1983; Jennings and Barry). Yet without such estimates it is impossible to determine whether systematic price changes imply fair-game pricing inefficiency.

Clearly, the problem of detecting pricing inefficiency is identical to the problem traders must solve in achieving efficiency. Econometricians do not have a better information vantage point than do traders; in many respects, they have an inferior vantage point. If, therefore, traders cannot in the short run learn the parameters of the equilibrium price forecasting equation, neither can analysts. And if analysts cannot do so, they cannot accurately detect inefficiency.

We should remember as well that a fair-game efficient market does not necessarily efficiently discover the competitive equilibrium price. The assumption that "competition" will on average force the market's weighted-mean price forecast into equality with competitive equilibrium is only an assumption, even if a reasonable one. It cannot be tested adequately unless competitive equilibrium is known.

Conclusions

Economists must, in brief, know the underlying structure of a market before assessing the efficiency of its price movements. This is no different from a requirement that engineers understand a motor's working parts before rating its force efficiency (Wheast and Astle, p. F-114). Ignorant of structure, the analyst has several alternatives.

First, he can choose a length of run sufficiently long that the market can be assumed to have equilibrated, and long enough therefore to permit reasonably unbiased parameter estimates. This involves choosing an adequate period over which to average price and other econometric information. Second, he can control market structure in a laboratory setting by assigning costs or demands to known subjects. Transaction prices then can be compared to the structural elements specified (Smith 1964). Although laboratory market prices probably do not reflect all features of nonlaboratory markets, they are uniquely suited for discriminating among alternative market efficiency hypotheses (Smith 1980).

Both market efficiency assessment and structural econometric market models are necessary for effective implementation of government economic policy. My intention has been not to deny the possibility of these types of analysis, only to outline their genetic weaknesses and possible antidotes. Economists should be inspired by traders' diligence in understanding the origins of market movements. Traders and economists jointly may improve market efficiency through their efforts to assess it.

Footnotes

1. The term "market" efficiency is typically used in this context in the economics literature, while "pricing" efficiency is most common in agricultural economics. The latter seems preferable since it distinguishes between efficiency of price and minimization of marketing costs. However, the terms will be used interchangeably.

2. Sosnick's (1964) criteria also involve the requirement that traders collectively maximize gains from trade, a reference to pricing efficiency in the above sense. Buccola (1983) argues this requirement is not a sufficient condition for competitive equilibrium.

3. Sporleder and Chavas' price "timeliness" is related to standard (a), although it seems more closely associated with the rate at which traders learn of a given discovered price. "Economic accuracy" in Sporleder and Chavas is equivalent either to (b) or (c). The authors do not appear to include standards (d) or (e).

4. Equation (2) does not require that the entire probability distribution of e_{t+k} be serially independent, that is that e_{t+k} be white noise or a random walk. Serial independence in (2) is expectation independence and does not rule out, for example, the variance of e_{t+k} depending upon that of e_t.

5. According to the context, $E(P_{t+1} \mid \Phi_t)$ will be used to represent either a forecasting equation or a particular forecast given a particular information set Φ_t. Note that weights used to calculate

mean forecast $E_a(P_{t+1} | \Phi_t)$ are quantities transacted by each individual (Figlewski, p. 585.)

6. Some forms of carrying costs (e.g. interest) may be better represented as coefficients of P_t rather than as linear terms (Samuelson, p. 46). The linear form is retained here for simplicity.

7. Cootner (pp. 399-400) has already observed that a preponderance of long hedging may produce a risk-induced downdrift in futures prices (which Hsieh and Kulatilaka call a "contango"). Unfortunately, the debate concerning the importance of risk premia in futures prices has not been cast in the most clarifying terms, namely, the relative risk premia of buyers and sellers. Buccola (1981) considers such an issue in forward deliverable contract markets.

8. No distinction is made here between small-sample and large-sample properties of forecasters. For certain contexts, "bias" and "least variance" are best replaced in this discussion with their asymptotic counterparts.

9. Besides implying the impossibility of linear serial dependence inherent in an ARMA process, rational expectations implies that adjusted price differences are free of any nonlinear serial dependence.

10. For this reason I disagree with Frydman's implication (pp. 658-9) that, under rational expectations, development of econometric price forecasting models has no social value.

11. Correct specification of fair-game variable (9) might conceivably be used to impute monopoly power if a positive average profit were detected in the variable's "storage costs." In practice it is difficult to do so accurately because some positive profit is a legitimate return to information, even under competitive conditions. Thus, fair-game analysis typically assumes a competitive environment instead of testing for it.

12. A counter-argument that model parameters depend only on "the relevant economic theory," and not on the personal views of others, would beg the question. Each individual must somehow know that others consider the relevant economic theory to be determining. This may be the case, but it cannot be known without learning.

13. At the limit, traders with infinite storage costs (even rationally expectant ones) never would be motivated to offer current bids on the basis of future price expectations. Thus, one would never expect to see (or be able to calculate) a martingale in these markets.

14. Another example of an efficiency index would be to use some function of the correlogram derived from an ARMA model of price changes. One would have to know the weights to assign the various serial correlations. In addition, such a measure would not reflect nonlinear serial dependence.

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