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An Experimental Economics Approach to Analyzing Price Discovery in Forward and Spot Markets

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ABSTRACT

Laboratory experiments are used to generate data that facilitate investigation of pricing behavior in forward and spot markets. Results suggest a tendency for prices in a spot market to converge to levels higher than those in a forward market. The difference in these market environments is the supply schedule. Buyers in a spot market are aware that supply is inelastic and become relatively aggressive bidders. Forward markets have a relatively elastic supply schedule and buyers fare better. This may motivate firms to promote forward markets and/or vertically integrate in the procurement of inputs.

Key Words: experimental economics, forward market, price discovery, spot market.

Trends are occurring in agricultural industries which are dramatically altering the basic structure of exchange. In particular, there are movements toward tighter vertical coordination in commodity and food distribution channels (Barkema, Drabenstott, and Welch; Boehlje). The purpose of this study is to explore, through observation of human behavior in the laboratory, one particular trend—an increased use of forward contracting in intermediate product markets.

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Study Objective

The objective of this study focuses on pricing behavior in forward (production-to-demand) and spot (advance production) markets. Trade prices in these two market institutions are explored in isolation (i.e., only one method of exchange or the other exists), in order to observe any similarities and differences in elicited behavioral tendencies, and to further the understanding of their relationship to and interaction with one another in the natural world. Attention is focused toward addressing the issue of the relative price level in spot and forward market institutions in a laboratory setting. A study of this behavior may be particularly useful, given that prices in naturally occurring forward markets are not observable, because they typically result from private negotiations.

Production precedes sales in a spot market, and there is a risk of failing to recoup costs that is not present in a forward market institution. We therefore collect data from laboratory markets in order to test the following hypothesis: H_0: $\mu_f = \mu_s$ versus H_a: $\mu_f \neq \mu_s$, where s refers to the spot market and f to the forward market, and μ_i is mean price in the ith market type.

Selected Previous Research

Mestelman and Welland, and Smith (1962) conducted laboratory studies particularly relevant to the current research which focused on aspects of advance production in double auction markets. A summary of Mestelman and Welland's results suggests that the production condition (advance or to-demand) does not have a statistically significant effect on mean contract prices. Market efficiency, however, was found to be slightly lower in the advance production market relative to the production-to-demand market. The researchers reasoned that this was due to the slightly lower levels of production and sales observed in the advance production markets. The results of Smith's experiment indicate lower prices in spot markets relative to forward markets. He attributes this finding to a "distress sale" characteristic of the spot market.

Other related laboratory studies have examined issues of price behavior in thin markets (Nelson and Turner) and asymmetric information (Adam et al.). In the former study, results of a laboratory thin market revealed no systematic price bias from a thin English auction market with eight traders, as compared to that from a thick private negotiation market with 22 traders. Price variation was found to be lower in the thin auction market. Adam et al. designed an experiment to analyze the effects of both market structure and quality of information held by participants on transactions prices in a single-sided English auction. Experiment results suggest that prices in such auctions can be depressed by buyers, particularly if those buyers possess market power.

Methods and Procedure

This study proposes the use of laboratory experimental methods (as described by Hoffman and Spitzer; Plott; and Smith 1982) as an approach to test the difference in spot and forward market prices. The primary interest is to observe the effect of risk of seller loss from advance production, which exists in a spot market, on market behavior and outcomes. Such risk is not present in a forward market. This suggests two treatments: a forward market treatment (henceforth identified as treatment F) and a spot market treatment (henceforth denoted as treatment S).

Six trading sessions were conducted, three under each treatment. Eight student subjects were recruited from agricultural economics and business courses for each session. Each of the six trading sessions began with an instructional phase, consisting of the following two steps. First, a written set of instructions was given to each participant and read aloud by the monitor. Participants were led through hypothetical trading examples from both a buyer's and a seller's perspective. Second, participants were led through a practice trading period on the computer. During this time, participants were instructed in the mechanics of submitting and accepting bids and asks; and for sellers under treatment S, choosing production levels.

With the exception of an instructional phase of the experiment, each session was conducted entirely over a network of personal computers. Subjects, in the exclusive role of either buyer or seller, interacted anonymously over this network producing and trading a commodity referred to generically as "units," following standard experiment procedure. In keeping with Smith's (1976) induced value theory, participants were compensated for their efforts through cash payments tied directly to the level of accumulated earnings gained through trade. The average cash reward over all sessions was $28.41, with a minimum of $21.55 and a maximum of $34.30. The average total earnings for each spot treatment were $25.75, $29.72, and $28.51. Average payoffs for the forward sessions were $28.46,

$29.12, and $28.93. The time commitment for experiment participants was about two and one-half hours.

The treatment variable, risk of seller loss or its absence, is operationalized via the timing of sales, i.e., sales take place either before (forward market) or after (spot market) production. Under treatment *F*, each trading period consisted of a computerized double auction (DA). Under treatment *S*, each trading period began with an explicit production phase, during which each seller chose the number of units he or she wished to produce for that particular period, followed by trading in a DA. Under both treatments, each DA in each trading period had a time limit of three minutes, while each session consisted of 15 to 16 trading periods. Sellers were allowed to sell, at most, the number of units they had produced, and inventory carryover between periods was not allowed. Production costs of any unsold units, having already been incurred, represented a sunk cost to the seller. Upon completion of trading, participants under both treatments were presented with a summary screen which detailed all transactions and updated token and cash balances (discussed below).

As noted above, the trading mechanism, identical under both treatments, was a double auction. DA markets have been used extensively in laboratory research and are well documented elsewhere (e.g., Davis and Holt). It is conceded that the DA provides a means of price discovery which is informationally richer than the various means generally encountered in real-world agricultural markets. In the present study, however, the use of a DA serves two purposes. First, the DA is an efficient and thoroughly documented trading institution, thus providing a baseline for future work exploring other trading institutions; and second, the DA provides a basis for comparison with past research, especially that of Mestelman and Welland, and also Smith (1962).

Redemption values (production costs) assigned to buyers (sellers) were held constant across both treatments and within each session (a stationary repetitive design). These values and costs were denoted in "tokens," an artificial currency converted into cash at the rate of one token equals one cent. The values and costs assigned for each of the eight units (the maximum allowed to trade per individual per period) are listed in table 1.

Table 1. Redemption Values and Production Costs

Unit	Redemption Value (tokens)	Production Cost (tokens)
1	130	30
2	120	40
3	110	50
4	100	60
5	90	70
6	80	80
7	70	90
8	60	100

Note: Redemption values and production costs were the same for each buyer or seller in the experiment.

For a buyer, earnings on each unit purchased equaled the redemption value of the particular unit less the price paid to the seller. For a seller, earnings on each unit sold equaled the price received by the seller less the production cost of the particular unit. At the conclusion of each session, subjects were paid their accumulated cash earnings.

Following Mestelman and Welland, four buyers and four sellers participated in each market session. While this competitive structure, in terms of numbers, may not be observed in natural markets, it serves as a useful first approximation for the conditions found in the real world and as a benchmark for the study of other structures (e.g., oligopsony). Moreover, a large number of market participants is not necessary to generate competitive outcomes in the double auction. "Competitive predictions are somewhat weakened when the market is reduced to only two sellers, but competitive price, quantity, and efficiency levels are often observed, even in monopolies" (Davis and Holt, p. 155).

Results and Discussion

The mean, across three sessions under each treatment, of average trade prices observed during a given period, along with mean quantities traded, are reported in table 2 and illustrated in figures 1 and 2. The competitive price equilibrium for the laboratory market is 80. From table 2, there is an apparent tendency for mean price under the spot treatment to be biased above the competitive equilibrium, and for mean price under the forward treatment to be below 80. We also observed that the variances of prices under both treatments generally decline over time.[1] The competitive quantity equilibrium for the laboratory market is between 20 and 24 units per period. The average total quantities traded over all 15 periods for the forward market and spot market sessions were 20.89 and 18.78 units, respectively. The null hypothesis of equal quantities traded in the forward and spot treatments was rejected in favor of the alternative hypothesis (quantity traded in the forward market not equal to quantity traded in the spot market) in only two of the 15 periods (table 2). The quantities traded in the forward market are only slightly higher than those in the spot markets using the nonparametric permutation test (Siegel and Castellan).

The two-tailed probability for the nonparametric permutation test is also displayed in table 2.[2] Clearly there is a tendency for prices under treatment *S* to converge to higher levels than under treatment *F*. The null hypothesis of equal mean price (H_0: $\mu_f = \mu_s$) is rejected in favor of the alternative hypothesis of unequal mean price in spot and forward markets (H_a: $\mu_s \neq \mu_f$) in the final nine trading periods.

The tendency for prices under treatment *S* to converge to significantly higher behavioral equilibria than those under treatment *F* is a result consistent with findings of the recently released Grain Inspection, Packers, and Stockyards Administration (GIPSA) report (U.S. Department of Agriculture). This is not a completely valid comparison, of course, since the two markets were studied in isolation in the experiment and occur as alternatives in real-world markets. Our laboratory results are, however, at odds with results found previously by both Smith (1962) and Mestelman and Welland. In order to understand the economic significance of our results, we must pursue the question of why our results differ from those of past related laboratory studies. We immediately note that the experiments reported herein used a computerized double auction, whereas Smith (1962) and Mestelman and Welland investigated similar treatments using an oral double auction. It is possible that the speed with which a computerized auction operates relative to an oral auction could have imparted more urgency on the part of buyers (discussed further below).

We believe a more important difference is that buyers and sellers in the present experiments were allowed (and given incentive) to purchase and sell a greater number of units than subjects in either Smith's or Mestelman

[1] Due to the small sample size, we are unable to plausibly test for heterogeneity across the two treatments. We are conceptualizing an observation as being the average of prices within a given period in a given session. Hence, for each period, we have three observations drawn from the forward market population and three observations drawn from the spot market population. Due to a learning effect, it is plausible to argue that the two populations evolve over trading periods; hence, testing period-by-period is a defensible strategy. The sample variance about the grand mean is calculated as

$$S_s^2 = \left[\sum_{j=1}^{3} (\bar{X}_{sj} - \bar{\bar{X}}_s)^2\right] \bigg/ 2,$$

and the standard deviations are reported in table 2. We conducted a standard *F*-test of the hypothesis,

$$H_0\colon \sigma_f^2 = \sigma_s^2 \quad \text{versus} \quad H_a\colon \sigma_f^2 = \sigma_s^2.$$

Using this test, we reject the null in periods 5, 9, and 12. It should be noted, however, that this test outcome is merely suggestive. In particular, the assumption of normality underlying the *F*-test is dubious given this data. In testing for a difference in means, we avoid any reliance on distributional assumptions by utilizing the nonparametric permutation test.

[2] The permutation test allows for the calculation of the exact probability associated with any possible set of observations under the assumption that the null hypothesis is true. It does not require any distributional assumptions to be made regarding the underlying populations under study, and is an especially powerful and useful test for small samples. In particular, it does not require the assumption of equal variances.

Table 2. Comparison of Mean Average Spot and Forward Trade Prices and Mean Quantities Traded

	Spot Market[a]				Forward Market[a]						
	Trade Prices		Quantities Traded		Trade Prices		Quantities Traded				
Period	Mean of Average Trade Prices	Sample Std. Dev. About Grand Mean	Mean	Std. Dev.	Mean of Average Trade Prices	Sample Std. Dev. About Grand Mean	Mean	Std. Dev.	Difference Between Average Spot and Forward Prices	Price, Two-Tailed Probability	Quantity Traded, Two-Tailed Probability
1	80.97	11.22	15.00	0.82	82.08	5.52	14.67	0.47	−1.11	0.90	0.40
2	73.53	3.87	16.00	1.63	76.56	3.61	18.67	1.25	−3.03	0.50	0.20
3	79.02	1.26	17.00	3.09	78.52	1.83	20.00	1.41	0.50	0.70	0.50
4	81.34	2.17	18.33	2.36	78.98	1.82	22.00	0.00	2.36	0.30	0.10
5	81.43	8.05	18.33	2.36	76.89	0.50	20.67	1.70	4.54	0.40	0.60
6	80.22	5.52	19.00	2.83	77.60	1.38	21.67	0.94	2.62	0.50	0.60
7	83.52	0.72	18.00	1.63	76.40	0.59	22.33	1.70	7.12	0.10	0.20
8	84.92	2.79	17.33	1.25	76.66	3.30	22.00	1.41	8.26	0.10	0.10
9	83.55	0.58	21.00	2.45	76.24	3.83	21.67	0.47	7.31	0.10	0.80
10	84.36	1.20	20.67	2.05	76.47	3.65	21.00	0.82	7.89	0.10	1.00
11	84.59	2.78	21.00	2.16	76.57	2.96	21.67	0.94	8.02	0.10	0.90
12	84.89	0.30	19.67	0.94	76.90	4.41	21.67	0.47	7.99	0.10	0.20
13	84.25	2.36	20.67	1.70	77.66	3.48	21.67	0.47	6.59	0.10	0.60
14	84.84	2.59	20.00	0.82	78.71	2.43	22.00	0.82	6.13	0.10	0.20
15	83.66	1.85	19.33	1.25	78.68	3.45	21.67	1.25	4.98	0.10	0.20
Overall Means and Std. Devs.	83.34	3.21	18.78	2.62	77.66	2.61	20.89	2.20	4.68		

[a] There are three sessions or replications under each treatment for the spot market and the forward market.

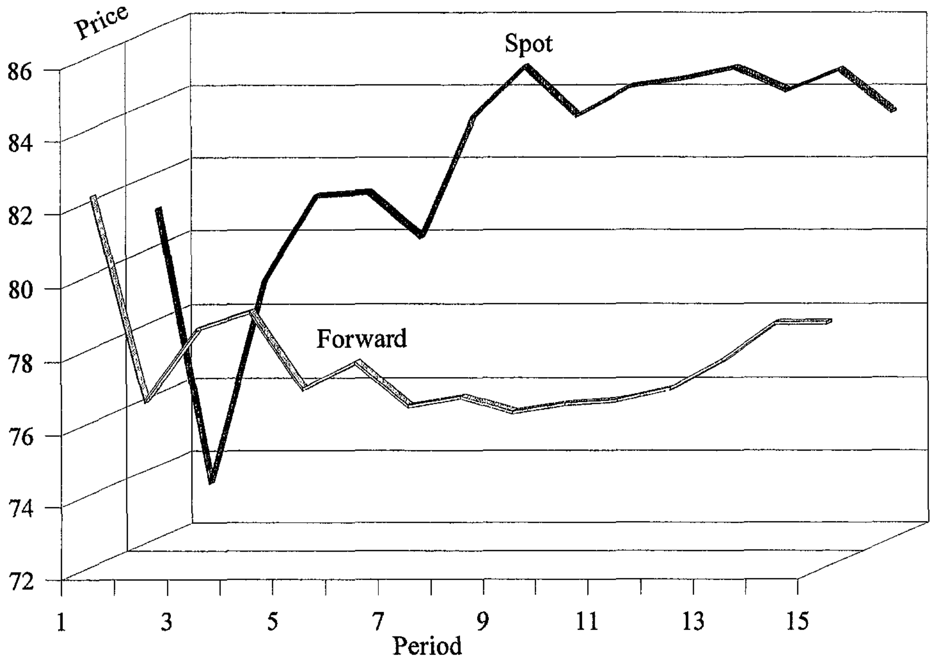

Figure 1. Mean of average trade prices in forward and spot markets

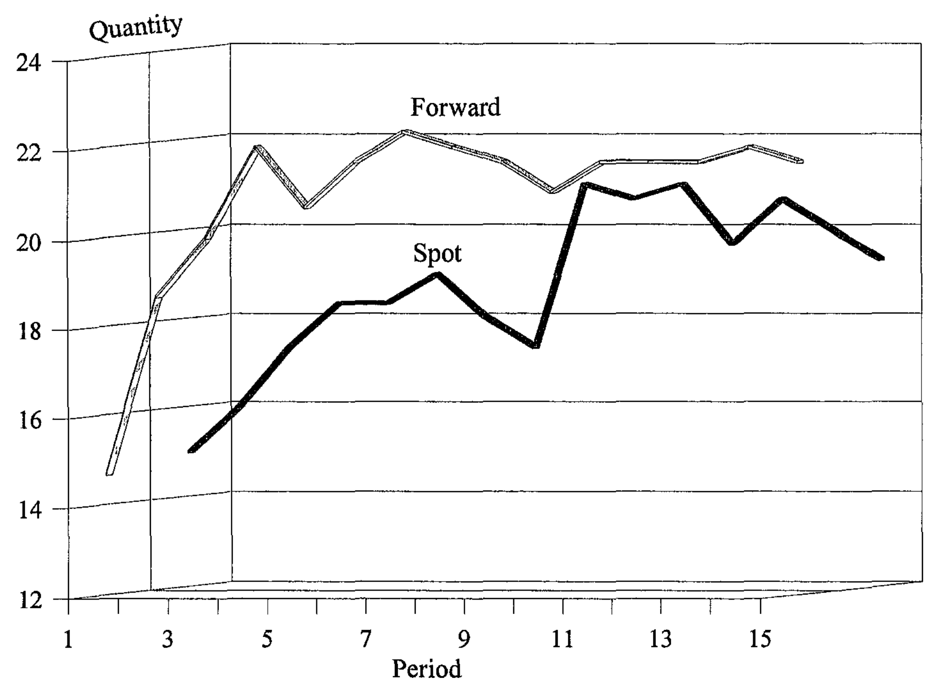

Figure 2. Mean of quantities traded in forward and spot markets

and Welland's experiments. In Smith's experiment, one portion of the participants could purchase (sell) only one unit, while the remaining portion could purchase (sell) up to two units. In the Mestelman and Welland study, a buyer (seller) could purchase (sell) up to six units, but the equilibrium level for either buyer or seller was only two. In the present experiment, the maximum number of units allowed per individual per period was eight, while the competitive equilibrium level was between five and six units. The incentive to purchase more than one or two units would contribute substantially to the urgency attributed to buyers in our spot markets.

In explaining the reason for lower prices in advance production (spot) markets relative to production-to-demand (forward) markets, Smith (1962) views the problem from the seller's perspective. Discussing the convergence to competitive equilibrium observed in his preliminary advance production market, Smith states:

> The approach is from below as might be expected by the 'distress sale' characteristics of the market. The pressure on producers to sell seems to have had its strongest effect in period 1, in which market prices tended to decline from the opening. Prices moved erratically in period 2, and in the remaining periods climbed steadily in the direction of equilibrium (p. 137).

In Smith's "distress sale" argument, sellers do not want to be left with excess stock that represents a sunk cost.

Since the results of our experiment contradict those found by Smith, the "distress sale" reasoning appears in doubt. To provide a plausible explanation for the behavior observed in the present experiment, we offer an alternative information-based argument as follows. Consider the perspective of a buyer. The information sets of buyers during a given trading period differed across treatments in the following sense. Under treatment *F*, the buyer knew from the instructions there was no meaningful limit to the number of units he or she could purchase in the market. In other words, it is almost certain that individual buyers could purchase up to eight units (the maximum allowable) if they were willing to bid a sufficiently high price. Under treatment *S*, this is not necessarily so. Here, the already produced quantity had been set *prior* to trading, and total production levels were unknown to buyers. There existed, therefore, a very real possibility of a limit to the number of units which could be purchased. Regardless of how high a buyer in a spot market was willing to bid, it was possible he or she would not purchase a "satisfactory" number of units. An implication of this subtle difference in information is that buyers under treatment *S* are apt to bid up prices since supply is inelastic at the quantity produced. Inelastic supply could plausibly lend a sense of urgency to a buyer's bidding strategy. This sense of urgency on a buyer's part would be compounded by the observed tendency of the majority of trades to occur relatively quickly within a trading period. An average of 61% of the trades were made during the first minute over the 15 periods in spot market sessions two and three. On average, 46% of the trades occurred during the first minute of trading in the first spot session. The average number of trades during the first minute over the 15 periods in the three forward market sessions ranged from 52% to 55%. Figure 3 illustrates that trading has a tendency (although not strong) to be more active during the first minute of trading in the spot market, as compared to the forward market.

From the observation that trades were occurring slightly more rapidly at the beginning of trading periods, along with the impact of inelastic supply on buyers' information sets, it is argued that buyers under treatment *S* were more aggressive relative to their counterparts under treatment *F*. It is noteworthy that this "quick trading" behavior also has been observed in actual livestock auctions (Buccola 1982; Turner, Dykes, and McKissick).

Our information-based argument, however, is in the nature of an *a posteriori* explanation, and should be viewed as speculative. Tying the cause of the difference in mean price between the spot and forward markets to differences in supply elasticities was not specifically addressed in the experiment, nor is it the result of a direct statistical test. Moreover, there may be alternative causes and explanations for the results observed in the experiment. Among these might be characteristics of traders, including their risk preferences (Buccola 1983) and costs of delay or waiting (McMillan). Each of these causes, including our inelastic-supply/information-based argument, would need to be the focus of further experiments to reach more definitive conclusions.

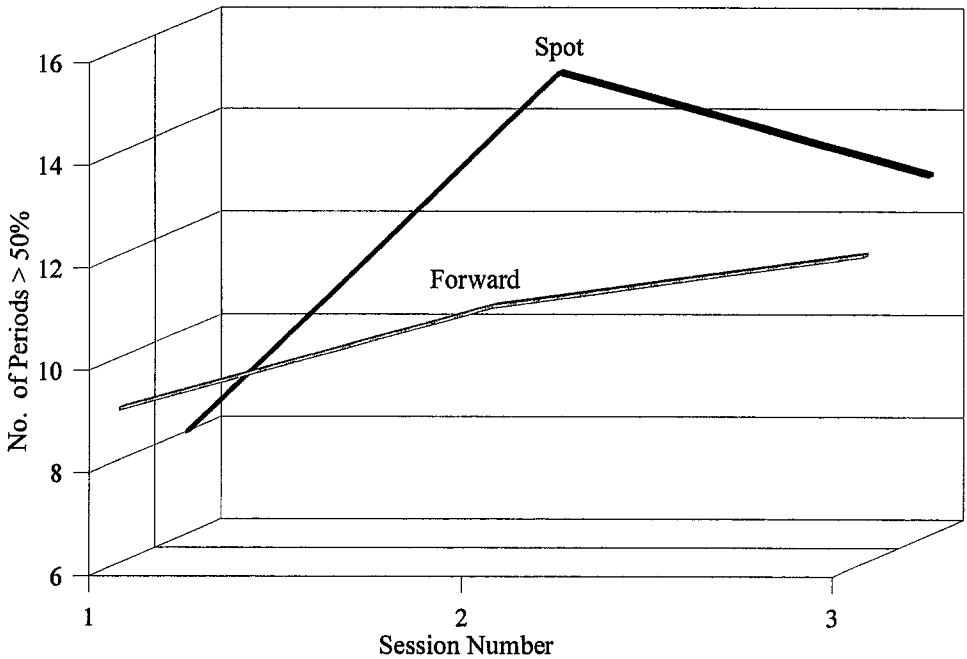

Figure 3. Number of periods in which 50% or more of the trades occurred in the first minute for three sessions, forward and spot markets

Implications

In the present inquiry into forward contract and spot market price discovery processes, laboratory methods were particularly well suited for two reasons. First, much of the data needed for a traditional econometric analysis are not readily available. Second, the task of collecting the relevant data needed to adequately specify an econometric model would necessitate that such a study be relatively narrow in space and time. The drawback to the method of inquiry used in this study is that laboratory methods are limited in terms of the treatments examined, and hence they lack direct application to real-world markets. All relevant features of a real-world market are difficult to duplicate in a laboratory setting, and, in the interest of establishing baseline results, were not duplicated in the present design.

Specific to this study, there are a number of differences between the structure of our experiment and existing agricultural markets. For example, the use of the double auction trading mechanism is both a strength and a weakness. Given its well-documented efficiency in generating competitive outcomes with small numbers of participants, the double auction procedure can be viewed as a strength because it allowed us to effectively identify whether economic agent behavior is different in forward and spot markets. A weakness of this trading mechanism is that it does not adequately parallel the institutional characteristics of the private treaty, English auction, or formula pricing mechanisms which are the basis for transactions in many agricultural markets. The double auction mechanism provides more information to buyers and sellers than is the case in the more typical trading mechanisms. Although the market prices generated in our experiment may not reflect all features of naturally occurring markets, they are uniquely suited for examining the differences in pricing behavior in double auction forward and spot markets.

As a result of not strictly incorporating features of the actual marketplace in the laboratory experiment, caution must be exercised in drawing inferences from experiment results to behavior in real-world markets. Nevertheless, as previously argued, our design allows for comparison of results with those of other laboratory studies. More importantly, the results of our experiment provide a baseline with which to compare future studies that explore pricing behavior in forward and spot markets using alternative trading mechanisms, as well as different numbers of market participants. For more in-depth understanding, we believe this type of laboratory work will require that the steps toward realism be small, but large in number.

Despite these caveats, the tendency observed in our experiment for prices to be relatively higher in the spot market may still have application to real-world markets. The information-based argument explaining higher relative spot prices is a working hypothesis which could have implications for naturally occurring markets. In a similar vein, Arrow proposed a model of vertical integration in which uncertainty on the part of downstream firms exists regarding the supply of an intermediate good by upstream firms. The need for information regarding the available production of this intermediate product motivates the downstream firm to integrate backwards into production of the intermediate good. The additional information gained via the integration improves the ability of the downstream firm to forecast spot prices, and thus facilitates production planning.[3] Williamson has argued that a prominent reason for vertical integration is the uncertainty that exists between buyers and sellers in the production chain. Contracts, bounded in scope by our limited ability to foresee all contingencies, cannot eliminate all of these uncertainties, so an incentive to integrate exists.

In an experimental market, we observed the effect of less information on downstream buyers. The effect was to increase competitive bidding in the spot market, hence driving prices up. This may indicate a further motive by firms to vertically integrate and/or promote forward contracting. Vertical integration and/or forward contracting partially solves an information problem faced by buyers and, no doubt, facilitates efficient operation of production facilities. It is tentatively posited that vertical integration and/or forward contracting may further enable the firm to avoid a consequence of this information problem which, given a competitive market, could force the buyer to bid prices higher.

Finally, the results of this study provide the basis for exploring in more detail the inelastic-supply/information-based hypothesis predicting higher prices in spot markets as compared to forward markets. The impacts of other potentially important factors such as risk preference and cost of delay, along with allowing for a choice among spot, forward, or both markets and alternative trading mechanisms, warrant examination.

[3] Hennessy argues that the type of motivation for vertical integration suggested by Arrow is of less relevance to food industries due to both the typical existence of futures markets and the extensive amount of information regarding agricultural markets disseminated by government agencies and universities.

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