Measuring Price Efficiency: Experience With Electronic Markets

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Dennis R. Henderson, E. Dean Baldwin
Cameron S. Thraen and W. Timothy Rhodus

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ABSTRACT

Measures of price behavior within potentially efficient markets, relative to Walras' theory of tatonnement, are: (1) increased frequency and diminished magnitude of price changes, (2) increased short-term plus decreased long-term price variability, and (3) increased correlation between price and market conditions. These measures were applied to three electronic markets.

Pricing Efficiency as a Perceived Marketing Problem

Over the past fifty years, pronounced structural changes have occurred in markets for agricultural products. Farm production units have become larger and more specialized. Buyers of farm products have relocated from central cities that were railroad terminals to country points that are closer to farms and ranches from which they obtain supply [USDA].

These changes have facilitated a transition in agricultural marketing from public to private trading [Packers and Stockyards]. At one time, terminal wholesale public markets were the nexus of trade for farm products, where trading was regulated by published rules. Even when prices were privately negotiated between buyers' and sellers' agents, the large assembly of commodities traded in the terminals allowed all participants to satisfactorily monitor the market and to obtain accurate and complete price information. Since observers assumed that the large volume of commodities traded in the market accurately reflected existing supply-and-demand relationships, few questions surfaced concerning the efficiency of prices established in these terminal markets.[1/]

Agricultural marketing became increasingly private as it moved from the central wholesale markets to the country, which was concurrent with the restructuring of agricultural production and processing. In many cases, prices reported on terminal markets became reference prices for privately negotiated sales that occurred between farmers and buyers. As an increasing share of all transactions became private, however, the base for trades at public markets became increasing "narrow". This narrowness caused market observers to question whether reported public market prices accurately represented true marketwide conditions and whether prices established by private traders using

off-market relationships accurately reflected true market values [Hayenga, Johnson and Marion].

These questions became even more forceful as formulas were negotiated between farmers and buyers which standardized, for an extended period of time, the off-market relationship between actual transaction prices and some base price quote. These formulas potentially remove from individual transactions the fine tuning process of price adjustment which is necessary for the most efficient matching of market supplies with demands and for the establishment of accurate product values (efficient prices). Resource misallocations then occur in response to the formulation of inaccurate or misleading transaction prices through private trades.

While the concern over pricing inefficiency and resource misallocation in agricultural markets is widespread, little concrete evidence of the magnitude of such distortions has been revealed [Hayenga]. The purposes of this paper are, therefore, to examine the concept of pricing efficiency relative to optimal resource allocation, to examine means of measuring pricing efficiency in this context, to apply those measures to actual price behavior in electronic markets, and to suggest ways of empirically validating these measurements.

A Working Concept of Pricing Efficiency

Efficient prices are viewed as those which yield the Pareto optimal allocation of resources. Theoretically, these are prices that evolve from a pricing mechanism which consistently and rapidly yields the competitive equilibrium price in a competitively structured market.

Smith has shown, for example, in reporting the results of more than 1,000 pricing experiments that prices in a double auction consistently and rapidly

converge to the competitive equilibrium level which results from supply and demand functions established by experimenters. Even though neither buyers nor sellers know the true equilibrium price in the experimental markets, a double auction pricing procedure rapidly establishes price at the true competitive equilibrium point. Smith's results show that other price establishment procedures, such as English or Dutch auctions and sealed bids, provide less assurance of arriving at the competitive equilibrium price. Others who replicated Smith's work and those who pursued similar but unique pioneering efforts collaborated his findings [Plott].

Thus, this concept of pricing efficiency (a pricing system in which prices converge rapidly and consistently toward a competitive equilibrium) seems consistent with actual pricing behavior that has been observed in laboratory or experimental settings. It also is consistent with the achievement of theoretically expected price levels in markets that are competitively and monopolistically structured [Plott].

Measuring Pricing Efficiency

While the evidence compiled by Smith and reported by Plott reveals that an assessment of pricing efficiency is possible in experimental situations where the true competitive equilibirum price is known a priori, this is of little help in real world situations where the competitive equilibrium price is not known.[2/] How does one determine, for example, if the price reported from an existing market is equal to, or is even converging toward, the true competitive equilibrium price? Market-wide supply and demand functions are generally not known before (or even after) pricing actually occurs, thus, there is no known competitive equilibrium price with which to compare actual market

prices. Furthermore, markets are dynamic which means that supply and demand functions are continuously shifting and establishing new equilibrium points.

Knowledge of marketwide supply and demand functions does not necessarily reveal the appropriate market equilibrium price at the conclusion of trading. This is so because markets are dynamic; thus it is neither empirically possible nor theoretically adequate to compare actual market prices to the true competitive equilibrium price for a market. What then, are the alternatives for evaluating efficient pricing mechanisms?

One approach is to compare the behavior of prices during the price establishment period in a market with that which would theoretically or conceptually generated competitive equilibrium prices. In such an analysis, if actual price behavior is consistent with that which logic suggests would cause prices to converge rapidly toward the competitive equilibrium (assuming a competitively structured market), then the pricing system would be judged to be efficient. On the other hand, lack of consistent price behavior would be construed as evidence of pricing inefficiency.

Traditional micro-economic theory has little to say about price behavior per se. Traditional theory assumes an efficient pricing procedure and deals largely with the outcome or the equilibirum price level [Edgeworth].

Walrus, writing before Edgeworth, utilized economic theory to investigate pricing behavior patterns. He explicitly recognized that, as the utility of any product or resource increases or decreases for one or more of the traders, or as the quantity in the hands of one or more holders increases or decreases, the equilibrium price, through a groping or "tatonnement" process, rises when the demand is greater than the offer or falls when the offer is greater than the demand. Such an equilibrium price remains constant in a

stationary market in which utilities and quantities possessed by the traders are expressed once and remain fixed thereafter. The equilibrium fluctuates in the dynamic market of the real world in which utilities and quantities continuously change.

Viewed in the above way, variability in individual transaction pricing indicates the level of groping that occurs within a market for the elusive but true equilibrium price. Assuming that the process of Walrasian tatonnement is indicative of pricing efficiency, the relevant empirical question is, how can the groping or tatonnement process be measured? And, the question for logic is, what level(s) of price variability represents optimum price behavior or pricing efficiency?

Three measures have been devised to answer the empirical question. All three seem logically appealing and include: (1) frequency and magnitude of price change, (2) long and short run price variability, and (3) correlation with previous price. We are not yet prepared to argue that all three measures are necessary for the assessment of pricing efficiency, nor are we prepared to argue that any or all of these measures are necessarily sufficient. Nonetheless, our investigations do suggest that they offer merit for further consideration.

The frequency and magnitude of price change is measured as the change in price between market transactions. Logic suggests that, more frequent price changes of smaller magnitude are indicative of more active tatonnement price establishment than is the case when transaction prices adjust less frequently and in larger increments. Thus, over the course of the market exchange, very frequent, minute price changes represent a price establishment process which is more sensitive (i.e., more efficient) in detecting changes in perceived

utilities and the quantities possessed by actual and potential market participants.

Short and long run price variability is measured as the change in price through time in response to changing market conditions. Using an extension of the efficient-market argument, logic again suggests that frequent, minute price changes in any short time period (such as a day for a daily market or a week for a weekly market) are indicative of an efficient pricing system which captures changes in marketing conditions through time. Prices should change more often and in smaller quantities for an efficient market relative to price changes in a more inefficient market.

Similarly, if the groping process associated with increased short term price variability is effective in establishing accurate transaction prices, then there should be fewer misallocations of resources (reduced cyclical instability) in the longer term. Thus, long term price variability throughout the production cycle should be lower in markets with the more efficient pricing system. The combination of higher short term and lower long term price variabilities constitutes our second measure of relative pricing efficiency.

The third measure is price correlation. It is argued that in markets where improved tatonnement prevails there should be a decrease in correlation between previous and current transaction price and an increase in correlation between current transaction price and other supply-demand parameters. If the price establishment procedure is efficient in tracking on-going changes in market conditions, the dependence of current price on past price should decrease, while the dependence of price on changes in supply-demand conditions should increase.

Empirical Evidence

These pricing efficiency measures have been applied to prices reported from three electronic markets.[3/] The pricing results from these markets are used in this analysis for several reasons. First, electronic markets are highly competitive, and therefore meet the competitive market structure criterion that is theoretically necessary to assure convergence of market prices with Pareto optimal equilibrium levels. Second, much of the literature on electronic markets indicates that they promote a significant improvement in pricing efficiency relative to privately negotiated markets and other less competitive marketing systems [Henderson]. And third, our direct involvement with electronic marketing experiments generated substantial trading data, including individual transaction prices.

All three measures, however, have not been applied to all sets of available data. The rationale for the price correlation measure was not developed until analysis had been completed on the electronic egg market and on butcher hog prices, generated by the Ontario Pork Producers Marketing Board. The price correlation analysis has been applied only to price data obtained in HAMS, which operated in Ohio and in surrounding states from November 1980 through June 1981. The other two measures, frequency of price change among transactions and price variability in the short and long run time, have been applied to all three sets of trading data.

The frequency and magnitude of price change and the long and short run price variation measures for egg prices are shown in Table 1, while these same measures comparing Ontario teletype auction hog prices with private treaty prices are shown in Table 2. The results of analyzing price behavior in the HAMS electronic market, along with comparable terminal and direct pri-

TABLE 1. Egg Price Behavior Comparisons: Private Trading Versus An Electronic Market, Egg Clearinghouse, Inc.

	1974-78	
	Private Trading [1]	Electronic Market [2]
Price Change Frequency [3]	0.481	0.687
Average Price Change [4]	2.32	2.18
Short-Run Price Variation [5]	2.19	2.47
Long-Run Price Variation [6]	8.46	8.43

Source: See Henderson et al., 1979, p. 13

[1] Prices for grade A large white eggs in private trade quoted by Urner Barry Publications, Inc.

[2] Daily average prices for Class I (large) gradable nest run eggs on Egg Clearinghouse, Inc. converted to grade A large white equivalent prices.

[3] Calculated by dividing the number of changes in reported prices by the total number of reported prices.

[4] Cents per dozen.

[5] Standard deviation in four week moving average of daily prices.

[6] Standard deviation in daily prices over entire observation period.

TABLE 2. Hog Price Behavior Comparisons: Private Trading Versus An Electronic Market, Ontario Pork Producers Marketing Board

	1979	
	Private Trading [1]	Electronic Market [2]
Price Change Frequency [3]	0.85	1.00
Average Price Change [4]	0.73	0.94
Short-Run Price Variation [5]	1.50	2.11
Long-Run Price Variation [6]	7.48	6.74

Source: Henderson, 1980, p. 37

[1] Prices for live U.S. No. 1 market hogs purchased by private treaty by Eastern Order Buyers, converted to carcass weight equivalent, with heads.

[2] Daily average prices for Canadian index 100 hog carcasses, with heads, paid by meatpackers on the teletype auction operated by the Ontario Pork Producers Marketing Board.

[3] Calculated by dividing the number of changes in reported prices by the total number of reported prices.

[4] Dollars per hundred weight.

[5] Average monthly standard deviation in daily prices.

[6] Standard deviation in daily prices over entire observation period.

TABLE 3. Hog Price Behavior Comparisons: Private Trading and Terminal Market Versus an Electronic Market, HAMS

	1980-81		
	Electronic Market [1]	Terminal Market [2]	Direct Trading [3]
Price Change Frequency [4]	98.6	88.4	85.0
Average Price Change [5]	0.51	0.66	0.55
Short-Run Price Variation [6]	0.49	0.57	0.49
Long-Run Price Variation [7]	2.82	2.82	2.83
Correlation with Previous Price [8]	.967	.981	.979

Source: Rhodus et al., 1983, p. 26

1/ Prices for U.S. No. 1 and 2 market hogs on the Hog Accelerated Marketing System, operated experimentally by Producers Livestock Association, Columbus, Ohio.

2/ Prices for U.S. No. 1 and 2 market hogs at the Peoria (Illinois) terminal livestock market.

3/ Prices for U.S. No. 1 and 2 market hogs in the Indiana direct trade.

4/ Calculated by dividing the number of changes in daily average prices by the number of days in which trading occurred.

5/ Dollars per hundred weight.

6/ Average weekly standard deviation in average daily prices.

7/ Standard deviation in average daily prices over entire observation period (November 1980 - June 1981).

8/ Partial correlation coefficient between current daily average price and the previous day's average price from "best fit" multiple regression models for each market that include several variables that measure changes in market supply and demand conditions.

vate treaty markets, including the measurement of price correlation, are included in Table 3.

The results are consistent among the three measures and with our a priori expectations, with minor exceptions. These results show for electronic markets, which are expected to be more price efficient, more frequent price changes than do the comparable less efficient price system(s). In all observations but one, the magnitude of average price change is also lower in the electronic market.

The short run price variation in the price-efficient electronic markets is likewise consistently below those in comparable markets with one exception: HAMS-Indiana direct comparison where no difference is detected. Consistent behavior is found in the corollary measure in that there is a decline in the long run price variation for the more efficient electronic market.

All differences are statistically significant, with the exception of the long run price variation comparisons between the HAMS, Peoria terminal, and Indiana direct markets. Available data limited observation to a 7 month period for these comparisons. This is not sufficient for accurate assessment of long run price behavior, given the 4 year nature of the typical hog cycle. No conclusion can, therefore, be drawn from the long run price variation in these markets. The comparison, however, does not reveal any evidence that would contradict the decline in long run price variation demonstrated in the other markets in which more appropriate long run time periods were observed.

The third measure, correlation with previous price, also demonstrates results entirely consistent with our logic and theoretical expectations.

Differences between the HAMS, Peoria terminal, and Indiana direct markets (Table 3) demonstrate increased sensitivity of individual transaction prices to factors other than previous transaction price in the electronic market. These results show greater price sensitivity to a range of variables that represent on-going changes in market conditions.

These observations strongly suggest that, when viewed collectively, these measures yield results that are consistent with a priori reasoning and theoretical expectations of efficient pricing. We are encouraged that these are useful empirical measures in making evaluations of pricing efficiency in markets where the true competitive equilibrium price is not known.

Limitations and Alternatives

The most pronounced limitation of our analysis is that there is no assurance that the prices in a market which demonstrate the measured characteristices associated with pricing efficiency do, in fact, converge toward the true competitive equilibrium. In real markets, the true competitive equilibrium price is not known. Following the Walrasian logic, that price is elusive, and efficient pricing behavior is that which constantly chases the elusive equilibrium. While our research reveals evidence of pricing behavior that is consistent with what we expect in price-efficient markets, we do not have evidence that the prices actually resulted from this behavior are efficient prices.

Smith and Plott, however, have shown that pricing experiments can be conducted to determine if efficient prices are established in markets where the competitive equilibrium price is known to the experimenter before the fact. A logical extension of our research is, therefore, to establish a series of pricing experiments. In these experiments, the equilibrium price would be determined a priori and various pricing procedures, using a combi-

nation of both efficient and inefficient pricing systems, would be used for price establishment through simulated trading. Actual pricing behavior would then be monitored and price behavior variables would be measured accordingly. A correlation then could be made between measures of efficient pricing behavior and the extent to which prices in the various pricing systems converged to the established competitive equilibrium. A high correlation would be strong validation that these empirical measures are useful for the assessment of pricing efficiency in real world markets.

Footnotes

1/ Many of the commodities were also traded in auctions where results were readily observable to all participants.

2/ Plott concludes with the statement that the ultimate usefulness of experimental work cannot be determined until the experimental findings are verified by closely examining price behavior in industries.

3/ The electronic markets include the Egg Clearinghouse, Inc. [Schrader]; a teletype auction operated by the Ontario Pork Producers Marketing Board [Engelman] and an experimental electronic market for Slaughter Hogs (HAMS) [Baldwin].

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