Journal of Agricultural and Applied Economics, 32,1(April 2000):159–173

Supply and Demand Risks in Laboratory Forward and Spot Markets: Implications for Agriculture

Dale J. Menkhaus, Chris T. Bastian, Owen R. Phillips, and Patrick D. O'Neill

ABSTRACT

Laboratory experimental methods are used to investigate the impacts of supply and/or demand risks on prices, quantities traded, and earnings within forward and spot market institutions. Random demand and/or supply shifts can be as much as 25 percent of the expected equilibrium outcome. Nevertheless, results suggest that the spot or forward trading institution itself has a greater influence on market outcomes than the presence of risk within the trading institution. Sellers tend to have relatively higher earnings in a spot market than buyers, regardless of the risk. Total surplus, however, generally is greater in a forward market.

Key Words: *laboratory markets, forward market, spot market, supply and/or demand risks.*

Institutional Description

Concerns about risk management in agriculture have been heightened by changes in the 1996 farm legislation that are designed to reduce agricultural subsidies and decouple government income payments to producers from market prices and production. In place of government guarantees, forward contracts are a well-known means by which to mitigate price risk, and are becoming increasingly common in agriculture (Barkema, Drabenstott, and Welch; Boehlje). One effect of increased forward trading is fewer trades in the spot or cash market. The spot market becomes thin. It is not obvious that forward contracting, when there is risk, is better than spot trading for buyers and sellers as a group. Our work shows that sellers fare better, in the sense that earnings are higher, when they trade in a spot market, and this happens in spite of large random moves in demand and costs. This paper empirically describes the behavior of agents facing alternative sources of risk in forward and spot market institutions.

The literature sometimes refers to a forward market, in its simplest form, as production-to-demand. That is, price and quantity are determined before production is completed. The seller in such an institution faces risk because costs at the time of the agreement may

Dale J. Menkhaus is professor, Department of Agricultural and Applied Economics, Universiy of Wyoming. Chris T. Bastian is extension marketing specialist, Department of Agricultural and Applied Economics, University of Wyoming. Owen R. Phillips is professor, Department of Economics and Finance, University of Wyoming. Patrick O'Neill is a former graduate student, Department of Agricultural and Applied Economics, University of Wyoming.

This research has been supported by the U.S. Department of Agriculture under contract 96-35400-3859. The findings and conclusions expressed in this paper are those of the authors and do not necessarily reflect the views of the funding agency.

be random. The buyer also faces risk in a forward market. A food processor, for example, as a forward buyer has locked in the input price but still faces an unknown final demand schedule. Hence forward contracting is never risk free for agents in the market. This risk is different than that experienced by buyers and sellers in a spot market.

In a traditional spot market costs and final demand are known, but the price and quantities exchanged are not known in advance of the trade time. The spot market is a cash-and-carry institution. The literature refers to it as a *cash market* or *advance production.* Before trades are made the production is held in inventory. The spot supply schedule is perfectly inelastic when there is no inventory carryover. Thus, no more than what is produced can be sold, and sellers may suffer the loss of unsold inventory or take losses on units sold at prices below their cost of production. Therefore, inventory generates risk for the seller. This risk is a significant issue for those producing nonstorable commodities such as livestock, fruits, vegetables and fluid milk.

The objective of this research is to compare the impacts of supply and/or demand risks within forward (production-to-demand) and spot (advance production) markets as distinct trading institutions. That is, the effects of random movements in supply and demand are assessed in a forward-only market and also in a spot-only market. Attention is directed toward measuring the impacts of alternative sources of risk on relative trade prices and quantities traded in these two market types. We collect data from computerized laboratory markets. A laboratory approach is warranted because data from many forward and spot transactions in naturally occurring markets are unavailable. Moreover, it would be difficult to isolate and analyze the impacts of alternative sources of risk from data in natural markets, because outcomes can result from a variety of uncontrolled and interacting factors, making it difficult to identify the influence of one factor.

We begin with the premise that all features of the real-world cannot be incorporated into an economic model or duplicated in a laboratory setting. Thus, we recognize that the study of the forward and spot markets in isolation simplifies the actual marketplace. Moreover, our basic definitions of forward and spot institutions do not strictly conform to those in naturally occurring markets. There are, for example, many varieties of forward contracts, and inventory carryover is possible in some spot markets. The intent, however, is to initially observe behavior in a very controlled setting that captures the essential features of spot and forward trading and the behavior of economic agents trading in these institutions. This approach also allows us to obtain baseline results that can be compared with field data or other experimental designs that add selected elements of naturally occurring markets. The tradeoff for realism is control, which is the strength of any laboratory approach.

Theoretical Considerations

We believe the expected value-variance framework (Robison and Barry) provides a useful analytical tool to investigate the theoretical impacts of alternative sources of risk on market behavior, when the supply and demand schedules have a stochastic distribution. Conditions for optimum quantity (q) and equilibrium price (p) for a buyer and seller facing alternative sources of risk in a forward and a spot market, along with the certainty state, are presented in the Appendix.

The direction of the predicted price for the risk-averse agent under alternative risk scenarios, as compared to the certainty case, depends on whether the seller or buyer incurs a cost associated with the source of risk. A random supply schedule, based on the model presented in the Appendix, should prompt higher prices in both the forward and spot markets for risk-averse agents, compared to when supply is certain. This results from an increase in the marginal cost due to the added cost of risk for each seller.

If there are random shifts in the demand schedule, then in a forward market the predicted price equilibrium is below that in the case of certain demand. Demand, which is modeled as a factor demand, decreases because of the additional cost of risk faced by

Table 1. Summary of the predicted effects of supply and/or demand risks on price and quantities traded by type of market institution and source of risk for risk-averse agents

		Predicted Effect Relative to Certain Equilibrium (Base)	
Institution	Source of Risk	Price	Quantity
Forward	None	Base	Base
	Supply	↑	↓
	Demand	↓	↓
	Supply and Demand	?	↓
Spot	None	Base	Base
	Supply	↑	↓
	Demand	?	↓
	Supply and Demand	?	↓

?—Indeterminate due to differences in risk preference between buyers and sellers, and relative variances in supply, demand, and/or spot prices.

each buyer. Forward trade prices in the case of both random demand and supply shifts are dependent on the relative risk preferences of buyers and sellers and the relative variances of the supply and demand shocks and are therefore indeterminate.

The impacts of random demand on trade prices in a spot market are indeterminate according to the model. The results depend on the relative magnitudes of added costs associated with risk of inventory loss for the seller and demand risk for the buyer, which depends on relative risk preferences of buyers and sellers. The market price depends on the relative decreases in supply and demand resulting from the costs of risk to the seller and buyer, respectively. Predictions of relative prices between forward and spot markets in the presence of risk also are difficult, again because of the dependence on the relative risk attitudes of agents and the relative variances due to supply and/or demand risks. The possibility of an added cost due to the risk of loss in the spot market, however, should prompt higher prices under supply risk in the spot market for risk-averse agents compared to prices in the forward market with supply risk.

Quantities traded under all risky scenarios, including risk of loss in the spot market, are expected to be less than those under the certainty state for risk-averse decision makers, because of the costs associated with risk. The added risk of inventory loss in the spot market should prompt lower quantities in the spot market under the random supply scenario, compared to the forward market with random supply. Table 1 presents a summary of the predicted effects of risk on prices and quantities traded in forward and spot institutions under alternative risk scenarios as suggested by the theory presented in the Appendix 1.

Experimental Methods and Procedures

Laboratory experimental methods (Plott; Smith) are used to investigate differences in trade prices and quantities traded under alternative sources of demand and supply risk in a spot market and a forward market. A separate forward laboratory market and a spot laboratory market with fixed supply and demand schedules are two control treatments. We then undertake (1) random supply, (2) random demand, and (3) both random supply and demand test treatments for the two market institutions. The basic design of the experiments follows that used by Krogmeier *et al.* and is summarized in Figure 1.

Three replications were conducted for each of the control and test treatments. Thus, 24 laboratory market sessions were completed. Consistent with previous studies (Krogmeier *et al.*; Mestelman, Welland and Welland; Noussair, Plott, and Reizman) four buyers and four sellers participated in each market session. Trading in each of these sessions was

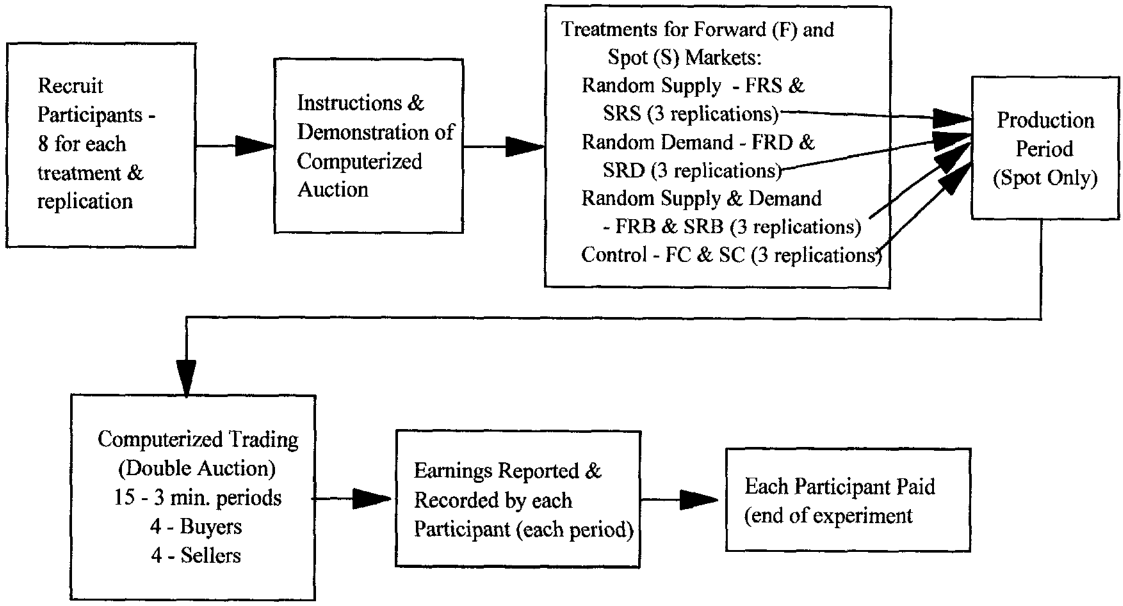

Figure 1. Mechanics of the experiments

conducted for 15 three-minute periods. Participants were not told the number of periods over which trading would occur, to mitigate the possibility of "unusual" behavior in the last periods. Fifteen periods were deemed sufficient to maximize subject experience, learning, and the chances of behavior settling down into a stable pattern. The trading mechanism, identical under all treatments, was a double auction. This trading mechanism has been used extensively in laboratory research and does not require a large number of participants to generate competitive outcomes (Davis and Holt). A total of 192 students recruited primarily from economics and business classes participated.

The double auction trading mechanism provides a means of price discovery, which is informationally richer than other trading mechanisms encountered in naturally occurring agricultural markets (Krogmeier *et al.*). Moreover, this type of trading mechanism is at odds with the individual seller being a price-taker (posted-bid auction) which characterizes exchange in some agricultural markets, and private negotiation which is the primary method of trade in other markets. The use of the double auction, however, serves two purposes. First, the double auction is an efficient and thoroughly documented trading institution, thus providing a baseline for future work exploring other trading institutions. Second, initial use of the double auction provides for better control, in that we are better able to isolate the interaction of market institution and risk without incorporating yet another influence, e.g., possession of market power, which has the potential of confounding the results. Differences observed in behavior under alternative risk scenarios would likely be even more prevalent in other trading institutions, such as private negotiation, than in the double action trading mechanism. This, however, is an empirical issue.

Buyers participating in the forward and spot control treatments were privately given a table which listed the maximum redemption (resale) values for each unit purchased; these values were described to buyers as unit values. Sellers were similarly provided with unit costs for the control treatments. Earnings were denoted on a monetarily convertible currency called *tokens*, with 100 tokens equaling $1.00. Unit values and unit costs were identical for each buyer and each seller, respectively. The unit values and production costs used in each

Table 2. Unit values and unit costs (tokens) for the control treatments

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

of the six sessions in the experiment are listed in Table 2. Each buyer was allowed to purchase, one at a time, up to eight units during each trading period. The first unit purchased in each period was the highest valued unit, the second unit purchased was the second highest valued unit, and so on. Likewise, each seller was allowed to produce and sell, one at a time, up to eight units in each trading period. The first unit produced (sold) was the lowest cost unit, the second unit produced (sold) was the second lowest cost unit, and so on.

Each trading period under the forward market began with a computerized double auction. After a round ended, the computer automatically calculated the earnings of the traders. Production was never greater than the number of units traded. Under the spot market, each trading period began with a production phase, during which each seller chose the number of units he or she wished to produce for that particular period. The production cost associated with these units was incurred before trading began, reflecting the advance production nature of a spot market. Trading in a double auction followed the production phase, identical to that used in the forward treatment. Sellers were allowed to sell only the number of units which they had produced, that is, no inventory carryover from one trading period to the next was allowed. The cost of any unit not sold in a particular period, therefore, represented a sunk cost or a risk of loss to the seller.

Relying upon induced value theory (Smith 1976, 1982), the values and costs listed in Table 2 constitute individual supply and demand for each trading period. When summed horizontally (over four sellers and four buyers) competitive price theory predicts an equilibrium price of 80 tokens and units traded between 20 and 24 units per period, as shown in the Appendix. This is the equilibrium for stable demand and supply conditions and represents a baseline against which we can compare behavior when the supply and demand schedules become random.

Earnings for a buyer on each unit purchased equaled the redemption value of the particular unit less the price paid to the seller. Earnings for a seller on each unit sold equaled the price received by the seller less the production cost of the particular unit. Earnings accumulated over the sequence of trading periods were displayed to each participant on his or her computer system at the end of each trading period. At the conclusion of each session, participants were paid the cash equivalent of these earnings.

Treatments incorporating random demand and supply allowed unit resale values, unit costs, or both, to vary by a random amount as explained in the Appendix. Participants facing risky resale values and/or costs were told that these values could range between high and low values of ± 10 from the amounts displayed on their record sheets. Subjects were informed that the actual cost and resale value amounts would be chosen randomly by the computer, and had an equally likely chance of taking an integer within the 21-token range. The entire schedule for the seller or buyer shifted by the random adjustment (or shift parameter) selected by the computer.

Each participant was given an initial token balance of 700 ($7.00) at the beginning of a session. This initial balance was deemed necessary in the spot markets, since sellers had to incur production costs before being given the opportunity to earn profit from sales. An additional concern was that the initial endowment should be large enough to preclude the possibility of individual bankruptcy early in the session. This was a concern for sellers in the spot market, where a failure to sell could result in large losses. In order that symmetry between buyers and sellers and across treatments be maintained, the initial balance was given to all participants under all treatments. The average individual earnings over all market experiment sessions was $28.32. Participants spent between two and two and a half hours in a session. This included an instruction and demonstration period before actual trading. Different redemption and cost values were used in the demonstration sessions than in the actual trading sessions.

The double auction in each trading period continued for a maximum of three minutes, which was ample time to conduct all trades desired by participants. At the conclusion of each trading period, each subject's screen showed his or her purchase (sale) prices and earnings on each unit purchased (sold). Also provided was the average price paid (received) for all units exchanged by the participant. The individual's beginning balance, total earnings for the period, and ending balance (denoted in both tokens and dollars) also were summarized. For the purpose of reinforcing the saliency of the reward structure, participants were asked to record this information on record sheets at the conclusion of each trading period.

Results

The experiments yielded observations on trade prices, quantities traded, and earnings by sellers and buyers. These data are summarized graphically and analyzed. Our statistical tests compare the different treatment means for prices, quantities, and earnings. The null and alternative hypotheses for treatments i and j are

$$\text{Ho:} \quad \mu_i = \mu_j \quad \text{for all } i \neq j$$

$$\text{Ha:} \quad \mu_i \neq \mu_j \quad \text{for all } i \neq j.$$

These 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. Duncan's multiple range test is used in this study. The 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).[1]

Trade Prices

Graphical representations of mean average trade prices for each trading cycle and the three treatments in the forward and spot markets are illustrated in Figures 2 and 3, respectively. Prices during the initial periods in both the forward and spot markets, under all treatments, exhibit considerable variability. Two price series, notably forward-random supply (FRS) and spot-random both supply and demand (SRB), do not appear to stabilize at a consistent level until after nine or ten trading periods. Prices, in general, are relatively more stable during the latter five cycles. These tendencies likely reflect a learning phenomenon by traders as the experiment proceeds (Friedman and Sunder, p. 30).

Prices for each treatment in the forward market, except for those generated in the random supply treatment (FRS), stabilize at prices slightly below the predicted competitive equilibrium of 80 tokens. We would expect from the theory that the risk associated with random demand in the forward market (FRD) will reduce price. Buyers facing demand risk are more conservative in their bids. Also, the theoretical model predicts prices to be higher under supply risk (FRS), which is consistent with the trends illustrated in Figure 2. In general, however, there does not appear to be much difference in prices among the treat-

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[1] Risk attitudes of each individual participating in the test treatments were assessed through a self-administered choice experiment. Each game involved a choice between an Option A which yielded $2.50 with certainty and a risky Option B that paid either $5.00 or $0.00. Option B differed from the certainty option (Option A) in that the probability of winning $5.00 increased monotonically from 10 percent in the first choice game to 90 percent in the ninth game. The payoff was determined randomly by first choosing the game and then the payment for Option B (either $0.00 or $5.00). Average risk attitude scores for sellers and buyers over the three replications for each treatment ranged from 4.75 (slightly risk seeking) to 6.42 (risk averse). Risk attitude scores for all participants in the experiments resulted in an overall mean of 5.43, suggesting a tendency toward risk aversion.

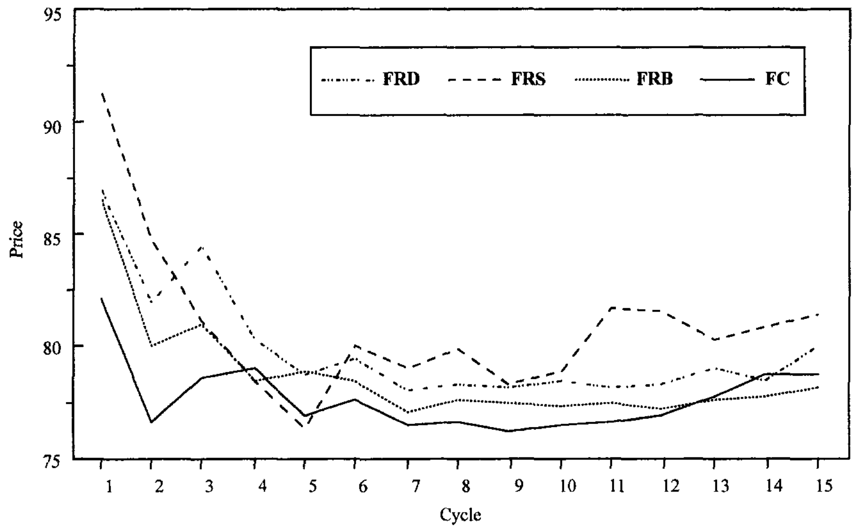

Figure 2. Average price in FRD, FRS, FRB, and FC

ments in either the forward or spot institutions.

Prices in the spot market under all treatments are noticeably higher than those in the forward market (Figures 2 and 3). Spot prices for each treatment appear to asymptotically approach an equilibrium price above the competitive equilibrium. The distinguishing feature of the spot market, compared to the forward, is advance production and the associated possibility of risk of loss faced by sellers if the inventory is not sold. The added cost of this risk, as suggested by the theoretical model, encourages trades at higher prices than in a production-to-demand setting. Buyers recognize that they face a fixed supply and bid at higher prices in the spot market, compared to the forward case.

Duncan's multiple range test was conducted using mean average prices across the three replications from the combined last five trading periods for each treatment. The decision

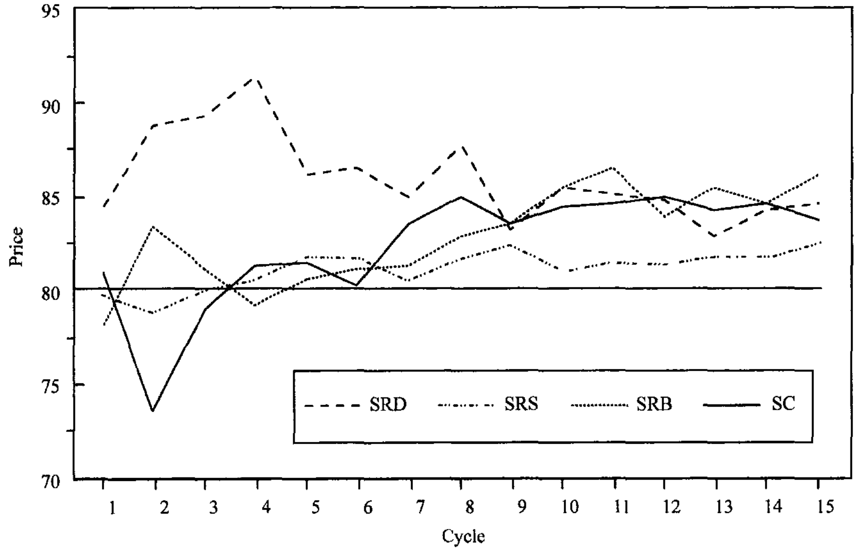

Figure 3. Average price in SRD, SRS, SRB, and SC

Table 3. Results of Duncan's multiple range test for average mean period prices (tokens) by treatment, periods 11–15, three replications

	Treatment Mean Price*			
Trading Institution	Control	Random Demand	Random Supply	Random Both
Spot	84.45[ab]	85.31[a]	81.72[abc]	84.33[ab]
Forward	77.70[c]	78.80[bc]	81.15[abc]	77.59[c]

α = 0.10, d.f. = 16, MSE = 14.16
Critical range of ranked means (number of means): 5.36 (2); 5.64 (3); 5.81 (4); 5.92 (5); 5.99 (6); 6.05 (7); 6.09 (8)

* Means with the same letter are not significantly different.

to use the last five periods for the statistical analysis is admittedly subjective. We justify our decision as follows. The primary purpose for conducting the experiments for multiple periods is to provide agents with the opportunity to learn and to adjust to the incentives created in the experimental markets. This takes time, particularly as agents face rapid and frequent interchange in a computerized auction. We believe time of adjustment is increased when we add random supply and/or demand shifts. The effects of learning and experience can be seen in the behavior of prices in Figures 2 and 3, as previously mentioned. Agents appear to learn relatively quickly during some treatments. Prices, on average, stabilize after about five periods. In some treatments, such as in FRS and SRB, it apparently took agents longer to iterate toward a relatively stable price level. Thus, we chose the last five periods to calculate means for Duncan's multiple range test to maintain consistency across treatments. At the same time, five periods provide ample observations to reduce the effects of any slight aberrations which may have occurred during those periods.[2] Results are presented in Table 3.

Mean average trade prices across all treatments in the spot market are generally higher, ranging from 85.31 tokens in SRD to 81.72 tokens in SRS, than those in the forward market which range from 81.15 in FRS to 77.59 in FRB. Prices generated in the spot markets and prices in the forward market under supply risk (FRS) are not significantly different (α = 0.10) from each other. Prices in all forward market treatments, along with those from the SRS treatment, are not significantly different. Thus, the impact of supply and/or demand risk on prices within the two market institutions does not appear to be overwhelming, as suggested by the graphical analysis.

Spot market prices in all treatments, except for supply risk, are significantly higher than those from the corresponding treatment in the forward market. We believe these differences reflect the importance of the cost associated with risk of inventory loss in the spot market, even when random demand and/or supply shifts can be as much as 25 percent of the expected equilibrium outcome as in our experiments. The presence of supply risk, on the other hand, seems to partially wash out or substitute for the effect of inventory risk, as prices between the spot and forward markets with uncertain supply are almost identical. Supply risk prompts sellers to produce less which reduces the possibility of inventory loss.

Quantities Traded

Average quantities traded during latter periods within each market setting (forward and spot) are consistently lower for treatments involving risk, compared to the control treatments (Figures 4 and 5). This result is consistent with that predicted by theory. The treatments incorporating both demand and supply risks yields the least number of units traded in both the forward and spot markets. Quantities traded in the spot market tend to be lower than those traded in the forward market, particularly for the random supply and demand scenarios. The effects of learning are evident during the early periods for each treatment, but as with prices, quantities traded tend to stabilize during the latter periods. Consistent with the

[2] A Duncan's multiple range test of the means of average trade prices generated over the three replications for periods 1–5, 6–10, and 11–15 reveal no significant (α = 0.10) differences in prices for the latter two groups of periods for all treatments. From a statistical perspective, we could have chosen either the final five periods, the middle five periods, or these two combined.

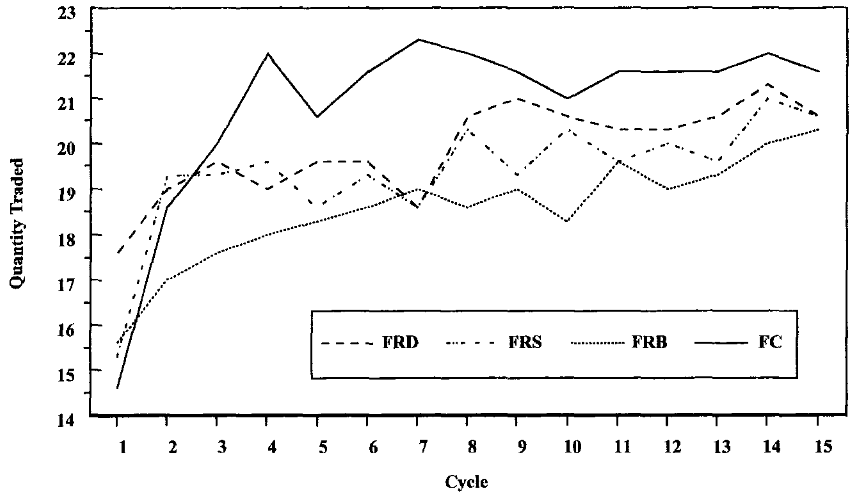

Figure 4. Average quantity traded in FRD, FRS, FRB, and FC

price series, there does not appear to be a great difference in quantities traded for each treatment within a market institution.

Table 4 reports average quantities traded over three replications for periods 11 through 15 combined for each treatment. Units traded range from 21.73 in the forward control treatment to 17.87 in the spot market with both supply and demand risks. Quantities traded, consistent with prices, appear to be more affected by trading institution than by supply and/or demand risks within either the forward or spot market. Average quantities traded in the forward market over the last five periods ranged from 19.67 (FRB) to 21.73 (F Control). Average quantities traded in the spot market over the same period ranged from 17.87 (SRB) to 20.13 (S Control).

The results of Duncan's multiple range test suggest that units traded in the forward market with demand risk (FRD) are significantly ($\alpha = 0.10$) greater than units traded in the demand risk treatment in the spot market (SRD). Similarly, trades are significantly greater in

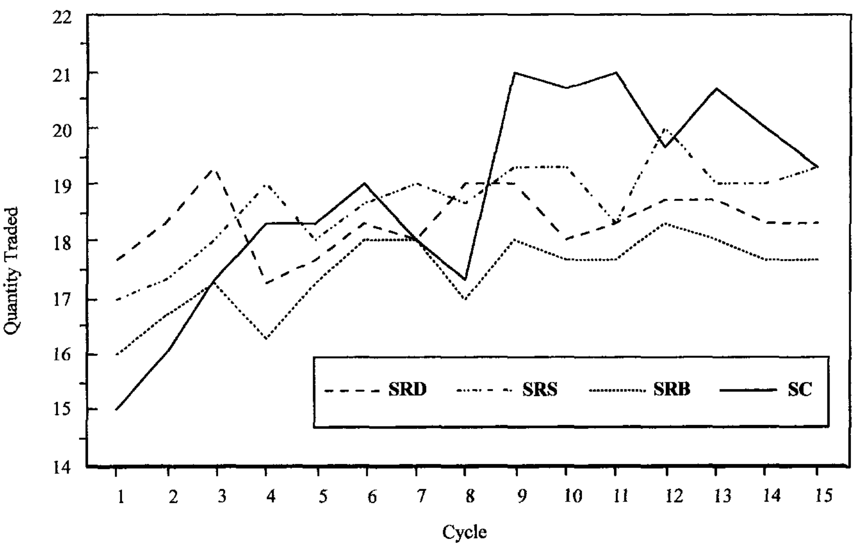

Figure 5. Average quantity traded in SRD, SRS, SRB, and SC

Table 4. Results of Duncan's multiple range test for mean period quantities traded by treatment, periods 11–15, three replications

	Treatment Mean Quantities Traded*			
Trading Institution	Control	Random Demand	Random Supply	Random Both
Spot	20.13[abc]	18.47[cd]	19.13[bcd]	17.87[d]
Forward	21.73[a]	20.67[ab]	20.20[abc]	19.67[bc]

$\alpha = 0.10$, d.f. = 16, MSE = 1.23
Critical range of ranked means (number of means): (2); 1.66 (3); 1.71 (4); 1.74 (5); 1.76 (6); 1.78 (7); 1.79 (8)

* Means with the same letter are not significantly different.

FRB than in SRB. The effect of risk on quantities traded in the spot market in the case of both supply and demand risks (SRB), in fact, is greater than the effects of all risk scenarios on units traded in the forward market. Risk, as indicated in the theoretical models, increases the marginal costs for both risk averse buyers and sellers. This results in lower equilibrium quantities traded under the conditions of random supply and/or demands, as generally observed from the experimental data. The additional cost associated with the risk of inventory loss in the spot market further increases costs and reduces quantities traded (although not significantly), compared to the forward market.

A result which emerges from the analyses of price and quantity data generated from the experiments is that the influence of trading institution is more dominant than the random shifts in supply or demand. That is, there generally is a significantly greater difference in prices and quantities traded between forward and spot markets under corresponding sources of risk than within each institution with different risks. Thus, the cost associated with the risk of inventory loss in the spot market seems to dominate the costs of supply or demand risks, even when demand or supply shifts can be as much as 25 percent of the expected equilibrium outcome. An exception to this general conclusion is the case of supply risk, where the interdependence of the risk of inventory loss and supply risk tends to offset their combined influences.

Buyer and Seller Earnings

A source of earnings variability in the test treatments is due to the random shifts in unit values or unit costs. This source of variance must be removed, in order to compare the earnings data across treatments. Adjusted average earnings can be calculated by determining the average level of the shift parameters over the periods of analysis for each replication and multiplying this by the average quantity traded in the corresponding replication. This total correction factor can then be added to or subtracted from the unadjusted or observed total earnings to obtain adjusted earnings. Average buyer and/or seller earnings can be adjusted by dividing the total correction factor by four.[3] The effects of the random shift variable on total and buyer and seller earnings are reflected in the differences between the unadjusted and adjusted means reported in Tables 5 and 6. Demand and/or supply risk, as expected, contribute to the variation in earnings, as indicated in the comparison of the mean square errors (MSE) for unadjusted and adjusted earnings. The following discussion focuses on the adjusted earnings.

The results of Duncan's multiple range test for the *total* adjusted earnings for buyers and sellers for all treatments are reported in Table 5. Total surpluses in the spot market, in general, are less than in the forward market. Earnings under alternative sources of risk in each

[3] An example calculation of adjusted average earnings follows. The shift parameters for periods 11 through 15 in the first replication of the FRD treatment are 8, −1, 4, 4 and −9, yielding an average of 1.20. The average units traded during the last five periods of replication one of the FRD treatment is 20.20. The total correction factor is 24.24 (20.20·1.20). This means that, on average, demand shifted to favorably influence earnings. Thus, the adjusted average total earnings is unadjusted average total earnings minus the correction factor or 1220.80 − 24.24 = 1196.56. The correction factor for buyer earnings (seller earnings are not directly affected by the random shift in demand) is 24.24 divided by 4 (the number of buyers) or 6.06. Adjusted average buyer earnings for the first replication of FRD for periods 11 through 15 is 161.7 − 6.06 = 155.64.

Table 5. Results of Duncan's multiple range test for mean total period unadjusted and adjusted earnings (tokens) by treatment, periods 11–15, three replications

	Treatment Mean Unadjusted Earnings*			
Trading Institution	Control	Random Demand	Random Supply	Random Supply & Demand
Spot	1147.33^{b}	1127.93^{b}	1191.13^{b}	1125.47^{b}
Forward	1189.33^{ab}	1257.60^{a}	1158.13^{ab}	1166.07^{ab}

α = 0.10, d.f.= 16, MSE = 4117.63

Critical range of ranked means (number of means): 91.50 (2); 96.20 (3); 99.00 (4); 100.90 (5); 102.20 (6); 103.10 (7); 103.80 (8)

	Treatment Mean Unadjusted Earnings**			
	Control	Random Demand	Random Supply	Random Supply & Demand
Spot	1147.33^{bc}	1149.51^{abc}	1170.08^{ab}	1127.25^{c}
Forward	1189.33^{a}	1191.07^{a}	1169.62^{ab}	1164.17^{abc}

Critical range of ranked means (number of means): 37.37 (2); 39.29 (3); 40.45 (4); 41.22 (5); 41.76 (6); 42.14 (7); 42.41 (8)

* Unadjusted mean earnings reflect the effects of the random shift variables for supply and/or demand. Means with the same letter are not significantly different.

** Adjusted mean earnings remove the effects of the random supply and/or demand shift variables. Again, means with the same letter are not significantly different.

market institution as a percent of total possible earnings (1200 tokens) range from about 94 percent in the SRB treatment to about 99 percent in the FRD and F Control treatments. Total earnings in the FRD and F Control treatments are significantly (α = 0.10) higher than earnings in the S Control and SRB treatments. The forward market tends to be more efficient than the spot market regardless of the source of risk. The influence of the combined risks associated with supply and demand, as expected, has the greatest impact on total earnings in each market type, compared to individual supply or demand risks.

Average adjusted earnings for periods 11 through 15 and three replications for buyers and sellers (Table 6) range from 118.03 (buyer–SRD) to 169.30 (seller–SRD). Buyers fare significantly better in the F Control, FRB and FRD treatments than in corresponding spot market treatments. Seller earnings between corresponding market and risk treatments are not significantly different. Sellers fare significantly better than buyers in the SRD, S Control and SRB treatments. Seller earnings, in general, are higher when they trade in a spot market, even when there are large random moves in demand and supply and demand.

Summary and Implications

A key distinction between a spot market and a forward market is the presence of risk of inventory loss in the former market type. The results of this study suggest that this risk, in general, has a greater impact on trade prices and quantities traded than risks associated with variation in supply and/or demand, at least when the two market types are in isolation. Sellers in a spot market seek higher prices for their product, compared to sellers in a forward market, to offset costs associated with the risk of loss. The impacts of this risk also are observed in the form of lower quantities in the spot market relative to the forward. Buyers potentially react to the fixed and inelastic supply in the spot market by increasing competitive bidding and driving prices up (Krogmeier *et al.*).

The analysis of relative buyer and seller earnings across market types for the same treatment suggests buyers tend to fare better

Table 6. Results of Duncan's multiple range test of mean period earnings (tokens) by treatment for buyers and sellers, periods 11–15, three replications

	Treatment Mean Unadjusted Earnings*							
Trading	Control		Random Demand		Random Supply		Random Supply & Demand	
Institution	Buyer	Seller	Buyer	Seller	Buyer	Seller	Buyer	Seller
Spot	123.58^{bc}	163.25^{a}	112.6^{bc}	169.30^{a}	138.47^{abc}	159.32^{a}	121.48^{bc}	159.88^{a}
Forward	159.92^{a}	137.42^{abc}	170.90^{a}	143.50^{abc}	141.62^{abc}	147.92^{ab}	168.27^{a}	123.25^{bc}

$\alpha = 0.10$, d.f. = 32, MSE = 473.04

Critical range of ranked means (number of means): 30.08 (2); 31.74 (3); 32.79 (4); 33.53 (5); 34.08 (6); 34.50 (7); 34.83 (8); 35.10 (9); 35.31 (10); 35.49 (11); 35.63 (12); 35.25 (13); 35.84 (14); 35.92 (15); 35.98 (16)

	Treatment Means Adjusted Earnings**							
	Control		Random Demand		Random Supply		Random Supply & Demand	
	Buyer	Seller	Buyer	Seller	Buyer	Seller	Buyer	Seller
Spot	123.58^{cd}	163.25^{ab}	118.03^{d}	169.30^{a}	138.47^{bcd}	154.03^{ab}	121.53^{cd}	161.27^{ab}
Forward	159.92^{ab}	137.42^{bcd}	154.50^{ab}	143.50^{abcd}	141.62^{abcd}	150.72^{abc}	158.00^{ab}	133.83^{bcd}

$\alpha = 0.10$, d.f. = 32, MSE = 341.40

Critical range of ranked means (number of means): 25.55 (2); 26.96 (3); 27.86 (4); 28.49 (5); 28.95 (6); 29.31 (7); 29.59 (8); 29.82 (9); 30.00 (10); 30.15 (11); 30.27 (12); 30.37 (13); 30.45 (14); 30.51 (15); 30.57 (16)

* Unadjusted mean earnings reflect the effects of the random shift variables for supply and/or demand. Means with the same letter are not significantly different.

** Adjusted mean earnings remove the effects of the random shift supply and/or demand shift variables. Again, means with the same letter are not significantly different.

in the forward market than in the spot market. Seller earnings, on the other hand, are not significantly different between the forward and spot markets under corresponding risk treatments. Seller earnings, however, tend to be higher in the spot market than earnings for buyers in the spot market. The forward market generally is more efficient than the spot market, as measured by the percent of total surplus extracted relative to the total possible surplus.

Structural change and risk are two interrelated issues facing agriculture. Increased forward contracting and higher vertical coordination is occurring in almost all sectors of the food industry. Changes in farm legislation to shift risk bearing from the public sector to the private sector, along with increased globalization, will contribute to increased risk faced by individual agents. The results of this study, at least for the levels of risk associated with supply and/or demand, suggest a greater influence due to structural change issues than from risk. That is, there seems to be a greater impact on market prices, quantities, and earnings between the forward and spot institutions than among the risk sources within an institution type.

Results from the experiments conducted in the study point to several possible implications for agriculture. Overall earnings to buyers or processors will be greater in forward contracting institutions compared to traditional spot markets. This disparity likely will be more prevalent in market institutions which are less efficient than the double auction used in the experiments reported in this study. At cyclical lows in prices, increased political pressure may be brought to bear to regulate forward contracting practices. While sellers would receive better prices in spot markets, the risk of loss compounded by price risk makes the forward market attractive to risk-averse sellers. The trade-off sellers make by doing this is a transfer of wealth from sellers to buyers under a forward contract dominated marketplace, relative to one dominated by spot markets. This will exacerbate the current structural change trends in agriculture and likely will increase concerns of those who oppose the industrialization of agriculture. Thus, while there may be less government in agriculture of the future, there may be need for more regulation. Moreover, end consumers may be better off if the increased surpluses from forward markets relative to spot markets, coupled with larger quantities, are passed on from intermediate buyers.

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APPENDIX

Economic Models Incorporating Selected Risks

Risk was incorporated into our experiments by varying unit costs for sellers (minimum willingness to accept) and/or unit resale values for buyers (maximum willingness to pay) by a random variable. We attach a random component, ϵ and ν respectively, to the unit cost and unit resale value functions that has a uniform distribution (all integers between -10 and $+10$). Thus, the probability distribution of ϵ and ν each is a discrete uniform distribution with mean zero and variance 33.33. Profit maximization conditions for both the buyer and seller under certainty, supply risk, demand risk, and both supply and demand risks in both forward and spot markets are derived from the certainty equivalent of each relevant profit expression [Robison and Barry]. The certainty equivalent of profit is expected risky profit less the risk premium at which the decision maker is indifferent between the risky and riskless alternatives.

Forward Market—No Risk

Seller profit is given by $\pi = pq - C(q)$, where p is price, q is units traded, and $C(q)$ is total cost. The first-order condition for the seller requires $MR_S = p = C'(q) = MC_S$, where MR and MC are marginal revenue and marginal cost, respectively. Buyer profit is given by $\pi = R(q) - pq$, where R(q) is total revenue. The first order condition requires $MR_B = R'(q) = p = MC_B$. The total cost and total revenue equations from the experiment can be used to compute the predicted equilibrium price and quantity for the individual seller and buyer. The total cost equation is $25q + 5q^2$ and the total revenue equation is $135q - 5q^2$. Solving $25 + 10q = 135 - 10q$ yields an equilibrium quantity for the individual agents of $q = 5.5$, and because units must be whole the equilibrium is between 5 and 6 units. Multiplying by four buyers and four sellers results in an equilibrium market quantity of between 20 and 24 units. The equilibrium price is 80 tokens.

Spot Market—No Risk

The spot market, by definition, occurs after the production decision. Thus, there is the possibility for the seller to lose all, or part of, the cost of production (risk of loss). Costs become sunk. Effectively, this is a risk associated with price in the spot market. Expected price in the spot market is $E(p + w) = p$ 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 price cannot be negative. Expected profit is $E(\pi) = pq - C(q)$ with variance $q^2\sigma_w^2$. The certainty equivalent of the profit expression, following Robison and Barry, is $\pi_{ce} = pq - C(q) - [(\lambda_s/2)(q^2\sigma_w^2)]$. The first order condition for the seller requires $MR_S = p = C'(q) + \lambda_S q\sigma_w^2 = MC_S$ and for the buyer is $MR_B = R'(q) = p = MC_B$. The additional cost associated with risk of inventory loss should result in reduced quantity for a risk-averse agent ($\lambda_S > 0$) in the spot market compared to the forward where this risk is not present. Prices in an advance production setting are expected to be higher, relative to a production-to-demand or forward market, because of a decrease in supply resulting from the added cost associated with the risk of inventory loss.

Forward Market—Supply Risk

Expected total cost for the seller with supply risk is $E(C(q) + \epsilon q) = C(q)$, where ϵ is a discrete uniform random variable as previously defined. Expected profit for the seller is $E(\pi) = pq - C(q)$ with variance $q^2\sigma_\epsilon^2$. The certainty equivalent of the profit expression is $\pi_{ce} = pq - C(q) - [(\lambda_s/2)(q^2\sigma_\epsilon^2)]$. The first-order condition for the seller requires $MR_S = p = C'(q) + \sigma_S q\sigma_\epsilon^2 = MC_S$ and for the buyer is $MR_B = R'(q) = p = MC_B$. For the risk averse decision maker, price offered (p) must offset the cost of risk associated with supply risk. In the market, equilibrium quantities traded should be less than those for the risk-free case and prices traded should be higher.

Forward and Spot Markets—Demand Risk

Expected total revenue for the buyer with demand risk is $E(R(q) + \nu q) = R(q)$ where ν is a discrete uniform random variable as previously defined. Expected profit for the buyer is $E(\pi) = R(q) - pq$ with variance $q^2\sigma_\nu^2$. The certainty equivalent of the profit expression is $\pi_{ce} = R(q) - pq - [(\lambda_B/2)(q^2\sigma_\nu^2)]$. The first order condition requires $MR_B = R'(q) = p + \lambda_B q\sigma_2^\nu = MC_B$. The first order condition for the seller is $MR_S = p = C'(q) = MC_S$ and $MR_S = p = C'(q) + \sigma_S q\sigma_w^2 = MC_S$, for the forward and spot markets, respectively. Quantities traded under demand risk in each institution are expected to be reduced. Price is expected to be lower in the case of demand risk for the risk-averse decision maker in the forward market, relative to the risk-free case. The predicted price in the spot market is indeterminate, as it depends on the relative risk preferences of buyers and sellers and the relative magnitudes of variances associated with demand risk and spot price. The first order conditions are identical in both the forward and spot markets for a buyer facing demand risk.

Forward Market—Supply and Demand Risks

The first-order conditions in the case of supply and demand risks in the forward market are as derived above.

Supply (Seller)

$$MR_S = p = C'(q) + \lambda_S q\sigma_\epsilon^2 = MC_S$$

Demand (Buyer)

$$MR_B = R'(q) = p + \lambda_B q\sigma_\nu^2 = MC_B$$

Quantities traded are expected to be less in this case than for the no risk case. Expected price, however, depends on the relative risk preference between buyers and sellers in the market and the relative variances of movements in supply and demand.

Spot Market—Supply Risk

Expected profit for the seller in the spot market with supply risk is $E(\pi) = pq - C(q)$ with variance $q^2\sigma_w^2 + q^{\sigma}\sigma_\epsilon^2 - 2q^2\rho\sigma_w\sigma_\epsilon$ where ρ is the correlation between w and ϵ. The certainty equivalent of the profit expression is $\pi_{ce} = pq - C(q) - [(\lambda_s/2)(\sigma_\pi^2)]$. The first order condition both for the seller requires $MR_S = p = C'(q) + \lambda_S(q\sigma_w^2 + q\sigma_\epsilon^2 - 2\rho\sigma_w\sigma_w) = MC_S$ and for the buyer is $MR_B = R'(q) = p = MC_B$. Quantities traded should be reduced. Price is expected to be higher in this case for the risk-averse agent relative to when there is no supply risk.

Spot Market—Supply and Demand Risks

The first-order conditions for supply and demand risk in the spot market are obtained from relevant derivations presented above.

Supply (Seller)

$$\begin{aligned} MR_S &= p \\ &= C'(q) + \lambda_S(q\sigma_w^2 + q\sigma_\nu^2 - 2q\rho\sigma_w\sigma_\epsilon) \\ &= MC_S \end{aligned}$$

Demand (Buyer)

$$MR_B = R'(q) = p + \lambda_B q\sigma_\nu^2 = MC_B$$

Quantities traded, as in the case of supply and demand risk in the forward market, are expected to be less, compared to the no risk case. Expected price depends on the relative risk preference between buyers and sellers in the market, along with the relative variances in the movement in supply and demand and the variance in spot price.