CONTENTS

NON-TECHNICAL SUMMARY

There are two basic ways in which an intermediate good may be exchanged in a market: (1) a producer may first produce the good and then sell it (advance production or a spot market); or (2) a producer may sign a contract with a buyer first and then produce the good (production to order or a forward market). In market economies commodities are typically traded both in spot and forward markets. Agents can choose whether to transact in the spot market or the forward market or both. In most cases there also exists a possibility to vertically integrate, i.e. to combine a buyer and a seller into one firm.

Most transactions between firms in the former Russian command system occurred in the way similar to intrafirm transactions. Spot and forward commodity markets have been formed only recently or are being formed now. Firms which transact in the spot market, which is just being formed, may be exposed to high risk. This market may be thin or nonexistent in some periods, creating additional costs for the firms which use it. Prices reported from such a market may not be good indicators of true supply-demand situations. As a result, firms making production decisions based on the reported market prices may not use resources in the most efficient manner.

Risks experienced in an infant spot market could be reduced via the use of simple forward contracts, which set the price, quantity, and quality of products to be traded in a future transaction. However, high uncertainty and undeveloped legal and market institutions in the transition economy raise a probability of a partner not fulfilling contractual obligations. Often the contract fails or its fulfillment requires additional transaction costs. The probability of a forward contract failure may have a significant economic effect. If methods of exchange such as open production or spot markets and simple contracts cannot ensure efficient price and quantity discovery and are costly, firms may have a strong motivation to vertically integrate or use integration-like contractual arrangements.

Such consolidation may solve problems in the short term, but in the long term it is unhealthy. Fewer market transactions with intermediate goods lead to inefficiencies, such as underutilization of processing facilities. The old Soviet command system, where whole industries were treated as a single firm, was the ultimate example of vertical integration, and of the inefficiency which it causes.

The objective of this research is to study price and quantity discovery when there is (1) an endogenous choice between alternative market institutions (forward and spot) and vertical integration; and (2) some probability of contract failure in the forward market. This research used models and laboratory experiments to measure how increased risk of forward contract failure reduces trading, pushes agents onto the spot market, and pushes them into vertical integration. The use of laboratory techniques rather than real data was inevitable due to the lack of reliable price and quantity field data on Russian commodity markets. Indeed, this lack is a symptom of the inefficiency of those markets.

Economic models of a competitive risk averse firm were tested in the laboratory setting. The results of the economic models suggest that when there is only a forward market, even a low (5%) probability of contract failure affects the market significantly resulting in a decreased quantity and increased price. Linking the forward market of a good with the relevant spot market reduces the effect of contract failure, if the goods that should have been traded forward after the breach can be retraded on the spot market. However, a high (50%) probability of contract failure decreases quantity traded in the forward market. In the latter case, risk aversion forces both forward and spot prices to increase, with the spot price being higher than the forward price. The models showed a significant worsening when forward failure and spot retrading do involve extra cost. In such a case, although agents still prefer to transact most business on the forward market, there is a major shrinkage in the forward market and growth in the spot market.

These theoretical results were confirmed by the results of 18 laboratory sessions. And applied to Russia, where spot markets are often thin or overpriced, the weakness of forward markets leads straight to vertical integration. Analysis of price, quantity and earnings data generated in the experimental sessions suggest that agents have strong motivation to vertically integrate when forward risk exceeds 5% and there is no linked spot market, or when forward risk exceeds 50% and spot retrading involves extra cost.

This project is one of a few empirical research studies in the transaction cost economics. The project's results emphasize the importance of reliable legal institutions. If legal institutions are not in place to enforce contracts between buyers and sellers in forward trading, a viable spot market is essential. The spot market acts like an insurance mechanism for forward trades and the forward markets remain dominant, even though there may be a possibility of high contract failure.

The results of the study explain reasons for consolidation tendencies observed in Russian food market. Contractual obligations often are not fulfilled (entirely or in part) as a result of some exogenous forces rather than the parties' opportunism. But risk of inventory loss in the evolving spot market, or its thin nature, prevents firms from relying on the spot market instead of the unreliable forward market. As a result, producers have started to expand processing facilities resulting in a significant decrease in agricultural products delivered to specialized processing firms. This creates inefficiencies resulting from plants not being utilized to capacity, and has induced processing firms to often initiate integration-like contractual arrangements. The state food policy supports the vertical integration, without giving attention to the fact that more vertical integration results in less market transactions of an intermediate good. State food policy must be refocused from facilitating consolidation in the food market toward strengthening the legal system and developing the market infrastructure, in order to facilitate making the forward and spot markets in the Russian food sector less risky. This may contribute to the creation of a system which makes resources to move to their most efficient use.

1. INTRODUCTION

Two successive stages in a vertical chain of production and marketing for a good may be connected either through vertical integration (intrafirm exchange), or through a market (interfirm) exchange. There are two basic ways in which an intermediate good may be exchanged in a market: (1) a producer may first produce the good and then sell it, or (2) a producer may sign a contract with a buyer first and then produce the good. The former is called production to stock (advance production) or a spot market; the latter is called production to order or a forward market (Carlton, 1989, p. 941).

The advantages of production to order are straightforward when the product is heterogeneous and a seller needs to know the exact characteristics a buyer desires in the good. But even when a good is homogeneous, both sellers and buyers may want to contract forward to avoid price and quantity risks. The simplest form of a forward contract which sets the price, quantity and quality of a product to be traded in a future transaction is called a market specification contract (Barkema, Drabenstott and Welch, 1991).

In market economies, often both a spot market and a forward market exist for a commodity. In this case agents can choose to transact in the spot market, in the forward market or both. In most cases there also exists a possibility to integrate vertically if the costs of transacting in these markets are too high.

Most transactions among firms in the former Russian command system were similar to intrafirm transactions. Spot and forward commodity markets have therefore been formed very recently or are being formed now. This is why it is particularly interesting and important to study how a firm chooses a marketing channel for its product.

Agricultural and food markets are among those for which such a study may be especially important. In countries with a market economy, for instance the USA, cattle, food and feed grains are traditionally sold mainly spot through so-called “organized markets”. Such markets are thought to provide an efficient method of price discovery, and the price information is widely used to make production and marketing decisions (Tomek and Robinson, 1972; Ward, 1981).

Spot agricultural markets in Russia must evolve in the presence of the dominance of administrative coordination. As a result, firms which transact in the spot market may be exposed to high risk. This market may be thin or nonexistent in some periods, creating additional costs for the firms which use it. One relevant concern is that the prices reported from spot markets which are just being formed may not be good indicators of true supply-demand situations. As a result, firms making production decisions based on the reported market prices may not use resources in the most economic manner (Center for Rural Affairs, 1990).

The risks experienced in the infant open market could be reduced via the use of simple forms of contracts. There is, however, another problem which is very common in the transition economy of Russia. Contract obligations may not be met or fulfilled by the parties, even when a state organization is one of the parties. There is some probability that contractual obligations may not be honored in any economic system. This problem, however, is much more prevalent in the case of a transition economy. In transition economies, legal, state and economic institutions are changing, and this (at least temporarily) reduces the efficiency of the legal system. In this case, it is much easier to break contractual obligations without suffering the consequences. Remedies for contract breach, in fact, could be included in the contract itself (Shavell, 1984). When the economic situation is unstable, as in a transition economy, the probability that a firm might prefer to break a contract and pay the damages is much greater than it is in a stable economic system. Finally, in the transition economy of Russia, delays in payments for goods and services delivered according to a forward contract quite often lead to a reduction in the benefits from the trade. Thus, weak legal and economic institutions may often generate additional costs for those who transact in such a market. The possibility of a contract failure may have significant economic impacts. If methods of exchange such as open production or spot markets and simple contracts cannot provide efficient price and quantity discovery and are costly, firms may have a strong motivation to integrate vertically or rely on integration-like contractual arrangements.

A complete and separate study would be required to estimate the severity of the contract failures in Russia. We can, however, provide data which highlight the importance of the issue of contract failure. About 85% of the milk producers, 75% of the producers of vegetables, livestock and grain and 65% of the sunflower producers have indicated that in 1995 state procurement organizations did not fulfill their contractual obligations with them ("О рынке сельскохозяйственной продукции...", 1996, p. 47). Delayed payments represented about half the value of goods and production services in 1996 ("Рыночные отношения...", 1997, p.57). In a private conversation in 1997 middlemen acting in the wholesale food market indicated that about 50% of the formal agreements about future transactions were not fulfilled. Such a situation necessarily influences a firm's choice of marketing (procurement) channels. Trades in agricultural products at commodity exchanges experienced growth during 1992-1993, but declined significantly beginning in 1994 (Алибеков, Лукинов, 1996). Only 6% of grain, 3% of livestock, 4% of sugar beets, and 17% of sunflower seeds were sold through wholesale markets, commodity exchanges and fairs in 1995. Agricultural producers are expanding their processing facilities. In 1995 producers sold 7% of grain, 54% of sugar beets and 33% of livestock after processing it. Almost one-quarter of producers had processing facilities, but two-thirds of them used only half of the capacity of these facilities because of the shortage of their own raw agricultural products ("О рынке сельскохозяйственной продукции...", 1996, p. 40). Today agricultural and processing firms achieve real cost reduction through long-term comprehensive contractual arrangements which are very integration-like (Хлыстун, 1997). These tendencies toward integration and consolidation may be the result of inefficient price discovery and market coordination systems in Russia. This study is focused on determining the extent to which contract failure contributes to inefficiency.

The objective of this research is to examine price and quantity discovery when there is (1) an endogenous choice between alternative market institutions (forward and spot) and vertical integration, and (2) some probability that a trading partner will not fulfill forward contract obligations (a contract failure). A laboratory experimental economics technique is used, because price and quantity data from open markets (for example, commodity exchanges, wholesale markets and auctions) are unreliable or lacking, and contract price and quantity data are mostly reserved information.

2. A REVIEW OF THE LITERATURE

A comparative analysis of alternative forms of vertical coordination is a primary focus of the transaction cost literature, which suggests that the transition from an open market system toward administrative coordination is set in motion because of the increased costs associated with a price oriented system (Williamson, 1989). Firms which use a spot market to sell their products (or to buy inputs) are exposed to price, quantity and quality risks and, therefore, to additional costs (Barkema, Drabenstott and Welch, 1991).

Several models have explored ways in which a competitive firm's decisions under uncertainty would deviate from those of a firm operating under certainty, and they have also examined the effects of an increase in risk aversion on a firm's decisions (Sandmo, 1971; Leland, 1972). These models show that a firm's response to uncertainty is to adjust its output or input levels. Holthausen (1979) proposes a model in which a risk-averse, competitive firm facing price uncertainty can choose to buy a product in a forward market at a fixed price. The major finding of the study is that the firm will produce a level of output that depends only on the forward price and that is, in particular, independent of the firm's degree of risk aversion and the probability distribution of the uncertain price. Finally, the existence of a forward market will generally induce the firm to produce a greater output than would have been the case in the absence of such a market.

Carlton (1979) has developed an equilibrium model of a market characterized by uncertainty and transaction costs. The model seeks to explain a firm's choice between long-term (forward contract) and short-term (spot) instruments. He shows that in the short and the long run (assuming a downward sloping demand) the magnitude and direction of price movements in the forward and spot markets can differ. In particular, cost shocks will induce price movements in the forward and spot market in the same direction, but by different magnitudes, and the demand shocks cause the two prices to move in different directions. Incidentally, this result raises concern regarding econometric attempts to measure the impact of forward contracting on market prices when the independent variable is some measure of spot prices alone. According to this result it is critical to examine both forward and spot prices in order to evaluate the impact of forward contracting on a particular market. A further implication of this model is that spot prices are more variable in the presence of forward contracts.

Polinsky (1987) addresses the effects of a fixed price contract and a spot price contract on the allocation of risk between parties when at least one of them is risk averse. The results of his theoretical analysis suggest that (p. 43),

> "a spot price contract tends to insure a seller against production-cost uncertainty and a buyer against valuation uncertainty (although it may overinsure them). A fixed price contract insures a seller against demand-side uncertainties and a buyer against supply-side uncertainties. Thus, which contract form will be preferred by the parties depends on their relative aversion to risk and the magnitudes of the supply-side and demand-side uncertainties."

Hubbard and Weiner (1989) construct a similar model. The implications of their model, like those of Polinsky, suggest that changes in contracting behavior can arise from several sources: the attitudes of the contracting parties toward risk can change or the relative importance of supply and demand shocks can shift or both.

Other research has attempted to measure the impact of forward contracting on price levels and variability using market generated data (Hayenga and O'Brien, 1991; Elam, 1992; Schroeder et al., 1993). The results of these studies show that forward contract deliveries may have a negative impact on the average cash price, although this effect is often found not to be statistically significant. The results of these econometric studies are mostly inconclusive and limited by their dependency on historical data and on the actual levels of forward contracting observed.

The first series of laboratory trading sessions utilizing an oral double auction trading mechanism was designed to investigate the validity of several of the hypotheses of neoclassical competitive market theory (Smith, 1962). Later, numerous studies in experimental economics involved the observation of the effects of various trading institutions on market behavior and outcomes. Advance production (spot) markets have received limited attention from experimentalists. In an experiment in which sellers had to commit to producing units before trading in a double auction, Smith (1962) observed that prices tended to converge more slowly (and from below) toward competitive equilibrium. More recent studies have focused on aspects of advance production in double auction or posted-offer markets or both (Mestelman and Welland, 1991a; Mestelman and Welland, 1991b; Mestelman and Welland, 1988; Mestelman, Welland and Welland, 1987).

Differences in efficiencies, quantity produced/traded, and prices in a double auction with advance production and production-to-demand are explored in Mestelman and Welland (1987). Their results suggest that the production condition does not have a statistically significant effect on mean trade prices. However, levels of production and sales and market efficiency were found to be slightly lower in the advance production market relative to production-to-demand.

Experimental studies of price and quantity discovery in a forward market versus spot market were continued by Krogmeier et al. (1996). As in Mestelman and Welland (1987) each of these two markets were separate treatments. However, increased equilibrium quantity per agent in their model relative to that in Mestelman and Welland (1987) permitted the authors to observe that prices converged to a higher behavioral equilibrium under the spot market treatment relative to the forward market treatment.

Phillips, Menkhaus and Krogmeier (1997) studied markets in a laboratory setting in which agents were given a choice of participating in forward and spot trades. The inventory costs or risk of loss incurred due to advance production diminishes spot activity and makes forward trading dominant. In this linked market design, spot sales were about 15% of the total. When there was only a spot market, seller surplus was found to be relatively high; in a forward only market, buyer surplus was relatively high. When traders were given a choice of institution, prices and quantities resembled a forward only auction, but buyer (seller) surplus was decreased (increased).

We are not aware of any studies of the impacts of a contract failure on price and quantity discovery in a forward market, whether in isolation or linked with a spot market. The economics literature discusses the issue of incomplete contracting and opportunism. This literature focuses on transactions which need investments in specific assets and thus which cause a fundamental transformation of an ex ante competitive situation into an ex post bilateral monopoly. Contracts aim at fulfilling two conflicting tasks: (1) reduce risks (including the risk of opportunism), and (2) offer the parties enough flexibility to adjust for unplanned future events (Al-Najjar, 1995). This motivates the parties to use non-price coordination widely (Williamson, 1989).

We do not intend to discuss issues of specific investments. In our study a contract failure is caused not by the opportunism of the parties, but by exogenous factors (for instance, non-payment problems when a processing firm which has not received payment for previously processed products cannot fulfill its obligation of buying a new portion of the agricultural good to be processed). The good is homogeneous, and the market is competitive both ex ante and ex post. We have tried to focus on a situation involving only simple contracts (of a classic type as in Williamson, 1989) in an economy which is very unstable and in which legal and market institutions are only just being formed so that there is some probability that a contract may either (1) fail completely and the respective parties need to make a new trade in the spot market, or (2) the performance of the contract requires some additional cost. The probability of contract failure is determined explicitly.

3. MODEL SPECIFICATION

Although many goods are sold in the spot and forward markets and forward contract failure is a general problem as well, we believe that the model and the experimental design outlined below are more applicable to the food market than to financial markets or even other commodity markets. First of all, we examine a competitive market, which is not the sort of market characteristic of industries with a two-price (forward and spot) system such as the coal or natural gas industries. Likewise, there is no inventory carryover in our model and experiments, and this is consistent with the market for perishables such as many agricultural products, but less applicable to other commodities. Finally, our model and experiments are more applicable to markets for commodities than they are to financial markets because sunk production costs are the key element which distinguishes the spot market (advance production) from the forward market (production to order).

We have used the expected value-variance (EV) approach to incorporate risk into the economic models. This approach was originally developed by Markowitz (1952) to explain diversification of financial assets by investors. It was later extended by Tobin (1958) to include risk-free assets, and then it was applied in an equilibrium analysis by Sharpe (1964), Fama (1976) and Lintner (1965) to the risk pricing of assets. Robison and Barry (1987, pp. 5-6 and 71-75) compare the EV and expected utility (EU) approaches and conclude that the use of the EV model is due to its strengths as an analytical tool rather than as a decision tool. The primary analytical strengths of the EV model are the relative ease with which it can be used to derive optimal solutions and conduct equilibrium analyses, the natural relationship between the concepts of risk and variability and the statistical concept of variance, and fact that the micro results can be extended readily to an aggregate analysis. The concepts of risk aversion, risk premium and the certainty equivalent are central to the economic theory of decisions under risk (Robison and Barry, 1987). The absolute risk aversion function may be incorporated into the certainty equivalent relationship through the use of Pratt's local approximation formula. Pratt's approximation relationship indicates that:

$y_{ce} = E(y) - \lambda/2\, \sigma^2$, where y_{ce} is the certainty equivalent of the income (profit) expression;

$E(y)$ is the expected risky return, and

$\lambda = R[E(y)] = -\frac{U''(y)}{U'(y)}$ is the Pratt-Arrow measure of risk attitude.

The models which follow reflect the case of a producer or seller in a competitive market. Market effects are also investigated through the development of the buyer case (Appendix B). Numerical examples are provided to demonstrate more clearly the effects of contract failure and the transaction costs in the linked forward/spot market (Appendix B).

3.1. Forward Only Market with Possible Contract Failure (FCF)

Consider a firm which is operating in a competitive forward market where each unit is sold through a separate contract and each contract might fail separately with some known probability. Moreover, the firm has an option to continue transacting in the market or to integrate vertically and receive an income G that is certain.[1]

Let ρ be the probability of failure for each unit traded in the forward market. Let $\varepsilon=\Sigma\varepsilon_i$, i = 1,...,$q_f$, be a binomially distributed random variable whereby a probability of success is (1-ρ) and q_f is the quantity traded and produced. Then, $E(\varepsilon) = q_f(1-\rho)$ and $\sigma^2(\varepsilon) = q_f(\rho-\rho^2)$.

The risky profit for the seller is $\Pi = p_f \times \varepsilon - C(q_f)$, where p_f is a sale price in the forward market and $C(q_f)$ is a production cost. The expected profit and variance of profit are:

$$E(\Pi) = p_f \times q_f(1-\rho) - C(q_f) \qquad \text{and} \qquad \sigma^2(\Pi) = p_f^2 q_f(\rho-\rho^2),$$

respectively.

The certainty equivalent of the profit expression following Robison and Barry (1987) is:

$$\Pi_{CE} = p_f \times q_f(1-\rho) - C(q_f) - \frac{\lambda}{2} \times p_f^2 q_f(\rho-\rho^2) \qquad (3.1.1)$$

If $\max\{\Pi_{CE}(q_f)\} < G$, a firm has an incentive to integrate vertically. If $\Pi_{CE}(q_f) > G$ for some q_f, the first order condition requires:

$$\frac{d\Pi_{CE}}{dq_f} = p_f(1-\rho) - C'(q_f) - \frac{\lambda}{2}\times p_f^2(\rho-\rho^2) = 0 \quad \text{and}$$

$$p_f(1-\rho) = C'(q_f) + \frac{\lambda}{2}\cdot p_f^2(\rho-\rho^2) \qquad (3.1.2)$$

The predicted effects of the risk associated with contract failure in a forward only market (FCF) from the economic model suggest that a risk averse producer would reduce output, resulting in a higher price, as compared to the no contract failure case (F). If the forward market with contract failure generates a profit for which the certainty equivalent is lower than the certain income in a vertical integration case, a producer is motivated to integrate vertically.

3.2. Linked Forward/Spot Market (L)

Consider a firm which can choose how it markets its products, whether to sell in the forward market or to trade in the spot market. Again, a firm can also vertically integrate and receive a certain income, G. Let q_f and q_s be the quantities of the units produced to be traded in the forward and spot markets, respectively, and $q_f+q_s = q$. Also, let p_f and p_s be forward and spot prices, respectively. Let v be a normally distributed random variable with $E(v) = 0$ and $\sigma^2(v)$. Then, the random spot price can be expressed as (p_s+v).[2]

The risky profit is:

$$\Pi = p_f\cdot q_f + (p_s+v)\cdot q_s - C(q)$$

The expected profit and the variance of the profit are:

$$E(\Pi) = p_f\cdot q_f + p_s\cdot q_s - C(q) \quad \text{and} \quad \sigma^2(\Pi) = q_s^2\cdot\sigma^2(v),$$

respectively.

The certainty equivalent of the profit expression is:

$$\Pi_{CE} = p_f\cdot q_f + p_s\cdot q_s - C(q) - \frac{\lambda}{2}\cdot q_s^2\cdot\sigma^2(v) \qquad (3.2.1)$$

If $\max\{\Pi_{CE}(q)\} < G$, a firm has an incentive to integrate vertically. If $\Pi_{CE}(q) > G$ for some q, the first order conditions require:

$$\frac{d\Pi_{CE}}{dq_f} = p_f - C_f'(q_f) = 0$$

$$\frac{d\Pi_{CE}}{dq_s} = p_s - C_s'(q_s) - \lambda q_s \cdot \sigma^2(v) = 0$$

Then,

$$p_f = C_f'(q_f) \qquad (3.2.2)$$

$$p_s = C_s'(q_s) + \lambda q_s \cdot \sigma^2(v) \qquad (3.2.3)$$

In the case of a reliable linked forward/spot market (L), for a producer (seller) to be indifferent as regards the forward and spot markets the spot price must be higher than the forward price. This is because of the added cost associated with the risk of inventory loss in the spot market. To understand more accurately what to expect in the case of a linked market, we have provided numerical calculations using the production cost and redemption value schedules for the experiment. According to the numerical calculations (see Appendix B), the risk of loss in the spot market would force a seller to trade all units in the forward market, and the forward price would be the same as in the case of a "reliable" forward only market (F).

3.3. Linked Forward/Spot Market with Possible Contract Failure (LCF)

Consider a firm which can choose how to market its products, whether to sell in the forward market with possible contract failure or trade in the spot market. Again, a firm can also vertically integrate and receive a certain income, G. Let q_f and q_s, p_f and p_s be as previously defined. As in the case of the forward only market with possible contract failure, let $\varepsilon = \Sigma\varepsilon_i$, $i = 1,\ldots,q_f$, be a binomially distributed random variable with the probability of success at $(1-\rho)$. Then, $\gamma = \Sigma(1-\varepsilon_i)$ is a random variable which equals the number of failures.

As in the previous case, the random spot price can be expressed as (p_s+v), where v is a normally distributed random variable, with $E(v) = 0$ and $\sigma^2(v)$. We assume that $\Sigma\varepsilon_i$ and v (and also $\Sigma(1-\varepsilon_i)$ and v) are independent. This assumption seems reasonable since an individual competitive seller would hardly see any dependency between the quantity of failed forward trades and a spot price.

The risky profit is:

$$\Pi = p_f \cdot \varepsilon + (p_s+v)\cdot[\gamma+q_s] - C(q)$$

The expected profit and the variance of profit are (for calculations of the variance of profit, see Appendix A):

$$E(\Pi) = p_f q_f (1-\rho) + p_s(q_f\rho+q_s) - C(q) \qquad \text{and}$$

$$\sigma^2(\Pi) = q_f(\rho-\rho^2)\cdot[(p_f-p_s)^2 + \sigma^2(v)] + \sigma^2(v)\cdot(q_s+\rho q_f)^2$$

The certainty equivalent of the profit expression is:

$$\Pi_{CE} = p_f q_f(1-\rho) + p_s(q_f\rho+q_s) - C(q) -$$

$$- \frac{\lambda}{2}\cdot\{q_f(\rho-\rho^2)\cdot[(p_f-p_s)^2+\sigma^2(v)] + \sigma^2(v)\cdot(q_s+\rho q_f)^2\} \qquad (3.3.1)$$

If $\max\{\Pi_{CE}(q)\} < G$, a firm has an incentive to integrate vertically. If $\Pi_{CE}(q) > G$ for some value of q, the first order conditions require:

$$\frac{d\Pi_{CE}}{dq_f} = p_f(1-\rho) + p_s\rho - C'_f(q_f) - \frac{\lambda}{2}\cdot\{(\rho-\rho^2)\cdot[(p_f-p_s)^2+\sigma^2(v)] +$$

$$+\sigma^2(v)\cdot(2\rho q_s+2\rho^2 q_f)\} = 0$$

$$\frac{d\Pi_{CE}}{dq_s} = p_s - C'_s(q_s) - \lambda\cdot\sigma^2(v)\cdot(q_s+\rho q_f) = 0$$

Then,

$$p_f(1-\rho) + p_s\rho = C'_f(q_f) + \lambda\cdot\{(1/2)\cdot(\rho-\rho^2)\cdot[(p_f-p_s)^2+\sigma^2(v)] +$$

$$+ \sigma^2(v)\cdot\rho\cdot(q_s+\rho q_f)\} \qquad (3.3.2)$$

$$p_s = C'_s(q_s) + \lambda\cdot\sigma^2(v)\cdot(q_s+\rho q_f) \qquad (3.3.3)$$

In the case of a linked forward/spot market with possible forward contract failure (LCF), the risk of contract failure increases the costs of transacting in the forward and the spot linked markets. The results of the numerical calculations from the theoretical models (Appendix B) suggest that, when the probability of forward contract failure is small (5%), risk aversion forces the agents to transact more heavily in the forward linked market. The forward quantity tends to be higher, while the forward price tends to be lower, as compared to the situation in the reliable forward only (F) and reliable linked (L) markets. According to the calculations there should be no spot production, although the spot price should be higher than the forward price. (Note that, even though there is no spot production, there still could be spot trades of units which failed in the forward market. Thus, there could be a spot price.) An increased probability of forward contract failure (50%) reduces the forward quantity, but by only a small amount, and prompts some spot production. In this case, the forward quantity is slightly lower than it is in the reliable forward only (F) or the linked (L) markets. Risk aversion forces the forward and the spot prices to be higher than they are in the case of a 5% probability of forward contract failure (and also higher than they are in the F and L markets), with the spot price still higher than the forward price. These results, however, are affected by the relative risk aversion of sellers and buyers.

3.4. Linked Forward/Spot Market with Possible Transaction Costs (LTC)

Again, a firm can choose whether to transact in the forward or the spot market, or vertically integrate and receive a certain income, G. We consider in this case that there is a possibility of an additional transaction cost for a trade in the forward linked market. As in earlier cases, let q_f and q_s be the quantities of units produced to be traded in the forward and spot markets, respectively, and $q_f+q_s = q$. Also let p_f and p_s be forward and spot prices, respectively. For the spot price we make the same assumptions as in the previous case.

This time "a failed trade" means that the respective buyer and seller each incurs an additional cost of transacting (t). Again, let $\varepsilon = \Sigma\varepsilon_i$, $i = 1,\ldots,q_f$, be a binomially distributed random variable with the probability of success (that is, $\varepsilon_i = 1$) at ρ. Here, the success in Bernoulli's exercise causes failure for a trade.

The risky profit is:

$$\Pi = p_f \cdot q_f + (p_s+v) \cdot q_s - C(q) - t \cdot \varepsilon$$

The expected profit and the variance of the profit are:

$$E(\Pi) = p_f \cdot q_f + p_s \cdot q_s - C(q) - t \cdot \rho \cdot q_f \quad \text{and}$$

$$\sigma^2(\Pi) = q_s^2 \cdot \sigma^2(v) + t^2 \cdot q_f \cdot (\rho - \rho^2),$$

respectively.

The certainty equivalent of the profit expression is:

$$\Pi_{CE} = p_f \cdot q_f + p_s \cdot q_s - C(q) - t \cdot \rho \cdot q_f - $$
$$- \frac{\lambda}{2} \cdot [q_s{}^2 \cdot \sigma^2(v) + t^2 \cdot q_f \cdot (\rho - \rho^2)] \qquad (3.4.1)$$

If $\max\{\Pi_{CE}(q)\} < G$, a firm has an incentive to integrate vertically. If $\Pi_{CE}(q) > G$ for some value of q, first order conditions require:

$$\frac{d\Pi_{CE}}{dq_f} = p_f - C_f{}'(q_f) - t \cdot \rho - \frac{\lambda}{2} \cdot t^2 \cdot (\rho - \rho^2) = 0$$

$$\frac{d\Pi_{CE}}{dq_s} = p_s - C_s{}'(q_s) - \lambda q_s \cdot \sigma^2(v) = 0$$

Then,

$$p_f = C_f{}'(q_f) + t \cdot \rho + \frac{\lambda}{2} \cdot t^2 \cdot (\rho - \rho^2) \quad \text{and} \qquad (3.4.2)$$

$$p_s = C_s{}'(q_s) + \lambda q_s \cdot \sigma^2(v) \qquad (3.4.3)$$

In the case of a linked market with possible transaction costs for a forward trade (LTC), a producer's choice between the forward and spot markets depends on the value of the sum of the expected transaction cost and the transaction cost risk in the forward market, as compared to the risk of loss in the spot market. The numerical results suggest that, when there is a 50% probability of an additional transaction cost of 10 tokens for a forward trade for both sellers and buyers, subjects still prefer to transact most units in the forward market, although the quantity traded forward is lower than it is in the case of the linked (L) and linked with contract failure (LCF) markets. Risk aversion forces a reduction in the quantity traded in the forward LTC market, an increase in the quantity traded spot, and higher prices in the forward and the spot linked markets, with the spot price higher than the forward price. For the same value of the risk aversion coefficient (0.01), the forward and spot prices in the LTC(50;10) market are slightly higher as compared to the linked market, with a 50% probability of forward contract failure, LCF(50). As in the case of a linked market with forward contract failure, these results are affected by the relative risk aversion of sellers and buyers. For each of the linked markets above, if none of the forward or spot linked markets generates a profit for which the certainty equivalent is higher than the certain income in a vertical integration case, a producer has an incentive to integrate vertically.

Overall, the results of the economic models and numerical examples developed in this study suggest that, when there is a forward only market, even a low probability of contract failure affects the market significantly, resulting in a lower quantity and a higher price. Linking the forward market with a spot market reduces the effect of contract failure, although a high probability of contract failure decreases the quantity traded in the forward linked market. In the latter case, risk aversion forces the forward and spot prices to increase, with the spot price higher than the forward price. If an additional transaction cost is associated with forward contract failure rather than an opportunity to retrade failed units in the spot market, the linked market is affected greatly. Although subjects still prefer to transact greater quantities in the forward linked market, the quantity traded forward decreases, and the quantity traded spot increases. Forward and spot prices increase relative to the no contract failure case, with the spot price higher than the forward price. These results, however, are affected by the relative risk aversion of sellers and buyers.

4. METHODOLOGY

4.1. Experiment Design and Risk Preference Assessment

Laboratory experimental economics (as described by Plott, 1982; Smith, 1982) is used to obtain data for the analysis. Fundamentally, experimental economics is the study of individual choice in the context of an economic institution (Smith, 1982). The objective is to set up a laboratory experiment which will create a manageable model of a real world phenomenon, whereby adequate control can be maintained and the accurate measurement of relevant variables can be guaranteed (Wilde, 1980).

During the fall of 1997 and winter of 1998, 18 experimental sessions were conducted: three replications for each of six treatments (forward market, forward with a 5% possibility of contract failure, linked forward/spot market, linked market with a 5% and then a 50% possibility of contract failure, and finally, linked market with a 50% possibility of additional transaction costs for a contract).[3] As in Mestelman and Welland (1987) and Krogmeier et al. (1996), four buyers and four sellers participated in each session. Market participants were mostly recruited from among those SPSUEF students of the third, fourth and fifth course year who expressed a willingness to participate in the laboratory experiment.[4] The advantages of using students as experiment participants are (Freidman and Sunder, 1994, p. 39) (1) the convenience of recruitment, (2) the low opportunity cost of student subjects, (3) the relatively steep learning curve, and (4) some lack of exposure to confounding external information. None of the participants possessed experience as agents in a laboratory study.

The experiments utilized an oral double auction. (We had to reject the use of computers because of technical problems. Moreover, oral auctions show a more rapid convergence toward a competitive equilibrium than do computerized auctions.) A double auction is a market institution in which buyers compete by increasing price bids, while sellers compete by reducing price offers. The transaction prices are found somewhere between the initial bids and the offers. Each session consisted of eight cycles, where a cycle was a time-span in which trades were conducted and terminated when the trading by participants was completed.

The buyers were given a table which listed the maximum reservation values for each unit purchased; these values were described to buyers as redemption values. Similarly, the sellers were informed of unit costs. The redemption values were identical for each buyer, and the production costs were identical for each of the four sellers. The redemption values and production costs which were used in each experiment session are listed in Table 1. Redemption values, costs and the earnings of the participants were denoted in an artificial currency called “tokens”, which were convertible into rubles at a rate of 50 tokens for each ruble (or 1,000 rubles in 1997).

Each buyer in each session was allowed to purchase, one at a time, up to eight units in each trading period. The units had to be purchased in a specified order: the first unit purchased in each period had to be the highest valued unit; the second unit purchased had to be the second highest valued unit, and so on. Likewise, each seller in a trading cycle was allowed to sell, one at a time, up to eight units. The units had to be produced and sold in a specified order: the first unit produced (sold) had to be the lowest cost unit; the second unit produced (sold) had to be the second lowest cost unit, and so on.

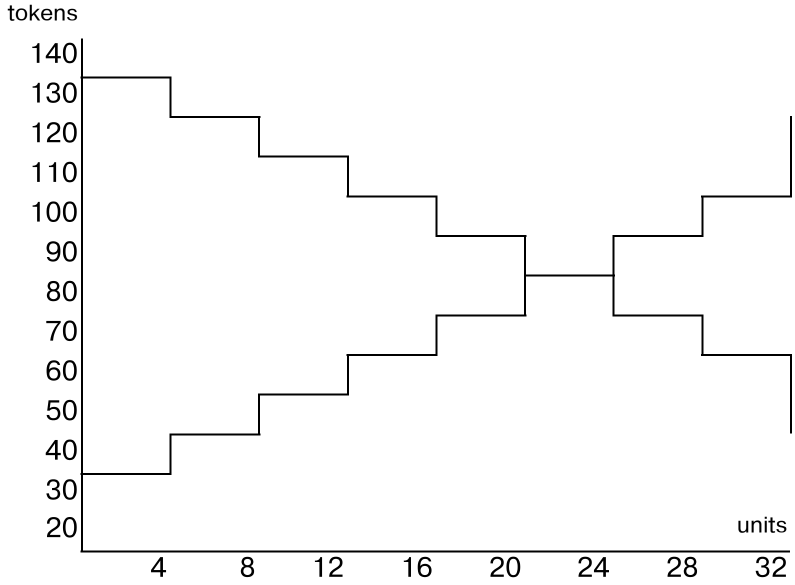
Table 1. Redemption Values and Unit Costs Used in the Experiment

UNIT	REDEMPTION VALUE	UNIT COST
1	130	30
2	120	40
3	110	50
4	100	60
5	90	70
6	80	80
7	70	90
8	60	100

According to induced value theory (Smith, 1982), the values and costs constitute individual supply and demand per trading period. When summed horizontally (over four buyers and four sellers), these represent the market supply and demand curves shown in Figure 1. The individual demand schedule is given by $p = 135\text{-}10q$, and the supply schedule has the form $p = 25+10q$. Competitive price theory predicts an equilibrium price of 80 tokens and market sales of between 20 and 24 units per period.

For a buyer, the earnings on each unit purchased equal the redemption value of the particular unit, less the price paid to the seller. For a seller, the earnings on each unit sold equal the price received by the seller, less the production cost of the particular unit. Earnings are accumulated over the sequence of trading cycles. Record sheets were prepared for use by the participants, so that they could keep track of their trades and earnings. Participants were paid at the end of the session, with earnings dependent on performance in the experiment.

Figure 1. Market Supply and Demand



As in the study reported by Phillips, Menkhaus and Krogmeier (1997), buyers were allowed to purchase at prices above the reservation value, and sellers were allowed to sell at prices below cost. Two reasons are given for this departure from the usual rule in previous studies (Phillips, Menkhaus and Krogmeier, 1997). First, it is felt that, by not forcing subjects to generate positive earnings, one allows for the validation of the clarity of the instructions and the sufficiency of financial motivation. One would not expect buyers (sellers) repeatedly to buy (sell) at prices above (below) the value (cost), if they fully understand the instructions, and the financial motivation is salient and dominant. Second, in the linked design, it is necessary to allow sellers in the spot session to sell below cost in order to mitigate the possible losses due to forward contract failure and over-production for the spot market. To maintain symmetry between buyers and sellers and across treatments, the usual rule was relaxed for all participants.

Each participant was given an initial token balance of 700 tokens (14 rubles) at the beginning of each session. Although a nonsalient reward, this initial balance seemed necessary in both markets, since, in the spot market of the linked design, sellers must incur production costs before they can be given the opportunity to earn profit from sales, and in the forward market a trade may fail. An additional concern is that the initial endowment be large enough to preclude the possibility of individual bankruptcy. This could be a particular concern for sellers in the spot market and in the “unreliable” forward market, where a failure to sell could result in large losses. Buyers (sellers) were told that they were allowed to buy (sell) units only until the total procurement (production) cost exceeded the token balance they had possessed at the beginning of a period. The level of the initial balance was chosen so that in the first period a buyer would be able to buy up to eight units. In order to maintain symmetry between buyers and sellers and across treatments, the initial balance was given to all participants.

During a double auction trading period, buyers were allowed to submit bids at any time for a single unit of a fictitious commodity. Valid bids had to follow an “improvement” rule, that is, for the bid to be displayed to the market, it had to be higher than the previously displayed bid. In addition, a valid bid could not exceed the asking price currently displayed to the market (if one existed).

Similarly, sellers were allowed at any time to submit asks to sell a single unit of the fictitious commodity. Analogous to bids, asks had to follow an “improvement” rule, that is, in order for the ask to be displayed to the market, it had to be lower than the previously displayed ask. In addition, a valid ask could not be lower than the bid price currently displayed to the market (if one existed).

Any valid bid or ask was allowed to be submitted. The experiment monitor conducted the auction and wrote bids and asks on a blackboard which was visible to all participants. Trades, along with seller and buyer identifications, were also identified on the blackboard. A recorder recorded each bid, ask and trade during the experiment. Since asks and bids were made orally, the complete anonymity rule used in the computerized auctions of Phillips, Menkhaus and Krogmeier (1997) was relaxed. Subjects were told that a bid (ask) was valid only if it was displayed (repeated by the auctioneer and written on the blackboard). For an aggressive group, it helped to keep subjects from trying to negotiate a trade directly. Individuals could make a trade by using one of two methods. First, the buyer (seller) could submit a bid (ask) which equaled the currently displayed "best" ask (bid). Second, the individual could simply indicate that he/she accepted the currently displayed "best" ask (bid).

During a typical session, the monitor first read the instructions. This was followed by a brief practice session using redemption values and costs which were different from those provided to participants during the actual sessions. The practice session was necessary to be sure that the subjects understood the instructions. While the instructions were being read and during the practice session, the subjects were permitted to ask questions. Although this was a time-consuming process (about one hour in the linked market sessions), this procedure seemed to help make the instructions clearer to the participants.

At the beginning of each session, participants were told that the double auction in a trading period would continue only until there were no additional bids and asks, but in any case would last no longer than 15 minutes. For most auctions, this was ample time, although there were some periods which lasted a little longer or less. In the beginning of a session, we stopped the trading process after 15 minutes even if there were subjects who wanted to continue trading. This seemed necessary during early periods so that subjects would not expand the trading time artificially. But during the later periods we permitted an auction to last a little longer (without telling the subjects about this) if some participants still wanted to make trades. On the other hand, if no one was interested in continuing trading, the monitor stopped the auction before the 15-minute time period was up.

The auctions for the forward and spot (in the linked design) markets were conducted as described above. The only difference between the forward and spot markets is the production decision before the spot auction. Before the spot auction, each seller had to record the number of units he/she wanted to produce for the spot market.

This completes the discussion of the basic design of the experimental market and the way experiments were conducted. We now focus on the experiment treatments. (Appendix C gives an example of a buyer and seller instruction and of the record sheets used in the LCF experiments.) We conducted three replications of each of the following six treatments:

- forward only market – production-to-demand – F;
- forward only market, with a 5% possibility of contract failure – FCF(5);
- linked forward/spot market – L;
- linked forward/spot market, with a 5% possibility of contract failure –LCF(5);
- linked forward/spot market, with a 50% possibility of contract failure – LCF(50);
- linked forward/spot market, with a 50% possibility of a transaction cost of 10 tokens for a contract – LTC(50;10).

Forward only market. The forward market is a production-to-demand design. A trade in a forward market means that the seller agrees to produce a unit for a buyer and the buyer agrees to pay the seller for that unit. All of this occurs before the unit has actually been produced. There is no over-production in such a market.

The treatment was almost the same as in Krogmeier et al. (1996), with one exception: the authors utilized a computerized double auction, while we used an oral double auction. A session started with a procedure which determined randomly who would be buyers and who would be sellers. This was done by picking "balls" out of a "box". There were eight balls in the box, numbered from 1 to 8. Those participants who picked out the balls with numbers from 1 to 4 were buyers, while those picking balls 5 to 8 were sellers. These numbers were the IDs of the participants, and the participants were placed around the room according to their numbers. Thus, the number and the identification of the buyers and sellers were common knowledge.

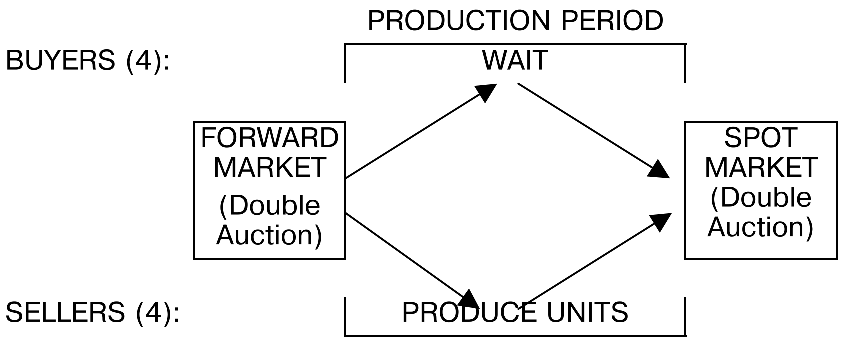
The monitor then read the instructions and conducted the practice session. Usually, this took about a half-hour in the forward only market (and an hour in the linked market). Then the actual redemption value and cost information was distributed among the participants. They were told not to share the information and not to talk with each other. This was facilitated by recruiting subjects from different groups of university students, so that most of them had not known each other before the session. Participants learned market information (except individual redemption values and unit costs) by the observation of bids, asks, trading prices, and the number of trades in the laboratory market.

Forward only market with contract failure. This treatment differed from the forward only market because of the incorporation of the possibility of a forward contract failure. This was operationalized by the random determination of the success or failure of each trade according to the selected probability level of failure. The probability of a forward contract failure (0.05 in our experiments) was known by the experiment participants. After a trading period had been completed, 20 balls numbered 1 to 20 were placed in a box. Participants were told that a contract failure would be associated with ball number 1. Then one of the participants (or the monitor) picked a ball out of the box for each trade made during the period. The monitor announced the identities of the respective buyer and seller and the trading price for each trade which had failed, and the buyer and the seller noted the failed trades on their record sheets. The number of failed trades and the identity of the affected parties were therefore common knowledge. After the failed trades had been determined, the participants corrected their earnings, and a new period began.

Linked forward/spot market. The basic linked forward/spot market design (developed in Phillips, Menkhaus and Krogmeier, 1997 and utilized in the present study) is illustrated in Figure 2. Each trading cycle consists of a forward market and a spot market. In a spot market sellers make a production decision and have units ready (or in stock) to be sold. When the demand is unknown, there is a possibility that too many or too few units will be produced. The forward and spot markets are therefore separated by a production period, during which sellers decide on the total number of units to be produced for the trading cycle. They must, of course, produce at least as many units as they have already sold in the forward market. Meanwhile, during the production period, buyers are waiting for the spot market to open. Information about the additional units produced for the spot market is strictly private, and participants can learn if there are units remaining only by observing the asks of sellers. There was no provision for inventory carryover in the initial design.

Each trading period in the linked market sessions of our experiment consisted of the forward auction (up to 15 minutes), production period (1-2 minutes) and the spot auction (up to 15 minutes). Since the number of units each subject was able to transact in the linked market during a trading period was the same as in the forward only market experiment (in the linked market this amount could be divided between the two auctions), the total time needed for a trading period did not vary greatly between the F and L markets. Usually, a trading period in the linked market sessions lasted about 20 minutes.

Figure 2. Organization of Trading



<u>Linked forward/spot market with forward contract failure</u>. In these linked market experiments, there was a possibility that a forward contract would fail. We ran three replications of this

treatment with a 5% possibility of contract failure and three replications with a 50% possibility of contract failure. It was important to decide when participants should learn about the trade failures, whether before or after they decided how many units they wanted to produce for the spot market which followed the forward market and the production period. In order to reduce the complexity of the decision process, before the production decision we identified which contracts failed. (The process for the selection of failed trades was similar to that described above for the FCF treatment.) The sellers, however, were required to produce all the units they sold in the forward market (both successful and failed).

In experiments with advance production, participants usually do not know how many units are produced and are available for trading. In our LCF experiments, however, the failed forward trades (if any) were common knowledge, and it was obvious that these units were available in the spot market (to make information about failed trades confidential would be difficult in an oral setting). Information about any additional units produced only for the spot market was, of course, strictly reserved.

Each trading period or cycle in the LCF market sessions of our experiment consisted of the forward auction (up to 15 minutes), the determination of failed forward trades (5-7 minutes), the production period (1-2 minutes), and the spot auction (up to 15 minutes). Since the failed forward units were available for retrading in the spot market, the total time needed for a trading period was a little longer in the LCF sessions (especially with a 50% possibility of contract failure) than it was in the L sessions. Usually, a trading period in the LCF(50) sessions lasted about 25 minutes.

<u>Linked forward/spot market with possible transaction costs for a contract</u>. In these experiments, there was again a 50% possibility for a contract to fail, but contract failure now meant that both buyer and seller incurred a transaction cost of an additional 10 tokens for the failed unit. Thus, the “failed” trade was still valid, but the respective earnings of both the buyer and the seller were reduced by 10 tokens each.

<u>Risk preference assessment</u>. In each of the 18 experimental sessions, a choice experiment was administered to assess the

risk attitudes of the individuals participating in the session (Menkhaus et al., 1997). Recruits were asked to complete the choice experiment before the market experiment began. This experiment consisted of 19 games (see Appendix C). Each game involved a choice between an Option A, which yielded 2.5 rubles (in all sessions, except F1, where it yielded 5 rubles) and a risky Option B, which paid either 5 rubles, or 0 rubles (10 rubles or 0 rubles in F1). Option A remained the same in each of the 19 games. In Option B the probability of winning 5 rubles decreased monotonically from 95% (a chance of 19 in 20) in the first choice game to 5% (a 1 in 20 chance) in the 19th game.

Participants were instructed that only one of the 19 games would be played after the market experiment was over, and the choice of the game would be determined by the random draw of a ball numbered between 1 and 19. The payment for Option B (either 5 rubles, or 0 rubles) was then determined by the random draw of a ball numbered between 1 and 20. The earnings from the choice experiment were added to the earnings from the market experiment.

The pattern of the choices made by a participant provides an ordinal measure of the risk attitude of the participant. Risk aversion is represented by the convexity or concavity of an individual's utility function when the individual is faced with a choice between a risky payoff and a payoff with certainty. The convexity or concavity of the utility function may be assessed, in the context of the choice experiment, by identifying the last game in which the participant chose the risky Option B before switching from it to the safe Option A (Menkhaus et al., 1997). Each subject was thus assigned a score from 1 to 19, with 1 the most risk averse and 19 the most risk seeking, while 10 was risk neutral.

4.2. Data Analysis

The experiments yielded trade prices, the quantities traded and the earnings of sellers and buyers. These data are analyzed from two perspectives: graphical and statistical analyses. One purpose of the statistical tests is to compare treatments in terms of mean prices, quantities and earnings. The null and alternative hypotheses for treatments i and j are:

Ho: $\mu_i = \mu_j$ for all i $\neq$ j

Ha: $\mu_i \neq \mu_j$ for all i $\neq$ j.

The nature of the price data and the average buyer (seller) earnings data and the Central Limit Theorem allow us to use the standard t-test for the statistical analyses. For the t-tests we used mean prices (buyer or seller earnings) for the periods 6-8 in each replication. (Data for the last three periods were considered in the statistical analysis to eliminate the learning effect; see Friedman and Sunder, 1994, p. 39.) Thus, we had nine observations for each treatment.

Since the assumption of normality for the quantity traded data and for the market efficiency (total earnings) data is tenuous, we used the nonparametric randomization (or permutation) test for these data. (We should point out that in most cases the t-test and the permutation test yielded the same results, but, when this was not the case, the results of the permutation test are taken as the more valid statistical test.) The permutation test is based on the differences in the summed observations for each of the treatments under investigation. In many cases the permutation test is more sensitive than are other nonparametric tests, for instance the Mann-Whitney test (Davis and Holt, 1933, p. 548). For the permutation test we averaged the quantity traded (earnings) for periods 6-8 of each replication. Thus, we had nine observations for each treatment.

We conducted F tests for differences in the variance of prices, the quantity traded and the earnings in alternative market institutions. Again, we considered only data from the last three periods to avoid a learning effect. The standard t-test was used to determine the significance of the differences in the risk preference scores from the choice experiment.

5. RESULTS

The results of the choice experiment to assess the risk preferences of experiment participants are outlined. This is followed by a presentation of the prices, quantities traded and produced, and market efficiency measures which were generated in the experiments conducted for each treatment.

5.1. Risk Attitudes

The choice experiment results are discussed first because of the importance of risk attitudes and the probable influence of these attitudes on the laboratory market results. We realize that we cannot make a complete study of the risk attitudes of participants through this choice experiment, but we hope at least to understand some tendencies in the risk preferences. After the verification of normality using the χ^2 -test, t-tests were conducted to determine the significant difference from risk neutral (a score of 10) for each group of sellers and buyers and the significant difference in risk attitude scores between buyers and sellers in each treatment and each replication (Table 2).

Buyers participating in the F (forward only) and LTC(50;10) (linked, transaction cost) treatments and sellers participating in the L (linked), LCF(5) (linked, 5% of contract failure), LCF(50) (linked, 50% of contract failure), and LTC(50;10) (linked, transaction cost) treatments displayed risk attitude scores significantly lower than risk neutral. The risk attitude scores for all other groups were not statistically different from risk neutral. The overall mean score, however, was 8.56 (the standard deviation is 3.37), suggesting a general tendency toward risk aversion by the participants in the experiment.

The risk attitude scores were significantly different between buyers and sellers in the F and L treatments ($\alpha = 0.1$). In the F treatment the risk attitude scores of the buyers were lower than those of the sellers; in the L treatment the risk attitude scores of the buyers were higher than those of the sellers. A comparison within each replication reveals that the risk attitude scores of the buyers were significantly higher than the risk attitude scores of the sellers in the L3, LCF(5)3, and LCF(50)1 sessions.

Table 2. The Risk Attitude Scores for Sellers and Buyers in Each Treatment and Replication

	F		FCF(5)		L		LCF(5)		LCF(50)		LTC(50;10)	
Replication	Buyer	Seller	Buyer	Seller	Buyer	Seller	Buyer	Seller	Buyer	Seller	Buyer	Seller
1	4	10	7	7	5	12	6	12	19	7	8	10
	6	10	9	6	12	0	6	9	13	10	7	10
	9	10	7	12	11	8	11	13	5	6	2	3
	10	8	6	14	8	5	6	5	11	2	11	6
Mean	7.25	9.5	7.25	9.75	9.0	6.25	7.25	9.75	12.0[b]	6.25[s]	7.0	7.25
2	13	12	13	15	14	5	9	11	2	7	11	9
	2	8	6	8	11	8	5	5	10	11	9	10
	10	5	13	4	5	8	10	8	10	12	10	12
	5	13	7	10	10	2	10	9	9	11	11	12
mean	7.5	9.5	9.75	9.25	10.0[b]	5.75[s]	8.5	8.25	7.75	10.25	10.25	10.75
3	8	7	9	8	9	9	5	8	9	11	6	10
	13	10	5	9	5	3	12	9	9	9	3	5
	7	11	9	5	6	5	10	2	7	8	6	6
	10	17	15	9	11	10	16	5	11	5	16	11
mean	9.5	11.25	9.5	7.75	7.75	6.75	10.75[b]	6.0[s]	9.0	8.25	7.75	8.0
Treatment Mean	8.08[ab]	10.08[s]	8.83	8.92	8.92[b]	6.25[as]	8.83	8.0[a]	9.58	8.25[a]	8.33[a]	8.67[a]
Std. Dev.	3.42	3.088	3.21	3.4	3.09	3.52	3.35	3.25	4.17	2.99	3.87	2.93

[a] Denotes the significant difference from risk neutral (a risk attitude score of 10), $\alpha = 0.10$.

[b] or [s] Denotes the significant difference in the risk attitude scores of buyers and sellers in a treatment (replication), $\alpha = 0.10$.

5.2. Prices

The mean prices and the standard deviations by period in each of the 18 sessions are displayed in Table 1D of Appendix D. Table 3 shows the mean prices averaged across the three replications for each of the six treatments. If we consider the forward only market treatments (reliable and with a 5% probability of contract failure), the FCF(5) average mean prices are slightly higher than the prices in the F treatment, although not statistically significant. According to theory (see Formula 3.1.2), we would expect the trade prices to be higher in the FCF(5) treatment than they are in the F treatment, although this could be influenced by the relative risk aversion of buyers and sellers.[5]

Table 3. The Average Mean Prices (tokens) in Different Markets by Period

Treatment / Period	F	FCF (5)	L	LCF (5)	LCF (50)	LTC (50;10)
1	90.16	80.82	76.27	67.93	95.96	82.42
2	86.42	83.68	76.41	75.08	85.29	77.36
3	82.82	80.94	80.66	74.23	84.73	76.12
4	81.53	82.41	80.18	76.34	83.83	76.08
5	81.04	82.75	78.88	77.36	83.36	77.29
6	80.95	81.97	79.88	78.24	82.41	79.10
7	81.31	82.94	79.50	79.13	81.01	79.34
8	82.01	82.05	79.82	79.53	80.90	80.20

When the reliable forward market is linked with a spot market in the L design, the mean prices are not significantly affected, although in Table 3 the average mean L prices are slightly lower than the F prices (statistically not significant). On the other hand, the addition of a spot market to the forward market with a 5% probability of contract failure results in lower mean prices.

The average mean prices in the LCF(5) market are lower than those in the F, FCF(5) and L markets. But only the difference between the LCF(5) and the FCF(5) trade prices was found to be statistically significant ($\alpha = 0.10$). The fact that the LCF(5) mean prices are lower than the FCF(5) mean prices and, although not statistically significant, slightly lower than the F and L prices is consistent with the results of the numerical calculations based on the theoretical models (see Appendix B). The addition of a spot market to the forward market with a 5% probability of contract failure in the LCF(5) treatment provides subjects with a possibility to retrade failed units and, thus, reduces the risk associated with forward contract failure (especially for sellers who have an opportunity in the LCF(5) market to cover all or part of the production cost for the failed unit). The reduced risk for a seller increases the quantity traded, resulting in a lower LCF(5) price relative to the FCF(5) price.

To understand more clearly why the average LCF(5) prices may be lower than the F and L prices, we need to compare forward and spot prices within the linked treatments and also consider the quantity traded and efficiency. This is addressed later in the paper. At this point, we suggest that the introduction of the 5% probability of contract failure into the linked market involves a contract failure risk cost for both buyer and seller. For a buyer this makes the forward linked market less attractive than the spot market, and buyers may want to reduce the forward price. On the other hand, for a seller the spot market involves the risk of inventory loss because of the uncertain spot price. In the reliable linked market (L) some sellers transacted in the spot market, but only limited trades were made in this market. In the LCF(5) market some sellers, without any initial intention of doing so, may be forced to transact in the spot market because some forward trades have failed. Since sellers know this, they may wish to make all possible trades forward (without leaving any units for the spot market) and then to participate in spot trading only if some trades fail. Thus, the forward market becomes even more attractive for sellers as compared to the no contract failure case, and, therefore, sellers may accept a lower forward price. If most units in the LCF(5) market are traded forward, this may result in a lower average price.

Note that the overall risk attitude score of the sellers participating in the LCF(5) treatment (a score of 8.00) was found to be significantly different from the risk neutral score (10.00). We should point out that mean prices were noticeably lower in the LCF(5)3 session than they were in the other two replications of the LCF(5) treatment, and this must have contributed to the lower LCF(5) average prices. Interestingly, LCF(5)3 was the only replication of this market type in which the risk attitude scores of the sellers were significantly lower than those of the buyers. This suggests that risk aversion may have helped make sellers more aggressive in the LCF(5) market.[6]

An increase in the probability of forward contract failure to 50% seems to drive mean prices up. In Table 3, the LCF(50) mean prices are higher than the L and LCF(5) mean prices, and the differences are statistically significant ($\alpha = 0.10$). Again, this is consistent with the results of the numerical examples based on the theory. This increase in mean price is logical. Since on average about 50% of forward trades fail, the implicit costs of transacting forward (contract failure risk cost[7]) for both buyers and sellers increases. But for a seller, failure in the forward market forces more units to the spot market, and sellers are exposed to the risk of inventory loss because of an uncertain spot price. Note that the average risk attitude score for sellers in the LCF(50) treatment (8.25) was significantly lower than risk neutral. This may result in a lower forward and total quantity produced and supplied and, hence, in a higher price.

To understand more clearly what has happened as a result of the forward contract failure probability (5% and 50%), we compared the mean forward prices in different markets, the mean spot prices in different linked markets, and, finally, the forward and spot prices within each of the linked market treatments (Table 4 and Appendix D, Figures D1 and D2 and Table D2). The results of the comparison are summarized in Tables 5 and 6. As expected from the theory, the difference in the mean forward prices in the F and L markets is not statistically significant, although the average mean L forward prices are slightly lower than the F prices, according to Table 4. Within the L treatment, the forward and spot mean prices are likewise not significantly different.[8]

Table 4. The Average Mean Forward and Spot Prices in Different Linked Markets by Period (tokens)

Treatment / Period	Average Forward Price				Average Spot Price			
	L	LCF (5)	LCF (50)	LTC (50;10)	L	LCF (5)	LCF (50)	LTC (50;10)
1	75.89	66.36	101.2	82.57	83.20	75.29	86.44	74.12
2	76.36	74.20	88.52	76.87	78.11	80.67	83.77	77.50
3	80.75	74.06	87.46	75.81	79.56	76.52	82.39	77.17
4	80.30	76.55	86.95	74.89	79.00	75.5	82.06	78.87
5	78.90	77.34	84.56	75.62	80.00	78.55	82.79	83.33
6	79.83	78.08	84.37	78.10	81.00	81.70	80.80	81.44
7	79.83	79.19	83.41	77.27	77.00	80.29	80.15	82.01
8	79.92	79.62	81.86	78.68	77.00	77.83	80.04	82.03

Table 5. A Comparison of Average Forward and Spot Prices across Different Treatments

Treatment Under Consideration	Average Forward Price					Average Spot Price		
	Control Treatment					Control Treatment		
	F	FCF (5)	L	LCF (5)	LCF (50)	L	LCF (5)	LCF (50)
FCF(5)	>							
L	<	<						
LCF(5)	<	<<	<			>		
LCF(50)	≈	≈	>>	>>		≈	≈	
LTC(50;10)	<<	<<	<<	<	<<	>	≈	>

> Denotes that the treatment under consideration generated average prices which were higher than those generated by the control treatment.

< Denotes that the treatment under consideration generated average prices which were lower than those generated by the control treatment.

≈ Denotes that it is not obvious which treatment generated the higher prices.

>> or << Denotes that the difference is statistically significant.

Table 6. A Comparison of Average Forward and Spot Prices within the Same Treatment

Forward Price Compared with Spot Price			
L	LCF(5)	LCF(50)	LTC(50;10)
≈	≈	>>	<<

≈, >> and << denote the same as in Table 5.

The LCF(5) forward mean prices are lower than the FCF(5) forward prices (statistically significant, $\alpha = 0.10$) and slightly lower (not a statistically significant difference) than the L forward prices, which is consistent with the theoretical predictions. Within the LCF(5) treatment, the mean forward and spot prices were not significantly different.

Raising the probability of forward contract failure (from 5% to 50%) resulted in an (statistically significant, $\alpha = 0.02$) increase in the LCF(50) forward prices relative to the LCF(5) forward prices. The LCF(50) forward prices are also (statistically significant, $\alpha = 0.10$) higher than the L forward prices. Within the LCF(50) treatment, the mean forward prices are higher than the spot prices (statistically significant, $\alpha = 0.10$). This suggests that the high (50%) probability of contract failure results in a higher forward price, which may be caused by a decrease in the forward quantity traded. Buyers accept the higher forward price in order to increase the total quantity produced. Failed units (that is, about half the units traded in the forward LCF(50) market) are supplied in the spot market, along with those units which were produced purposely for the spot market. Of course, the demand unfilled as a result of the failed forward trades is present in the spot market as well. Even knowing this, sellers become more aggressive in the spot market (accepting lower spot prices) because they need to sell all the units produced. Nonetheless, the LCF(50) spot price is not significantly different from (and, according to Table 4 and Figure D2, is sometimes even higher than) the L and LCF(5) spot prices. Because of the fact that the average spot price in the LCF(50) market is lower than the average forward price, most failed units are retraded spot at a lower price.

The situation is completely different when an explicit additional transaction cost of 10 tokens for each failed forward trade is substituted for an implicit transaction cost (contract failure risk cost). The LTC(50;10) mean prices are significantly ($\alpha = 0.10$) lower than the LCF(50) mean prices and are not significantly different from the L or the LCF(5) mean prices. To understand this situation, we again need to consider the forward and spot mean prices. Consistent with the numerical examples based on the theory, the LTC(50;10) forward prices are lower than the spot prices (statistically significant, $\alpha = 0.02$). In fact, the LTC(50;10) average mean forward prices are lower than the forward prices under any other treatment, and these differences are significant ($\alpha = 0.10$), except for the difference between the LTC(50;10) and LCF(5) forward mean prices. On the other hand, according to the later periods in Table 4, the LTC(50;10) spot prices are higher than the spot prices in other linked markets (although not statistically significant). This suggests that buyers were compensating for the possible explicit transaction cost through a lower price in the forward market, while sellers tried to compensate for it through a higher price in the spot market. For a buyer the forward LTC(50;10) market is risky and the spot market is not. A buyer agrees to buy in the forward LTC(50;10) market only if the risk cost is offset by a lower price. On the other hand, for a seller both the forward and the spot LTC(50;10) markets are risky: the risk of an additional transaction cost in the forward market and the risk of an inventory loss in the spot market. If a seller wants to trade forward, she has to accept a lower price offered by the buyers. This makes the forward market even less attractive for the sellers. But the risk of loss in the spot market forces the sellers to sell some units forward, thus diversifying between the two markets. This activity is likely to decrease the total quantity produced, resulting in a higher price in the LTC(50;10) spot market.

The results of tests of the price variances related to different treatments suggest that the price variance in the F market was the highest (statistically significant everywhere, $\alpha = 0.002$). The second highest was the price variance in the FCF(5) market (statistically significant everywhere, $\alpha = 0.002$). The price variance in the LTC(50;10) market is not significantly different from that in the LCF(5) market, but is higher than that in the LCF(50) market (α = 0.01). On the other hand, the price variances in the LCF(5) and LCF(50) markets are not significantly different. Finally, the price variance in the LCF(5) market is significantly higher than that in the L market (α = 0.01), although the latter is not significantly different from the price variance in the LCF(50) market.

The order of price variance magnitudes changes somewhat if we compare the price differences in the respective forward markets. In this case, the price variances in the F and FCF(5) markets are again the first and the second highest, respectively (statistically significant everywhere, α = 0.002). But the third highest is the price variance in the forward LCF(5) market. It is significantly higher than the price variances in the LCF(50), L and LTC (50;10) forward markets (α = 0.02, 0.002 and 0.002, respectively). The last three are not significantly different from each other.

Among the linked spot markets, the price variances in the L and LTC(50;10) spot markets are not significantly different, but both are higher than the spot price variance in the LCF(50) market (α = 0.10 and 0.002, respectively). This last is significantly higher than the spot price variance in the LCF(5) market (α = 0.02), this being the lowest spot price variance among all the linked markets.

A comparison of the forward and spot price variances within each of the linked treatments suggests that the forward prices are more variable than the spot prices in the LCF(5) market (α = 0.002) and that the spot prices are more variable than the forward prices in the L and LTC(50;10) markets (α = 0.10 and 0.002, respectively). In the LCF(50) market the difference between the forward and spot price variances is not statistically significant.

5.3. The Quantity Traded and Produced

The quantities traded and produced in the different markets according to treatment and replication are displayed in Table D3, Appendix D. The average total quantities traded in the different markets (valid transactions without failed trades) are displayed in Table 7. The average total quantities traded in the

F, L and LCF(5) markets are within the predicted competitive range (20-24 units). The total quantities traded in periods 1 and 2 in the LCF(50) market and also in periods 3 through 5 in the LTC(50;10) market are below the competitive range. In the FCF(5) market the average total quantities traded (valid transactions) are below the competitive range in five of the eight periods. The number of valid transactions in the FCF(5) market is the smallest (statistically significant everywhere), which is reasonable since in this treatment failed forward trades could not be retraded. The random nature of contract failure contributes to the variability in this quantity series from period to period.

Table 7. The Average Total Quantity Traded in Different Markets by Period

(valid transactions)

Treatment / Period	F	FCF (5)	L	LCF (5)	LCF (50)	LTC (50;10)
1	21.33	20.67	23.00	21.00	17.00	23.00
2	20.30	18.67	22.33	22.33	19.67	20.67
3	21.00	20.33	22.33	22.00	20.00	19.67
4	21.00	18.00	22.33	22.00	21.00	19.00
5	21.00	20.00	21.67	21.67	20.67	19.67
6	21.00	19.00	21.33	21.00	20.67	20.33
7	21.67	19.67	21.33	21.33	20.00	20.00
8	21.67	18.67	21.67	21.67	21.67	20.00

The average total quantities were noticeably higher in the L and LCF(5) treatments than they were in the F treatment up to period 6. This suggests that the addition of a spot market to the forward market increased the total quantity traded in early periods. This may be due to the advanced production in the linked spot market.[9] In periods 6 through 8 the total quantities traded in the F, L and LCF(5) markets were not significantly different. This is consistent with the numerical examples based on the theoretical models and suggests that the low level of forward contract failure probability (5%) did not result in a decrease in the total quantity. When the probability of contract failure is raised to 50%, the total quantity traded becomes slightly (not significantly) lower than it is in the F market and significantly lower that it is in the L (α = 0.10) market. This is consistent with the higher mean price level in the LCF(50) treatment and confirms our hypothesis that the high probability of contract failure leads to a reduced total quantity. In Table 7, the total quantity traded in the LCF(50) market is also mostly below that in the LCF(5) market, but the difference is not statistically significant. According to the data presented in the table, the total quantity traded in the LTC(50;10) market is slightly lower than that traded in the LCF(5) and LCF(50) markets (which is consistent with the numerical examples) and is slightly higher than that traded in the FCF(5) market; though these differences are not statistically significant. However, the total quantity traded in the LTC(50;10) market is significantly lower than that traded in the F and L markets (α = 0.10).

Once more, we compare the quantity traded forward and spot under different treatments to understand more clearly the impact of contract failure (Table 8 and Appendix D, Table D3 and Figure D3). The results of the comparison are summarized in Table 9. For treatments such as FCF(5), LCF(5), LCF(50), and LTC(50;10), the quantity traded forward includes failed trades. The actual number of failed trades varied considerably from period to period: from none to four trades within the FCF(5) and LCF(5) treatments and from three to 17 in the LCF(50) and LCF(50;10) treatments. In all, 5.3% of the forward trades failed in the FCF(5) market, 4.7% in the LCF(5) market, 55.4% in the LCF(50) market, and 54.9% in the LTC(50;10) market.

The average forward quantity traded in Table 8 reflects a willingness of the subjects to trade in respective forward markets, even though they know that some trades may fail later. According to the table, the highest quantity traded forward is that in the F market. The quantity traded forward is significantly lower in the LCF(50) and LTC(50;10) markets than it is in the F market (α = 0.10). The quantities traded forward in the L and LCF(5) markets are not significantly different from the

Table 8. The Average Quantity Traded Forward and Spot in Different Markets

(with failed trades)

Treatment / Period	Average Quantity Produced for Forward Trades						Average Quantity Produced Spot and Traded Spot			
	F	FCF (5)	L	LCF (5)	LCF (50)	LTC (50;10)	L	LCF (5)	LCF (50)	LTC (50;10)
1	21.33	20.67	20.67	18.00	15.00	19.33	2.33	3.00	3.67	3.67
2	20.33	20.33	20.00	20.33	16.00	17.33	2.33	2.00	3.67	3.33
3	21.00	20.67	20.00	20.00	17.00	16.33	2.33	2.00	3.00	3.33
4	21.00	19.67	20.33	20.67	18.67	14.33	2.00	1.33	2.33	4.67
5	21.00	20.67	19.67	19.33	16.67	14.00	2.00	2.33	4.00	5.67
6	21.00	20.67	20.33	16.33	18.33	14.33	1.00	4.67	2.33	6.00
7	21.67	20.67	20.00	20.00	19.33	11.00	1.33	1.33	0.67	9.00
8	21.67	20.33	21.00	20.33	18.00	10.00	0.67	1.33	3.67	10.00

Table 9. A Comparison of Average Forward and Spot Quantities across Different Treatments

Treatment Under Consideration	Average Quantity Produced for Forward Trades					Average Quantity Produced Spot and Traded Spot		
	Control Treatment					Control Treatment		
	F	FCF (5)	L	LCF (5)	LCF (50)	L	LCF (5)	LCF (50)
FCF(5)	<							
L	<	≈						
LCF(5)	<	<	<			≈		
LCF(50)	<<	<<	<<	≈		≈	≈	
LTC(50;10)	<<	<<	<<	<<	<<	>>	>>	>>

≈, <, >>, and << denote the same as in Table 5.

quantity traded in the F market, and this is consistent with the theory and the numerical examples, although this could be influenced by the risk attitudes of some participants.[10] We would expect from the theory that the quantity traded forward would be lower in the FCF(5) market than it is in the F market. Although this difference was not statistically significant, we noticed during the experiment that, as a result of the possibility of contract failure, a seller would often reject trading a marginal unit because the failure of the trade could generate a large loss (the production cost is large).[11]

The quantities traded forward in the FCF(5), L and LCF(5) markets are not significantly different from each other, although from the theory we might have expected the quantity in the FCF(5) market to be lower than the quantities in the other two markets. The addition of a spot market and a 5% possibility of forward contract failure did not make trading forward less attractive for subjects. Forward trading becomes less attractive for subjects when the probability of contract failure is 50%: the quantity traded forward in the LCF(50) treatment is lower than that in each of the F, FCF(5) and L treatments (statistically significant, $\alpha = 0.10$). In most periods (period 6 is an exception), the average quantity traded forward is also lower in the LCF(50) market than it is in the LCF(5) market, which is consistent with the numerical examples, although this difference is not statistically significant. The lower level of the quantity traded forward corresponds to a higher forward price level in the LCF(50) market relative to the other treatments (see Figure D1).[12]

When an additional cost of 10 tokens (keeping the 50% probability) was substituted for the need to retrade failed units spot, the forward trades decreased greatly. The quantity traded forward is significantly lower in the LTC(50;10) market than it is in any other market ($\alpha = 0.10$). From the numerical examples based on theory, we would have expected a reduction in the quantity traded forward in the LTC(50;10) market relative to the other treatments, although the degree of the real reduction is higher.[13] This drop in forward trades does not generate a higher forward price in the LTC(50;10) market since buyers are also affected by the high probability of additional transaction costs. They agree to trade forward only if the forward price is sufficiently low. Thus, buyers and sellers both move some of their trades from the forward market to the spot market.

Figure D3 in Appendix D shows the ratio of the units produced to be traded spot (and actually traded spot) to the total quantity transacted in different linked markets. In the LCF(5) and LCF(50) treatments, more units than the total shown in Figure D3 were supplied in the spot market, because some units were traded twice: first in the forward market and then, after failure there, in the spot market. But the figure shows the relative attractiveness of the spot market for subjects in different linked treatments. This can also be seen in Table 8, which displays the average quantities produced and traded spot in different linked markets. The forward market dominated in every linked market treatment. The figure suggests that the relative attractiveness of the spot market was the least in the L treatment, although the quantities produced for spot trading in the L, LCF(5) and LCF(50) markets are not significantly different. The numerical examples based on the theory indicate that there should not be any spot production in the L or the LCF(5) markets. However, in the experiments, the quantity produced to be traded in the spot market was generally about 8% of the total quantity produced in a period in the L market (one or two units) and about 10% of the total quantity produced (two units) in the LCF(5) market. In period 8 these ratios became 3% and 6%, respectively.[14] The existence of spot production in these linked markets may have been caused by sellers who were taking the risk of an uncertain spot price and trying to take advantage (by increasing the spot price) of low supply levels in the spot market. On the other hand, the results of our experiments suggest that a 5% level of contract failure does not affect appreciably the mix of trading activity between the forward and spot markets in the linked design.[15]

According to the numerical examples, the desire to produce and trade spot rises with the increase in the probability of contract failure to 50%. In our LCF(50) experiments, in general, 14% of the total quantity produced (two or three units) represented spot production. This is a very modest increase (from 10% to 14%) relative to the tenfold increase in the probability of contract failure (from 5% to 50%). But this is consistent with the numerical calculations. Adding a 10 token cost for each failed forward trade instead of the need to retrade failed units boosted the spot production to 29% overall and to 50% in the later periods. The quantity produced and traded spot in the LTC(50;10) market is higher than that in any other linked treatment (statistically significant, $\alpha = 0.10$). The higher spot quantity in the LTC(50;10) market relative to other linked markets is consistent with the numerical examples based on the theoretical models, but, again, the increase in the spot quantity in our experiments was much higher than we would have expected from the theory.

Another interesting observation from the spot market within all the linked market treatments and replications is that in all sessions and all periods only two units were produced but not sold (one unit in period 4 of session LCF(5)3 and the other unit in period 1 of session LTC(50;10)2). For a spot market, because of advance production, some units may be produced but not sold. Krogmeier, et al. (1996) studied the spot market as a separate treatment (without any linkage to a forward market) with the same supply-demand schedule as we have, but in a computerized setting. In those experiments, a total of 26 units went unsold. This represented 2.9% of the total of 911 units produced in three spot market sessions. The fact that in our linked market sessions only two units produced for the spot market went unsold (and even these could have been sold easily if the sellers had been willing to take a little loss) can be explained by the information which subjects obtain by observing forward trading. The forward market, even in early periods, offers sellers a price range and, thus, gives them some orientation about the quantity to produce. During all replications of the L treatment, only eight units in total were produced beyond the competitive range, and all of these units were produced by seller 8 in the L4 session (the risk attitude score of this seller was 10). During the three LCF(5) sessions, only four units were produced beyond the competitive range. We think that this was because of the price information supplied by the forward linked market.

5.4. Market Efficiency

Market efficiency can be measured as the share of the total surplus available that is extracted in any one period as buyer and seller earnings. The analysis of earnings focuses on the way the market type and the risk affect the distribution of earnings between buyers and sellers, as well as the total surplus obtained by buyers and sellers together. The supply and demand schedules (Figure 1) provide each subject an equal opportunity to earn 150 tokens in each period, and all subjects in total could earn 1,200 tokens in a period.[16]

Table 10. The Average Total Earnings (tokens) in Different Markets by Period

Treatment / Period	F	FCF (5)	L	LCF (5)	LCF (50)	LTC (50;10)
1	1186.67	1143.33	1185.00	1189.00	1096.67	966.67
2	1186.67	933.33	1193.33	1193.33	1163.00	1013.33
3	1186.67	1133.33	1195.33	1160.00	1174.00	1010.00
4	1200.00	980.00	1190.00	1166.67	1193.33	1020.00
5	1176.67	1100.00	1190.00	1146.67	1156.67	1000.00
6	1200.00	986.67	1193.33	1196.00	1192.67	1000.00
7	1200.00	1083.33	1196.67	1196.67	1180.67	1110.00
8	1196.67	996.67	1200.00	1200.00	1200.00	1053.33

In the F, L and LCF(5) markets agent earnings (averaged for the three replications for periods 6-8) are 99.91%, 99.72% and 99.80% of the available surpluses, respectively (Table 10 and Figure D4 in Appendix D). The average total earnings in these three treatments are therefore about equal (the difference is not statistically significant), reflecting nearly equal prices and quantities. If all the units traded in the FCF(5) market had been successful, market efficiency would have been 98.87%, but the failed trades reduced the extracted surplus to 85.19%. Thus, the total surplus was reduced on average by about 15%, with an average of 5% of the contracts failing in the FCF(5) market. Total earnings are significantly lower in the FCF(5) markets than they are in all other treatments (α = 0.10), except for LTC(50;10).

The total earnings in the LCF(50) market (Table 10) are 99.26% of the available surpluses, and this is not significantly different from the F, L and LCF(5) markets. In the LTC(50;10) market, the total earnings are only 87.87% of the available surpluses. This is significantly (α = 0.10) lower than the share in any other market, except for FCF(5). Thus, adding a 10 token cost for each failed forward trade reduces the total surpluses by more than 10%.

Table 11. The Average Mean Buyer and Seller Earnings (tokens) in Different Markets by Period

Period	Average Buyer Earnings						Average Seller Earnings					
	F	FCF (5)	L	LCF (5)	LCF (50)	LTC (50;10)	F	FCF (5)	L	LCF (5)	LCF (50)	LTC (50;10)
1	97.42	148.25	167.58	211.42	78.50	112.75	199.25	137.58	128.67	85.83	195.67	128.92
2	117.50	122.83	169.83	177.42	124.08	140.92	179.17	110.50	128.50	120.92	166.67	112.42
3	130.42	143.08	147.58	173.42	124.17	145.50	166.25	140.25	151.25	116.58	169.33	107.00
4	142.42	129.00	149.00	171.08	132.92	147.42	157.58	116.00	148.50	120.58	165.42	107.58
5	143.83	130.50	155.17	152.33	133.50	137.92	150.33	144.50	142.33	134.33	155.67	112.08
6	145.00	123.67	150.25	159.58	137.92	129.67	155.00	123.00	148.08	139.42	160.25	120.33
7	142.50	129.17	151.42	154.25	146.33	141.92	157.50	141.67	147.75	144.92	148.83	135.58
8	138.75	125.33	150.92	152.58	146.42	128.83	160.42	123.83	149.08	147.42	153.58	134.50

Mean buyer and seller earnings by session and period are displayed in Table D4 of Appendix D. The average earnings for a buyer and a seller across market types are displayed in Table 11 and illustrated in Figures D5 and D6 in Appendix D. The results of the comparison across market types are also summarized in Table 12. The average buyer earnings in the F and L markets are not significantly different, since quantities and prices were also not significantly different. Adding a 5% probability of contract failure to the forward only market yields buyer earnings which are slightly lower than those in the F treatment and significantly lower than those in each of the L, LCF(5) and LCF(50) treatments ($\alpha = 0.05$). On the other hand, the addition of a 5% probability of contract failure to the linked design does not change buyer earnings significantly relative to the F and L markets.

Table 12. A Comparison of Average Buyer and Seller Earnings across Different Treatments

Treatment Under Consideration	Average Buyer Earnings: Control Treatment					Average Seller Earnings: Control Treatment				
	F	FCF (5)	L	LCF (5)	LCF (50)	F	FCF (5)	L	LCF (5)	LCF (50)
FCF(5)	<					<<				
L	>	>>				<	>>			
LCF(5)	>	>>	>			<	>	<		
LCF(50)	≈	>>	<	<<		≈	>>	>	>	
LTC(50;10)	<	>	<<	<<	<<	<<	≈	<<	<<	<<

Note: ≈, >, <, >>, and << denote the same as in Table 5.

Raising the probability of contract failure to 50% resulted in a slight (not statistically significant) reduction in buyer earnings in the LCF(50) treatment relative to those in the L market and to a significant reduction relative to those in the LCF(5) market ($\alpha = 0.10$). This is consistent with the higher price and the lower quantity in the LCF(50) market compared to the L and LCF(5) markets (see Tables 3 and 7). It should be noted that the actual buyer earnings (that is, calculated using the spot price for the retrade units which failed in the forward market) are higher than the buyer earnings calculated using the initial forward prices for failed forward trades. This was a result of the lower spot prices compared to the forward prices in the LCF(50) market.

The buyer earnings are significantly lower in the LTC(50;10) market than they are in the L and LCF(50) markets (α = 0.10) and slightly (not significantly) lower than they are in the LCF(5) market. This reduction can be attributed to both the additional transaction costs for the failed units and the reduction in the total quantity traded.

The average seller earnings seem to be the highest in the F market. In the L market the average seller earnings are slightly lower, although this difference is not statistically significant. The addition of a 5% probability of contract failure has varying effects on the average seller earnings in the forward only market and in the linked market (Table 12). In the former, the seller earnings decreased significantly (α = 0.10), this being, of course, the result of the failed contracts and the respective uncovered sunk costs. In the LCF(5) market, the drop in the average seller earnings relative to those in the L market was due to the slightly lower price and was not statistically significant.

When the probability of contract failure increased to 50%, seller earnings also increased, becoming slightly (not significantly) higher than they were in the L and LCF(5) markets (Table 12 and Figure D6). Because the quantity traded in the LCF(50) market was lower than that traded in the L and LCF(5) markets, the rise in seller earnings was caused by the relatively higher prices. The seller earnings calculated using the initial forward prices for the failed units were even higher than those actually received after the retrading of failed units in the spot market.

The seller earnings are significantly lower in the LTC(50;10) market than they are in the F market (α = 0.02) and all other linked markets. Again, this may be due to the added transaction costs for the failed units and the reduction in the total quantity traded.

Table 13. A Comparison of Average Buyer and Seller Earnings within the Same Treatment

Buyer Earnings Compared to Seller Earnings					
F	FCF(5)	L	LCF(5)	LCF(50)	LTC(50; 10)
<	≈	>	>>	<<	≈

Note: ≈, >, >>, and << denote the same as Table 5.

Thus, from the standpoint of both the sellers and the buyers the FCF(5) and LTC(50;10) markets are the least desirable of all the market types under consideration. Buyers tend to fare better in the L and LCF(5) markets, and sellers tend to fare better in the F and LCF(50) markets (although the earnings in the F and L markets are not significantly different for buyers or for sellers).

An evaluation of the average earnings for a buyer and a seller within the same treatment (Tables 11 and 13) suggests that the sellers earned significantly more than did the buyers in the LCF(50) market, but the buyers earned significantly more than the sellers in the LCF(5) market ($\alpha = 0.10$). For other markets, buyer and seller earnings were not significantly different.

We also compared the variances in the earnings in different markets. Total earnings are most variable in the FCF(5) market (statistically significant relative to other treatments, except for the LTC(50;10) treatment). The second highest is the total earnings variance in the LTC(50;10) market, and the third highest variance is in the LCF(50) market. This last is significantly higher than the total earnings variances in the L, LCF(5) and F markets, these not being significantly different from each other.

The buyer earnings variances in the FCF(5) and F markets are not significantly different, but both are significantly higher than the variances in all other markets. The variance in the buyer earnings in the LTC(50;10) market is not significantly different from that in the LCF(5) market, but it is significantly higher than those in the L and LCF(50) markets. The variance in the LCF(5) market is not significantly different from the variance in the L market, but it is significantly higher than that in the LCF(50) market. Finally, the variances in the L and LCF(50) markets are not significantly different.

The seller earnings variance is the highest in the FCF(5) market (significantly different relative to other treatments). The second highest is the seller earnings variance in the F market, this not being significantly different from the variance in the LTC(50;10) market. This last is significantly higher than the seller earnings variances in the LCF(5), LCF(50) and L markets, these not being significantly different from each other.

6. SUMMARY AND CONCLUSIONS

The results of the economic models developed in this paper suggest that, in the presence of a risk associated with contract failure in a forward only market (FCF), a risk averse producer is likely to reduce output, resulting in a higher price compared to the no contract failure case (F). If the forward market with contract failure generates a profit for which the certainty equivalent is lower than the certain income in a vertical integration case, a producer is motivated to integrate vertically.

In the case of a reliable linked forward/spot market (L), for a producer to be indifferent in the choice between the forward and spot markets, the spot price must be higher than the forward price. This is because of the cost associated with the risk of inventory loss in the spot market. Economic theory predicts that in the linked market a seller will trade all units in the forward market, and the forward price will be the same as it is in the case of a reliable forward only market (F).

In the case of a linked forward/spot market with possible forward contract failure (LCF), the risk of a contract failure increases the costs for a seller of transacting in both the forward and the spot linked markets. Theoretical models suggest that, if the probability of a forward contract failure is small (5%), risk aversion forces the agents to transact more in the forward linked market. Relative to both the reliable forward only market (F) and the reliable linked (L) market, the forward quantity tends to be higher, while the forward price tends to be lower. There should be no spot production, although the spot price should be higher than the forward price. (Note that, even though there is no spot production, there still could be spot trades involving retraded units which have failed in the forward market. Thus, there could be a spot price.) A tenfold increase in the probability of a forward contract failure (50%) reduces the forward quantity, though only by a very small amount, and prompts some spot production. The spot market serves as a sort of insurance mechanism for the retrading of failed forward units. The forward quantity is slightly lower in this case than it is in the reliable forward only market (F) or the linked (L) market. Risk aversion forces the forward prices and the spot prices to be higher than they are in the case of a 5% probability of forward contract failure (and also higher than they are in the F and L markets), and the spot price is still higher than the forward price. These results, however, are affected by the relative risk aversion of sellers and buyers.

In the case of a linked market with a possible transaction cost associated with a failed forward trade (LTC), a producer's preference for a forward market or a spot market depends on the value of the sum of the expected transaction cost and the transaction cost risk in the forward market compared to the cost associated with the risk of inventory loss in the spot market. The numerical results suggest that, when there is a 50% probability of an additional transaction cost of 10 tokens for a failed forward trade for both sellers and buyers, subjects still prefer to transact most units in the forward market. The quantity traded forward, however, is less than it is in the linked market (L) or the linked with contract failure (LCF) market. Risk aversion forces the quantity traded in the forward LTC market to decrease and the quantity traded spot to increase, while the prices in the forward and the spot linked markets are expected to be higher, with the spot price higher than the forward price. For the same level of risk aversion, the forward and the spot prices in the LTC(50;10) market are a little higher compared to the prices in the linked market with a 50% probability of forward contract failure (LCF(50)). As in the case of the linked market with forward contract failure, these results are affected by the relative risk aversion of sellers and buyers. For each of the linked market cases, if none of the forward or spot linked markets generates a profit for which a certainty equivalent is higher than the certain income in a vertical integration case, a producer is motivated to integrate vertically.

The predictions based on the theoretical models were generally confirmed by the data obtained from the laboratory experiments. The experimental results suggest that, when there is a forward only market, even a low probability of contract failure (5%) leads to a reduced quantity traded and to a slightly increased average price. The total earnings are reduced on average by about 15% and become much more variable, with seller earnings affected more than buyer earnings.

Linking a reliable forward market with a spot market reduces forward trades, since some units are traded spot (less than 10% of the total quantity traded in the linked market). However, this does not cause a significant change in the average price or the total quantity traded or a significant difference between the forward and the spot mean prices. The average total earnings and both buyer and seller earnings are likewise not significantly affected. However, buyer and seller earnings are less variable in the reliable linked market than they are in the reliable forward market.

The incorporation of a low (5%) probability of forward contract failure into the linked design does not affect the market significantly with respect to the reliable case. The variables under consideration (that is, the average price, the forward price, the spot price, the forward quantity traded, the spot quantity produced, total earnings, and the average buyer and seller earnings) were not significantly different from the corresponding variables in the reliable linked market case.

On the other hand, compared to the unreliable forward only market, in the linked market with the same (5%) probability of contract failure, the average price is significantly lower and the total amount of valid transactions is significantly higher and much less variable. As a result, the total earnings and both the buyer and the seller earnings are significantly higher and less variable in the case of the linked design than they are in the forward only market when both have a low probability of contract failure.

The linked market is affected significantly when the probability of contract failure is high (50%). In this case, the total quantity traded becomes significantly lower and the average price becomes significantly higher than they are in the reliable linked market case. The forward quantity traded is also reduced because of the high probability of contract failure, resulting in a forward price which is higher than it is in the case of the reliable linked market. At the same time, the high probability of contract failure does not appreciably affect spot prices relative to the reliable linked market case; this means that the forward price is significantly higher than the spot price in the linked market with a high probability of contract failure. Yet, the total earnings in the linked market with a high probability of contract failure are not significantly different either from those in the reliable linked market case, or from those in the reliable forward only market case. The buyer earnings are slightly reduced as a result of the high probability of contract failure, but the seller earnings are about the same as they are in the reliable linked market. The fact that the forward linked market remains dominant even when the probability of contract failure is high suggests that sellers consider the spot market very risky, although the spot market is important as a residual market. This confirms the hypothesis that a high probability of contract failure results in increased vertical integration.

If failed contracts in the forward market are assessed an additional transaction cost of 10 tokens (instead of allowing failed units to be retraded in the spot market) and if the probability of contract failure is high (50%), the linked market is greatly affected. In this case, the total quantity traded is significantly lower than it is in the reliable linked market. This reduction is due to the lower number of units traded in the forward market. Spot production is much higher than it is in the case of the reliable linked market or the linked market with contract failure. Although the average price is about the same as it is in the reliable linked market, a possible transaction cost affects the forward and the spot prices. The forward price becomes significantly lower as a result of a downward shift in the forward demand. But the spot price becomes slightly higher than it is in the reliable linked market; this is caused by the reduced total production. As a result of the high probability of an additional transaction cost in the forward market, the total earnings are reduced greatly and exhibit more variability. The buyer and the seller earnings are about equal, and both are much lower than they are in the reliable linked market or in the linked markets with contract failure with the option of retrading in the spot market.

The above results suggest that, if there is no spot market, even a low probability of contract failure may create a strong motivation for both the buyer and the seller to integrate vertically. Because a 5% possibility of contract failure reduces total earnings by about 15%, subjects may choose to integrate vertically even if this does not increase earnings up to 100% of the available surplus. (Vertical integration is likely to be less efficient than is the reliable forward market as a result of bureaucratic costs, changing incentives and so on; see Williamson, 1989.) The motivation to integrate vertically is likely to be stronger among more risk averse producers.

The existence of a spot market linked to the forward market with contract failure renders the motivation to integrate vertically much weaker. In the case of a low probability of contract failure, the total earnings are almost equal to the available surplus, and both buyer and seller earnings are not significantly different from those in the case of a reliable linked market. Thus, if there is a linked market with a low probability of contract failure, the motivation to integrate vertically is very weak.

Vertical integration is likely to increase as the probability of contract failure becomes high (50%). The total earnings in this case are still more than 99% of the available surplus, but are quite variable. Buyers might be particularly interested in vertical integration since the high probability of contract failure cuts into their earnings. Sellers, especially those who are strongly risk averse, may also prefer to integrate vertically so as to avoid the risks. Again, the benefits of vertical integration must offset the costs.

The motivation to integrate vertically may be much stronger if the failed contracts in the forward market are subject to an additional transaction cost so that one may not simply retrade the failed units with no explicit cost. Since a 50% probability of a cost of an additional 10 tokens for each forward trade reduces total earnings by about 10% and since buyer and seller earnings are both affected about equally, buyers and sellers each have an incentive to integrate vertically. In this case, for vertical integration not to occur the cost of vertical integration must be considerably higher than it is in the case of the linked market with contract failure and with the option of retrading spot.

Overall, the results of the analyses conducted in this research seem to suggest that if legal institutions are not in place to enforce contracts between buyers and sellers in forward trading, a viable spot market is essential. The spot market acts as an insurance mechanism for forward trades, and the forward markets remain dominant, even though there may be high contract failure. The incentive to integrate vertically, however, is increased when contract failure is prevalent, particularly if real costs are associated with the failed units. This conclusion is consistent with transaction cost economics, which posits, *ceteris paribus*, that the vertical coordination of the various stages of a production, processing and distribution chain will be carried out in the most efficient manner in terms of transaction costs (Coase, 1937; Williamson, 1989). Increased vertical integration, however, has the potential of making the spot market thin.

Further evidence is available from the agricultural and food markets in Russia today. Contractual obligations are often not fulfilled (entirely or in part) as a result of exogenous forces rather than the opportunism of the parties. (For example, state procurement organizations sometimes do not receive the expected funds from a state budget in a timely manner, or processors often cannot pay for inputs because they have not received payment for the output they have already produced.) Thus, parties must often break initial contracts or incur additional costs so as to enforce transactions (for instance, considerable time delays in receiving payments). But the risk of inventory loss in the evolving spot market or the thinness of the spot market prevents firms from relying on the spot market instead of the unreliable forward market. As a result, producers have started to expand processing facilities. This has led to a significant dropoff in the amount of the products delivered to specialized processing firms (up to 30-40% in 1997) (Хлыстун, 1997). This creates inefficiencies, since plants are not being used to capacity, and has induced many processing firms to initiate integration-like contractual arrangements. Another direction in which the vertical integration in Russian agriculture is evolving is the organization of cooperatives, whereby old processing firms are linking up with local agricultural producers. An important impetus for such a trend is the promotion of vertical integration in the food sector by state food policy. Vertical integration has been supported so as to favor an efficient food market, although little attention has been paid to the fact that more vertical integration results in fewer market transactions for intermediate goods. State food policy must therefore be refocused from the effort to facilitate consolidation in the food market toward strengthening the legal system and developing market infrastructure in order to render the forward and spot markets in the food sector less risky. This may also lead to more viable spot markets. A system must be in place whereby resources can find their most economic use.

Increased vertical integration will likely lead to thinner markets for intermediate goods. Thus, market failure may be the result of increased vertical integration, since there are fewer institutional mechanisms for enforcing contracts. This conclusion merits additional investigation, perhaps through a series of experiments which incorporate vertical integration as an alternative to participation in the market.

This study has focused primarily on a particular transaction cost, that is, the enforcement cost which arises after a transaction. This cost is especially relevant in transition economies, where the institutions may not be in place to enforce contracts among agents in the market. The empirical applications of transaction cost economics are limited in number because transaction costs, by their nature, are difficult to measure (Hobbs, 1997). We believe the experimental economics approach employed in this study can be useful in providing empirical content to the theoretical developments in transaction cost economics. Moreover, laboratory techniques are valuable in studying markets in transition economies, where data are scarce or do not exist.

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APPENDIX A. Calculation of the Variance of Profit in the Linked Market with Possible Contract Failure

$\sigma^2(\Pi) = \text{var}\{p_f \cdot \Sigma\varepsilon_i - p_s \cdot \Sigma\varepsilon_i + vq_f - v \cdot \Sigma\varepsilon_i + vq_s\} =$

$= \text{var}\{(p_f - p_s) \cdot \Sigma\varepsilon_i + v(q_f+q_s) - v \cdot \Sigma\varepsilon_i\}$

We consider this variance as a variance of the sum of two random variables. The first is $\Sigma\varepsilon_i$ times (p_f+p_s) plus v times (q_f+q_s), and the second is a product of the two random variables $\Sigma\varepsilon_i$ and v times (-1). Then,

$\sigma^2(\Pi) = \text{var}\{(p_f-p_s) \cdot \Sigma\varepsilon_i + v(q_f+q_s)\} + \text{var}\{v \cdot \Sigma\varepsilon_i\} -$

$- 2 \cdot \text{cov}\{(p_f - p_s) \cdot \Sigma\varepsilon_i + v(q_f+q_s); v \cdot \Sigma\varepsilon_i\}$

Let us consider each of the additives separately.

$\text{var}\{(p_f - p_s) \cdot \Sigma\varepsilon_i + v(q_f+q_s)\} = (p_f-p_s)^2 \cdot q_f \cdot (\rho-\rho^2) + (q_f+q_s)^2 \cdot \sigma^2(v)$

$\text{var}\{v \cdot \Sigma\varepsilon_i\} = [E(v)]^2 \cdot \sigma^2(\Sigma\varepsilon_i) + [E(\Sigma\varepsilon_i)]^2 \cdot \sigma^2(v) + \sigma^2(v) \cdot \sigma^2(\Sigma\varepsilon_i) =$

$= 0 + q_f^2(1-\rho)^2 \cdot \sigma^2(v) + q_f(\rho-\rho^2) \cdot \sigma^2(v) =$

$= q_f^2(1-\rho)^2 \cdot \sigma^2(v) + q_f(\rho-\rho^2) \cdot \sigma^2(v)$

$\text{cov}\{(p_f-p_s) \cdot \Sigma\varepsilon_i + v(q_f+q_s); v \cdot \Sigma\varepsilon_i\} =$

$= (p_f-p_s) \cdot \text{cov}\{\Sigma\varepsilon_i; v \cdot \Sigma\varepsilon_i\} + (q_f+q_s) \cdot \text{cov}\{v; v \cdot \Sigma\varepsilon_i\}$

Consider the two covariances:

$\text{cov}\{\Sigma\varepsilon_i; v \cdot \Sigma\varepsilon_i\} = E[(\Sigma\varepsilon_i) \cdot (v \cdot \Sigma\varepsilon_i)] - E(\Sigma\varepsilon_i) \cdot E(v \cdot \Sigma\varepsilon_i) =$

$= E[(\Sigma\varepsilon_i)^2] \cdot E(v) - [E(\Sigma\varepsilon_i)]^2 \cdot E(v) = 0$

$\text{cov}\{v; v \cdot \Sigma\varepsilon_i\} = E[(v) \cdot (v \cdot \Sigma\varepsilon_i)] - E(v) \cdot E(v \cdot \Sigma\varepsilon_i) = E[(v)^2] \cdot E(\Sigma\varepsilon_i) - 0 =$

$= \{[E(v)]^2 + \sigma^2(v)\} \cdot E(\Sigma\varepsilon_i) = \{0 + \sigma^2(v)\} \cdot q_f(1-\rho) = \sigma^2(v) \cdot q_f(1-\rho)$

Thus,

$\text{cov}\{(p_f - p_s) \cdot \Sigma\varepsilon_i + v(q_f+q_s); v \cdot \Sigma\varepsilon_i\} = 0 + (q_f+q_s) \cdot \sigma^2(v) \cdot q_f(1-\rho) = (q_f+q_s) \cdot \sigma^2(v) \cdot q_f(1-\rho)$

Then,

$$\sigma^2(\Pi) = (p_f\text{-}p_s)^2 \cdot q_f \cdot (\rho\text{-}\rho^2) + (q_f+q_s)^2 \cdot \sigma^2(v) + q_f^2(1\text{-}\rho)^2 \cdot \sigma^2(v) +$$
$$+ q_f\ (\rho\text{-}\rho^2) \cdot \sigma^2(v) - 2(q_f+q_s) \cdot \sigma^2(v) \cdot q_f(1\text{-}\rho) =$$
$$= q_f(\rho-\rho^2) \cdot [(p_f\text{-}p_s)^2+\sigma^2(v)] + \sigma^2(v) \cdot [(q_f+q_s)^2+q_f^2(1\text{-}\rho)^2 -$$
$$- 2(q_f+q_s) \cdot q_f(1\text{-}\rho)] =$$
$$= q_f(\rho-\rho^2) \cdot [(p_f\text{-}p_s)^2 + \sigma^2(v)]+$$
$$+ \sigma^2(v) \cdot [q_f^2+2q_fq_s+q_s^2 + q_f(1\text{-}\rho) \cdot (q_f(1\text{-}\rho) - 2q_f\text{-}2q_s)] =$$
$$= q_f(\rho-\rho^2) \cdot [(p_f\text{-}p_s)^2+\sigma^2(v)] +$$
$$+ \sigma^2(v) \cdot [q_f^2+2q_fq_s+q_s^2 +(q_f\text{-}\rho q_f) \cdot (q_f(\text{-}1\text{-}\rho)\ \text{-}2q_s)] =$$
$$= q_f(\rho-\rho^2) \cdot [(p_f\text{-}p_s)^2+\sigma^2(v)] +$$
$$+ \sigma^2(v) \cdot [q_f^2+2q_fq_s+q_s^2 - (q_f\text{-}\rho q_f) \cdot (q_f+\rho q_f+2q_s)] =$$
$$= q_f(\rho\text{-}\rho^2) \cdot [(p_f\text{-}p_s)^2+\sigma^2(v)] +$$
$$+ \sigma^2(v) \cdot [q_f^2+2q_fq_s+q_s^2\text{-}q_f^2\text{-}\rho q_f^2\text{-}2q_fq_s+\rho q_f^2+\rho^2q_f^2+2\rho q_fq_s] =$$
$$= q_f(\rho-\rho^2) \cdot [(p_f\text{-}p_s)^2+\sigma^2(v)] + \sigma^2(v) \cdot [q_s^2 + \rho^2q_f^2+2\rho q_fq_s] =$$
$$= q_f(\rho-\rho^2) \cdot [(p_f\text{-}p_s)^2+\sigma^2(v)] + \sigma^2(v) \cdot (q_s+\rho q_f)^2$$

APPENDIX B. Numerical Examples

1. Linked Forward/Spot Market

To understand the way in which risk aversion can influence equilibrium prices and quantities in the forward and spot linked markets, we need to develop a model for a buyer in the linked market. Consider a buyer who has an option to buy a good in the forward or spot markets. Let q_f and q_s be the quantities of units bought in the forward and spot markets, respectively, and $q_f+q_s = q$. Also, let p_f and p_s be the forward and spot prices, respectively. In our experiment a buyer does not face any price risk in the spot market (at least no extra risk relative to that in the forward market).

Then, buyer profit is $\Pi = W(q) - p_f \times q_f - p_s \times q_s$

First order conditions require:

$$\frac{d\Pi_{CE}}{dq_f} = W_f'(q_f) - p_f = 0 \qquad \frac{d\Pi_{CE}}{dq_s} = W_s'(q_s) - p_s = 0$$

Now, we have two first order conditions for a seller and two for a buyer. We can solve the four equations to find the four variables (q_f, q_s, p_f, and p_s). To carry out the calculations we must determine $C'_f(q_f)$ and $C'_s(q_s)$ and also $W'_f(q_f)$ and $W'_s(q_s)$. Consider the total cost and redemption value in each of the markets, taking into account the fact that the forward auction is run first.

$C_f(q_f)=25q_f+5q_f^2 \Rightarrow C'_f(q_f)=25+10q_f$

$C_s(q_s)=[25(q_f+q_s)+5(q_f+q_s)^2]-[25q_f+5q_f^2] \Rightarrow C'_s(q_s)=25+10(q_f+q_s)$

$W_f(q_f)=135q_f-5q_f^2 \Rightarrow W'_f(q_f)=135-10q_f$

$W_s(q_s)=[135(q_f+q_s)-5(q_f+q_s)^2]-[135q_f-5q_f^2] \Rightarrow W'_s(q_s)=135-10(q_f+q_s)$

Solving the four first order conditions for any value of λ and $\sigma^2(v)$ yields the following results: $q_f = 5{,}5$ (5-6 units); $p_f = 80$; $q_s = 0$; and $p_s = 0$ (more precisely, $p_s = 80$, but this does not make sense because, according to the calculations, there should be no spot trades). Thus, when there is a linked forward/spot market, all trades are made in the linked forward market; the price level in the linked forward market is the same as in the forward only market. Risk aversion does not influence these results.

2. Linked Forward/Spot Market with Contract Failure

Consider a buyer who has an option to buy a good in the forward or spot markets in a situation in which each forward contract can fail separately with some known probability (ρ).

Again, let q_f and q_s be the quantities of units bought in the forward and spot markets, respectively, and $q_f+q_s = q$. Also, let p_f and p_s be the forward and spot prices, respectively. Let $\varepsilon = \Sigma\varepsilon_i$, $i = 1,\ldots,q_f$, be a binomially distributed random variable with the probability of success at $(1-\rho)$. Then, $\gamma = \Sigma(1-\varepsilon_i)$ is a random variable which equals the number of failures.

As in the experiment, let each unit bought be associated with a distinct redemption value for a buyer w_i. Then, w_i is a marginal redemption value, and summing w_i through $i = 1,\ldots,q$ we get the total redemption value function: $\Sigma w_i = W(q)$, $i = 1,\ldots,q$.

Again, in our experiment a buyer does not face any price risk in the spot market (at least no more so than in the forward market). Then, the risky profit for the buyer is:

$$\Pi = \sum_{1}^{qf} (w_i \cdot \varepsilon_i) - p_f \cdot \sum_{1}^{qf} \varepsilon_i + \sum_{1}^{qf} [w_i \cdot (1-\varepsilon_i)] + \sum_{qf+1}^{qf+qs} w_i - p_s \cdot \sum_{1}^{qf} (1-\varepsilon_i) - p_s \cdot q_s =$$

$$= \sum_{1}^{qf+qs} w_i - p_f \cdot \sum_{1}^{qf} \varepsilon_i - p_s \cdot (q_f - \sum_{1}^{qf} \varepsilon_i) - p_s \cdot q_s =$$

$$= W(q_f+q_s) - p_f \cdot \sum_{1}^{qf} \varepsilon_i - p_s \cdot (q_f - \sum_{1}^{qf} \varepsilon_i + q_s)$$

$$E(\Pi) = W(q) - p_f q_f (1-\rho) - p_s (q_f \rho + q_s)$$

$$\sigma_P^2 = (p_f - p_s)^2 q_f (\rho - \rho^2)$$

$$\Pi_{CE} = W(q) - p_f q_f (1-\rho) - p_s (q_f \rho + q_s) - \frac{\lambda}{2} \cdot (p_f - p_s)^2 q_f (\rho - \rho^2)$$

$$\frac{d\Pi_{CE}}{dq_f} = W'_f(q_f) - p_f(1-\rho) - p_s\rho - \frac{\lambda}{2} \cdot (p_f - p_s)^2 (\rho - \rho^2)$$

$$\frac{d\Pi_{CE}}{dq_s} = W'_s(q_s) - p_s$$

To make the calculations we must select an appropriate value of λ (the absolute risk aversion coefficient) and $\sigma^2(v)$ (the spot price variance). There is little consistency in the literature (for example, Raskin and Cochran, 1986) on the appropriate coefficients of absolute risk aversion or on the classifications of specific coefficient values. The lower bounds in strongly risk-averse preferences range from 0.000042 to 6.0. However, to present an illustrative numerical example, we will use $\lambda = 0.01$.

For the numerical examples we use the actual values of $\sigma^2(v)$ from the experiments. The spot price variance calculated using the spot prices from the last three periods of each replication of the LCF(5) market is 3.2, and the spot price variance for the LCF(50) market was 7.5. We also use expressions for $C'_f(q_f)$ and $C'_s(q_s)$ and also $W'_f(q_f)$ and $W'_s(q_s)$, as in the previous example.

The models predict the following results for the 5% and 50% levels of the probability of contract failure:

Risk aversion coefficient		$\rho = 0.05$ $\sigma^2(v) = 3.2$				$\rho = 0.5$ $\sigma^2(v) = 7.5$			
		Equilibrium quantity		Equilibrium price		Equilibrium quantity		Equilibrium price	
λ_{buyer}	λ_{seller}	$q_{forward}$	q_{spot}	$p_{forward}$	p_{spot}	$q_{forward}$	q_{spot}	$p_{forward}$	p_{spot}
0	0	5-6 (5.50)	0	80.00	80.00	5-6 (5.50)	0	80.00	80.00
0.01	0	5-6 (5.49)	0 (0.001)	80.00	80.00	5-6 (5.5)	0	80.00	80.00
0	0.01	6-7 (6.75)	0 (-1.25)	66.80	79.96	5-6 (5.49)	0	80.10	80.10
0.01	0.01	6 (6.12)	0 (-0.62)	77.37	80.00	5-6 (5.4)	0-1 (0.1)	80.01	80.10

The numerical results suggest that, when the probability of a forward contract failure is small (5%), risk aversion forces the agents to transact more in the forward linked market, and the forward price is going down and is below the spot price. (Note that, even though there is no spot production, there still could be spot trades involving retraded units which failed in the forward market. Thus, there could be a spot price.)

A tenfold increase in the probability of a forward contract failure (50%) reduces forward trades, but only by a very small amount, and allows for some spot production.**]** Risk aversion forces both the forward and the spot prices up relative to the case of a 5% probability of a forward contract failure, though the spot price is still higher than the forward price.

3. Linked Forward/Spot Market with Transaction Cost

As in previous examples, to understand the way in which possible transaction costs and risk aversion can influence equilibrium prices and quantities in the forward and spot linked markets, we need to develop a model for a buyer in a linked market with a possible transaction cost. Consider a buyer who can transact in the forward or spot market, while there is a possible additional transaction cost for a trade in the forward linked market.

Again, let q_f and q_s be the quantities of units produced to be traded in the forward and spot markets, respectively, and $q_f+q_s = q$. Also, let p_f and p_s be the forward and spot prices, respectively. As in the previous example, a buyer does not face any price risk in the spot market (at least no more than is present in the forward market).

Let $\varepsilon = \Sigma\varepsilon_i$, $i = 1,\ldots,q_f$, be a binomially distributed random variable with a probability of success (that is, $\varepsilon_i = 1$) ρ. Here, success in Bernoulli's exercise causes failure for a trade (the buyer has to incur an additional cost of transacting, t).

The risky profit is $\Pi = W(q) - p_f \cdot q_f - p_s \cdot q_s - t \cdot \varepsilon$

The expected profit and the variance of the profit are:

$E(\Pi) = W(q) - p_f \cdot q_f - p_s \cdot q_s - t \cdot \rho \cdot q_f$ $\sigma^2(\Pi) = t^2 \cdot q_f \cdot (\rho - \rho^2)$

The certainty equivalent of the profit expression is

$$\Pi_{CE} = W(q) - p_f \cdot q_f - p_s \cdot q_s - t \cdot \rho \cdot q_f - \frac{\lambda}{2} \cdot t^2 \cdot q_f \cdot (\rho - \rho^2)$$

First order conditions require:

$$\frac{d\Pi_{CE}}{dq_f} = W_f'(q_f) - p_f - t \cdot \rho - \frac{\lambda}{2} \cdot t^2 \cdot (\rho - r^2) = 0$$

$$\frac{d\Pi_{CE}}{dq_s} = W_s'(q_s) - p_s = 0$$

Again, for the numerical examples we use the actual values of $\sigma^2(v)$ from the experiments. The spot price variance calculated using spot prices from the last three periods of each replication of the LTC(50;10) market was 15.0. We also use expressions for $C'_f(q_f)$ and $C'_s(q_s)$ and also $W'_f(q_f)$ and $W'_s(q_s)$ as in previous examples.

The models predict the following results for a 50% probability of an additional transaction cost of 10 tokens for a forward trade:

Risk aversion coefficient		Equilibrium quantity		Equilibrium price	
λ_{buyer}	λ_{seller}	$q_{forward}$	q_{spot}	$p_{forward}$	p_{spot}
0	0	5 (5.00)	0-1 (0.5)	80.00	80.00
0.01	0	4-5 (4.99)	0-1 (0.51)	79.90	80.00
0	0.01	4-5 (4.99)	0-1 (0.51)	80.03	80.04
0.01	0.01	4-5 (4.99)	0-1 (0.51)	80.00	80.05
0.10	0.10	4-5 (4.88)	0-1 (0.58)	80.05	80.40
0.50	0.50	4-5 (4.38)	0-1 (0.81)	80.05	83.10

The numerical results suggest that, when there is a 50% probability of an additional transaction cost of 10 tokens for a forward trade for both sellers and buyers, subjects still prefer to transact most units in the forward market. Risk aversion forces the quantity traded forward to go down, the quantity traded spot to go up, and the prices in both the forward and the spot linked markets to be higher, with the spot price higher than the forward price.

APPENDIX C. Examples of Participant Instructions

Choice Experiment

For each of the following 19 choices, put an X in the column following either Option A, or B. One of the choices will be selected at random, and the lottery to determine your payment will be conducted at the end of the experiment. At the end of the experiment the 19 balls numbered 1 through 19 will be placed in the lottery game. The first ball selected by the machine will identify the option which will determine your payoff. Then 20 balls numbered 1 through 20 will be placed in the machine, and another ball will be selected to determine the outcome of the lottery in Option B.

Choice	Option A		Option B	
1	2	3	4	5
1	$2.50 for sure		$5 if the number is greater than 1 (95% chance) versus $0 if the number is 1 (5% chance)	
2	$2.50 for sure		$5 if the number is greater than 2 (90% chance) versus $0 if the number is 2 or less (10% chance)	
3	$2.50 for sure		$5 if the number is greater than 3 (85% chance) versus $0 if the number is 3 or less (15% chance)	
4	$2.50 for sure		$5 if the number is greater than 4 (80% chance) versus $0 if the number is 4 or less (20% chance)	
5	$2.50 for sure		$5 if the number is greater than 5 (75% chance) versus $0 if the number is 5 or less (25% chance)	
6	$2.50 for sure		$5 if the number is greater than 6 (70% chance) versus $0 if the number is 6 or less (30% chance)	
7	$2.50 for sure		$5 if the number is greater than 7 (65% chance) versus $0 if the number is 7 or less (35% chance)	
8	$2.50 for sure		$5 if the number is greater than 8 (60% chance) versus $0 if the number is 8 or less (40% chance)	
9	$2.50 for sure		$5 if the number is greater than 9 (55% chance) versus $0 if the number is 9 or less (45% chance)	

1	2	3	4	5
10	$2.50 for sure		$5 if the number is greater than 10 (50% chance) versus $0 if the number is 10 or less (50% chance)	
11	$2.50 for sure		$5 if the number is greater than 11 (45% chance) versus $0 if the number is 11 or less (55% chance)	
12	$2.50 for sure		$5 if the number is greater than 12 (40% chance) versus $0 if the number is 12 or less (60% chance)	
13	$2.50 for sure		$5 if the number is greater than 13 (35% chance) versus $0 if the number is 13 or less (65% chance)	
14	$2.50 for sure		$5 if the number is greater than 14 (30% chance) versus $0 if the number is 14 or less (70% chance)	
15	$2.50 for sure		$5 if the number is greater than 15 (25% chance) versus $0 if the number is 15 or less (75% chance)	
16	$2.50 for sure		$5 if the number is greater than 16 (20% chance) versus $0 if the number is 16 or less (80% chance)	
17	$2.50 for sure		$5 if the number is greater than 17 (15% chance) versus $0 if the number is 17 or less (85% chance)	
18	$2.50 for sure		$5 if the number is greater than 18 (10% chance) versus $0 if the number is 18 or less (90% chance)	
19	$2.50 for sure		$5 if the number is greater than 19 (5% chance) versus $0 if the number is 19 or less (95% chance)	

Linked Forward / Spot Market with Possible Contract Failure (LCF)

Introduction

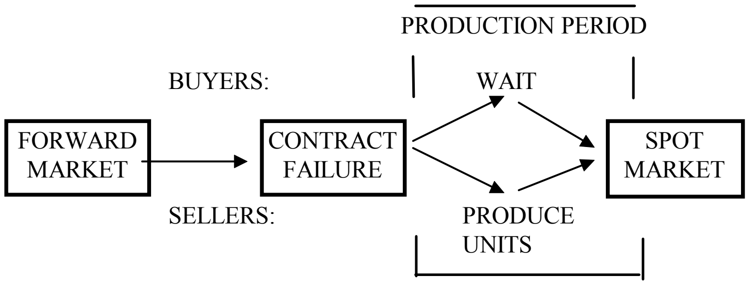
This is an experiment in the economics of market decisionmaking. In this experiment, some of you will be BUYERS, and some of you will be SELLERS. You have been provided with forms which are labeled either BUYER RECORD SHEET, or SELLER RECORD SHEET. The sheet you have received reveals whether you are a buyer or a seller in this experiment and also gives you an ID number. These record sheets will be used for the purpose of illustration only. You will receive actual record sheets just prior to the beginning of the experiment.

The commodity you are trading is referred to as a "unit". Sellers make earnings by producing units at a cost and selling these units to buyers. Buyers make earnings by purchasing units from sellers and then redeeming (or reselling) these units to the experimenter. Earnings are recorded in a fictitious currency called tokens. Tokens are exchanged for cash at the rate of ________. Your earnings will be paid to you in CASH at the end of the experiment. To begin, every seller and buyer will be given an initial beginning balance of ________. You may keep this money, PLUS any you earn. Your goal is to maximize your earnings by selling or buying units. You can add to the initial balances only by buying or selling units during the experiment.

Buyers and sellers will exchange units for tokens over a sequence of trading cycles. The organization of a trading cycle is depicted below in Figure 1.

Each trading cycle consists of a forward market, an assessment of the success or failure of selected trades in the forward market, a production period, and a spot market. The forward market occurs before sellers have produced any units. In this experiment, trades in the forward market may fail. An **equal and known probability** of failure will be assigned to each trade. In this session, the probability that each trade will fail will be _____. All of this occurs before the unit has actually been produced. The spot market occurs after sellers have produced units. In the spot market sellers therefore have units ready (or "in stock") to be sold.

Figure 1. Organization of Trading Cycle



The forward and spot markets are therefore separated by a production period. During the production period, sellers decide on the total number of units they will produce for the cycle. **They must produce at least as many units as they have already sold in the forward market, including those which have failed.** Any units produced which have not already been sold in the forward market are then available to sell in the spot market, along with units which may have failed in the forward market.

All trading in the forward and spot markets is conducted via an oral double auction. During every trading cycle, you account for the sales or purchases which you have made and adjust your token (ending) balance accordingly on the record sheet. This ending balance becomes the beginning balance in the next cycle. After you have properly recorded and totaled this information, a new trading cycle will begin. This experiment will consist of approximately seven or eight trading cycles. We will conduct practice cycles to familiarize you with the mechanics of the auction and the recordkeeping before the actual experiment begins.

Specific Instructions to Buyers

If you have been designated as a buyer, please refer to your BUYER RECORD SHEET for practice cycle 1. Remember, the values on this sheet are hypothetical. You will receive actual record sheets (with values for the experiment) after the practice cycle.

During each trading cycle you are free to purchase **up to eight units**. You may purchase units in the forward market or in the spot market or both. For the first unit that you buy during a trading cycle, you will receive the amount listed under UNIT VALUE for Unit 1. In this example, this amount is 529 tokens. The redemption value of Unit 1 is 529 tokens. For the second unit that you buy you will receive the amount listed under UNIT VALUE for Unit 2, which is 483 tokens. The redemption values for subsequent units are found in the same way.

The earnings for each unit that you purchase (which are yours to keep) are computed by taking the difference between the redemption value and the purchase price of the unit bought. That is,

Your Earnings = **Redemption Value** − **Purchase Price**

Suppose, for example, that you buy two units in the forward market. One of these, say the purchase of Unit 2 in the forward market, is randomly chosen to fail. You must then renegotiate a purchase price for this unit in the spot market using the UNIT VALUE for that unit, along with any other units you wish to purchase in the spot market. If you pay 400 tokens for the first unit and initially agreed to pay 410 tokens for the second unit in the forward market, but renegotiated Unit 2 for 420 tokens in the spot market, your earnings are:

earnings for Unit 1 = **529 - 400** = **129**

earnings for Unit 2 = **483 - 420** = **63**

total earnings = **129** + **63** = **192 tokens**

On the other hand, if you fail to buy Unit 2 in the spot market, the earnings would be zero for that unit, and the total earnings would be 129 tokens instead of 192.

There are blanks on the record sheet for the recording of the purchase price and the earnings of each unit that you may purchase. Note that there is also a column which you may use to identify the trades, if any, that failed in the forward market. Again, in the spot market you may purchase units which failed in the forward market using the UNIT VALUE for the failed unit. If you do not renegotiate the purchase of a failed unit, you get zero earnings for that unit. Also, note that the unit earnings must be revised using the New Purchase Price for failed units. During the experiment you will record information as you purchase units. Buyers should also be aware that, to buy units, they cannot spend more than the number of tokens that they have in their beginning balances in any one cycle. Finally, buyers need not and should not trade a unit unless they can realize positive earnings for that unit. Thus, you need not purchase all eight units.

Specific Instructions to Sellers

If you have been designated as a seller, please refer to your SELLER RECORD SHEET for practice cycle 1. Remember, the costs on this sheet are hypothetical. You will receive actual record sheets (with costs for the experiment) after the practice cycle.

During each trading cycle you are free to produce and sell **up to eight units**. The first unit that you produce during a trading cycle will cost you the amount listed under UNIT COST for Unit 1. In this example, this cost is 71 tokens. The unit cost of Unit 1 is 71 tokens. The second unit that you produce will cost you the amount listed under UNIT COST for Unit 2, which is 117 tokens. The unit costs for subsequent units are found in the same way.

The earnings from each unit that you produce and sell (the earnings are yours to keep) are computed by taking the difference between the sale price and the unit cost of the unit sold, that is,

Your Earnings = Sale Price − Unit Cost

You may sell units in the forward market or in the spot market or both. Units sold in the forward market are sold BEFORE you have produced them. **You must produce any unit sold in the forward market, including those which have failed**. (The monitor will remind sellers of this responsibility during the experiment.) Suppose, for example, that you sell two units in the forward market. Once trading in the forward market has finished, you must produce at least Unit 1 and Unit 2. If you have decided to produce a total of three units, you would then have Unit 3 to sell in the spot market, assuming neither Unit 1, nor Unit 2 fails. (Note that there is a blank on the record sheet for the recording of “Units Produced”.) Be aware that if you fail to sell Unit 3 in the spot market, you will still incur the cost of producing Unit 3. If this occurs, your unit earnings for Unit 3 would be -169 tokens (that is, your unit earnings for Unit 3 would be negative). In other words, you will not be permitted to carry over units to the next trading cycle.

Let’s suppose that in the forward market you initially sell Unit 1 for 210 tokens and Unit 2 for 230 tokens. The sale of Unit 1 in the forward market is randomly chosen to fail. You must then renegotiate a sale price for this unit in the spot market using the UNIT COST for that unit, along with any other units you wish to sell in the spot market. Say you sell Unit 1 for 200 tokens and also sell Unit 3 in the spot market for 220 tokens. Your earnings would then be:

earnings for Unit 1 = 200 - 71 = 129

earnings for Unit 2 = 230 - 117 = 113

earnings for Unit 3 = 220 - 169 = 51

total earnings = 129 + 113 + 51 = 293 tokens

If you failed to sell Unit 1 in the spot market, you would lose the UNIT COST; the earnings for that unit would be − 71, and the total earnings would be 93 tokens, instead of 293.

There are blanks on the record sheet for recording the productive decision, the sale price, and the unit earnings of each unit that you may produce and sell. Note that there also is a column which you may use to identify the trades, if any, that failed in the forward market. Again, using the UNIT COST for each failed unit, you may sell in the spot market the units which failed in the forward market. **If you fail to renegotiate the sale of a failed unit, you lose the unit cost for that unit.** Also, note that earnings must be revised using the New Sale price for failed units. During the experiment you will record information as you sell units. Sellers should also be aware that they cannot incur a production cost greater than the amount in their beginning token balance in any one cycle.

Finally, in the forward market, sellers need not and should not trade a unit unless they can realize positive earnings on that unit. They may, however, wish to trade at a loss in the spot market, so as not to lose the entire cost of a unit which has been produced for sale. Thus, you need not produce and sell all eight units.

Trading Rules for Both the Forward and the Spot Markets

Only one unit may be bought and sold at a time. Buyers compete with other buyers to purchase units by making "bids". A "bid" is the proposed price at which a buyer is willing to purchase a unit; obviously, it should be below the redemption or resale value for the particular unit being purchased. Bids must become progressively higher. In other words, if the first bid for a unit is 100 tokens, then the second bid must be higher than 100 tokens. Suppose the second bid is 120 tokens, then the third bid must be higher than 120, and so on. Bids will be recorded on the chalkboard as they occur.

Sellers compete with other sellers to sell units by making "offers". An "offer" is the proposed price at which a seller is willing to sell a unit; obviously, it should be higher than the cost for the particular unit being sold. Offers must become progressively lower. In other words, if the first offer to sell a unit is for 200 tokens, then the second offer must be lower than 200 tokens. Suppose the second offer is 180 tokens, then the third offer must be less than 180, and so on. Offers will be recorded on the chalkboard as they occur.

There is one further set of restrictions on bids and offers. These are common sense restrictions. A buyer's bid cannot be higher than the best or lowest offer displayed on the chalkboard. In other words, a buyer cannot attempt to pay a price which is higher than that at which some seller is willing to sell. Similarly, a seller's offer cannot be lower than the best or highest bid displayed on the chalkboard. In other words, a seller cannot attempt to sell at a price below that which some buyer is willing to pay.

A bid is made by simply calling out a price in tokens, for instance: "bid x tokens". Similarly, an offer is made by calling out a price in tokens, for example: "offer x tokens". During a market, buyers will be making bids at the same time that sellers are making offers.

It should be apparent that the difference between the BEST BID and the BEST OFFER gradually decreases. A trade is made when the BEST BID equals the BEST OFFER. Suppose the BEST BID is 150 tokens and the BEST OFFER is 160 tokens. If a buyer decides that he or she is willing to purchase the unit for 160 tokens, he or she calls out "bid 160 tokens" or "accept".

Likewise, suppose the BEST BID is 150 and the BEST OFFER is 160. If a seller decides that he or she is willing to sell the unit for 150 tokens, he or she calls out "offer 150 tokens" or "accept".

After a seller and buyer have made a trade, the monitor records the respective ID numbers of the buyer and seller making the transaction. The buyer and the seller then record the trade price in the appropriate place on their respective record sheets. The buyer and seller who have made a transaction then move on to the next unit on their record sheet. **Each buyer and seller must move to the next unit in the record sheet only after having bought/sold the previous unit.** Buyers and sellers may then resume making bids and offers for additional units.

Trades may occur until such time as bids and offers cease or the monitor stops trading. Again, after trading ceases in the forward market, there is an assessment of whether or not each trade in the forward market failed. This is followed by a production period, which in turn is followed by a spot market. Each trade will have an equal chance of failing, with a probability of ______. After trading ceases in the spot market and all participants have completed their record sheets, another trading cycle begins.

SELLER RECORD SHEET (Practice Cycle)

Seller ID: ___________ Units Produced ________________

Trading Cycle: ________

UNIT	MARKET (F or S)	FAILED (Y or N)	SALE PRICE	NEW SALE PRICE	- UNIT COST	= UNIT EARNINGS	REVISED UNIT EARNINGS
1					71		
2					117		
3					169		
4					227		
5					291		
6					361		
7					437		
8					519		
					Total:		

TOKENS

Beginning Balance: _____(Initial balance or ending balance from the previous trading cycle.)

+ Total Unit Earnings: ______ (Total unit earnings from this trading cycle.)

= Ending Balance: ______

BUYER RECORD SHEET (Practice Cycle)

Buyer ID: ___________

Trading Cycle: ________

UNIT	MARKET (F or S)	FAILED (Yes or No)	UNIT VALUE -	PURCHASE PRICE	NEW PURCHASE PRICE =	UNIT EARNINGS	REVISED UNIT EARNINGS
1			529				
2			483				
3			431				
4			373				
5			309				
6			239				
7			163				
8			81				
					Total:		

TOKENS

Beginning Balance: _____(Initial balance or ending balance from the previous trading cycle.)

+ Total Unit Earnings: ______ (Total unit earnings from this trading cycle.)

= Ending Balance: ______

APPENDIX D. Laboratory Experiment Data

Table D1. Average Trade Prices (tokens) and Standard Deviation by Treatments and Replications

Per.	F						FCF(5)						L					
	F1		F2		F3		FCF(5)1		FCF(5)2		FCF(5)3		L2		L3		L4	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
1	107.6	15.85	91.7	9.0	71.17	15.09	82.35	8.32	98.44	6.45	61.67	9.40	84.70	4.69	69.19	6.06	74.92	6.37
2	103.1	15.77	81.05	4.45	75.1	12.07	85.33	5.12	98.59	6.48	67.13	11.29	83.65	5.51	74.00	5.98	71.58	7.53
3	94.55	11.66	77.2	3.79	76.71	3.29	81.24	3.05	90.67	8.83	70.91	8.15	82.43	3.27	85.33	3.10	74.22	6.34
4	91.29	10.68	79.3	2.11	74	5.90	80.65	1.90	92.11	3.51	74.48	6.67	79.96	0.56	84.82	3.23	75.77	3.52
5	87	11.75	81.53	1.43	74.59	5.54	79.95	0.22	90.4	5.28	77.91	5.90	77.90	2.05	81.27	3.89	77.45	4.03
6	86.62	10.89	81.43	0.81	74.81	4.08	79.52	0.60	88	4.41	78.38	6.42	78.67	1.15	83.30	2.32	77.68	2.44
7	86.18	8.42	81.18	0.85	76.57	3.19	79.67	0.58	87.9	4.13	81.24	4.46	78.85	0.81	81.78	3.37	77.86	2.67
8	87.73	8.40	80.86	0.77	77.43	2.44	79.6	0.60	86.5	3.66	80.05	6.13	79.64	1.09	80.45	2.40	79.38	1.99

Table D1 continued

Per.	LCF(5)						LCF(50)						LTC(50;10)					
	LCF (5)1		LCF (5)2		LCF (5)3		LCF (50)1		LCF (50)2		LCF (50)3		LTC (50;10)1		LTC (50;10)2		LTC (50;10)3	
	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD
1	69.14	6.71	67.68	5.30	66.96	6.17	93.50	20.77	90.57	10.34	103.8	6.87	74.09	5.43	68.78	10.94	104.3	35.0
2	73.83	3.73	77.79	3.67	73.63	7.97	79.79	3.02	79.41	4.11	96.67	6.55	74.00	2.00	77.21	4.33	80.86	9.69
3	73.08	2.71	76.36	2.13	73.25	4.21	80.82	5.93	80.00	1.98	93.38	6.75	73.16	1.95	78.85	4.27	76.35	4.43
4	75.04	4.14	79.18	1.50	74.78	4.77	81.03	2.46	80.00	1.77	90.47	6.06	74.58	1.22	78.24	4.72	75.43	2.27
5	77.64	3.91	80.55	1.06	73.9	2.53	80.62	2.46	80.16	0.58	89.31	3.30	75.95	1.47	79.39	4.80	76.52	5.25
6	79.74	3.92	80.67	0.86	74.32	3.55	81.50	1.93	80.43	1.04	85.31	4.05	76.38	2.04	81.38	2.60	79.53	2.01
7	81.38	2.50	80.24	0.63	75.77	2.00	82.41	1.96	80.38	0.55	80.25	4.31	76.81	2.04	80.37	5.72	80.85	2.46
8	81.59	2.42	80.05	0.38	76.95	2.54	82.47	1.50	80.53	0.57	79.69	3.51	77.40	1.50	82.67	4.44	80.53	1.61

Table D2. Average Trade Prices (tokens) and Standard Deviation in Forward and Spot Linked Markets by Replication

Per.	L2		L3		L4		LCF(5)1		LCF(5)2		LCF(5)3	
	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD
	Forward linked											
1	84.23	4.22	68.70	5.78	74.75	6.97	66.76	5.57	66.38	4.62	65.95	5.62
2	84.45	5.47	73.68	5.97	70.95	7.85	73.62	3.68	77.21	3.63	71.76	5.53
3	83.25	2.59	85.45	3.14	73.55	6.54	73.28	2.80	76	1.86	72.91	3.65
4	80.05	0.50	85.40	2.76	75.45	3.53	75.65	3.81	79.21	1.58	74.78	4.77
5	77.75	1.97	81.56	4.18	77.38	4.12	77.35	4.37	80.75	0.85	73.90	2.53
6	78.65	1.18	83.21	2.35	77.62	2.48	79.7	5.10	80.72	0.83	73.81	2.69
7	78.85	0.81	82.79	2.12	77.86	2.67	81.4	2.56	80.39	0.50	75.77	2.0
8	79.64	1.09	80.71	2.12	79.40	2.04	81.90	1.97	80.11	0.31	76.86	2.56
	Spot linked											
1	95.00	0	79.00	-	75.60	3.44	77.2	2.58	74.67	2.52	74	6.82
2	78.33	0.58	80.00	-	76.00	1.73	75.33	4.51	80	3.24	86.67	11.55
3	77.00	1.73	83.00	-	78.67	1.15	72.57	2.57	80	0	77	9.90
4	79.00	0	79.00	0	79.00	0	72	4.97	79	1	-	-
5	81.00	0	80.00	2.16	79.00	-	78.6	1.51	78.5	0.71	-	-
6	79.00	-	85.00	-	79.00	-	79.77	0.60	80.33	1.15	85	0
7	-	-	77.00	4.40	-	-	81.25	2.5	79.33	0.58	-	-
8	-	-	75.00	-	79.00	-	75	0	79.5	0.71	79	-

Table D2 continued

Period	LCF(50)1		LCF(50)2		LCF(50)3		LTC(50;10)1		LTC(50;10)2		LTC(50;10)2	
	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD
	Forward linked											
1	106.00	16.90	96.39	6.60	107.20	6.88	73.53	5.83	66.33	11.15	107.86	34.72
2	78.73	2.89	79.63	4.57	100.50	4.15	74.28	1.84	75.38	3.86	80.95	9.93
3	82.17	4.41	79.72	2.47	98.80	2.21	73.07	2.15	78.00	4.74	76.35	4.43
4	81.83	2.41	80.22	0.55	92.70	4.51	74.57	1.40	74.89	3.62	75.20	2.07
5	80.75	2.18	80.22	0.55	90.50	2.58	75.17	0.94	75.80	2.62	75.90	4.52
6	81.89	1.64	80.72	1.18	87.37	3.08	74.92	0.67	80.33	1.80	79.06	1.73
7	82.32	2.00	80.55	0.51	82.47	3.76	75.00	0.63	76.27	1.56	80.55	1.57
8	82.59	1.42	80.53	0.51	81.56	2.87	76.11	1.27	79.25	1.60	80.67	1.66
	Spot linked											
1	74.18	5.62	84.41	10.14	100.73	5.46	76.75	0.96	77.60	2.30	68.00	2.83
2	81.00	2.80	79.00	3.23	91.30	5.48	72.33	2.52	81.17	2.04	79.00	-
3	79.20	7.19	80.38	0.96	87.57	4.77	73.50	1.00	80.83	2.04	-	-
4	79.92	2.14	79.50	3.16	86.75	6.65	74.60	0.55	82.00	2.33	80.00	-
5	80.46	2.85	80.08	0.64	87.85	3.58	77.13	1.36	83.88	2.42	89.00	-
6	81.00	2.22	80.00	0.60	81.40	2.50	78.33	1.50	84.00	2.53	82.00	1.73
7	82.60	1.96	80.08	0.51	77.76	3.51	78.80	0.63	86.00	4.24	81.22	3.31
8	82.31	1.65	80.54	0.66	77.29	2.73	78.45	0.52	87.22	2.22	80.40	1.65

Table D3. Quantity Traded and Produced by Replication and Treatment

Period	F			FCF(5)						L					
	F1	F2	F3	FCF(5)1		FCF(5)2		FCF(5)3		L2		L3		L4	
				All	Fail	All	Fail	All	Fail	Forw	Spot	Forw	Spot	Forw	Spot
1	21	20	23	23	0	18	0	21	0	22	1	20	1	20	5
2	20	20	21	21	3	17	1	23	1	20	3	19	1	21	3
3	22	20	21	21	0	19	1	22	0	20	3	20	1	20	3
4	21	20	22	20	3	18	2	21	0	21	2	20	2	20	2
5	22	19	22	20	1	20	1	22	0	20	1	18	4	21	1
6	21	21	21	21	1	20	1	21	3	21	1	19	1	21	1
7	22	22	21	21	2	20	1	21	0	20	0	19	4	21	0
8	22	22	21	20	1	20	1	21	3	22	0	21	1	20	1

Table D3 continued

PERIOD	LCF(5)									LCF(50)									LTC(50;10)								
	LCF(5)1			LCF(5)2			LCF(5)3			LCF(50)1			LCF(50)2			LCF(50)3			LTC11			LTC2			LTC3		
	Forw		Sp	Forw		Sp	Forw		Sp	Forw		Sp	Forw		Sp	Forw		Sp	Forw		Sp	Forw		Sp	Forw		Sp
	All	Fail		All	Fail		All	Fail		All	Fail		All	Fail		All	Fail		All	Fail		All	Fail		All	Fail	
1	17	0	5	16	0	3	21	2	3	17	10	11	18	12	17	10	6	11	19	6	4	18	10	5*	21	11	2
2	21	0	3	19	3	5	21	2	3	15	10	13	19	7	10	14	5	10	18	12	3	13	6	6	21	8	1
3	18	4	7	20	0	3	22	2	2	18	14	15	18	12	13	15	7	14	15	7	4	14	7	6	20	10	0
4	20	1	4	19	2	3	23	0	0*	18	10	13	18	5	8	20	11	12	14	7	5	9	5	8	20	9	1
5	17	0	5	20	0	2	21	0	0	16	10	13	18	9	13	16	8	13	12	10	8	10	4	8	20	12	1
6	10	2	13	18	0	3	21	1	1	18	12	14	18	9	12	19	8	10	12	9	9	15	7	6	16	13	3
7	20	2	4	18	1	3	22	0	0	19	9	10	20	11	12	19	17	17	11	3	10	11	5	8	11	3	9
8	21	0	1	19	0	2	21	0	1	17	8	13	19	11	13	18	10	14	9	5	11	12	8	9	9	5	10

Table D4. Average Buyer and Seller Earnings in a Session by Period

Period	Session								
	F1	F2	F3	FCF(5)1	FCF(5)2	FCF(5)3	L1	L2	L3
					Buyers				
1	5	89	198.25	136.5	62	246.25	116.75	206.75	179.25
2	34.5	142.25	175.75	102.25	56	210.25	129.00	180.00	200.50
3	70	161.5	159.75	143.5	85.75	200	136.00	122.00	184.75
4	90.75	153.5	183	118	90	179	150.25	123.50	173.25
5	114	140.25	177.25	137.75	92.25	161.5	158.50	143.00	164.00
6	115.25	142.5	177.25	142.5	102.5	126	157.00	131.00	162.75
7	116	143.5	168	141.5	102.5	143.5	153.25	139.75	161.25
8	107.5	145.25	163.5	139.25	110	126.75	152.00	147.50	153.25
					Sellers				
1	295	206	96.75	156	203	53.75	177.00	93.25	115.75
2	258	155.25	124.25	112.75	164	54.75	171.00	117.50	97.00
3	230	136	132.75	156.5	164.25	100	164.00	175.50	114.25
4	209.25	146.5	117	92	135	121	149.75	171.50	124.25
5	188.5	142.25	120.25	129.75	165.25	138.5	139.00	154.50	133.50
6	184.75	157.5	122.75	127.5	152.5	89	143.00	166.50	134.75
7	184	156.5	132	108.5	160	156.5	144.25	160.25	138.75
8	190	154.75	136.5	128.25	152.5	90.75	148.00	152.50	146.75

Table D4 continued

Period	Session								
	LCF(5)1	LCF(5)2	LCF(5)3	LCF(50)1	LCF(50)2	LCF(50)3	LTC (50;10)1	LTC (50;10)1	LTC (50;10)1
					Buyers				
1	209.75	203.50	221.00	78.00	105.00	52.50	169.00	189.50	-20.25
2	187.00	160.75	184.50	145.50	151.75	75.00	151.50	145.75	125.50
3	185.75	170.25	164.25	140.75	146.25	85.50	160.00	135.75	140.75
4	179.00	154.25	180.00	147.00	150.25	101.50	155.75	135.00	151.50
5	163.00	114.50	179.50	145.50	149.25	105.75	140.25	137.75	135.75
6	152.25	146.50	180.00	142.75	147.50	123.50	146.50	125.25	117.25
7	143.00	146.50	173.25	138.50	148.50	152.00	159.25	130.75	135.75
8	141.25	149.75	166.75	136.50	147.75	155.00	143.00	116.00	127.50
					Sellers				
1	87.75	90.50	79.25	182.00	190.00	215.00	98.50	30.50	257.75
2	110.5	136.75	115.50	144.25	145.75	210.00	88.50	114.25	134.50
3	114.25	127.25	108.25	147.25	148.75	212.00	97.50	119.25	104.25
4	118.50	145.75	97.50	153.00	147.25	196.00	104.25	115.00	103.50
5	132.00	153.00	118.00	147.00	150.75	169.25	104.75	132.25	99.25
6	144.75	153.50	120.00	154.25	150.00	176.50	108.50	139.75	112.75
7	157.00	151.00	126.75	159.50	151.50	135.50	125.75	134.25	146.75
8	158.75	150.25	133.25	163.50	152.25	145.00	124.50	141.50	137.50

Figure D1. Average Mean Forward Prices in Different Markets

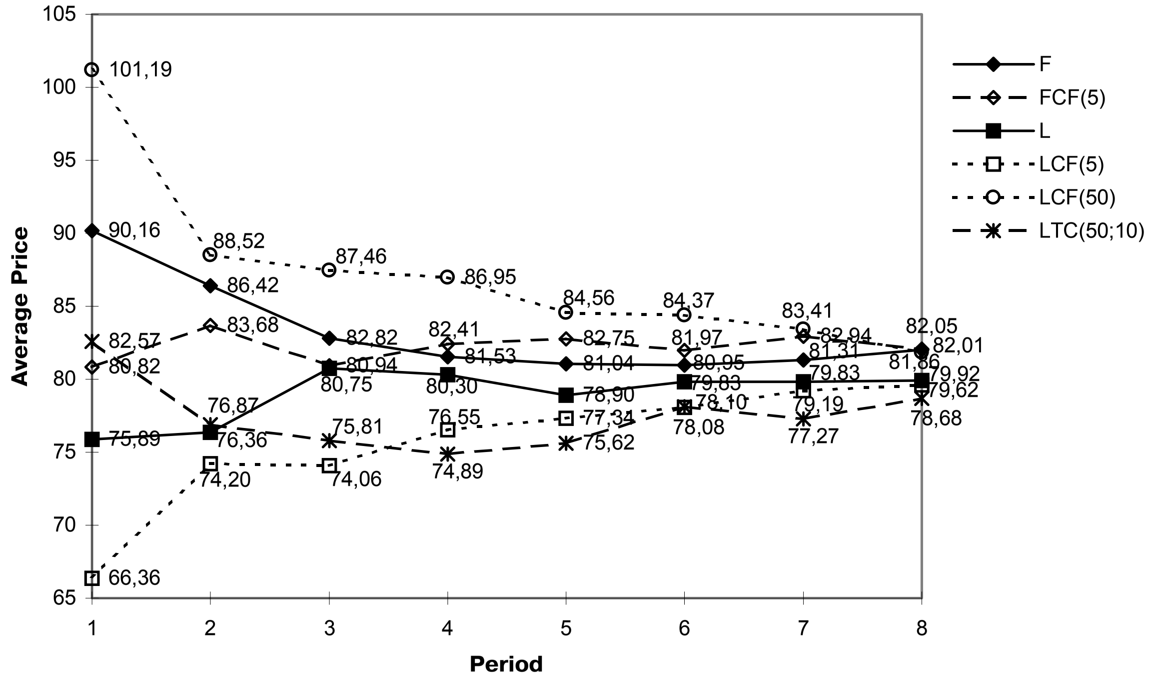


Figure D2. Average Mean Spot Prices in Different Markets

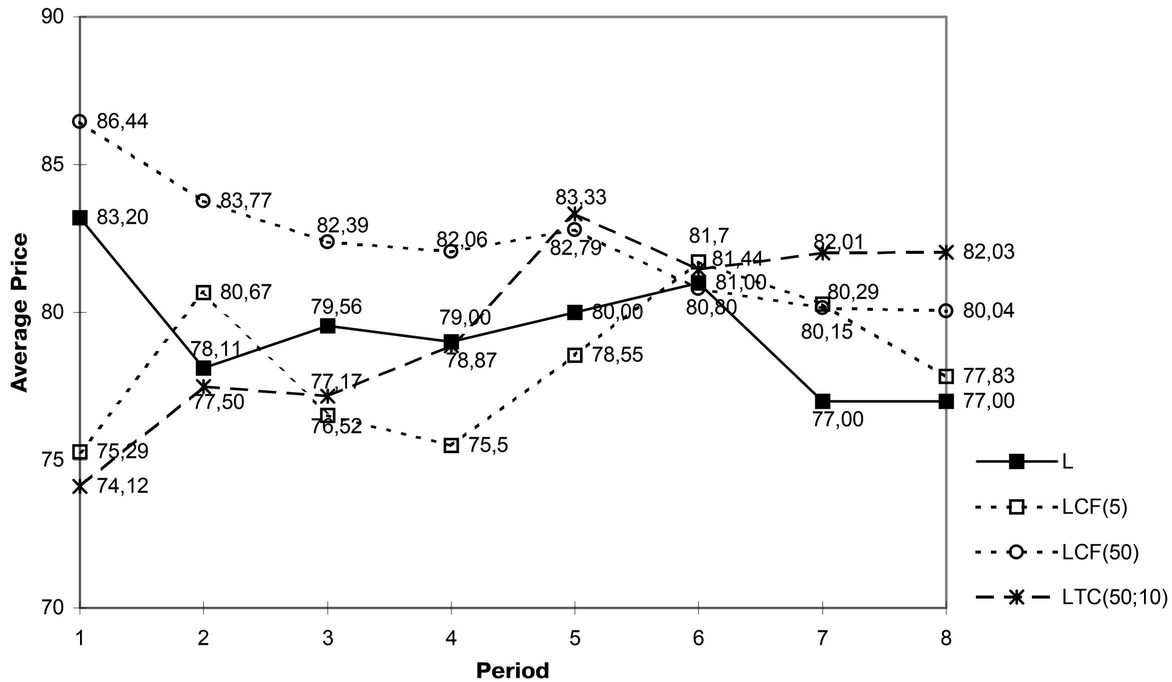


Figure D3. Ratio of Quantity Produced and Traded Spot to Total Quantity Traded in Different Markets

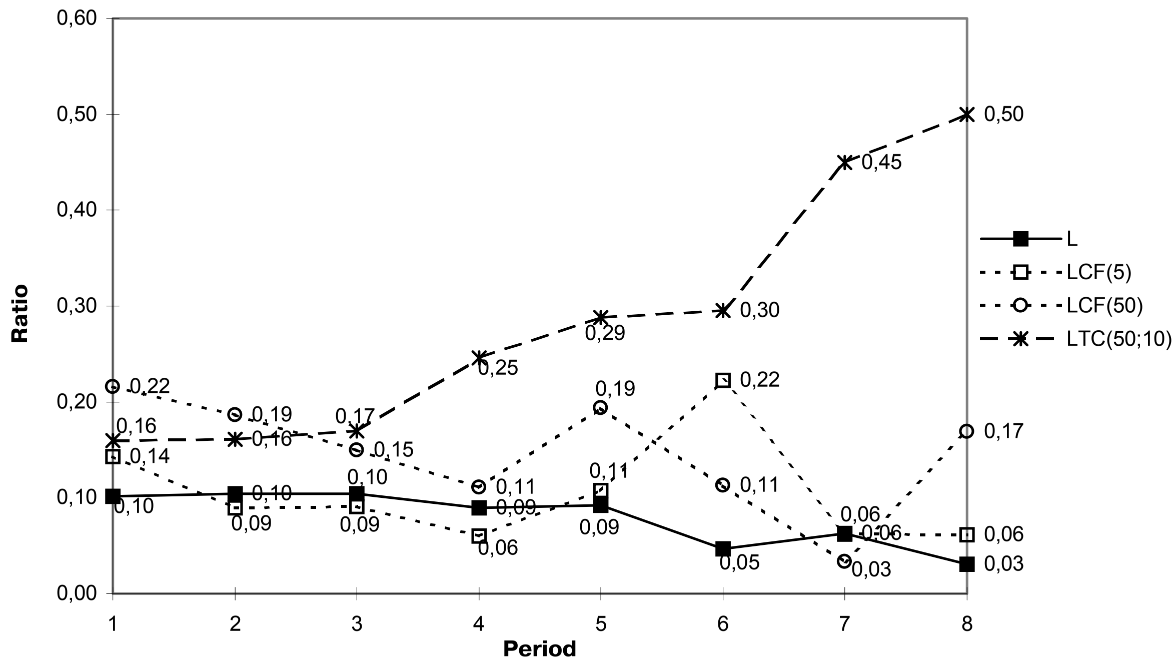


Figure D4. Average Total Earnings in Different Markets

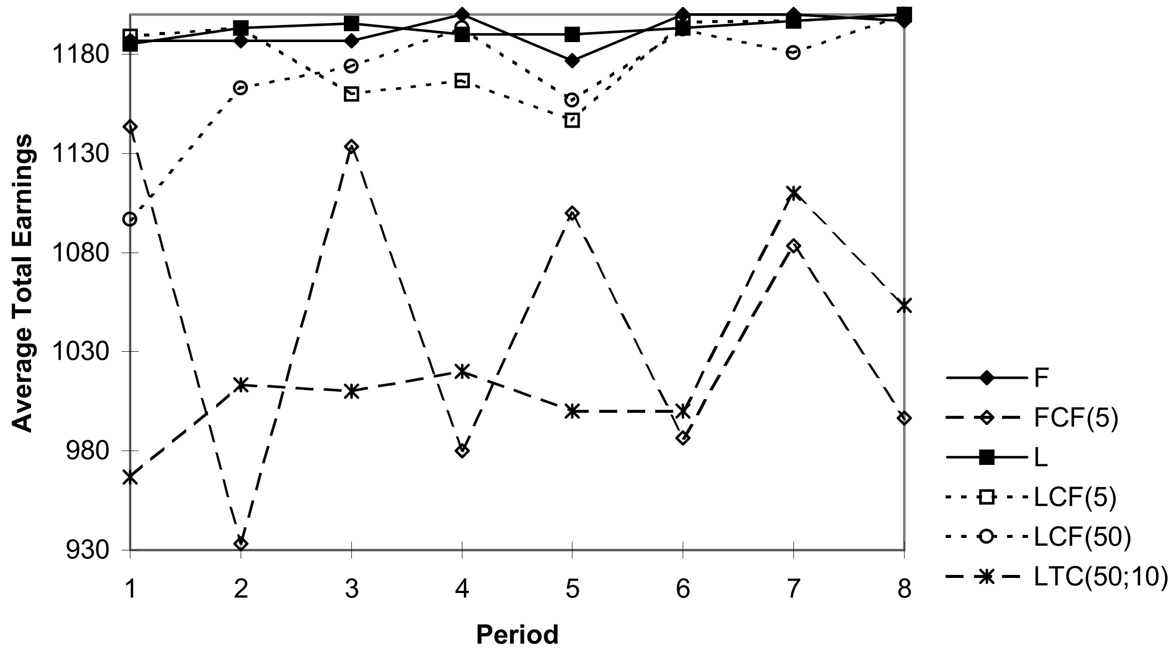


Figure D5. Average Buyer Earnings in Different Markets

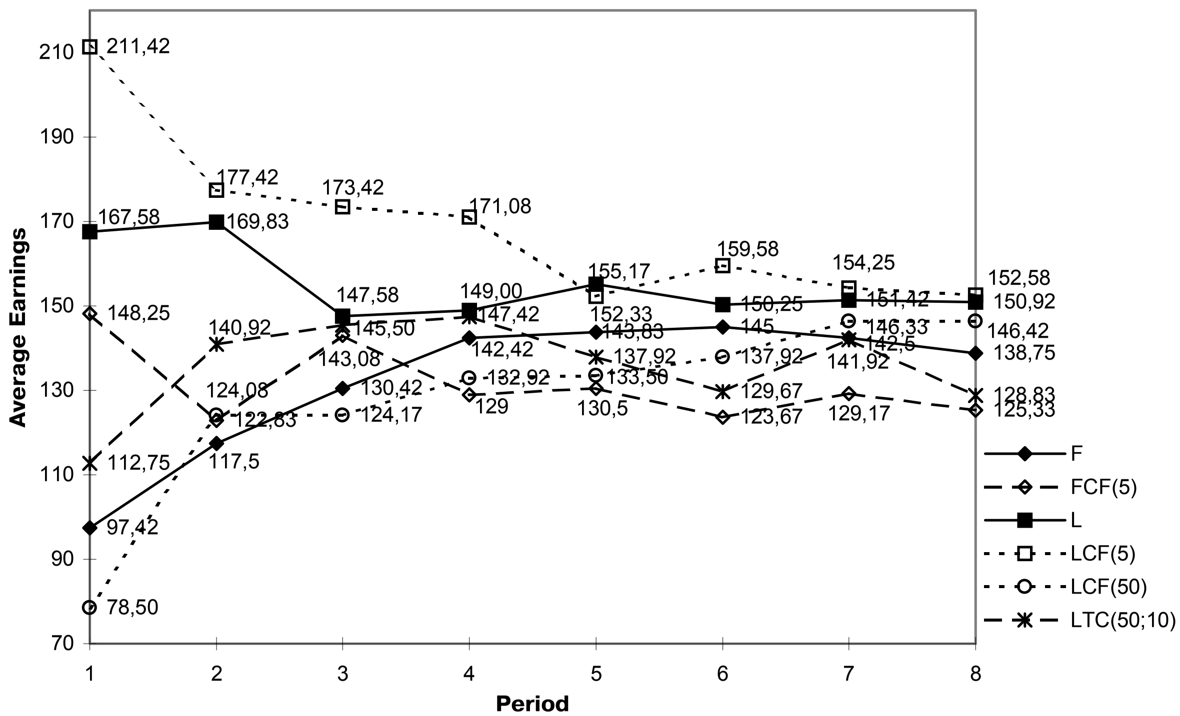
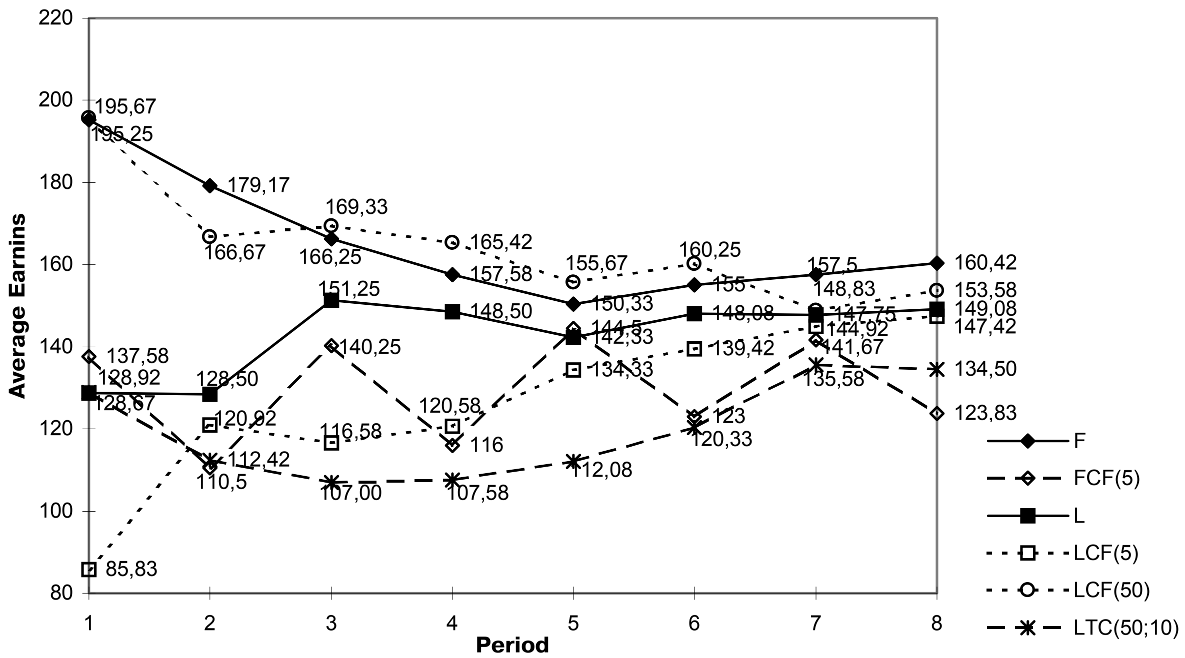


Figure D6. Average Seller Earnings in Different Markets



NOTES

[1] G could be interpreted as the difference between the quantity produced times a transfer price within the integrated firm, minus production cost.

[2] We will ignore for convenience the problem of the extreme negative values of v that would generate a negative spot price. Robison and Barry (1987, p. 91) have formulated an uncertain price in a market with advance production in the same way.

[3] In fact, we ran 19 sessions, but we had to reject the results of the first replication of the linked market (session L1) because the experiment had to be stopped after period 6, one participant having become ill.

[4] Several students from other universities and several students in the second course year of SPSUEF also participated.

[5] Since the risk attitude scores of buyers in the FCF(5) market were not significantly different from those of sellers and since the scores of the buyers and the sellers were not significantly different from risk neutral, theory predicts that the agents will merely maximize their expected profit. If we solve the economic models using the equations from the experiment and = 0, we get the price in the FCF(5) market equal to 82.05 tokens, which is very close to the experiment results (Table 3).

[6] In this case an aggressive seller is a seller making lower than expected asks (or accepting lower than expected bids).

[7] This cost involves retrading the effort cost and the risk cost of the uncertain spot price which results from the failed units.

[8] This result is in contrast to the findings of Krogmeier et al. (1996), where the spot market and the forward market are separate treatments, with no exogenous shock, and Phillips, Menkhaus and Krogmeier (1997), where there is endogenous choice among the market institutions, with no exogenous shock. In the first paper the authors find the spot prices significantly (about seven tokens) higher than the forward prices, while in the second paper the spot prices are about three tokens lower than the forward prices. (Note that in both these cases the experiments used the same supply-demand schedule employed in this study, though they were computerized.)

[9] In the early periods, when the equilibrium price was not certain, some sellers produced a little more for the spot market than they could sell for a profit. In an attempt to minimize losses, a seller may sell a unit even if the cost is not covered entirely. As the sellers learn the supply-demand situation in the spot market, they produce only those units for which the cost is covered by the prevailing price.

[10] Some sellers, for example, may want to risk an uncertain spot price for the sake of benefiting if the spot price is higher than the forward price.

[11] In periods 6 through 8 in sessions FCF1 and FCF3, no more than one seller of the four in each session sold unit number 6 (with a cost of 80 tokens). In session FCF2 the marginal unit was sold more often even at the end of the session. At the same time seller 6 in that session was selling only two or three units even during the last periods. This must have caused the higher price we observed in that session and made the sale of marginal units more attractive for the other sellers. The behavior of seller 6 (FCF2) is difficult to explain: she

was not extremely risk averse according to her risk attitude score (8).

[12] The main results of our oral version of the LCF(50) market experiment are consistent with the results of the computer version which has recently been conducted by Menkhaus and his colleagues at the University of Wyoming, U.S.A. The latter results suggest that in this market the total quantity and the quantity traded forward decrease as compared to the situation in the L market (computer version), but the forward market still dominates. In the computer version of LCF(50), market forward prices are also higher than are the spot prices.

[13] This may be partly explained by the fact that both buyers and sellers have risk attitude scores in the LTC(50;10) treatment that are significantly lower than the risk neutral score.

[14] These results for the L market are consistent with previous research. Phillips, Menkhaus and Krogmeier (1997) observe that about 10% to 15% of the total transactions occur in the spot market in a linked setting.

[15] In our LCF(5) experiments, however, in period 6 (because of the LCF(5)1 session) the average spot trades accounted for 27% of the total quantity produced in the LCF(5) market, and the average spot production was 22%. At the same time, in four of the eight periods of session LCF(5)3 no units were produced to be traded spot. (Interestingly, in this replication the sellers were significantly more risk averse than were the buyers. A higher level of risk aversion leads sellers to trade more quantity forward, and this is consistent with the theoretical model.) In session LCF(5)2, from one to three units were produced for the spot market. Even at the peak of spot production in period 6 of the LCF(5) market, it is obvious that forward trading dominated.

[16] This opportunity is the same for all treatments, except FCF(5), where 5% of the trades fail without a possibility of being retraded. In the LTC(50;10) treatment, with a possible additional transaction cost in the forward market, subjects can transact in the spot market.