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Endogenous Choice of Institution Under Supply and Demand Risks in Laboratory Forward and Spot Markets

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Laboratory methods are used to investigate the impacts of supply and demand risks in a forward market on prices, quantities traded, and earnings when the choice of transacting in a forward or spot market is endogenous. Forward market activity dominates spot trading, with 80–90% of the trades taking place in the forward market regardless of how risk arises. Buyer earnings tend to be higher than earnings for sellers when there is risk. A correspondence exists between risk type and the relative increase in buyer earnings. Buyer earnings increase significantly when demand is random, and also when both supply and demand are random.

Key words: experimental economics, forward and spot markets, supply and demand risks

Introduction

Risk is pervasive within agricultural commodity markets. The use of forward contracting has been advanced as a strategy to manage risk. The increased use of forward contracting in agriculture, in fact, has altered the basic structure of exchange in agricultural markets by reducing the number of trades made in traditional spot or cash markets (Barkema, Drabenstott, and Welch; Boehlje). The issues of risk and structural marketing changes in agriculture are therefore closely related. Changes in the 1996 farm legislation that decouple government income payments to producers from market prices and production have the effect of increasing risk to the producer, and thus carry the potential to stimulate additional use of forward contracting.

The purpose of this research is to investigate the impacts of random supply and demand schedules in a forward market on buyer and seller behavior in laboratory forward and spot markets, when the choice to participate in these markets is endogenous. We therefore study the institutional setting for which agents have the opportunity to transact in a forward and/or a spot market. Such trading options are becoming more prevalent throughout the food and mineral industries, but have not been studied in the experimental economics literature. Supply and demand risks are incorporated into

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the laboratory market by allowing unit costs for sellers and/or unit values for buyers to be affected by a random variable. This randomly shifts the supply and/or demand schedule(s) faced by buyers and sellers in the experiments. Specific attention is given to the changes in prices, quantities traded, and the division of earnings between buyers and sellers generated from the experiments when agents face this kind of risk and are given the choice of trading institution.

A distinguishing feature of a forward market, as defined in this research, is that price and quantity sold are determined before production is completed, and consequently before the majority of variable production costs have been incurred. Buyers still face risk, however, because demand, and thus unit resale value, is unknown; sellers still face risk because unit production costs at the time of the agreement are random. In the traditional spot market (which in its most elementary state is characterized by sales after production), these production costs and resale values may be known, but the final prices and number of units traded in the market are random, i.e., sellers face price risk after incurring production costs.

To analyze the behavior of agents facing risks in forward and spot markets, college students are recruited to buy and sell in computerized auction markets. Earnings are paid in cash at the end of a trading session that consists of a number of production periods. A laboratory setting provides a controlled environment where there are no unplanned shocks to the system, the trading rules are well defined, and information held by the agents is known. By using a sufficiently simple framework, the effects of risk in forward and spot trading can be isolated. Data from experimental markets are a viable alternative to field data, particularly where the latter may be difficult to obtain, since much of it is proprietary for forward-contracting transactions. Field observations on prices and quantities also result from a variety of uncontrollable factors whose effects may not always be separated.

Economic Theory

The expected value-variance (EV) approach (Robison and Barry) is used to model the effects of supply and/or demand risks in a forward market, along with price risk in a spot market, when buyers and sellers are given the choice of trading institution. Risk may be incorporated into an EV model by generally assigning random variables to prices and costs and forming the certainty equivalent of the profit expression. Specifically, the supply and demand risks faced by sellers and buyers in the forward market are incorporated by assigning random variables (ε and v) to the unit cost and unit price, respectively. (The expected values of ε and v are zero, with respective variances σ_ε^2 and σ_v^2.) Profit-maximization conditions for both the buyer and seller under certainty, supply risk, demand risk, and both supply and demand risks in a forward/spot market are derived from the certainty equivalent of each relevant profit expression. The certainty equivalent of profit is expected profit less the risk premium at which the decision maker is indifferent between the uncertain and certain alternatives.

The economic models that follow present the first-order conditions for both the seller and the buyer in a forward/spot market setting under alternative supply and demand risk scenarios. The control case is initially presented, followed by supply risk, demand risk, and then both supply and demand risks.

Forward / Spot Markets: Fixed Supply and Demand Schedules (Control)

In the derivations which follow, p_f and q_f are price and quantity sold in the forward market; p_s and q_s are price and quantity sold in the spot market. Total cost and total revenue are $C(q)$ and $R(q)$, respectively, and $q = q_f + q_s$. Spot trading, by definition, occurs after the production decision, and involves price risk for the seller.

Let the risky spot market price be $p_s + w$, where w is a random variable with expected value zero and variance σ_w^2. The distribution of w is assumed to be such that the price cannot be negative. Expected profit for the seller in a forward/spot market when supply and demand are certain is

$$E(\Pi) = p_f q_f + p_s q_s - C(q). \tag{1}$$

The variance of profit for the seller is $\sigma_\Pi^2 = q_s^2 \sigma_w^2$. The certainty equivalent of the profit expression (Π_{ce}), following Robison and Barry, for the seller is

$$\Pi_{ce} = p_f q_f + p_s q_s - C(q) - \frac{\lambda_s}{2}\left(q_s^2 \sigma_w^2\right), \tag{2}$$

where λ_s is the Pratt-Arrow measure of risk attitude for the seller.

The first-order conditions follow:

$$\frac{\partial \Pi_{ce}}{\partial q_f} = p_f - C_f'(q) = 0 \tag{3}$$

and

$$\frac{\partial \Pi_{ce}}{\partial q_s} = p_s - C_s'(q) - \lambda_s q_s \sigma_w^2 = 0, \tag{4}$$

where $C_f'(q)$ and $C_s'(q)$ are the marginal costs in the forward and spot markets, respectively. [Note that since $q = q_f + q_s$, $C_f'(q) = C_s'(q)$.] The cost associated with price risk faced by the seller in the spot market is given by $\lambda_s q_s \sigma_w^2$.

The buyer, in the case of fixed supply and demand schedules, does not face any risks in either the forward or spot markets, and therefore is indifferent about the trading institution through which units are purchased. Price risk in the spot market will tend to drive trading by sellers toward the forward market for risk-averse agents when they are given the choice of trading institutions. Thus price in the forward market will be near the predicted competitive equilibrium.

Forward / Spot Markets: Random Supply Schedule and Fixed Demand Schedule

Expected price for the seller in the spot market, as in the previous case, is $E(p_s + w) = p_s$, and expected cost in the forward market is written as $E(C(q_f) + \varepsilon q_f) = C(q_f)$. We consider the case of a random cost in the forward market only, as in the experiment. The sequence of events in the experiment in this treatment is as follows: commit to selling in the forward market before costs are known, learn costs, produce for both the forward and spot markets, and trade in the spot market. Expected profit and variance of profit for the seller are shown by (5) and (6), respectively:

$$E(\Pi) = p_f q_f + p_s q_s - C(q) \tag{5}$$

and

$$\sigma_\Pi^2 = q_s^2\sigma_w^2 + q_f^2\sigma_\varepsilon^2 - 2q_s q_f \rho\sigma_w\sigma_\varepsilon, \tag{6}$$

where ρ is the correlation between w and ε. The certainty equivalent of the profit expression for the seller is specified as

$$\Pi_{ce} = p_f q_f + p_s q_s - C(q) - \frac{\lambda_s}{2}\left(q_s^2\sigma_w^2 + q_f^2\sigma_\varepsilon^2 - 2q_s q_f \rho\sigma_w\sigma_\varepsilon\right), \tag{7}$$

and the first-order conditions are

$$\frac{\partial\Pi_{ce}}{\partial q_f} = p_f - C_f'(q) - \lambda_s q_f \sigma_\varepsilon^2 + \lambda_s q_s \rho\sigma_w\sigma_\varepsilon = 0 \tag{8}$$

and

$$\frac{\partial\Pi_{ce}}{\partial q_s} = p_s - C_s'(q) - \lambda_s q_s \sigma_w^2 + \lambda_s q_f \rho\sigma_w\sigma_\varepsilon = 0. \tag{9}$$

The first-order conditions for buyers are the same as for the control case, because they are not directly affected by the price risk or supply risk. Activity in the forward/spot markets will be influenced by the added costs of both price risk in the spot market and supply risk in the forward market for the sellers. The added cost of risk in the forward market for the seller results in a lower number of units traded and higher prices in the forward market, relative to the fixed supply and fixed demand cases. Trading activity between the two markets depends on the variances of supply (cost) and spot price risks. When costs are revealed prior to the production decision for the spot market, as in the experiment, a lower cost will entice more activity in the spot market, as compared to when costs are higher. This will tend to make the quantities traded and prices in the spot market more variable, compared to when supply and demand are fixed.

Forward / Spot Markets: Fixed Supply Schedule and Random Demand Schedule

The first-order conditions for sellers are the same as for the fixed supply/demand schedules case previously derived [equations (3) and (4)]. That is, the only source of risk is that associated with price risk in the spot market. Expected revenue in the forward market for the buyer is $E(R(q_f) + \nu q_f) = R(q_f)$. We consider demand risk in the forward market only, which is consistent with the design of the experiment. That is, there is no demand risk in the spot market. Expected profit in this case is

$$E(\Pi) = R(q) - p_f q_f - p_s q_s, \tag{10}$$

and the variance of Π is

(11) $$\sigma_{\Pi}^2 = q_f^2\sigma_v^2.$$

The certainty equivalent of the profit expression for the buyer is written as

(12) $$\Pi_{ce} = R(q) - p_f q_f - p_s q_s - \frac{\lambda_B}{2}\left(q_f^2\sigma_v^2\right),$$

and the first-order conditions are

(13) $$\frac{\partial \Pi_{ce}}{\partial q_f} = R_f'(q) - p_f - \lambda_B q_f \sigma_v^2 = 0$$

and

(14) $$\frac{\partial \Pi_{ce}}{\partial q_s} = R_s'(q) - p_s = 0.$$

The buyer, as a result of the risk associated with demand in the forward market, prefers to trade in the spot market when given a choice of forward and spot markets. Or, the price in the forward market must be such (lower) that the cost of risk associated with demand is offset. Activity in the forward/spot markets depends on the relative costs associated with the price risk for the seller in the spot market and demand risk for the buyer in the forward market. These costs are related to relative risk preferences of buyers and sellers, along with variances associated with demand risk and spot prices. Activity (both price and quantity) in the spot market depends on the nature of the revealed resale values for the buyers, as in the experiment. Higher resale values will prompt higher spot prices, and lower resale values will result in lower spot prices.

Forward / Spot Markets: Random Supply and Demand Schedules

The first-order conditions for sellers are the same as derived in the supply risk case [(8) and (9)], and for the buyers, the first-order conditions are the same as in the demand risk scenario [(13) and (14)]. Equilibrium conditions under the case of both supply and demand risks depend on the relative risk preferences of sellers and buyers. The nature of price in this market setting is indeterminate. We would expect quantities traded in the forward market to be reduced because of the costs associated with risk, versus when the supply and demand schedules are fixed.

Economic Models, Summary

The theoretical models, summarized in table 1, reflect the effects of the price risk incurred by sellers in spot markets. In the absence of supply or demand risks, quantity traded in the forward market is greater than that in the spot market. Increased (decreased) quantities traded in the spot market, given the information of relatively low (high) costs,

Table 1. Summary of Predicted Results from the Theoretical Models

	Predicted Changes Relative to No-Risk Treatment			
	Price		Quantity	
Treatment	Forward	Spot	Forward	Spot
Supply Risk	↑	?[a]	↓	?[a]
Demand Risk	↓	?[b]	↓	?[c]
Supply & Demand Risks	?	?	↓↓	?

[a] Indeterminate depending on the nature of revealed cost as sellers enter the production decision for the spot market. When costs are high, sellers will reduce production and spot prices are predicted to increase, and vice versa when the costs are low.
[b] Indeterminate depending on the nature of revealed unit values when buyers enter the spot market. When unit values are high, buyers will be inclined to bid higher prices for available units, and vice versa when the unit values are low.
[c] Units traded on the spot market will depend on the influence of price risk faced by the sellers and the production decision, as in the fixed supply and fixed demand cases.

will induce lower (higher) spot prices. The impacts of forward demand risk in the forward/spot market setting depend on the relative costs associated with the price risk in the spot market for the seller and demand risk for the buyer, which depend on relative risk preferences of agents and variances associated with demand risk and spot prices. Lower prices are expected in the forward market for the demand risk treatment, as compared to the no-demand-risk cases, because with demand risk, buyers will prefer to trade in the spot market. Quantities traded in the forward market are expected to be lower under the condition of combined demand and supply risks, as compared to when these risks are not present. The quantity traded in the forward market with both supply and demand risks should be lower than in other treatments.

Overall, the theoretical models are not precise in predicting price and quantity in forward/spot markets when there are supply and/or demand risks (table 1). Random supply and demand shocks, coupled with the design of providing a choice in institution (i.e., forward or spot), point to the necessity of empirical observation to better understand behavior in this more complex market environment. A laboratory market provides a means to isolate the effects of supply and demand risks in a controlled setting.

Experimental Methods and Procedures

Laboratory experimental methods, as described by Plott and by Smith (1982), were used to obtain data for the analyses. The trading institution chosen for the experiments conducted in this study was the double-auction market. A double-auction is a market institution in which buyers compete by increasing price bids and, at the same time, sellers compete by reducing price offers. Transaction prices occur somewhere in between the initial bids and offers. The use of a double-auction provides a means of price discovery that is informationally richer than the means generally encountered in real-world agricultural markets. Markets organized under double-auction trading rules,

Table 2. Unit Values and Unit Costs (Tokens) for the Control Treatment

Unit	Unit Values (Buyer)	Unit Cost (Seller)	Unit	Unit Values (Buyer)	Unit Cost (Seller)
1	130	30	5	90	70
2	120	40	6	80	80
3	110	50	7	70	90
4	100	60	8	60	100

however, generate competitive outcomes more quickly and reliably than markets organized under alternative trading rules. Because they mimic perfect competition, double-auction markets have been used extensively in laboratory market research. Moreover, a large number of participants are not required to generate competitive outcomes (Davis and Holt).

During an auction session, the monitor first read the instructions. This was followed by a brief practice session using different demand and cost schedules than those provided to participants during the actual trading period. Record sheets were prepared for use by the participants, so that they could keep track of their trades and earnings. The basic features of the forward/spot market design are illustrated in figure 1.

Each trading period consisted of a forward market trading session followed by a production period. Randomly selected unit costs and/or unit values, depending on the risk treatment, were revealed to sellers and buyers, respectively, following the conclusion of the forward market in experiments incorporating supply and/or demand risks. During the production period, sellers were required to produce at least the number of units contracted for in the forward market. Any units produced in excess of the forward contract obligations were available for sale in the spot market trading session, which followed the production phase. There were no provisions for inventory carryover between trading periods (i.e., storage), and the units traded were assumed to be of identical quality.

Thirteen auction sessions were conducted—four sessions with no supply or demand risk served as the control, and three sessions each for which there was random supply, random demand, and both random demand and supply in the forward market. Trading in each of these sessions was conducted for 15 periods.[1] Fifteen periods were deemed sufficient to give subjects experience and to allow behavior to reach a stable pattern. Each computerized forward and spot auction period lasted three minutes, for a total of six minutes over the entire trading period. As in Mestelman and Welland, and in the auction markets conducted by Noussair, Plott, and Riezman, four buyers and four sellers participated in each market session. Market participants, inexperienced with the particular trading institutions under examination, were recruited from undergraduate and graduate economics and business courses.

Using the standard approach, buyers participating in the control treatment were privately given a table that listed the maximum resale values for each unit purchased (table 2). These values were described to buyers as resale or unit values, and

[1] During the third replication of the random supply and demand schedule treatment, the computer failed and we were forced to terminate the experiment after 13 trading periods.

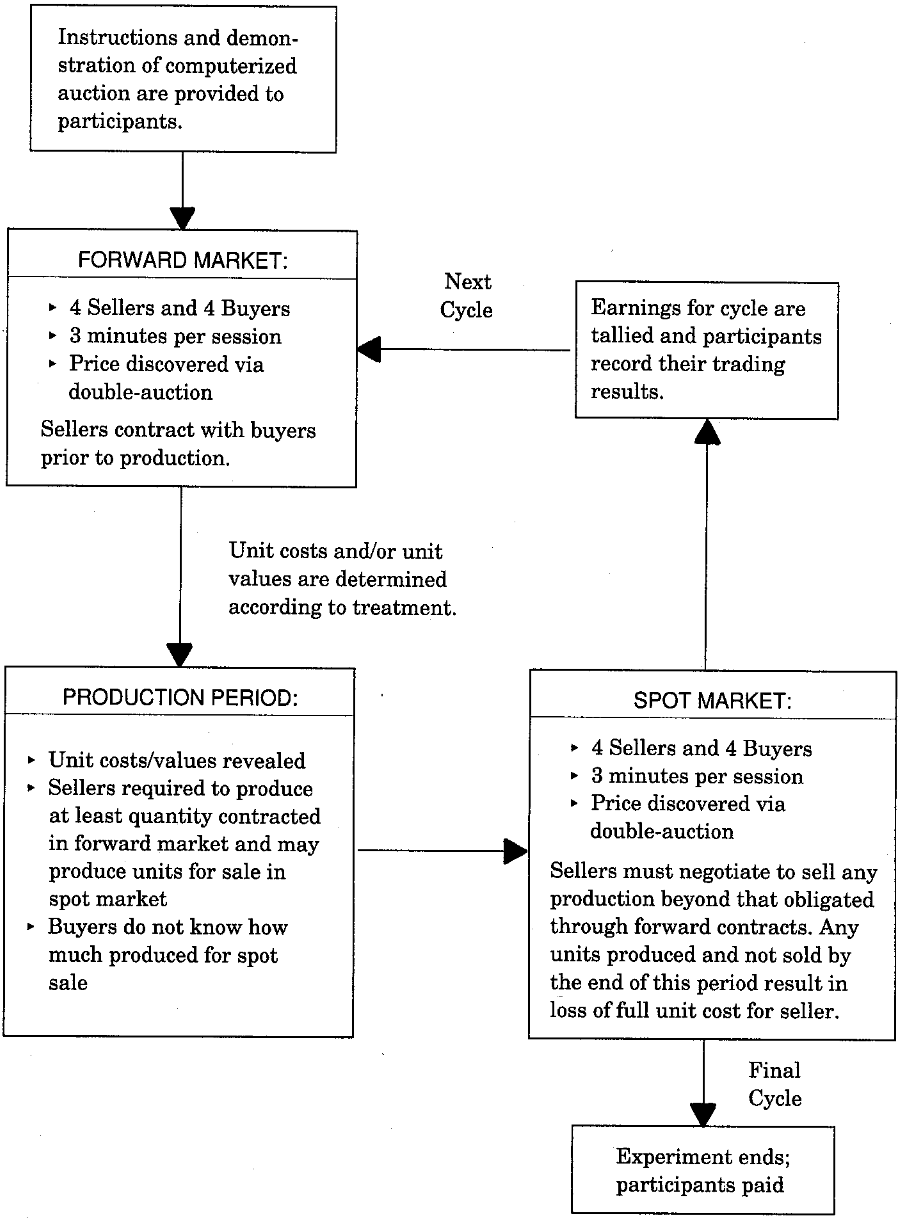

Figure 1. Organization of trading: Forward/spot design

represented final demand in the market. Sellers were similarly informed of unit costs for the control treatment. Earnings were denoted in a monetary convertible currency called "tokens" (100 tokens = $1). Resale values were identical for each buyer, and production costs were identical for each seller in the control treatment.

Treatments incorporating random demand and/or supply allowed unit values, unit costs, or both to vary by a random variable. Participants facing risky resale prices and/or costs were told that these values could range between high and low values that were ±10 tokens from the amounts shown in table 2, and as displayed on their record sheets.[2] Participants also were informed that the actual amount would be chosen randomly by the computer, and had an equally likely chance of taking any value within the 21-token range. Once a random adjustment number was selected for the buyer or seller, all resale prices or unit costs were adjusted by this amount. The random adjusted number was not necessarily the same for supply and demand, when both supply and demand were random. Participants in the risk treatments were informed of the actual resale prices and/or unit costs after the forward market of each trading period. Thus, unit cost information was available to sellers prior to their production decision.

Each buyer and seller in a session was allowed to trade, one unit at a time, up to eight units in each trading period. Units were traded in a specified order—with the first unit traded first, and the second, and so on. Relying upon induced value theory (Smith 1976, 1982), the resale values and unit costs listed in table 2 constituted individual supply and demand schedules per trading period. Competitive price theory predicts an equilibrium price of 80 tokens and total sales in both the forward and spot markets of between 20 and 24 units, when summed over four buyers and four sellers (figure 2). Treatments incorporating random demand and/or supply effectively allow the competitive equilibrium to change between production periods, as is common in many real-world markets.

Earnings for a buyer for each unit purchased equaled the resale value of the particular units less the price paid. Seller earnings for each unit sold equaled the price received from the buyer less the production cost of the particular unit. Earnings accumulated during the trading period and over the sequence of trading periods, and were displayed to agents on their respective computer screens. Participants were paid the cash equivalent of their earnings at the conclusion of each session.

An initial token balance of 700 ($7) was given to each participant at the beginning of each session. This initial endowment, although a nonsalient reward, provided buyers and sellers with the funds to purchase and produce units during the initial periods. The beginning balance was adjusted each period to reflect earnings from the previous period. Buyers were not allowed to spend more tokens for purchasing units than the amount they had available in their adjusted beginning balance in any one period. Similarly, sellers could not incur a production cost greater than the amount in their adjusted beginning token balance in any one period.

Buyers (sellers) were allowed at any time during the double-auction trading periods to submit bids (asks) for a single unit of a fictitious commodity. Bids and asks were submitted via a computer by striking the space bar and typing the numerical value of the bid or ask. Bids and asks were displayed to the entire market on each individual's computer screen. Valid bids and asks were made to follow an "improvement" rule. That is, for a bid to be displayed to the market, it was required to be higher than the previously displayed bid. A valid bid also was required to be less than the asking price

[2] The ±10 tokens range translates into an average change of 25% at the competitive equilibrium price of 80. This range of probable costs and unit values captures the upper/lower limit of most actual price changes within a production period for nonstorable commodities for the five-year period 1993–97. (The experiment was conducted in 1997.) There are, of course, a few exceptions for specialty crops such as lettuce, apples, and citrus fruits, where the average change in annual prices may have been as high as 46%. These cases are rare, however, even for crops adversely affected by weather in a production period. Since this study was conducted, extreme price changes have been observed in the pork industry, resulting in fluctuations that have not been observed for several decades. We argue that the ±10 tokens range reasonably sets an upper/lower bound on price changes between production periods for a great majority of observations. Recent large price fluctuations reinforce the need to study and understand agent behavior in increasingly volatile markets.

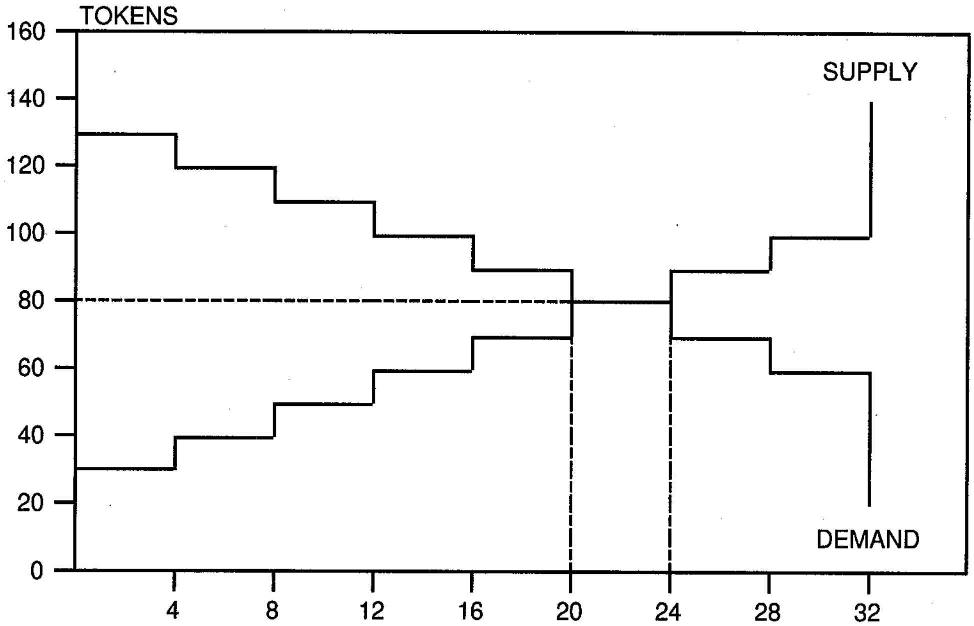

Figure 2. Induced market supply and demand

currently displayed to the market if one existed. In order for the ask to be displayed to the market, it was required to be lower than the previously displayed ask. A valid ask also was not allowed to be lower than the bid currently displayed to the market if one existed. Bids and asks meeting these criteria were displayed to the entire market as the "best" bid or ask. Error messages were displayed to the individual if invalid bids or asks were submitted. The identities of the buyer and seller holding the best bid and ask were not revealed.

Trades could be made using one of two methods. The buyer (seller) would match the "best" ask (bid) or the buyer (seller) could strike the "A" key on the keyboard to accept the best ask (bid). The screen then flashed "Trade Made" to all participants in the market, and a new round of negotiations began. The unit number and trade price were recorded on the screen of the two individuals making the trade. After each trade, the best bid and best ask displayed on each individual's screen were cleared, and new bids and asks for the next trade could be submitted. Participants were allowed to anonymously vote (by typing "V") to discontinue trading if they so desired (Williams). A participant was allowed to continue trading, even after voting to stop trading, until the vote to stop was unanimous or time expired.

Results

The experiments conducted in this study yield observations on trade prices, quantities traded, and earnings by sellers and buyers. These data are summarized graphically and are statistically analyzed. The statistical tests compare all pairs of the four treatment

Table 3. Results of Duncan's Multiple-Range Test by Treatment for Prices, Forward and Spot Markets, Periods 11–15

Forward		Spot	
Treatment	Mean Price*	Treatment	Mean Price*
Control	80.19 [a]	Control	79.82 [a]
Supply Risk	79.07 [a]	Demand Risk	78.70 [a]
Demand Risk	77.54 [a]	Supply & Demand Risks	78.08 [a]
Supply & Demand Risks	76.30 [a]	Supply Risk	77.42 [a]

*Means in each column with the same superscript alphabetical letter are not significantly different at the $\alpha = 0.10$ level.

means for prices, quantities, and earnings. The null and alternative hypotheses for treatments i and j are as follows:

$$H_0: \mu_i = \mu_j \ \forall\, i \neq j \quad \text{and} \quad H_a: \mu_i \neq \mu_j \ \forall\, i \neq j.$$

There are numerous methods for making such multiple comparisons, including the least significant difference method, Duncan's multiple-range test, the Newman-Keuls test, and Tukey's test. For this analysis, we use Duncan's multiple-range test. Our choice is based on the relative power of this test and its performance in detecting true differences in Monte Carlo simulation studies (Carmer and Swanson).

Market Prices

Graphical representations of average prices (across quantities traded and replications) for each trading period and treatment for the forward and spot trades are illustrated in figures 3 and 4, respectively. In the forward market, prices in the control (fixed supply and fixed demand) treatment converge to a level slightly higher than the predicted competitive equilibrium of 80 tokens. Prices from each of the risk treatments converge to a level slightly lower than the control and the predicted competitive equilibrium price (figure 3). Prices from the spot market (figure 4) exhibit more variability than prices from the forward market. There is no consistent pattern among the prices generated in the spot market.

Duncan's multiple-range test was conducted using average prices across the replications from the combined last five of the 15 trading periods. Results are presented in table 3. Average prices in the forward market range from 76.30 (supply and demand risks) to 80.19 (no risk). There are no significant ($\alpha = 0.10$) differences in average prices generated in the forward market from the alternative treatments. In the spot market, average prices range from 77.42 (supply risk) to 79.82 (no risk). As in the forward market, there are no significant differences in the average prices from the treatments in the spot market. Variances in trade prices (over replications for periods 11–15) tend to be greater in the spot market, ranging from 6.39 (control) to 36.40 (supply and demand

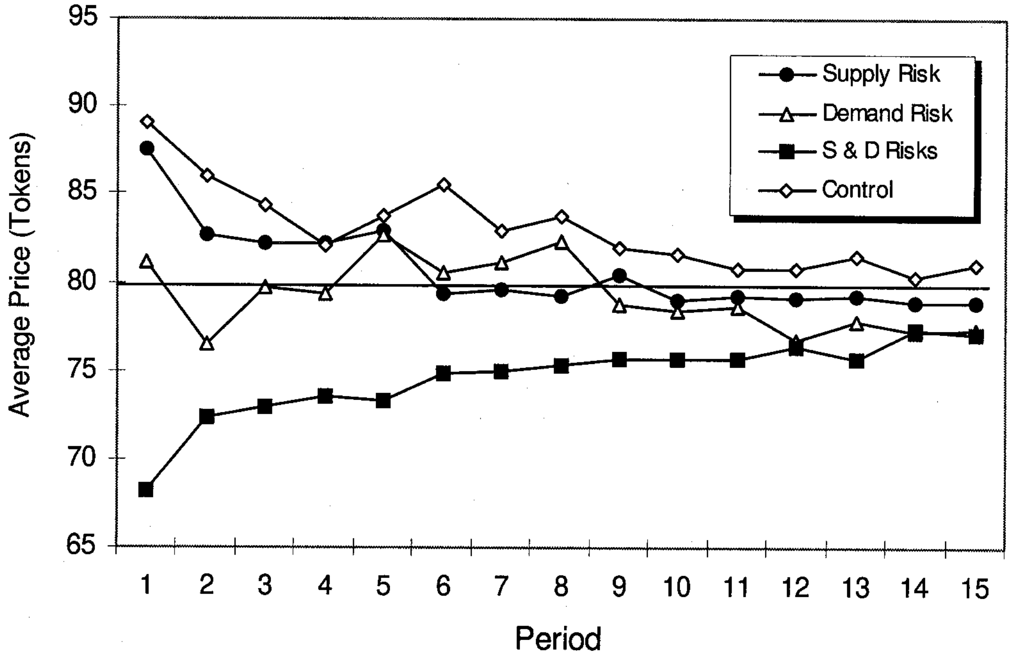

Figure 3. Forward market: Average prices across quantities traded and replications

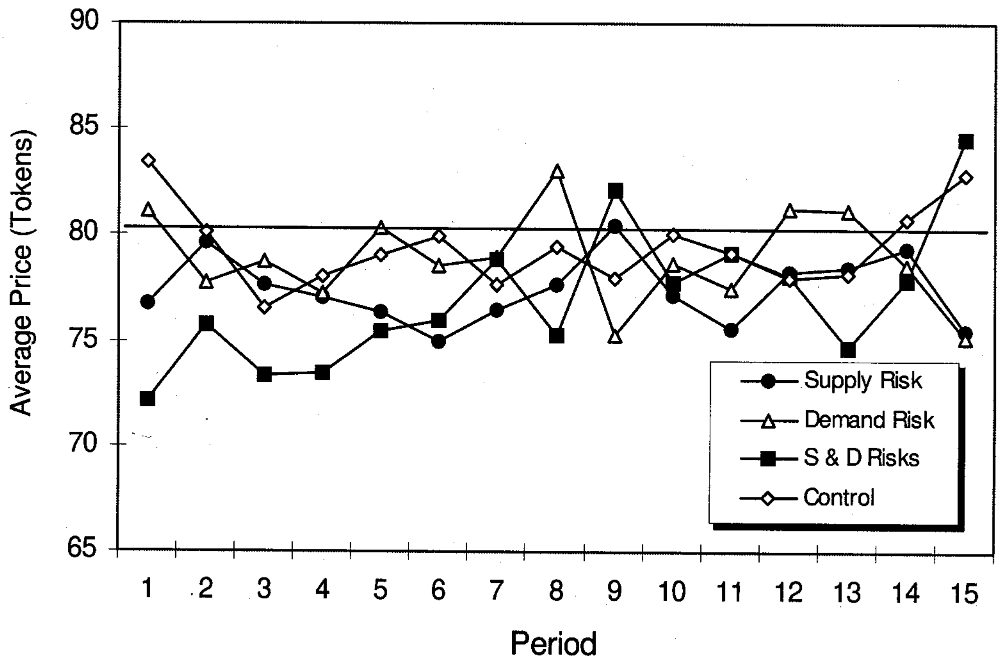

Figure 4. Spot market: Average prices across quantities traded and replications

risks), than in the forward market, which range from 1.63 (supply and demand risks) to 10.80 (demand risk).[3]

Economic theory predicts a price in the forward market in a forward/spot setting without risks to be near the competitive equilibrium (80 tokens), a result that is supported by the laboratory markets. Prices in the forward market under all treatments are not significantly different from the competitive equilibrium price. Theory also predicts an overall higher price in the forward market when there is supply risk in the forward market. The forward price observed from the laboratory markets in the supply risk treatment is the highest among all risk treatments, but not significantly different from prices in other treatments. The costs associated with demand risk, as per theory, entice buyers to bid lower prices in the forward market, which is a tendency observed in the laboratory market.

Quantities Traded

Average total quantities traded for the combined forward and spot markets across replications for each treatment range from 20 units in the supply and demand risk treatment to 23.7 in the supply risk treatment, for periods 11–15. This range is consistent with the predicted competitive equilibrium of 20 to 24 units. The majority of trades, approximately 80–90%, are made in the forward market, regardless of the risk treatment (figure 5). Approximately 18 to 19 trades are made in the forward market, and only about two to three units are traded in the spot market. Average quantities traded across the treatments are not significantly different in either the forward market or the spot market (based on results of Duncan's multiple-range test, not reported here).

Interestingly, the proportion of trades in the forward market of the demand risk treatment are greater than the proportion of forward trades in the no-risk treatment for the latter periods. Theory would suggest that under demand risk in the forward market, buyers should be prompted to move more trading to the spot market, at least at predicted competitive equilibrium prices. An explanation for our finding is that sellers must be willing to accept lower prices from buyers in the forward market to avoid the price risk in the spot market.

There is a general tendency for quantities traded in the forward market to be lowest, although not statistically significant, in the supply and demand risk treatment relative to other treatments, as predicted by theory (table 1). Average quantities traded in the forward market across replications for each treatment are depicted in figure 6. Average forward quantities range from 17.8 in the supply and demand risk treatment to 19.3 in the supply risk treatment, but are not significantly different across treatments.

The variances in total quantities traded across all replications are 3.11 for the supply risk and 2.41 for the supply and demand risk treatments, as compared to 1.41 for the control and 1.31 for the demand risk treatments.[4] The higher variances under supply

[3] Trade prices in the forward market exhibit significantly (F-test, $\alpha = 0.10$) greater variances in the control treatment than in the supply risk and the supply and demand risks treatments. Variances in prices in the spot market are significantly greater in each of the risk treatments, as compared to the control or no-risk treatment.

[4] The F-test was used to test for equality of pairwise variances (calculated over replications and periods 11–15) in total quantities traded by treatment. The variances in units traded in the supply risk and the supply and demand risks treatments are among the largest from any treatment. Each, in fact, is significantly larger than the variances in units traded in both the demand risk and no-risk treatments. This result is consistent with the behavior of sellers responding to differences in costs in their production decisions for the spot market.

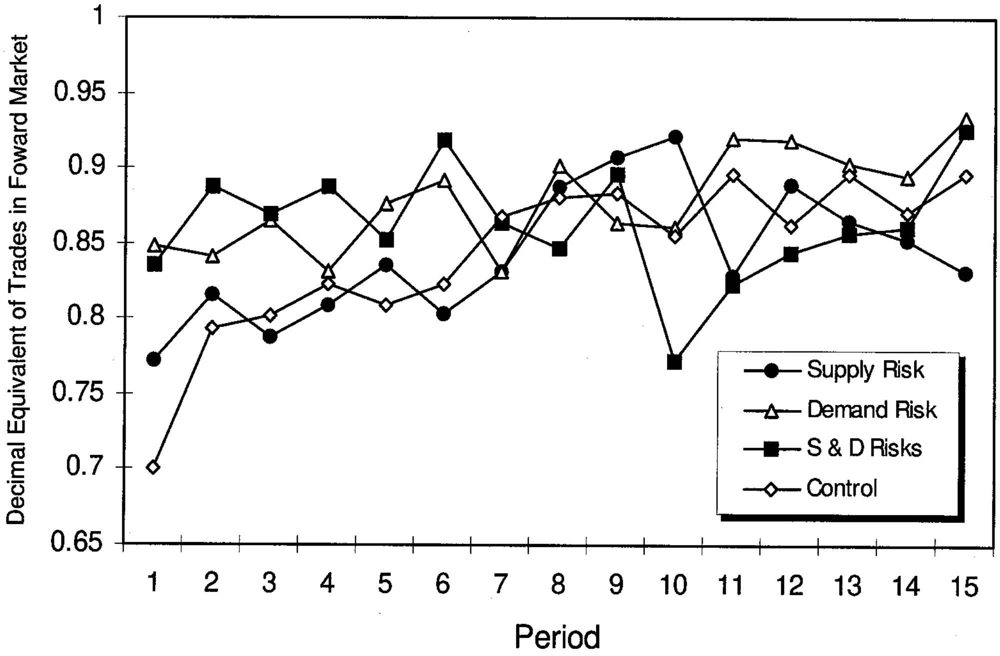

Figure 5. Combined forward and spot markets: Percentage of trades in the forward market

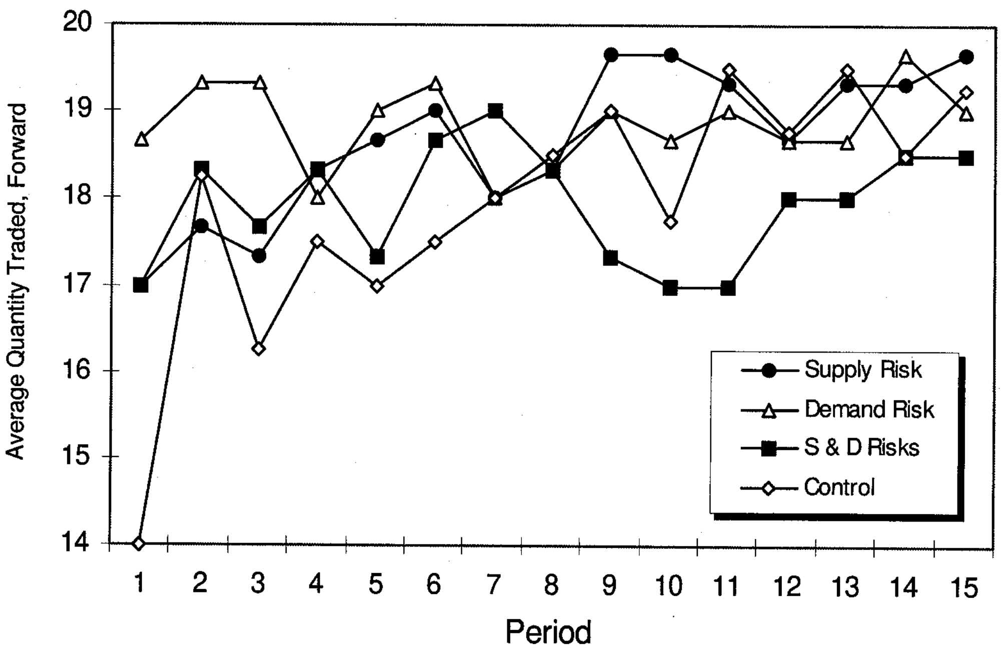

Figure 6. Forward market: Average quantities traded across replications

risk are likely due to the opportunity for sellers to adjust their production decisions for sale in the spot market depending on the nature of cost, which is revealed to them after trading in the forward market.

Earnings

Random shifts in unit values and/or unit costs are a source of earnings variability in the test treatments. This source of variance must be removed in order to compare the earnings data across treatments. An adjustment to earnings can be calculated by multiplying the amount of the shift parameter for cost and/or resale value by the average (across replications) quantity traded in the market period. This adjustment factor then can be added to or subtracted from the unadjusted or observed total earnings to obtain adjusted earnings.[5]

Average adjusted buyer earnings and average adjusted seller earnings for periods 11–15 are illustrated in figures 7 and 8, respectively. Adjusted buyer earnings in each of the test treatments are higher than in the control treatment. Treatments exhibiting uncertain demand yield the highest adjusted earnings for the buyer. Adjusted seller earnings, in contrast to buyer earnings, are lower for each of the test treatments, as compared to the control treatment. These results follow from the relative prices among the treatments. Prices are lower in the test treatments in both the forward and spot markets as compared to the control. This provides a price advantage to the buyer. Thus, relative earnings are higher for buyers when there are supply and/or demand risks in the forward/spot trading institution.

Results of Duncan's multiple-range test for buyer and seller adjusted earnings by treatment are reported in table 4. Mean adjusted buyer and seller earnings across replications for periods 11–15 range from 130.92 tokens for the seller in the supply and demand risks treatment to 166.82 for the buyer in the supply and demand risks treatment. Buyer adjusted earnings are not significantly ($\alpha = 0.10$) different for any treatment. This also is the case for seller adjusted earnings. For corresponding treatments between buyers and sellers, buyers earn significantly more than sellers in both the supply and demand risks and the demand risk treatments.[6]

An interesting pattern emerges in the distribution of earnings between buyers and sellers when supply and demand risks are incorporated into the experiments. Earnings

[5] An example of the calculation of adjusted average earnings follows. The shift parameters for periods 11–15 in the first replication of the uncertain demand treatment are 7, –10, 3, 1, and –1. The total adjustment due to the random shift is the shift parameter times the quantity traded during the respective period, or 7×21, -10×19, 3×21, 1×23, and -1×20 (giving 147, –190, 63, 23, and –20). These are the correction factors. The adjusted total earnings for each period are the unadjusted or observed total earnings minus the correction factor, or 1,217 – 147, 890 + 190, 1,233 – 63, 1,223 – 23, and 1,150 + 20 (giving 1,070, 1,080, 1,170, 1,200, and 1,170). The average correction factor for buyer earnings is the total adjustment in each period divided by four (the number of buyers): 36.75, –47.50, 15.75, 5.75, and –5. Adjusted buyer earnings are the observed buyer earnings in each period minus the respective average correction factor for buyer earnings (210 – 36.75, 140.25 + 47.50, 191.75 – 15.75, 192 – 5.75, and 169 + 5).

[6] The F-test was used to test for equality of pairwise variances (calculated over replications and periods 11–15) for adjusted buyer and seller earnings. The variances in earnings range from 74.59 for the buyer in the supply risk treatment to 513.43 for the seller in the demand risk treatment. The variance in adjusted earnings for the buyer is significantly ($\alpha = 0.10$) higher in the demand risk treatment than in the supply risk treatment. The variance in earnings for the seller is significantly higher in both the demand risk and no-risk treatments than in the supply risk and the supply and demand risks treatments. For corresponding treatments, the variance in seller earnings is greater than that for the buyer in the demand risk treatment, and the variance in buyer earnings is greater than the variance in seller earnings in the supply risk treatment.

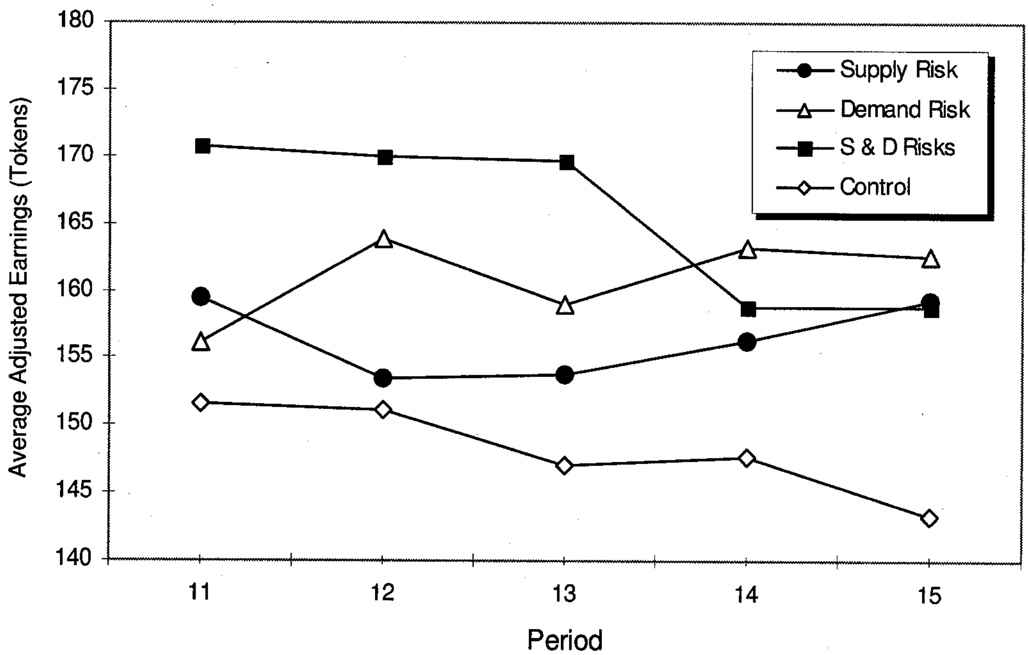

Figure 7. Combined forward and spot markets: Average adjusted buyer earnings, periods 11–15

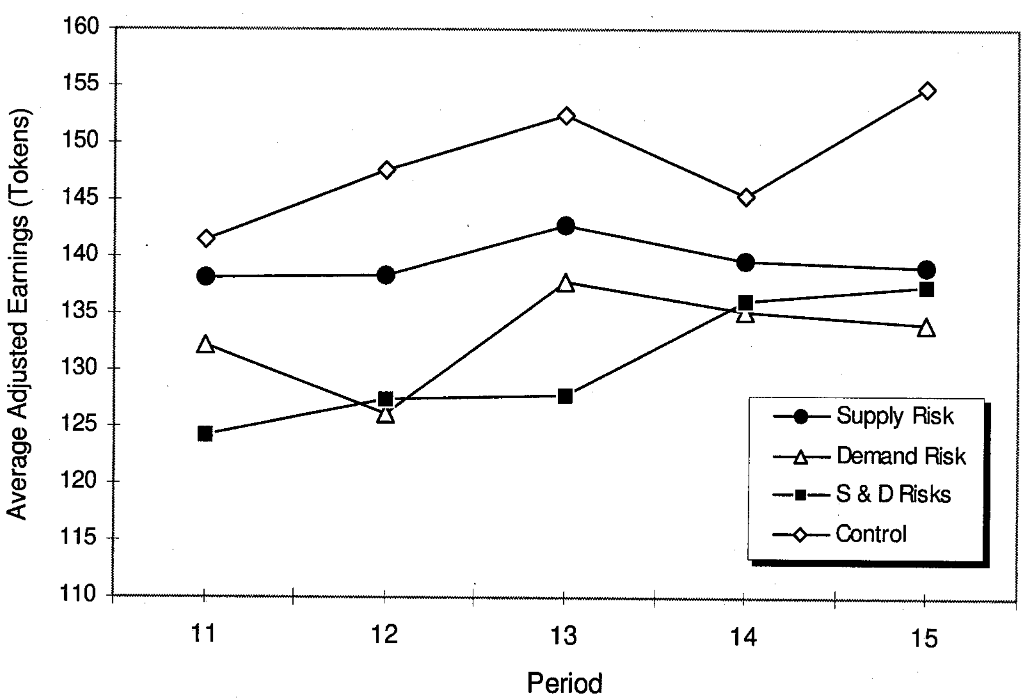

Figure 8. Combined forward and spot markets: Average adjusted seller earnings, periods 11–15

Table 4. Results of Duncan's Multiple-Range Test for Buyer and Seller Adjusted Earnings by Treatment in the Forward/ Spot Markets, Periods 11–15

Buyer (B) or Seller (S)	Treatment	Mean Adjusted Earnings*
B	Supply & Demand Risks	166.82 [a]
B	Demand Risk	161.42 [ab]
B	Supply Risk	156.47 [ab]
S	Control	148.35 [abc]
B	Control	148.15 [abc]
S	Supply Risk	141.82 [bc]
S	Demand Risk	133.08 [c]
S	Supply & Demand Risks	130.92 [c]

*Means with the same superscript alphabetical letter are not significantly different at the $\alpha = 0.10$ level.

for buyers and sellers are about equal with no supply and demand risks. Earnings for buyers increase, as compared to the control treatment, when there is supply risk, although the difference in earnings between buyers and sellers is not statistically significant. The share of total earnings which goes to buyers increases even more when there is demand risk, as compared to supply risk, and is highest when both supply and demand are uncertain. Seller earnings are about 22% lower than buyer earnings for supply and demand risks, and about 12% lower when there is no risk. These experimental results suggest that the buyer benefits from risks at the expense of the seller.

A question arises as to why buyers benefit to such an extent from demand risk. The explanation likely is due to the additional price risk faced by sellers in the spot market. It is important to recognize that sellers face this price risk regardless of risk treatment. Sellers respond by accepting lower prices in the forward market because they wish to reduce the price risk in the spot market. Krogmeier et al. report a tendency for prices in a forward market to converge to levels lower than those in a spot market when there is no other risk and no endogenous choice in market institution. When buyers face uncertain redemption values, they likely respond by lowering their bids. The desire by sellers to reduce price risk in the spot market works to the advantage of buyers when submitting lower bids due to demand risk. Thus, sellers appear to be willing to offset price risk in the spot market, particularly when faced with other risks, by trading in the forward market and taking less earnings relative to the buyer.

Total adjusted earnings range from 1,178.01 in the demand risk treatment to 1,193.13 in the supply risk treatment. Total possible earnings are 1,200 tokens; thus 98–99% is obtained by buyers and sellers. Total adjusted earnings are not significantly different across treatments (based on results of Duncan's multiple-range test, not reported here). Efficiency of the market therefore is not affected significantly by the random shifts in supply and/or demand.

Summary and Implications

Trading in the forward market dominated over spot market trading when agents were given the choice of participating in a forward market and/or spot market. This occurred even in the presence of supply and/or demand risks in the forward market. These risks were incorporated into laboratory markets by randomly shifting the supply and/or demand schedule(s). Approximately 80–90% of the trades were made in the forward market regardless of the risk treatment. There seem to be incentives for both buyers and sellers to avoid the risks associated with production and price in the spot market, even when there are risks in the forward market.

There were no significant differences in trade prices or quantities traded across risk treatments in either the laboratory forward or the spot markets in the forward/spot design. Variances in prices in the spot market were significantly greater in each of the risk treatments than in the control treatment. When supply (cost) risk was present, the variance in units traded was significantly greater than when this risk was not incorporated into the experiments.

Random supply and/or demand did not significantly affect the efficiency of the market, as judged by the total earnings after adjusting for the random supply and demand shifts. Between 98% and 99% of the total possible earnings was obtained by the buyers and sellers in the alternative treatments. Adjusted earnings were not significantly different across treatments for buyers or sellers. When buyer earnings were compared to seller earnings, buyer adjusted earnings tended to be higher than earnings for sellers, and were significantly higher in both the supply and demand risks and the demand risk treatments.

The results of the experiments conducted in this study suggest that the current trend toward increased forward contracting in food markets will continue and likely will become more prevalent. The distribution of buyer and seller earnings tends to favor the buyer, particularly under demand risk, when there is endogenous choice between forward and spot markets. Consequently, there is likely to be increased pressure to monitor firm behavior in the food industry. While the trend toward more forward contracting may be justified in terms of risk management and efficiency, seller earnings may be reduced.

Issues related to structural change, including the impacts of forward contracting and price risk, are increasingly important in agricultural markets. It is difficult, however, to determine the impacts of either increased forward contracting or price risk in naturally occurring markets. The specific terms of forward contracts are often unavailable. The effects of confounding and uncontrollable factors influencing prices in observed market data are not easily separated. Laboratory experiments in economics offer an approach to gather data that may not otherwise be available. Control in obtaining data can be maintained when using experimental techniques, and thereby reduce confounding influences of factors determining price and quantity.

A shortcoming of this approach, however, is the limited number of treatments that can be examined, and hence laboratory results come from a simplified version of what occurs in real-world markets. All relevant features of real-world markets are difficult to duplicate in a laboratory setting, or any economic model for that matter. Despite this weakness, experimental methods in economics can reveal basic agent behavior in a controlled environment and can contribute to an understanding of a real-world phenomenon. Issues such as information asymmetry, equity, and market efficiency—which are likely to become more prevalent as agricultural markets evolve to an increasingly forward-contract-dominated environment—may warrant analysis using experimental techniques.

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