PATRICIA REAGAN
RENÉ M. STULZ

Contracting Costs, Inflation, and Relative Price Variability

A LARGE LITERATURE examines the relation between inflation and relative price variability.[1] This literature derives its importance from the belief that, if higher inflation leads to higher relative price variability, the welfare cost of inflation is greater than otherwise.[2] Earlier research predicated on this belief has focused mainly on the costs of increased relative price variability arising from the necessity to adjust prices more often and from the wrong decisions made by economic agents when prices are misleading.[3] In this paper, we investigate the question of whether greater relative price variability leads to greater contracting costs and hence lower economic efficiency. The stylized fact we try to explain is that, as inflation increases, there is a decrease in the use of long-term contracts. We show that greater relative price variability, under some conditions, makes long-term contracts, especially those supported by reputation, more expensive relative to spot contracts. Further, we argue that in the presence of long-term contracts, greater price-level volatility leads to an increase in contracting costs.

The authors are grateful to Dean Corbae, Richard Jefferis, and especially Joe Haubrich for useful comments.

1. This literature is reviewed by Fischer (1981) and Marquez and Vining (1984).

2. Since, as argued by Fischer (1981) and others, increased relative price variability is likely to increase expected utility for given expected income, this belief must rest on the idea that relative price variability decreases expected real income. Many papers have been written on the issue of whether an increase in expected inflation causes greater price volatility. See Danziger (1987) for a recent perspective on this evidence.

3. See Tommasi (1992) for a recent theoretical analysis of the welfare costs of inflation resulting from the lower informational content of relative prices and further references.

PATRICIA REAGAN *is associate professor of economics at The Ohio State University.*
RENÉ M. STULZ *is Riklis Chair in Business and professor of finance at The Ohio State University.*

Journal of Money, Credit, and Banking, Vol. 25, No. 3 (August 1993, Part 2)

To make our point, we focus on a widely used contract and study how the conditions under which that contract is self-enforcing are affected by relative price variability. In this contract, a risk-neutral limited liability firm, the buyer, promises to buy a good at a future date from a risk-averse individual, the seller, at a price set at the time of contracting.[4] Examples of such contracts are labor contracts where the buyer promises a fixed wage to workers for several periods of time or agricultural contracts where the buyer promises to buy the harvest at a fixed price. Forward and futures contracts are other examples of such contracts, where the risk-averse sellers benefit because the buyers bear risk that the sellers would be saddled with if they were to use the spot market to sell the good. These contracts reduce risk for the sellers only insofar as the buyers fulfill their obligations, but the buyers will always be tempted to act opportunistically at the time that the good is supposed to be delivered if they can buy the good more cheaply on the spot market. For instance, with the labor contract, the buyers might want to walk away from the contract if the price of labor falls so that new workers can be hired at lower wages.

If prices are stable, there are fewer incentives for buyers not to honor contracts because the spot price is likely to be close to the long-term contract price. At the same time, however, if prices are stable, such contracts have little benefit. With volatile prices, the spot price when the good has to be delivered may be very different from the long-term contract price. When the spot price is much lower than the long-term contract price, there is considerable temptation for the buyer to walk away from the contract. In this paper, we focus on the case where the seller cannot enforce the contract using the courts. A simple argument why this may be so is that the use of the courts may be too expensive and the outcome too uncertain. In our analysis, we simply assume that the buyer is a limited liability firm that can pay a liquidating dividend just before the long-term contract has to be executed. With this assumption, we can focus on our main point without adding unnecessary complications. It should be noted, however, that rather than simply defaulting on long-term contracts, buyers are often more likely to seek ways to renegotiate contracts to decrease their losses relative to using the spot market. For instance, when gas prices were high, the Columbia Gas System committed to buy gas through long-term contracts. After gas prices fell, some of the contracts forced Columbia to acquire gas at five times the spot price. To reduce its losses, Columbia filed for bankruptcy to increase its bargaining power with its suppliers in its contract renegotiations.[5]

Whereas it would be interesting to analyze how contracting costs depend on the various ways that contracts can be enforced by sellers, we choose in this paper to focus on how buyers can make contracts credible. We simplify the problem further by assuming that there is no room for ex post opportunism on the part of the seller. As we will explain later, this lack of symmetry plays no role in our results. Our simplifications allow us to focus on our main point, namely that some mechanisms

4. Implicitly, we assume that the firm's risks are diversifiable for its shareholders. The only role of the difference in risk aversion between the buyer and the seller in our analysis is that it motivates a contract whereby the buyer bears all the risk.

5. See "Columbia Gas Enters Bankruptcy," New York Times, August 1, 1991.

used to make contracts self-enforcing become more expensive as relative price variability increases. We will discuss where appropriate how our results would be affected by taking into account more complex situations and discuss some extensions of our analysis later.

Since sellers cannot enforce the contract, each buyer must find a way to convince sellers that it will not default if the spot price is lower than the contract price it offers. We call a contract for which the buyer can credibly claim that it will not default a credible contract. Three mechanisms whereby buyers can credibly commit are studied: (1) contracts whereby buyers give up the right to take some actions, (2) establishment of a bond for each contract, and (3) the building of a reputation. These three mechanisms have different costs yet achieve the same result. We argue that, under some conditions, the reputation mechanism is cheaper for low price volatility than the other two. However, as relative price volatility increases, the cost of the reputation mechanism increases also. This is because, with greater relative price volatility, the potential benefit from cheating increases and it therefore becomes more expensive for the buyer to convince the seller that no cheating will take place. As relative price volatility increases, it is possible that long-term contracts vanish altogether and that the only efficient contractual arrangements are those involving spot markets.

The paper proceeds as follows. The model we use to make our point is presented in section 1. We show that a contract in which the price equals the expected spot price is not a credible contract even though the buyer is risk neutral. In section 2, we derive an equilibrium in which the buyer posts a bond. In section 3, a reputation-signaling equilibrium is derived. In section 4, the equilibrium long-term contract price of the reputation-signaling equilibrium is compared to the one for the bonding equilibrium obtained in section 2, and the implications of the analysis for the contracting costs of increased relative price volatility are discussed. Section 5 discusses how the analysis extends to alternative distributional assumptions for the spot price. Section 6 shows how contracting costs increase with price level variability. Concluding remarks are provided in section 7.

1. POST-CONTRACTUAL OPPORTUNISM AND LONG-TERM CONTRACTS

In this section, we introduce our notation and the model we use to make our main point. Consider an infinite-horizon model in which risk-averse individuals, called sellers, know at date $t - 1$ that they will each have one unit of some perishable good to sell at date t, for all t. At each date, the good can be sold and bought on a spot market. The spot price of the good is exogenously given and is an i.i.d. random variable such that the price at date t, $p(t)$, has mean $E(p)$ and is distributed uniformly between p^L and p^H, for all t. We relax the i.i.d. assumption later. The good sold by the sellers is used as an input by limited liability firms, called buyers, in the production of a product. To produce a unit of the product, a firm must buy the input and pay an additional c dollars as production costs, where c is a constant. There are no barriers to entry or exit in the industry, so that the consumer product sells for $p(t) + c$ at date t, for all t. Technological factors constrain each firm to produce either zero or one unit of the product.

Because sellers are risk-averse while buyers are risk-neutral, buyers could make sellers better off without making themselves worse off by agreeing at date $t - 1$ to enter a credible contract to buy the good at date t at a price at or slightly below the expected spot price for that date. By a credible contract, we mean here one which will be honored by both parties with probability one. We assume throughout the paper that the seller can be costlessly forced to deliver the good and that if the buyer does not pay the promised price, the sellers who had contracted with that buyer become the owners of the buyer firm. This implies that the long-term contracts will be honored unless the value of the buyer as an ongoing concern is too small. Hence, in this model, the only source of opportunistic behavior is the buyer's ability to walk away from the contract.

In this model, the value of the buyer as an ongoing concern is endogenous because we impose no restriction on the buyer's ability to pay dividends or raise equity. Consequently, by paying a large dividend before long-term contracts mature, a buyer can reduce its value to zero and hence become unable to fulfill its long-term contracts. In contrast, if the firm does not have funds to pay for its long-term contracts when it is optimal to do so, it can raise equity. While the assumption that a firm can pay out any dividend it chooses to may appear extreme, it is important to note that firms can engage in a wide variety of actions that benefit shareholders at the expense of other parties, such as the sellers in our model, besides paying out a large dividend. Further, contracts may be hard to enforce through the courts even if the buyer could pay the promised price. If the firm does not have enough money to satisfy the terms of its contracts, the courts cannot force shareholders to put up additional funds.

To derive explicit results, it will prove useful to add some structure to the model by specifying the order of the buyer's actions at each point in time and the information set of buyers and sellers. At any date t, buyers first learn the spot price for that date.[6] Then, they decide whether they want to honor the long-term contracts entered into at date $t - 1$ to buy the good at time t for $LP(t)$. If they decide to honor the contracts, they raise funds if necessary so that they do not default; otherwise, they pay a liquidating dividend. The buyers who have not defaulted proceed to produce their output which is then sold and they enter into new long-term contracts and, finally, choose whether to pay a dividend to their shareholders. We let $v(t)$ represent the value of the buying firm after it sold the goods produced at $t - 1$ and entered long-term contracts at that date, but before it pays out dividends or raises funds at t and before contracts are settled at that date. In this section, sellers have all the information that buyers have.

So far, we have not introduced a mechanism to enable firms to offer credible con-

6. The analysis is a partial equilibrium analysis since we assume both the spot price and the price for the consumer product to be exogenously given.

tracts. Not surprisingly, in the absence of such a mechanism, there are no credible contracts:

RESULT 1. *With the assumptions made in this section, buyers cannot offer credible contracts.*

With our assumptions, if sellers believe that a buyer will never default, there is a policy available to that buyer that dominates the policy of never defaulting. With this policy, the buyer pays a liquidating dividend at t and defaults on long-term contracts unless $p(t) \geq LP(t)$. If the buyer does not default, it may have to raise funds to honor the long-term contracts and we assume that it does so by selling equity. Since the buyer purchases the good for $LP(t)$ if $p(t) \geq LP(t)$ and for $p(t)$ if $p(t) < LP(t)$, its expected purchase price is lower than the expected spot price and it expects to make money from this policy. Hence, it is rational for sellers to believe that the buyer will default when $p(t) < LP(t)$. If sellers rationally believe that buyers will default if $p(t) < LP(t)$, they will not enter long-term contracts at $t - 1$ since these contracts decrease their expected utility relative to using the spot market.

The key to Result 1 is that, because buyers who have a policy of never defaulting have zero expected profits, they lose nothing by defaulting, so that they cannot offer credible contracts at a price $LP(t) = E(p)$. A buyer can choose a policy whereby default takes place if $p(t) < E(p)$ because it can pay a dividend at date t such that the firm has no value when it has to pay for the goods it contracted to buy. Hence, to offer credible contracts, the buyer has to find a way to credibly commit that, at date t, before long-term contracts are settled, the value of the firm's assets will equal at least $LP(t) - p(t)$. Such a commitment requires a promise to raise additional funds at date t if required and/or a promise to restrict dividend payments and invest funds appropriately. Importantly, a promise only to restrict dividend payments is not sufficient to make contracts credible. To see this, suppose that at date t, before paying dividends, the buyer has funds equal to $v(t)$. If no dividends are paid and these funds are invested at the risk-free rate, these funds may be large enough to guarantee that default will not take place. However, if funds are not invested at the risk-free rate, the buyer might choose a risky investment policy that has positive payoffs only when $p(t) > LP(t)$, that is, only when default would not take place anyway.

It is clear that, so far, the assumption that the seller cannot act opportunistically simply allows us to concentrate on one type of opportunistic behavior. If the seller could act opportunistically, she would not deliver the good when the spot price is high, so that neither the seller nor the buyer could credibly commit to fulfill the terms of the contract.

2. SETTING UP A BOND

How can the buyer make the contract credible? One way to do so is to offer to sellers a contract that regulates what the firm can do. Such a contract would require $v(t)$ to be sufficiently large, in other words, the firm to be sufficiently capitalized, that its shareholders lose too much if the firm walks away from the contract and the sellers attach the firm's assets. In addition, however, the firm would have to accept restrictions on dividend policy so that it cannot pay a liquidating dividend and restrictions on investment policy so that it cannot take risks that make $v(t)$ small when $p(t)$ is small. Whereas restrictions that limit dividend and/or investment policy are frequently observed in contracts between firms and bondholders,[7] they are rare in contracts between firms and suppliers. It would be costly for individual suppliers to monitor and enforce the provisions of such contracts; these costs would be increased by the duplication of efforts across suppliers. As argued by Fama (1990), these individual suppliers may free-ride on the efforts of bondholders and banks to force the firm to maintain a low level of credit risk. However, this generally does not preclude the firm from acting opportunistically when the benefit from doing so is large enough. Hence, what this suggests is that suppliers will become more concerned about the buyer acting opportunistically when the potential benefits become large for the buyer, that is, when spot prices can differ from contract prices by large amounts. When this becomes the case, one would expect the sellers in the long-term contracts to require contracts that specify the actions of the buyer more carefully and to become more concerned about the credit risk of the buyer. Because such contracts limit the actions of the buyer, they have the additional cost of restricting the buyer's ability to respond to new opportunities since doing so will typically require renegotiation of existing contracts. Relative price variability, therefore, increases the costs of writing and enforcing contracts in this sense.

A simple solution to avoid contracts that limit the actions of the firm and might be too expensive to enforce by individuals is for the firm to post the equivalent of a bond, that is, to set aside an amount of money that will be paid to the seller if the buyer does not fulfill the terms of the contract. With debt, this is equivalent to providing collateral for the loan.[8] As the firm provides collateral, the bondholders need not be concerned about the other actions of the firm since they can always attach the collateral in the event of default. In the case of forward contracts, this is equivalent to backing up the forward position with a line of credit. Posting the bond is expensive, in that a contract has to be drawn up and money set aside. If the money set aside to insure that the terms of the contract will be adhered to has no opportunity cost, the costs of posting the bond are the fixed costs of drawing up a contract and hiring a third party to enforce it. Whereas in many cases the money set aside will have an opportunity cost, in others the buyer can simply set aside Treasury Bills that keep accumulating interest for the buyer. For instance, in futures markets, margins can be posted in the form of marketable securities.

To formalize the posting of a bond in our model, we first consider the case where the funds set aside have no opportunity cost, so that they earn the buyer's discount rate per period, R. Since the buyer is risk-neutral, R is the interest rate over a period, which is assumed constant in the following. In this case, the only cost of posting a bond is the fixed cost, which is also assumed constant, and is denoted by q. To have

7. See Smith and Warner (1979) for an analysis of such restrictions.

8. See Stulz and Johnson (1985) for an analysis of collateralized loans.

collateral B available at date t, the buyer therefore needs to set aside $[1/(1 + R)]B$ and pay q at date $t - 1$. If the buyer sets up a bond of size B for each long-term contract entered into at date $t - 1$, sellers rationally assume that the firm will have no other resources to honor contracts at date t. Therefore, the gain in value for the firm entering a long-term contract at time $t - 1$ with price $LP(t)$ and bond B is

$$\Delta v(t - 1) = (1 + R)^{-1}\left[\int_{\mathrm{Max}(LP(t)-B,p^L)}^{p^H} [p(t) - LP(t)] \frac{dp}{p^H - p^L} - \int_{p^L}^{\mathrm{Max}(LP(t)-B,p^L)} B \frac{dp}{p^H - p^L} \right] - q \,. \tag{1}$$

In equilibrium, competition drives the gain in firm value from entering a long-term contract to zero. We now provide a condition that B must satisfy for long-term contracts to be feasible. If B satisfies this condition, there is a unique long-term contract price that maximizes the value of the firm. If the buyer defaults at date t on a contract entered into at date $t - 1$, he loses B per contract at that date. With the assumptions made so far, if the firm pursues a policy of not defaulting, the marginal cost of an increase in the bond is zero. Hence, a buyer can offer credible contracts by paying q per contract to set up a bond large enough that it never has an incentive to default. This bond is any amount B such that $B \geq LP(t) - p^L$, since the right-hand side of this inequality is the maximum loss that the buyer can suffer. Consequently, we can solve for the long-term contract price for a credible contract by replacing B with an amount at least equal to $LP(t) - p^L$ in equation (1). Since the second integral in equation (1) is equal to zero for any such amount, the long-term contract price does not depend on B as long as B is at least equal to $LP(t) - p^L$ and is given by

$$LP(t) = E(p) - q(1 + R) \,. \tag{2}$$

Note that equation (2) implies that the long-term contract price is the same each period, which is not surprising given that the distribution of the spot price is the same each period and that neither q nor R change over time. To simplify the notation, we therefore simply write LP for the long-term contract price. The long-term contract price falls with the cost of posting the bond and increases with the expected spot price. With equation (2), the smallest bond that has to be posted to insure that there is no default can be written in terms of exogeneous variables as $E(p) - p^L - q(1 + R)$. Hence, as the fixed cost of posting the bond increases, the size of the smallest bond that makes long-term contracts feasible falls because the long-term contract price falls and hence the maximum gain from walking away from the contract decreases. With a fixed cost for the bond, the contract price is not affected by the variance of the spot price. This is not the case if there is an opportunity cost for the funds set aside. To see this, suppose that to post a bond of size B for date t the buyer has to pay a fixed cost at $t - 1$ of q and a variable cost at t equal to ϵB. In this case, the present value at time $t - 1$ of the cost of a bond of size B for date t becomes $q + [\epsilon/(1 + R)]B$. With this modification, the buyer always chooses the smallest possible bond that implies it will not default. Hence, now B always equals $LP - p^L$. However, to have B available at maturity of a long-term contract the buyer has to set aside $(LP - p^L)(1 + \epsilon)(1 + R)^{-1}$ when the contract is agreed upon. In this case, the long-term contract price becomes

$$LP = (1 + \epsilon)^{-1}[E(p) - q(1 + R) + \epsilon p^L] . \tag{3}$$

Using this equation, we can obtain the value of the bond in terms of exogenous variables:

$$B = LP - p^L = (1 + \epsilon)^{-1}[E(p) - q(1 + R)] - p^L . \tag{4}$$

When the funds set aside have an opportunity cost, the cost of a given bond is higher so that the long-term contract price for that bond is lower. An increase in relative price volatility that keeps the expected spot price constant increases the size of the bond and hence increases the cost of posting the bond. Consequently, an increase in relative price volatility increases contracting costs when the funds set aside have an opportunity cost. To find out how an increase in relative price volatility affects contracting costs, we need to take the partial derivative of LP with respect to p^L:

$$\frac{\partial LP}{\partial p^L} = \frac{\epsilon}{1 + \epsilon} . \tag{5}$$

The partial derivative of LP with respect to p^L is positive, so that a decrease in p^L is accompanied with a fall in LP. Hence, an increase in relative price volatility makes sellers worse off since they get paid less for delivering their products.

If the sellers can act opportunistically, they have to make it credible that they will fulfill the terms of the contract and can do so by posting a bond like the buyer. With our assumptions, the long-term contract price is unchanged in this case, but the expected utility of the seller is lowered by the decrease in expected income resulting from having to post a bond. However, if the risk-aversion of the seller is low, it is possible that the contracting costs do not make it worthwhile to enter a long-term contract. This would obviously be the case if the seller is risk neutral. Finally, if the buyer is risk averse as well as the seller, the contracting costs will be split between the two parties depending on their respective degree of risk aversion.

3. A REPUTATION-SIGNALING EQUILIBRIUM IN THE PRESENCE OF PRODUCTION BENEFITS FROM LONG-TERM CONTRACTS

So far, we assumed that buyers derive no benefits from entering long-term contracts. Such an assumption is excessively strong. For instance, long-term contracts may facilitate buyers' planning and production.[9] We now generalize the model to allow for production benefits to the buyers from long-term contracts. Suppose that not all buyers get the same level of benefits. Benefits per long-term contract are worth at most δ^H dollars and there is a continuum of potential buyers with benefits per contract from δ^L to δ^H dollars. Our earlier analysis is a special case. The supply of each type of buyers is perfectly elastic. Each firm knows the benefit it gets from a long-term contract.

Suppose first that the benefit a firm gets from a long-term contract is known by the sellers. In this case, the only firms that enter long-term contracts are those with the greatest benefit from long-term contracting since they are able to offer the highest long-term contract price to sellers and hence make it impossible for buyers with a lower benefit from long-term contracting to enter long-term contracts without making losses. The firms with a benefit from long-term contracting equal to δ^H have to post a bond at least equal to $LP - \delta^H - p^L$ and set a long-term contract price equal to

$$LP = E(p) + \delta^H - q(1 + R) . \tag{6}$$

Consequently, it is now possible for the long-term contract price to exceed the expected spot price if δ^H exceeds $q(1 + R)$. Note that in this case the maximum loss from defaulting is $LP - \delta^H - p^L$, since by defaulting the buyer loses the production benefit from long-term contracting. Since the benefit from long-term contracting increases the long-term contract price by δ^H, it has no impact on the size of the bond when posting the bond has only a fixed cost.

Consider next the case where a firm's benefit from long-term contracting is known only to the firm. In this case, if the long-term contract price is set by the firms with benefit δ^H, the firms with a smaller benefit from long-term contracting, say δ', might gain from entering the market for long-term contracts and defaulting when $LP - \delta' - p(t) > B$. With our distributional assumptions, a sufficient condition for firms with benefit $\delta' < \delta^H$ to find it unprofitable to imitate firms with benefit δ^H is that $\delta^H - \delta' < p^H - p^L$, for all $\delta' < \delta^H$. This condition always holds if the largest production gain from long-term contracts is smaller than the range of the spot price, which we now assume to be the case. With this assumption, there is a unique bonding equilibrium where the only buyers with long-term contracts are those with the highest production benefit from long-term contracts.

If there is an opportunity cost to putting funds aside to guarantee contract performance, the long-term contract price becomes

$$LP = (1 + \epsilon)^{-1}[E(p) - q(1 + R) + (1 + \epsilon)\delta^H + \epsilon p^L] . \tag{7}$$

9. To illustrate this, consider the following example: A firm's production process requires information about the identity of its suppliers; although this information can be taken into account costlessly at date t for use at date $t + 1$, it is costly to incorporate it at date $t + 1$ for use at the same date.

Reputation can under some circumstances substitute for the posting of a bond. We now explore an infinite-horizon reputation-signaling equilibrium that arises when the production benefit from long-term contracting is the buyer's private information and investigate how the contracting costs for such an equilibrium are affected by an increase in relative price variability. We first derive the model assuming that the bonding equilibrium is not possible and then investigate the firm's choice between the bonding mechanism and the reputation mechanism in the next section. In the presence of benefits for buyers, entering credible long-term contracts reduces production costs, but buyers still have incentives to walk away from the contracts. However, the following result shows that there is a unique reputation-signaling equilibrium with credible long-term contracts:

RESULT 2. *There is a unique reputation-signaling equilibrium such that only buyers with benefit δ^H per long-term contract buy through long-term contracts at a price*:

$$LP = (1 + R)^{-1}[Rp^L + E(P)] + \delta^H \; . \tag{8}$$

Before entering their first long-term contract, these buyers make a sunk investment worth

$$W = (1 + R)^{-1}[E(p) - p^L] \; . \tag{9}$$

With our assumptions, one would expect competition among buyers to imply that in equilibrium they derive no gains from long-term contracting. This is the case here because the per period total cost of buying through long-term contracts, $LP + RW - \delta^H$, is equal to $E(p)$, so that the net present value to the buyer of using long-term contracts is zero. The cost RW is the per period amount that the firm has to receive to recover the sunk cost W, that is, the present value of the payments RW equals W. This cost increases the long-term contract price in equilibrium because if the buyer cannot recover this sunk cost over time, buying through long-term contracts is a negative net present value project. If the buyer of type δ^H defaults, it ceases to exist as a firm since its assets belong to the sellers. It therefore loses the present value of per period payments equal to RW which is simply W and W is such that defaulting is never profitable.

To understand why firms of type δ^H never default, note that by defaulting at t, $\forall\, t$, such a firm avoids paying to sellers $(LP - p(t))$ at most, as by paying LP the firm gets a good valued at least $p(t)$, $\forall\, p(t)$. However, the cost of defaulting is that the firm loses the immediate benefit from long-term contracting, δ^H, and loses W. Hence, the firm suffers a cost equal to $\delta^H + W$ and a gain equal to $(LP - p(t))$. Inspection shows that, with our choice of W,

$$[LP - p(t) - \delta^H - W] = p^L - p(t) \leq 0 \tag{10}$$

so that the firm cannot possibly gain by defaulting. Hence, the firm with benefit level δ^H never defaults.

For the equilibrium to be such that firms of type δ^H can separate themselves from the other firms, it must be that these other firms with lower production benefits from long-term contracts cannot profitably imitate firms of type δ^H. Consider now a firm with benefit level $\delta' < \delta^H$. With the long-term price given by equation (8) and W given by equation (9), such a firm will find it profitable to default if the spot price is close enough to p^L since for $\delta' < \delta^H$, the term in square brackets in equation (10) is positive for $p(t)$ close to p^L. However, the firm with benefit δ' has a per period cost of long-term contracting equal to $LP + RW - \delta' > LP + RW - \delta^H = E(p)$. Hence, given the firm of type δ^H's choice of LP and W, the firm of type δ' never recovers W. This implies that for a firm of type δ', long-term contracting is a negative net present value project. Even though the δ^H firm would not want to default when the δ' firm does, it cannot convince sellers that it will never default unless it acquires a reputation of being a δ^H firm. It acquires such a reputation by spending W before entering long-term contracts.[10] It does not matter how the firm spends W as long as sellers know that W was spent and that the firm cannot sell part or all of the sunk investment for cash. The δ' firm cannot afford to mimic the behavior of the δ^H firm since, by doing so, it has to pay too much on the long-term contracts to break even.

If $\delta^H = \delta^L$, there is no role for a signaling equilibrium, but there is still a role for a reputation equilibrium, in the sense that a sunk investment of W still insures that the buyer will not default. This would be the case even if $\delta^H = 0$ since the condition that makes default unprofitable, that is, equation (10), still holds in that case. Hence, there is a reputation equilibrium in the case where there is no production benefit from long-term contracts and both LP and W for that equilibrium are obtained from Result 2.

4. CONTRACTING MECHANISMS AND THE COST OF RELATIVE PRICE VARIABILITY

We now turn to the issue of when the reputation-signaling equilibrium dominates the bonding equilibrium discussed in the previous section. We first address the case where the posting of a bond only has a fixed cost per contract. In our model, competition among buyers prevents buyers from earning positive profits and drives out the buyers that use less efficient contracting mechanisms because the prices they offer to sellers are too low. As sellers always sell to the buyers that have the highest prices, the reputation-signaling equilibrium dominates the bonding equilibrium if it enables buyers to attract sellers by offering a higher long-term contract price than the one that prevails with the bonding equilibrium. When the bond has a fixed cost, the contracting cost is q per unit bought when a bond is posted. In contrast, with the reputation-signaling equilibrium, the buyer pays W once and for all to make all future contracts credible, so that the cost per unit bought is RW. Using equation (9) for

10. The notion that a firm must incur sunk costs to support a reputation-signaling equilibrium can also be found in the literature that discusses how firms try to acquire a reputation for producing at a given quality level. See Rogerson (1987) for such a model with a continuum of firms in which differences in production costs support the equilibrium in the presence of free entry. Uncertainty plays no role in that literature, while it is central to our analysis. Diamond (1989) has a reputation model in which the outcome of a firm's actions is stochastic.

W, we get that the contracting cost for the bonding equilibrium exceeds the contracting cost for the reputation-signaling equilibrium if

$$q > (1 + R)^{-2}R\omega \tag{11}$$

where ω is equal to $0.5[p^H - p^L]$ and is an increasing function of the variance of the spot price. Interestingly, the magnitude of the gain from long-term contracting δ^H plays no role in equation (11). This is because the gain δ^H is the same in both equilibria.

It follows from equation (11) that the reputation-signaling equilibrium dominates the bonding equilibrium when (1) the cost of the bond is high, (2) the discount R rate, is low and (3) the variance of the spot price is low. Since R corresponds to the interest rate for a period of same length as the contract, the discount rate can be low either because interest rates are low or because a period is short. Hence, the bonding equilibrium is likely to dominate when buyers buy infrequently. This is because the sunk investment of establishing a reputation for a buyer is amortized over all future contracts a buyer enters into, so that the cost of that investment per contract falls as the number of contracts increases. In contrast, the cost of setting up a bond is the same per contract irrespective of the number of contracts entered into. The result that a reputation has more value if it can be used frequently is well known for models that exhibit reputation effects.[11] The variance of the spot price plays an important role here because a higher variance means a lower value for the lowest possible spot price and hence a higher maximum value for the gain from defaulting, defined as $LP - p_L - \delta^H$. As the maximum gain from defaulting increases, the long-term contract price in the reputation-signaling equilibrium must fall so that the present value of rents lost through default increases. Since the long-term contract price in the reputation-signaling equilibrium falls as the variance of the spot price increases, it follows that contracting costs increase with relative price variability in that equilibrium. However, when the variance of the spot price is high enough, the bonding mechanism dominates the reputation-signaling one. With the bonding mechanism, contracting costs are unaffected by relative price volatility if the cost of posting a bond for a long-term contract does not depend on the size of the bond. It follows that contracting costs increase with relative price volatility up to the point at which the reputation-signaling contracting mechanism stops being viable and beyond that point contracting costs are unrelated to relative price variability.

If the cost of establishing a bond has a variable component, the analysis leads to a similar result as long as the variable cost is lower than R. If the variable cost of the bond is equal to R per unit posted, the reputation mechanism always dominates the bonding mechanism. If the variable cost ϵ is less than R, the reputation mechanism dominates for low enough volatility, but as the volatility increases, the bonding contract dominates provided the fixed cost and variable costs of the bond are not too high.

11. See Kreps and Wilson (1982) and Diamond (1989), for instance.

5. ALTERNATIVE DISTRIBUTIONS FOR THE SPOT PRICE

The results obtained so far are derived assuming that the spot price is distributed uniformly. While this assumption is convenient, it is important to understand how its relaxation affects our results. Suppose that the spot price is distributed lognormally. In this case, the spot price is bounded from below by zero but $p^H = \infty$. Hence, the buyer must make a sunk investment determined by $p_L = 0$ in our earlier analysis. Otherwise, there is a positive probability that $p(t + 1)$ will be low enough to induce the buyer to default. In this case, however, p_L is not related to the variance of the spot price and, consequently, neither are contracting costs.

When the distribution of the spot price is bounded below by zero rather than by a strictly positive number, it means that the buyer has to expend resources to make the contract credible for spot prices close to zero which may have a very low probability of occurring. This argument suggests that we ought to look at a broader class of contracts where the loss suffered by the buyer in states where the spot price is low can be limited, where we define the buyer's loss as the amount in excess of the spot price the buyer has to pay. With the contract analyzed so far, the maximum loss of the buyer is $LP - p^L$ or LP when the distribution of the spot price is lognormal. We now consider a contract where the maximum loss is $M < LP$, so that the seller receives LP if $M + p(t)$ exceeds LP and receives $M + p(t)$ otherwise. For sellers, the advantage of such a contract is that in equilibrium they receive a higher expected income since the buyers have to expend fewer resources to make the long-term contract credible. To make this point more precise and to show that in this case our earlier results still hold, we have to make assumptions about the utility function of sellers. We assume that sellers have an indirect utility function that is strictly concave in terminal wealth, $U(W)$, and that they have no other source of wealth besides the good they plan to sell. Hence, if the buyers credibly commit to buy the good for LP or $LP - p(\min) + p$ if $p < p(\min)$, where $p(\min) = LP - M$, the expected indirect utility of a seller is

$$EU(W) = (1 - F(p(\min)))U(LP) + \int_0^{p(\min)} U(LP - p(\min) + p)f(p)dp \qquad (12)$$

where $f(p)$ is the density function of the spot price p and $F(p)$ is the cumulative distribution function. The optimal contract is the one where LP and $p(\min)$ maximize the seller's expected utility subject to the condition that the expected profits of the buyer are zero. With the reputation mechanism, the buyer's zero profit condition becomes:

$$\begin{aligned} &E(p) + \delta^H - [1 - F(p(\min))]LP \\ &- \int_0^{p(\min)} [LP - p(\min) + p]f(p)dp - R(LP - p(\min) - \delta^H) = 0 \qquad (13) \end{aligned}$$

where the last term in parentheses is the value of the sunk investment in this case. The optimal contract for the reputation-signaling model satisfies the following first-order conditions:

$$\int_0^{p(\min)} U'(LP - p(\min) + p)f(p)dp = \lambda[F(p(\min)) + R]$$

$$\lambda = (1 + R)^{-1}\left[(1 - F(p(\min)))U'(LP) + \int_0^{p(\min)} U'(LP - p(\min) + p)f(p)dp \right] . \quad (14)$$

The second condition states that the multiplier on the zero-profit condition equals the discounted expected marginal utility of the seller. The first condition states that the gain in expected utility of the seller from a decrease in $p(\min)$ equals the decrease in the buyer's marginal utility or profit from decreasing $p(\min)$ weighted by the expected marginal utility of the seller.

When the bonding mechanism has a fixed cost, however, LP does not depend on $p(\min)$ for the buyer and therefore there is no reason for the buyer to choose a contract that has a maximum for the loss he can suffer. When the cost of posting a bond has a variable component, any increase in $p(\min)$ decreases the variable cost, that is, decreases the cost of the bond by $[\epsilon/(1 + R)]\delta p(\min)$. In the case of the reputation mechanism, the cost decrease is greater and equivalent to $[R/(1 + R)]\delta p(\min)$. For continuous distributions that have measure zero at p^L, sellers will be better off if $p(\min) > p^L$ since an infinitesimal increase in $p(\min)$ increases expected income and sellers that bear no risk will be willing to bear a small amount of risk if doing so increases expected income.

For a given $p(\min) > 0$, it is straightforward to show that if p follows a lognormal distribution, an increase in the variance of p increases contracting costs with the reputation mechanism. To see this, note that now the sunk investment is smaller than before, since it has to be high enough to prevent default for prices greater than $p(\min)$ rather than prices greater than p^L. With this lower sunk investment, the zero profit condition implies that the long-term price is

$$LP = (1 + R)^{-1}[E(p) + E(\text{Max}(p(\min) - p, 0)) + Rp(\min)] + \delta^H . \quad (15)$$

Hence, the cost of the long-term contract is the cost we had earlier minus the expected payoff from a put option that pays $\text{Max}\{p(\min) - p, 0\}$.[12] With our assumptions, an increase in volatility increases the probability that $p < p(\min)$ and hence reduces the expected payoff of the seller. To keep the buyer's expected profit equal to zero, LP has to increase if $p(\min)$ is kept constant because the increase in vol-

12. With our assumptions, the put option's value and comparative statics are given by Black and Scholes (1973).

atility increases the value of the put option. However, an increase in LP requires an increase in W. This means that, as volatility increases, the expected income of the seller has to fall if $p(\min)$ is kept constant because more resources are spent on making contracts credible. To keep the seller's expected income constant would require an increase in $p(\min)$, which would force the seller to bear more risk. Given the increase in risk, the seller will, however, prefer a contract with lower expected income and less risk, so that $p(\min)$ will not fall sufficiently to keep expected income constant. In this model, since the expected spot price is constant, a decrease in the expected income of the seller is equivalent to an increase in contracting costs. Hence, in the extended model of this section, an increase in variance increases contracting costs with the reputation mechanism and, if the reputation mechanism is more efficient than the bonding mechanism for low relative price volatility, it is not so for sufficiently high relative price volatility.

We now investigate the relaxation of another distributional assumption, namely, the assumption that the mean of the spot price is constant. Our results assuming a uniform distribution for the spot price depend on $p^H - p^L$ rather than on $E(p)$. Hence, if the expected spot price changes over time while the variance of the spot price stays constant, our results are unchanged. In contrast, if both the expected spot price and the variance change over time, the analysis involving the reputation-signaling model becomes more complicated in that the required sunk investment becomes a function of the future changes in variance. In this case, we conjecture that it becomes possible for the firm to post a bond for a period of time and then switch to the reputation-signaling mechanism. However, it will still be the case that a change in volatility will generally increase contracting costs because it will increase the benefits from cheating.

6. INFLATION AND CONTRACTING COSTS

The analysis conducted so far focused on the variance of relative prices. If relative prices are fixed but nominal prices are volatile, contract prices can be indexed to the price level and there is no moral hazard. The main point of our analysis has implications for the case where the only uncertainty is price level uncertainty, however. To see this, consider the buyer we studied so far, but assume now that he has income that is fixed in nominal terms equal to d per unit produced. Sellers are concerned about their real income, so that with a volatile price level, the sellers would like to have indexed long-term contracts. With such contracts, an unexpectedly high price level implies that the firm will have to make high payments in nominal terms to the sellers and will receive the same income as when the price level is low. The firm will therefore be tempted to walk away from its long-term contracts. Hence, it will have to choose a mechanism that insures that the contracts are credible.

To analyze this case, we can use the same notation as before. However, now the firm's income in nominal terms per unit produced is

$$d - pc - pLP$$

where d is the fixed nominal price of the good, p is the price level, c is the real production cost, and LP is the real fixed payment to sellers. Hence, as p is high, the firm makes a loss from producing and is tempted to walk away from the contract. If the distribution of p is bounded from above, the analysis developed for the case where p has a uniform distribution carries over to this case in a straightforward way. If the distribution of p is not bounded from above, then the buyer cannot offer a credible contract with full insurance. In this case, the analysis of the previous section applies.

The extension discussed in this section has interesting implications for the degree and costs of indexing. It follows from our analysis of the earlier section that the contracting costs necessary to make a given level of indexing credible increase with the variance of the price level since, with greater inflation volatility, the temptation for the indexing firm to renege on the contract increases.

7. CONCLUSION

This paper argues that contracting costs increase with relative price variability. Higher relative price variability makes it more likely that a party to a long-term contract will obtain a bad payoff from the contract. Under some circumstances, this argument extends to the case where relative prices are fixed but nominal prices are uncertain. In this paper, the buyer can default on a long-term contract if his payoff from the contract is low. Consequently, for the seller to enter a long-term contract with the buyer requires the buyer to post a bond or invest in building a reputation. If the buyer builds a reputation, the required investment increases when the bad payoffs from the contract become worse because of an increase in the volatility of the spot price. Hence, an increase in relative price volatility increases the cost per contract of establishing a reputation. As the cost of building a reputation increases, it is possible that setting up a bond for each contract becomes a cheaper contracting mechanism.

Since an increase in contracting costs means that more resources must be expended to yield a constant amount of output, it follows that an increase in relative price volatility, ceteris paribus, decreases real output. The importance of this phenomenon clearly depends on the pervasiveness of contracts supported by reputation considerations in the economy. If such contracts are the prevalent contracting form, then one would believe that a substantial increase in relative price volatility can have a significant impact on aggregate output. It is interesting to note that, if the quantity theory of money holds and if the money supply is given, a decrease in aggregate output increases the price level. This means that our model suggests that an increase in relative price variability can increase inflation.

LITERATURE CITED

Black, F., and M. Scholes. "The Pricing of Options and Corporate Liabilities." *Journal of Political Economy* 81 (1973), 637–54.

Danziger, L. "Inflation, Fixed Cost of Price Adjustment, and Measurement of Relative Price Variability: Theory and Evidence." *American Economic Review* 77 (1987), 704–14.

Diamond, D. "Reputation Acquisition in Debt Markets." *Journal of Political Economy* 97 (1989), 828–62.

Fama, E. F. "Contract Costs and Financing Decisions." *Journal of Business* 63 (1990), S71–S93.

Fischer, S. "Towards an Understanding of the Costs of Inflation: II." In *Carnegie-Rochester Conference Series on Public Policy* 15 (1981), 5–41.

Kreps, D. M., and R. Wilson. "Reputation and Imperfect Information." *Journal of Economic Theory* 27 (1982), 253–79.

Marquez, J., and D. Vining. "Inflation and Relative Price Behavior: A Survey of the literature." In *Economic Perspectives: An Annual Survey of Economics* 3, edited by M. Ballabon, pp. 1–56. New York: Harwood Academic, 1984.

Rogerson, W. P. "The Dissipation of Profits by Brand Name Investment and Entry When Price Guarantees Quality." *Journal of Political Economy* 95 (1987), 797–809.

Smith, C. W., and J. B. Warner. "On Financial Contracting: An Analysis of Bond Covenants." *Journal of Financial Economics* 7 (1979), 117–62.

Stulz, R. M., and H. Johnson. "An Analysis of Secured Debt." *Journal of Financial Economics* 14 (1985), 501–22.

Tommasi, M. "The Welfare Effects of Inflation: The Consequences of Price Instability on Search Markets." Working paper, University of California, Los Angeles, 1992.