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# Experimental Examination of a Thin Market: Price Behavior in a Declining Terminal Market Revisited

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## *Abstract*

Perceived characteristics of thin markets are described and approaches to furthering their study are suggested. Design features of a laboratory thin market, patterned after a typical livestock marketing situation, are described. Price bias and variation from a "thick" private negotiation market with 22 traders is compared to that from a "thin" auction market with 8 traders. No systematic price bias was found in any of the markets. Price variation was actually lower in the thin auction market.

**Key words:** auction, experimental economics, price discovery, thin market

In agricultural commodity markets, the popular conception of a thin market seems to be associated with a public market that once had large numbers of buyers and sellers but has evolved into a market with only a few buyers. A widely held opinion is that prices reported from a thin public market are not representative of those that would result from a larger population of buyers and sellers, either because of sample selection, or price manipulation through collusive agreements among buyers. In his classic article on price behavior in a declining terminal market Tomek remarked: "a major concern about thin markets is that the number of transactions (per unit of time) is so small that 'unwarranted' price behavior occurs" (p. 434). The competitive market model is the usual standard for establishing the warranted price. Price behavior is typically characterized by the level of average price (price bias) and the variability of prices (price risk). In this paper we attempt to translate the perceived characteristics of thin markets into a conceptual model and then construct a laboratory model with

the minimal set of underlying conditions that will still allow us to make generalizations about the real-world market environment.

Since the concept of bias is defined as the deviation of a sample value from a "true" or population value, the first problem is to identify that population value. The competitive equilibrium price derived from the universe of supply and demand seems to be an accepted standard for the population value, but that value is difficult to measure in practice. A second problem is that changes in observed prices could either be caused by collusive manipulation of markets or simply by exogenous shifts in supply and demand. Clearly we require some knowledge of the true equilibrium price, and preferably some control over changes in the conditions generating the price, before we can proceed to evaluate the effects of departures from that price. Experimental laboratory markets are especially suited to provide that knowledge and control.

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Thin markets are not merely a theoretical curiosity. Changing market structure in the United States livestock industry and the impact on price has been of chronic concern and a frequent topic of research (Stiegert, Azzam, and Brorsen; Purcell; Azzam and Schroeter; Azzam and Pagoulatos; Schroeter and Azzam; Ward; Schroeter). The experimental thin markets described in this study employed trading practices commonly found in livestock markets, particularly cattle. In this context there are significant contrasts between auction and private negotiation institutions as price discovery mechanisms. While thin markets are by no means unique to livestock marketing, the majority of the literature on the problem has been associated with the livestock sector.

The objectives of the study were three-fold: (1) to define the concept of a thin market in order to describe the appropriate equilibrium and price discovery processes; (2) to model these processes in a laboratory setting and specify the parameters to be controlled or manipulated; and (3) to assess the degree of price bias and variability resulting from these manipulations. Results of the study suggest that the adverse welfare implications of thin markets may be exaggerated.

### **Defining Thin Markets**

Ever since Gray popularized the term "thin market" in the context of futures markets, research has focused on pricing problems in thin markets. At a conference entitled the "Symposium on Pricing Problems in the Food Industry (with Emphasis on Thin Markets)" held in 1978 in Washington, D.C., Hayenga, et al. defined thin markets as "markets with little trading volume and liquidity in which individual firms or offers to buy or sell can sometimes exert 'undue' influence on price or other terms of trade..." (p. 7).

In their widely-used textbook, Tomek and Robinson described the conditions that give rise to thin markets: "As the volume sold through central markets becomes smaller, the prices established on such markets may not fully reflect aggregate supply and demand conditions; furthermore, they are more susceptible to manipulation. This is commonly

referred to as the 'thin market' problem. A thin market is one in which relatively few transactions establish prices." (p. 204)

The recent edition of the popular textbook by Kohls and Uhl notes: "With decentralization, many terminal markets have become *thin markets*; that is, they handle a small and declining volume of product. Many feel that the prices discovered in these thin markets do not represent true market conditions and should not be used as guides in pricing direct sales." (p. 213)

Rhodus, Baldwin, and Henderson summarized the general opinion of the market for slaughter hogs as follows: "This trend away from terminal markets causes market observers to question whether reported terminal market prices accurately represent true market-wide conditions. Prices established by private traders using terminal market relationships may not accurately reflect local supply and demand relationships and may not efficiently allocate resources." (p. 874)

Tomek systematically addressed many of these issues in his article on pricing behavior in the Denver cattle market, where he stressed the need for a concept of thin markets that has empirical content. His approach invoked statistical sampling theory, from which he argued that the precision of reported prices is strictly a function of the number of observations: "...the results are clearly compatible with the hypothesis that declining volume results in imprecise pricing..... Moreover, logic alone suggests that declining information will result in larger pricing errors" (p. 443). However, in a footnote responding to reviewer comments he did acknowledge that the price discovery mechanism or market institution might have special features beyond sample size: "...the mere use of number of transactions misses the possibility that one transaction may contain more information than another; all transactions are not equal in the amount or quality of information provided" (p. 443). The present study explores this important distinction.

### **Welfare Implications of Thin Markets: Three Paradigms**

A number of approaches from the field of industrial organization can be used to evaluate the

welfare implications of thin markets. We consider three of these approaches: (1) the traditional paradigm of structure, conduct, and performance; (2) game theory; and (3) transaction cost theory.

Conventional arguments under the Structure-Conduct-Performance (S-C-P) paradigm involve the number of buyers and sellers, and possibly also the number of public transactions, but not necessarily the volume of product (Quail, et al.; Menkhaus, St. Clair, and Ahmaddaud). Thus, even a large volume traded among small numbers of agents may give rise to the thin market problem. A stylized S-C-P argument for policy intervention in thin markets would be something like the following: "When there are few participants on one side of the market this is reflected in market concentration. Concentration is often associated with market power. Market power facilitates monopoly pricing behavior. Monopoly pricing behavior not only redistributes surplus inequitably to the powerful side of the market, but also results in an overall welfare loss through the deadweight triangle and wasteful rent-seeking behavior. Regulatory intervention is thus required in order to prevent this loss to society." The weakest link in this argument is the correlation between concentration and market power. A large body of experimental studies has demonstrated that while concentration may be a necessary condition for collusive behavior, it is not a sufficient condition in a surprising number of cases.

Game theory can be useful in examining aspects of thin markets in terms of cooperative and non-cooperative behavior (Koontz, Garcia, and Henderson). This approach presents an image of warranted pricing behavior that differs substantially from the standard of Walrasian competition, since game theory strives for an explicit account of the effects of each player's actions on the actions of others, instead of assuming that they act independently.

The game theoretic approach entails precise mathematical definitions of how much information participants have and whether they can bluff, lie, threaten, cheat, etc. Furthermore, game theoretic models require the researcher to be specific about characteristics of players, available strategies and actions, payoffs and other possible outcomes, and concepts of equilibrium. While the last point is of

paramount importance, game theory unfortunately offers an embarrassingly large number of possible equilibria. For example, the Cournot-Nash equilibrium in a non-cooperative oligopoly can have a higher price and smaller quantity than the Walrasian competitive equilibrium but still be more frequently observed simply because all players can make themselves individually better off if they move away from competitive outcome. But under the competitive yardstick, the Cournot-Nash outcome could be considered unwarranted market behavior. By judicious selection of experimental parameters, such distinctions can be examined in laboratory markets.

Transaction cost theory is yet another approach to the study of thin markets (Thompson). One explanation for the abandonment of centralized commodity markets is simply that it is less expensive to negotiate privately. The use of standardized contracts for relatively homogeneous and perishable goods lowers the marginal cost of searching the price distribution and thus expedites trade at a lower transaction cost (Telser).

A characteristic response to costly market transactions is for the firm to internalize the market function through vertical integration. However, this response is seldom observed in commodity markets exhibiting the thin market phenomenon. To the contrary, for many commodities more volume is traded in decentralized markets now than was ever traded through central, public, or terminal markets in the past. Nor is the auction the principal form of price discovery any longer. Private negotiation of contracts and longer-term trading relationships are more common.

In those cases where thin markets do not become vertically integrated, the exposition of Grossman and Hart suggests that the following factors may be relevant: (1) assets in the form of specialized equipment or processes are not so specific that buyers and sellers become vulnerable to opportunistic behavior once a contract is signed; (2) the future is usually not so uncertain that changing market conditions make it difficult to specify contract terms; (3) monitoring and enforcing contracts is not difficult or costly.

Unlike the previous three approaches, experimental methods are not presented as a

paradigm but simply as a supplementary way of observing phenomena or verifying predictions made by theories with empirical content. The strength of the experimental approach is that, in contrast to aggregate data from agricultural markets, observations are generated in a closely controlled environment and the effects of omitted variables are mitigated by randomization (Bessler and Covey).

Even though experimental economics does not claim the status of a paradigm, a considerable body of accumulated evidence from various market experiments provides some insight into the problem of thin markets. In the first place, a credo of experimental economists is that "institutions matter"-the market environment or price discovery mechanism plays a fundamental role in determining outcomes. This has been largely overlooked in the thin markets literature despite numerous laboratory experiments that indicate that price behavior in private negotiation markets is quite different from that of auction markets (for example, see Davis and Holt, ch. 5). Prices are generally less stable when pairs of buyers and sellers negotiate privately than when an auctioneer calls out progressively improving bids in a room with several buyers (Plott, p. 1139).

A second consideration, familiar to experimentalists but not dealt with satisfactorily in the thin markets literature, is how information is made available. It is frequently observed in auction markets that prices tend to converge to an asymptote (usually the competitive equilibrium in laboratory markets). One explanation for this is that not only are successive contract prices made common knowledge, but so are unaccepted bids. Neither of these sources of price information is generally available in private negotiation markets. Thus, one hypothesis of our study was that price variation would be lower in auction markets than in private negotiation markets.

Probably the most difficult hurdle to be overcome in addressing the thin market problem in an empirical context is that in the real world it is usually difficult, if not impossible, to know the equilibrium prices in the thin (sample) and complete (population) markets with the precision required to conduct robust econometric tests of price bias. When the competitive yardstick or other equilibria

are proposed as performance standards for thin markets, laboratory experiments that precisely specify demand and supply conditions may be the only way to test certain hypotheses. Rhodus, Baldwin, and Henderson acknowledged this problem and modified their econometric analysis of the hog market to examine *dis*-equilibrium behavior, i.e. how rapidly traders reacted to a change in market conditions. Faminow and Benson chose a laboratory setting in order to control buyer response and isolate the impact of price reporting on seller behavior. Adam et al. argued that an experimental approach was required to observe the micro-level impacts of market power and asymmetric information that are masked in aggregate data.

### **Design of a Laboratory Thin Market**

Several measures of market performance are available in experimental settings. A list of performance measures could include price patterns, volume, income distribution, and market efficiency (total surplus). Price can either be measured as the average of contract prices during a period or as the last contract price in a period (Plott, p. 1119).

Buccola lists several additional measures of pricing efficiency. These include: (1) the rate at which an expected price series approaches an asymptote (if any), (2) the difference between this asymptote and the competitive equilibrium price, (3) the difference between overall mean price and competitive equilibrium, (4) the rate of change in price variability around the expected series, and (5) the overall variability around overall mean price. The first three are measures of price bias while the last two are measures of price risk. In this study, measures (1), (3), and (5) were the focus.

In designing laboratory markets, it becomes necessary to make a number of assumptions concerning real-world conditions. For our study, the Denver cattle market described by Tomek was chosen to be the real-world setting for the model. First, a number of complex questions about cattle markets had to be addressed in order to operationalize the important parameters for the laboratory market. For example, do supply and demand curves exist for cattle markets such that a competitive equilibrium is determined by their intersection? Our interpretation of the literature on

thin cattle markets was that this is the appropriate conceptualization of equilibrium. Are all the units to be sold (as well as the set of buyers and sellers) assembled in one place at one time? Entry of new buyers or sellers was forbidden after the trading period opened. How does a trading period end? The experiment was designed to clear stocks of output, rather than to deal with continuous flows of product with inventory carryover. Thus, when the market cleared (or, more precisely, when there was no more interest in bidding) the period ended. How is information about the quality of units handled? All units were homogeneous and nondescript. Buyers were perfectly informed about the resale value of their units; sellers knew their cost of production.

Each thin market was designed to be a randomly sampled subset of the complete market. Random sampling may be just one of a number of sampling methods appropriate to cattle markets, but it is consistent with Tomek's exposition based on sampling theory. The subset remaining after assigning the thick market was designated as the thin market. The thin market institution was the familiar ascending bid or English auction. The thick market institution was private negotiation, with all the buyers and sellers in the same room.

The experiment consisted of 12 trading periods, each with randomly chosen supply and demand schedules. Two sets of supply and demand schedules were constructed deliberately to produce noticeable variations in equilibrium prices. The High set had five supply schedules with costs of production ranging from \$4.13 to \$6.20, and five demand schedules with resale values ranging from \$7.07 to \$5.00. The Low set had five supply schedules ranging from \$0.26 to \$2.82, and five demand schedules ranging from \$4.10 to \$1.54. Thus, with either set of schedules any one of 25 possible equilibria could be randomly selected in a given period. The High set produced equilibria over a range from \$5.40 to \$5.90, while the Low set was in the \$1.80-2.50 range.

The total market was comprised of 15 buyers and 15 sellers each holding three units. In each period, 11 buyers and 11 sellers were randomly selected to trade in the thick private negotiation market. The other four buyers and four sellers were assigned to the thin auction market.

Sellers remained sellers throughout the experiment but could be selected for either the negotiation or the auction market in any period; similarly for buyers. In the thin market, each unit was chosen randomly by the auctioneer to be put up for bids. Sellers were given the right to refuse sale of a unit if they desired. There were no commissions charged.

The value of units to buyers was induced by giving them a resale value for each unit they acquired through trade with sellers (Smith, 1976). Each of a buyer's three units had a different resale value. Buyers' profits averaged about \$0.70 per unit per period. The value of units to sellers was induced by giving them units at varying costs of production. The net revenue from the sale of a unit was theirs to keep, and also averaged about a \$0.70 per unit per period. Sellers were not charged for the cost of unsold units.

Subjects were recruited by posting announcements on campus. Payments consisted of a \$5 show-up fee plus the profits from trading. The experiment was conducted over four evenings. On the first evening, instructions (available from the authors) were read to the subjects, followed by four practice periods from which the data is not reported. Four trading periods were conducted on each of the other three evenings, for a total of 12 trading periods with reported data. Periods lasted up to 15 minutes. A pool of 39 subjects was available for the 12 experiments. The first 30 people to show up each evening were chosen to participate. Subject payments totalled \$1,716.

The experiment was designed to test several hypotheses about pricing efficiency in the two markets relative to the three competitive equilibria (total, private negotiation, and auction). Few significant differences by trading period were expected between the average price observed in the negotiation market and the competitive equilibrium in either its own market or the total market, i.e. the thick market was expected to be unbiased. The literature on livestock markets suggests that this might not be the case when a thick market uses formula pricing based on price reports from a thin market. However, in order to establish baseline results, price reporting was not an explicit design feature of this investigation, and therefore it was hypothesized that (in the absence of formula

pricing) the thick negotiation market would not be biased.

In terms of price bias, one would anticipate that the average price observed in any single auction trading period would often be significantly different from both the negotiation and the total market equilibria because of the small sample. According to Tomek and Robinson, thin markets can be expected to produce unstable prices, but they found little evidence of consistent bias in prices (p. 205). Thus the average difference between the auction mean price and the total market equilibrium price over the 12 periods was not expected to be significantly different from zero. This was also hypothesized to be the case for the average difference between the auction mean price and the negotiation market equilibria.

There is conflicting evidence supporting the prediction of bias within particular market institutions, i.e. between the average contract price in a market and its own equilibrium. Early experimental studies of single-sided auctions (e.g. one seller, many buyers) concluded that contract prices in English auctions tended to converge to equilibrium from above, favoring sellers (Smith, 1964; Plott and Smith). More recent literature suggests that with repetition and experience this effect is diminished (Burns). To our knowledge there is no body of evidence suggesting that private negotiation consistently favors one side of the market or the other.

Finally, in terms of price risk, the variance of prices from the auction market was hypothesized to be much smaller than that from the negotiation market, again because of information availability and the related convergence properties of that price discovery mechanism.

## Results

Figure 1 shows one set of graphical results, here illustrated by the three markets from Period 5. Recall that the total market was constructed from a random sample of either of two sets of supply and demand schedules (High or Low). The total market was then split into the two operative markets, private negotiation and auction, by randomly assigning buyers and sellers to either market. In the

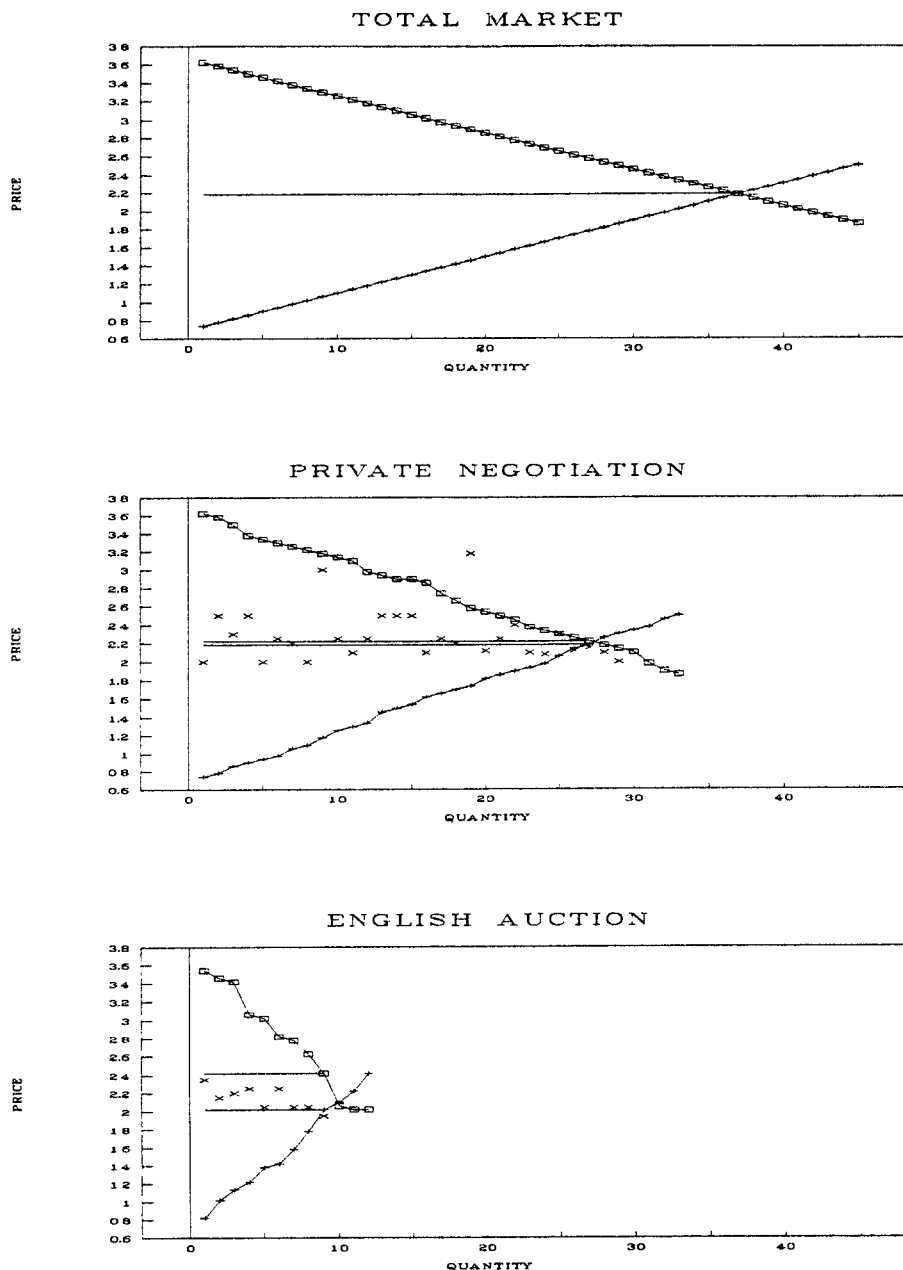
illustration of Period 5, the larger sample in the negotiation market had a narrow band of equilibrium prices at about the same equilibrium price as the total market (\$2.18), but the thin auction market had a wide band of indeterminate equilibrium prices between \$2.02 and \$2.42. Upon reflection one can appreciate that such bands of indeterminacy could be quite common in thin markets, particularly those in which the inframarginal buyers have similar resale values and the inframarginal sellers have similar costs of production. This phenomenon alone would recommend a less dogmatic concept of equilibrium and welfare impacts in thin markets.

The  $x$ 's overlaid on the supply/demand graphs represent contract prices in the order that units traded. For example, the first unit in the Period 5 auction traded at \$2.35 and the last unit at \$1.95. In most periods, auction prices either converged quickly to the equilibrium band when it was narrow, or at least stayed fairly consistently within the equilibrium band when it was wide, as in the graph of Period 5. In contrast, prices showed no such tendencies in the private negotiation markets. Many of the graphs of other periods provided similar evidence of these characteristic patterns of convergence (in the auction markets) or non-convergence (in the negotiation markets), illustrating the differential capabilities of these two institutions in disseminating price information.

Table 1 shows the equilibrium prices and quantities for the total market ( $P_T^*$  and  $Q_T^*$ ) for each of the 12 periods. The equilibrium prices for the negotiation market did not always correspond to an integer unit of quantity so the lower and upper bounds ( $P_N^*L$  and  $P_N^*U$ ) for the marginal unit ( $Q_N^*$ ) are shown. The average contract price for the period ( $P_N$ ), the coefficient of variation ( $CV P_N$ ), and the total quantity traded ( $Q_N$ ) are also shown in table 1. Similar results are shown for the auction market.

Average prices are compared to various equilibrium prices using  $t$ -statistics, shown in table 2. In the negotiation market, only Period 7 showed a significant difference (at the 5 percent level) between the average contract price and the total market equilibrium ( $P_N$  vs.  $P_T^*$ ) in a two-tail test, and between the average contract price and both the lower and upper negotiation market equilibrium

Figure 1. Supply and Demand Schedules and Contract Prices from Period 5



bounds ( $P_N$  vs.  $P^*_N L$  and  $P^*_N U$ ) in one-tail tests. A paired-difference test over the 12 periods confirmed that the mean difference between the period-average negotiation price and the total equilibrium price was not significantly different from zero ( $t = 0.47$ ). This lends some support to the argument of Kirman and Vignes that buyers in negotiation markets may not search aggressively for the best prices since they expect their average price to be "fair" over a long

association with a few sellers. In future work, this latter suggestion can be investigated by examining the frequency of trades between the same buyers and sellers.

Using the 5 percent level as the general criterion for significance, average prices from the auction market were biased from the total equilibrium in eight periods and from the



negotiation equilibrium in eight periods, but not consistently in one direction. A paired-difference test showed that the mean difference across all 12 periods was not significantly different from zero using either the total market ( $P_A - P^*_T$ ;  $t = -0.50$ ) or the negotiation market ( $P_A - P^*_N$ ;  $t = -0.30$ ) as the standard.

Even though price reporting from thin to thick markets was not an explicit design feature of these experiments, our results provide some indirect evidence of what might happen with formula pricing under similar conditions. If an average price from an auction market were reported to a negotiation market before it started trading, and was used in a purely mechanical formula, it would frequently misrepresent the equilibrium in any single period (67 percent of the time, in this study). But over time prices discovered under such a mechanism would average out to be the same as the long-term mean equilibrium price, whether represented by the total market or the negotiation market.

A test of within-market bias was done by comparing the average price in each period to the equilibrium bounds. In this test, when the average price was outside the equilibrium band it was compared to the nearest bound using a one-tail  $t$ -test. When the average price was inside the band the difference was set equal to zero. The average price for the negotiation market was below its lower equilibrium bound four times, above its upper bound six times, and between bounds twice. A paired-difference test showed no significant bias ( $P_N - P^*_N$ ;  $t = 1.28$ ). This was similarly the case for the auction market ( $P_A - P^*_A$ ;  $t = -0.96$ ). These tests suggest that neither of these market institutions favored sellers or buyers as a group, under these experimental conditions.

The coefficient of variation serves as a measure of price risk within a market for a given period. Table 1 shows that in every period the coefficient of variation was higher for the private negotiation market than for the auction market. Statistical significance is corroborated by the F-test in table 2 which, in 11 out of 12 periods, rejects the null hypothesis that the variance of prices in the negotiation market is the same as in the auction market.

Tomek and Robinson suggest that "prices on thin markets may fluctuate greatly from day to day and even within a day." (p. 205). To the extent that the trading periods used here are analogous to their days, prices in this laboratory model of a thin market certainly fluctuated greatly from period to period. However, these fluctuations were related almost entirely to shifts in supply and demand, which were deliberately designed to be large in order to induce substantial price risk. For example, in the extreme case, a random draw of a \$2.02 equilibrium price was taken from the Low set of supply/demand schedules in Period 7, and immediately followed by a random draw of a \$5.75 equilibrium price from the High set in Period 8. This represents a 185 percent increase in the equilibrium price between the two periods. In a real-world thin market it is difficult to know when daily prices are fluctuating due to shifts in supply and demand or because of some unwarranted factor. Laboratory experiments are able to evaluate these factors separately.

Supply and demand conditions in the laboratory auction markets only fluctuated between periods, not within periods. To the extent that these conditions differ from cattle markets, the contrast may be due to intra-day supply shifts in the form of unanticipated deliveries or removals of cattle throughout the day. Such intra-period shifts would of course alter the concept of equilibrium as applied here and elsewhere in the literature on thin markets, but could still be accommodated in an experimental framework.

## Conclusions

In the study of thin market phenomena, laboratory techniques can provide a level of resolution that is unattainable in econometric studies of the problem, where errors in measurement can be larger than the fluctuations in prices. One of the important contributions of the experimental method is that it forces the investigator to be precise in specifying the important parameters, such as the numbers of buyers and sellers qualifying as a thin or thick market, methods for assigning traders to markets, trading rules, relevant prices to serve as data, concepts of equilibrium, and so on.

**Table 1.** Equilibrium and Average Prices<sup>a</sup>, Quantities<sup>b</sup>, and Coefficients of Variation<sup>c</sup> for Three Markets (Total, Negotiation, and Auction)

	Period =>	1	2	3	4	5	6	7	8	9	10	11	12
TOTAL	$P^*_T$	5.69	2.26	2.02	5.60	2.18	5.45	2.02	5.75	5.90	2.50	5.66	1.86
TOTAL	$Q^*_T$	38	35	37	40	37	40	41	40	40	41	42	41
NEGOT'N	$P^*_N U$	5.66	2.26	2.02	5.66	2.22	5.45	2.06	5.75	5.90	2.50	5.69	1.78
NEGOT'N	$P^*_N L$	5.63	2.26	2.02	5.63	2.18	5.42	1.98	5.72	5.90	2.46	5.69	1.74
NEGOT'N	$Q^*_N$	28	25	27	29	27	29	29	28	28	30	32	31
NEGOT'N	$P_N$	5.60	2.30	2.03	5.61	2.28	5.43	2.18	5.69	5.87	2.47	5.72	1.82
NEGOT'N	$CV P_N$	0.053	0.146	0.112	0.061	0.122	0.053	0.153	0.038	0.040	0.146	0.043	0.173
NEGOT'N	$Q_N$	32	28	27	31	29	29	31	31	29	31	32	31
AUCTION	$P^*_A U$	5.84	2.38	2.10	5.54	2.42	5.63	2.10	5.87	5.96	2.66	5.66	1.90
AUCTION	$P^*_A L$	5.66	2.22	2.06	5.48	2.02	5.51	1.94	5.69	5.81	2.58	5.57	1.86
AUCTION	$Q^*_A$	9	10	9	11	9	10	11	11	12	11	10	11
AUCTION	$P_A$	5.63	2.38	2.23	5.61	2.14	5.29	2.17	5.48	5.73	2.54	5.53	1.91
AUCTION	$CV P_A$	0.013	0.054	0.111	0.030	0.060	0.023	0.040	0.015	0.008	0.076	0.011	0.032
AUCTION	$Q_A$	9	9	11	12	9	9	11	9	9	12	9	11

<sup>a</sup>  $P^*_i$  is the equilibrium price for market  $i$ , and  $P_i$  is the average contract price from market  $i$ , where  $i=T$  (Total),  $N$  (Negotiation), or  $A$  (Auction).  $U$ =upper bound;  $L$ =lower bound.

<sup>b</sup>  $Q^*_i$  is the equilibrium quantity for market  $i$ , and  $Q_i$  is the total quantity traded in market  $i$ , where  $i=T$  (Total),  $N$  (Negotiation), or  $A$  (Auction).

<sup>c</sup>  $CV P_i$  is the coefficient of variation of prices from market  $i$ , where  $i=N$  (Negotiation) or  $A$  (Auction).

The results suggest that perceived price bias and price risk in thin markets may simply reflect transitory small-sample phenomena and unanticipated shifts in supply and demand between trading periods. Even in the presence of considerable fluctuations in price, bias was not significantly systematic over 12 periods. Price risk was actually lower in the thin markets, which is attributed to their use of the English auction, a more information-efficient institution than private negotiation.

Increased incidence of negotiated contracting is probably the result of reduced transaction costs in markets with homogeneous products, negligible (or off-setting) supply and demand shocks, and stable, long-term buyer-seller associations. Whether prices reported from thin auction markets can lead to welfare inefficiencies in negotiated markets with formula pricing, perhaps

due to strategic actions by agents operating in both markets, is a question of sufficient complexity to warrant an expanded research agenda in this area.

The livestock industry's continued concern with thin markets is still appropriate from a number of perspectives. Individuals who enter thin markets infrequently can expect prices to be biased in any *single* trading period. Furthermore, any single formula-priced transaction based on a thin market can also be expected to be biased. But it appears that the direction of the bias depends simply on the sample of the participants present in the market at the time, and the reservation prices they bring to the market. The inference from this study is that, over time, price bias cancels out. Small-sample idiosyncrasies that result in a biased price for any one period are neutralized with repeated trading. This suggests that individuals who frequently participate in thin markets, or base their formula

**Table 2.** *t*-Statistics Comparing Average Prices ( $P_t$ ) to Equilibrium Standards ( $P_t^*$ ), *F*-statistics Comparing Variances of Negotiation and Auction Market Prices, and Paired Difference Tests Comparing 12-Period Average Prices to Equilibrium

Period=>	1	2	3	4	5	6	7	8	9	10	11	12
NEGOTIATION (for $\alpha=0.05$ and $df=27$ : one-tail $t=1.70$ ; two-tail $t=2.05$ ):												
$P_N$ vs. $P_T^*$	-1.74	0.66	0.32	0.23	2.00	-0.47	2.66*	-1.58	-0.73	-0.48	1.46	-0.65
$P_N$ vs. $P_N^*U$	-1.17	0.66	0.32	-0.75	1.22	-0.47	1.99*	-1.58	-0.73	-0.48	0.78	0.76
$P_N$ vs. $P_N^*L$	-0.61	0.66	0.32	-0.26	2.00	0.09	3.33*	-0.82	-0.73	0.14	0.78	1.46
AUCTION (for $\alpha=0.05$ and $df=9$ : one-tail $t=1.83$ ; two-tail $t=2.26$ ):												
$P_A$ vs. $P_T^*$	-2.46	2.77	2.76	0.16	-0.84	-3.79	5.82	-9.79	-11.57	0.77	-6.22	2.44
$P_A$ vs. $P_A^*U$	-8.43	-0.05	1.68	1.38	-6.44	-8.15	2.78	-14.11	-15.73	-2.10	-6.22	0.27
$P_A$ vs. $P_A^*L$	-1.27	3.71	2.22	2.60	2.89	-5.24	8.86	-7.63	-5.34	-0.66	-1.81	2.44
$P_A$ vs. $P_N^*U$	-1.27	2.77	2.76	-1.06	-1.77	-3.79	4.30	-9.79	-11.57	0.77	-7.69	6.79
$P_A$ vs. $P_N^*L$	-0.08	2.77	2.76	-0.45	-0.84	-3.06	7.34	-8.71	-11.57	1.49	-7.69	8.96
<i>F</i> -test comparing variance of prices in negotiation market to auction market ( $H_0: \text{var } P_N = \text{var } P_A$ , for $\alpha=0.05$ and $df(27,9)$ : $F=2.9$ )												
$\text{var } P_N$ vs. $\text{var } P_A$	15.71	6.92	0.86	4.00	4.66	5.35	14.56	6.84	29.38	3.48	16.41	26.80

Paired difference tests over all 12 periods comparing various average prices to equilibrium prices:

	<u>mean</u>	<u>t-stat</u>		<u>mean</u>	<u>t-stat</u>		<u>mean</u>	<u>t-stat</u>	
$(P_A - P_T^*)$	-0.02	-0.50	$(P_A - P_A^*)$	-0.03	-0.96		$(P_A - P_N^*)$	-0.01	-0.30
$(P_N - P_T^*)$	0.01	0.47	$(P_N - P_N^*)$	0.02	1.28				

prices on thin market reports, rationally expect prices to be unbiased on average.

All markets evolve with time. As new market institutions develop, old ones decline. Thin markets may thus be viewed simply as transitional anomalies in the evolution of markets. Whether the transition has adverse welfare impacts probably

determines the speed at which the new institution evolves. The recent growth of tele-auctions and satellite video auctions indicates a continued preference for the auction institution by the livestock industry. This coupling of larger numbers of traders with reduced transaction costs and efficient information transfer seems entirely appropriate in light of the experimental results.

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