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NOMINAL CONTRACTING AND PRICE FLEXIBILITY IN PRODUCT MARKETS

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ABSTRACT

The search for microeconomic foundations of non-Walrasian outcomes in labor and product markets has spawned many studies of contracting. This paper emphasizes the role of contracts for market equilibrium--for many raw materials and basic industrial commodities--in which long-term contractual arrangements and spot markets coexist. Our principal goals are two--(i) to explain the existence of contracts and the equilibrium fraction of trades carried out under contract, and (ii) to consider the impact of demand and supply shocks on spot prices when market trades also take place through long-term contracts.

We find that the relative importance of contracting depends on, *inter alia*, the variance of the spot price and the sources of underlying fluctuations. Consistent with the findings of previous macroeconomic studies, we find that contracting and price rigidity are more likely the more important demand shocks are relative to supply shocks. We adapt our static model of contract price and quantity determination to discuss the adjustment of contract prices. Finally, we discuss three important applications of our multiple-price modeling structure--to (i) analyses of the effects of changes in vertical market structure on market equilibrium in commodity markets (with specific reference to petroleum and copper), (ii) models of the optimal degree of contract indexation, and (iii) aggregate studies of "sticky prices" in macroeconomics.

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I. INTRODUCTION

Studies of price adjustment in commodity and industrial product markets have been a key element of research in macroeconomics and industrial organization for decades. Outside the static and instantaneous market clearing in textbook models, an important goal for economic theory is to provide an explanation of how prices move to clear markets. For a variety of issues from assessing the efficiency of commodity markets to testing price flexibility in industrial markets to measuring the sensitivity of aggregate prices and quantities to demand-management policies, it is not sufficient to maintain that Walrasian equilibria will be obtained, without describing the process of adjustment.

The failure of the Walrasian, market-clearing framework to explain movements in prices and quantities has been a focus of macroeconomics since the Keynesian revolution.[1] Particular emphasis has been placed on "sticky wages" in labor markets and "sticky prices" in goods markets.[2] Outside of Keynesian macroeconomics, Means's (1935) assertion that market power led to sticky "administered" prices prompted an ongoing debate in industrial organization.

Previous efforts at motivating these rigidities have classified product markets into "auction" and "customer" categories (the terms are from Okun, 1981).[3] The principal goal of this paper is to characterize price flexibility in markets exhibiting both fixed-price and flexible-price behavior. The basic model put forth in section II is of interest as an intermediate case between the "no contracting, instantaneous price adjustment" Walrasian model and the "contracting only, no price adjustment" models recently investigated by Carlton (1978, 1979b) and

Gould (1978). The model is an alternative to one constructed by Akerlof and Yellen (1985a, 1985b), in which the intermediate case arises because a fixed fraction of the agents in the market are assumed to be non-maximizers. Some of the results from our model, in which all agents optimize, are similar to theirs.

A line of research in the recent macroeconomics literature has focused on the microfoundations of price flexibility (Rotemberg, 1982; Mankiw, 1985; Taylor, 1979). When prices are neither inflexible nor perfectly flexible, multiple prices are likely to occur.[4] Multiple-price arrangements are prevalent in commodities[5], and in industrial goods.[6] In the static model, we consider both cases of competitive and monopoly producer behavior. We illustrate how an endogenously determined multiple-price system can provide a foundation for models of the form suggested by Taylor (1979), and contrast it with the alternative foundation suggested by Akerlof and Yellen (1985b).

Our modeling framework is based on Carlton (1979a). Carlton derived the relationship between spot and contract prices in a model with two types of buyers--those who must contract in advance for planning purposes and those who can purchase on auction markets. In our model, buyers and sellers choose the extent to which they rely on contracting. In general, the contracting regime and hence the degree of price flexibility depend on the variance of the spot price, relative prices in spot markets, and the covariances of these prices with buyer and seller profits in the absence of contracting. An extension to multiperiod contracts is also presented.

In Section III, we apply the model to analyze the impact of contracting on the adjustment of prices to demand and supply fluctuations in a framework based on the labor-market model of Taylor (1979) and the one-price commodity market model of Turnovsky (1983). Introducing speculative storage, we find that even transitory demand and supply fluctuations exhibit "persistence effects" on spot prices in the presence of contracts. At the close of the paper, we put forth three potential applications of the multiple-price modeling structure--to (i) analyses of the effects of changes in vertical market structure on market equilibrium in commodity markets (with specific reference to petroleum and copper), (ii) models of the optimal-degree of contract indexation, and (iii) aggregate studies of "sticky prices" in macroeconomics.

II. CONTRACTING AND MULTIPLE-PRICE SYSTEMS IN PRODUCT MARKETS

Equilibrium Spot and Contract Trades: Static Model

The coexistence of "predetermined" and "flexible" factors in a market requires at least two prices. For simplicity, suppose that contracts are identical, thereby reducing the number of prices to two -- the "contract price" and the "spot price." In a multiple-price system, the decision of how much to buy (to produce) is accompanied by a decision of how to divide purchases (sales) between spot and contract markets. We define a contract as an ongoing agreement to purchase a commodity at a given price. Because of the definition of contracts, shocks (unanticipated exogenous changes in demand or force majeure interruption of contract completion) are absorbed through adjustment on the spot market.

Buyers' Problem

Buyers use the commodity purchased as an input in production and are subject to random demand disturbances. They can buy on both spot and contract markets. The tradeoff between the two types of purchasers stems from the fact that while price is fixed for contract purchases, spot purchases can be tailored to meet demand exactly. Once contract purchases have been optimized (Q^{c*}), spot purchases are chosen to maximize the expected profit Π^b :

$$(1) \qquad \Pi^b = P\, Z(Q^s + Q^{c*}) - P^s Q^s - P^c Q^{c*},$$

where Z is the production function ($Z' > 0$, $Z'' < 0$), and P is the output (downstream) price. Buyers are assumed to be price-takers in the input market.

The first-order condition yields the standard result for inputs, namely that the factor price and the value of marginal product are equalized:

$$(2) \qquad Q^{s*} = Z'^{-1}(P^s/P) - Q^{c*} .$$

Buyers are assumed to exhibit constant absolute risk aversion and choose contract purchases Q^c to maximize

$$(3) \qquad E\,\Pi^b - \frac{\gamma}{2}\ \mathrm{var}\ \Pi^b,$$

where γ measures the degree of risk aversion, and $E\,\Pi^b$ and var Π^b respectively represent the expectation and variance of the outcome conditional upon available information. The optimal contract purchase follows from the first-order condition, and is equal to

$$(4) \qquad Q^{c*} = \frac{E\ P^{s} - P^{c}}{\gamma\ \mathrm{var}\ P^{s}} - \frac{\mathrm{cov}\ (P^{s},\ \hat{\Pi}^{b})}{\mathrm{var}\ P^{s}} ,$$

where $\hat{\Pi}^{b}$ denotes the (*ex ante*) profit in the absence of contracting, and cov $(P^{s}, \hat{\Pi}^{b})$ represents the covariance of the spot price and $\hat{\Pi}^{b}$. It is important to note that risk aversion is not necesary for the form of these results. Carlton (1979a) puts forth a similar model in which the incentive to offer long-term contracts stems from the influences of cash-flow variability on a firm's costs.

The first term in equation (4) demonstrates that desired contract purchases depend on the spread between the contract price and the expected spot price, the degree of buyer risk aversion, and the variance of the spot price. An increase in the variance of the spot price, *ceteris paribus*, lowers the reliance on long-term contracts. The second term in (4) recognizes the importance of the covariance of the spot price and *ex ante* profit, and its sign depends on the origin of the shock. For example, if all shocks stemmed from the supply side, cov $(P^{s}, \hat{\Pi}^{b}) < 0$, and buyers could purchase through contracts even when the quoted contract price exceeds the expected spot price. With the addition of demand shocks, cov $(P^{s}, \hat{\Pi}^{b})$ could be positive, so that purchasers desire contracting only when the contract price is offered at a discount to the spot price.[7]

Producers' Problem

Producers (sellers) are assumed to maximize the certainty equivalent of profit Π^{p}, and to exhibit constant absolute risk aversion. Their objective is to

$$(5) \quad \max \{P^{c}Q^{c} + E\,(P^{s}\,Q^{s}) - E\,C\,(Q^{c} + Q^{s}) - \frac{\beta}{2}\,\mathrm{var}\,[P^{s}Q^{s} - C\,(Q^{c} + Q^{s})]\}$$

where C is the cost function ($C' > 0$) and β measures the degree of risk aversion.

Below we formulate the solution under the polar cases of competition and monopoly. For a competitor, the equilibrium spot price will satisfy the condition that price equals marginal cost, while the monopolist's analogue is the equalization of marginal revenue and marginal cost. That is, under competition,

$$(6) \qquad P^{s*} = C'(Q^{c*} + Q^{s*})$$, and under monopoly,

$$(7) \qquad P^{s*}\,(1+\eta_{D}^{-1}) = C'(Q^{c*} + Q^{s*}) \quad ,$$

where η_{D} is the price elasticity of demand.

For the case of competition, (5) is maximized with respect to Q^{c} subject to

$$(8) \qquad Q^{s} = C'^{-1}(P^{s}) - Q^{c*},$$

to yield

$$(9) \qquad Q^{c*} = \frac{P^c - E\,P^s}{\beta \text{ var } P^s} + \frac{\text{cov }(P^s, \hat{\Pi}^p)}{\text{var } P^s} ,$$

where $\hat{\Pi}^p$ denotes profit in the absence of contracting. The similarity between the general form of the optimal contract purchase (in equation (4)) and the optimal contract sale (in equation (9)) is clear. Ceteris paribus, producers prefer to sell more through long-term contracts the greater is the excess of the contract price over the expected spot price. With demand variability only, contracting can take place even if the contract price is less than the spot price. With both supply and demand shocks, the second term in (9) can be negative, so that no contract trade occurs unless $P^c > E\,P^s$.

Hence, knowledge of both buyers' and sellers' contract decisions and of the source of the shocks is necessary to determine market equilibrium. So that we can determine market equilibrium from the contracting behavior of individual firms, we suppose that the upstream and downstream industries consist of identical firms: s sellers and b buyers. Under the assumption of rational expectations, equating simultaneously supply and demand in the spot and contract markets yields the following expressions for the contract price and the spot price:

$$(10) \qquad P^c = E\,P^s - \frac{\text{cov }(P^s, s\hat{\Pi}^p + b\hat{\Pi}^b)}{(\frac{b}{\gamma}) + (\frac{s}{\beta})} \quad \text{and} ,$$

$$(11) \qquad P^s = P \quad Z'(\bar{Q}^s + \bar{Q}^c) = C'(\bar{Q}^c + \bar{Q}^s) ,$$

where $\bar{Q}^s$ and $\bar{Q}^c$ denote total spot and contract volumes, respectively.

Equation (10) reveals that the expected spot price is an unbiased predictor of the spot price only if at least one of the parties is risk-neutral (i.e., only if $\gamma=0$ or $\beta=0$). The difference between the two prices depends in sign and in magnitude on the correlation between the spot price and total profits in the absence of contracting.

When sellers are competitive, the equilibrium volume of total contract trades is just

$$Q^{c*} = \frac{\beta \text{ cov } (P^s, \hat{\Pi}^p) - \gamma \text{ cov } (P^s, \hat{\Pi}^b)}{(\frac{\gamma}{b} + \frac{\beta}{s}) \text{ var } P^s} \quad . \tag{12}$$

No contract trade takes place unless the right-hand side of equation (12) is positive. In equilibrium, the extent of contracting depends on a weighted average of the covariance of the spot price with sellers' profits in the absence of contracting and (the opposite of) the covariance of the spot price with buyer's *ex ante* profits, with the weights being measures of the parties' risk aversion.

The components of the covariance terms in (12) have an intuitive interpretation. The standard deviations of the profits in the absence of contracting indicate the varibility of buyer and seller profits in auction markets. Signs and magnitudes of the correlations of the spot price with buyer and seller profits depend on the source of the underlying shocks, that is, whether shocks come more from the demand side or the supply side. Under reasonable assumptions about the production function and demand curve, it can be shown that the correlation coefficients are positive when most uncertainty stems from the demand side, and negative when most uncertainty stems from the supply side (see Weiner, 1985 for a derivation). We measure the "vulnerability" of market participants when there is no contracting by the absolute value of the product of the risk aversion coefficient and the covariance of profits with the spot price. Some cases are reviewed below.

First, note that if we let ρ and σ represent a correlation coefficient and standard deviation, respectively, we can rewrite (12) as

$$(12') \qquad Q^{c*} = \frac{\beta(\rho_{p^s,\, \hat{\Pi}^p})\sigma_{\hat{\Pi}^p} - \gamma(\rho_{p^s,\, \hat{\Pi}^b})\sigma_{\hat{\Pi}^b}}{(\frac{\gamma}{b} + \frac{\beta}{s})\sigma_p} \quad ,$$

so that contracting takes place whenever

$$(12a) \qquad \beta(\rho_{p^s,\, \hat{\Pi}^p})\sigma_{\hat{\Pi}} > \gamma(\rho_{p^s,\, \hat{\Pi}^b})\sigma_{\hat{\Pi}^b} \quad .$$

This condition is most easily understood as follows. If only sellers are risk-averse, then contracting takes place only if $\rho_{p^s,\, \hat{\Pi}^p} > 0$, that is, if demand shocks are the source of uncertainty. Similarly, if only buyers are risk-averse, contracting takes place if uncertainty stems from the supply side (i.e., $\rho_{p^s,\, \hat{\Pi}^b} < 0$). More generally, both demand- and supply-side uncertainty will be present, so that both the source of disturbances (sign of the correlation coefficients) and the relative vulnerability (again measured by the absolute value of the product of the covariance of the spot price and profits in the absence of contracting weighted by the risk aversion parameter) are needed to determine the extent of contracting. These results are summarized in Table I.

TABLE I

Conditions Characterizing Contracting in the Market

	Seller Profits More Vulnerable $(\lvert\beta(\rho_{ps}, \hat{\Pi}p)\sigma_{\hat{\Pi}p}\rvert > \lvert\gamma(\rho_{ps}, \hat{\Pi}b)\sigma_{\hat{\Pi}b}\rvert)$	Buyer Profits More Vulnerable $(\lvert\gamma(\rho_{ps}, \hat{\Pi}b)\sigma_{\hat{\Pi}b}\rvert > \lvert\beta(\rho_{ps}, \hat{\Pi}p)\sigma_{\hat{\Pi}p}\rvert)$
Demand Shocks Dominate $(\rho_{ps}, \hat{\Pi}b, \rho_{ps}, \hat{\Pi}p > 0)$	Contracting	Contracting
Supply Shocks Dominate $(\rho_{ps}, \hat{\Pi}b, \rho_{ps}, \hat{\Pi}p < 0)$	No Contracting	No Contracting

Equation (12') and Table I suggest intuitively that contracts are signed (i) when most shocks come from the supply side and buyers' profits are more vulnerable than sellers' to spot price risk, and (ii) when demand shocks are more important and sellers' profits are more vulnerable.

As a convenient summary statistic, we can write the equilibrium fraction of trades carried out under contract α as

$$(13) \qquad \alpha = \frac{1}{\frac{\gamma}{b} + \frac{\beta}{S}} \left[\frac{\beta \text{ cov } (P^S, \hat{\Pi}^p) - \gamma \text{ cov } (P^S, \hat{\Pi}^b)}{C'^{-1}(P^S) \text{ (var } P^S)}\right] .$$

Note that this is not a "solution" for α, since α and var P^S are simultaneously determined (i.e., $\partial\alpha/\partial \text{var } P^S < 0$ from (13), and $\partial \text{var } P^S/\partial\alpha > 0$ by Le Chatelier's principle--the greater the fraction of trades carried out under contracts, the more variable the market-clearing spot price). We return to this issue later.

In general, sellers' profits should be more vulnerable to spot price fluctuations than buyers' profits, so long as the value of any given intermediate purchase is small relative to the value of output.[8] Then, in the context of the model presented here, contracting is more likely the more important demand shocks are relative to supply shocks. These results are consistent with those of some previous studies. As would be predicted by the price asynchronization model of Blanchard (1982), prices should be more flexible in industries in early stages of production than in finished-goods industries. Finally, the predictions of the model may be useful in explaining failures in obtaining reasonable econometric estimates of price equations. Certainly, problems with estimating such price equations with government price indices (e.g., Bureau of Labor Statistics data) are well known (see for example Nordhaus; 1972; Carlton, 1979a). Carlton notes particularly that the influence of demand fluctuations on prices has been difficult to isolate. In this model, a dominance of demand fluctuations would lead to nominal price rigidity, and precisely the inability to estimate demand influences on prices.

Monopoly

The monopolist's problem is to choose the contract price P^c or contract sales Q^c so as to maximize the certainty equivalent of profit.[9] We let the producer choose P^c to maxmize equation (5) above subject to the condition that

$$(14) \qquad Q^s = R^{-1}(P^s) - Q^c \ ,$$

where R denotes the marginal revenue function.

Incorporating the information about the buyers' spot and contract demands conditions on P^c and P^s, we can rewrite (5) as

$$(15) \max_{P^c} \Big\{ P^c\Big[\frac{E\ P^s - P^c}{\gamma \text{ var } P^s} - \frac{\text{cov } (P^s,\ \hat{\Pi}^b)}{\text{var } P^s} \Big] + E\ \big[P^s\ R^{-1}(P^s) - P^s Q^c\big]$$

$$-E\ C(R^{-1}(P^s)) - \frac{\beta}{2} \text{ var } [P^s\ R^{-1}(P^s) - P^s\ Q^c - C(R^{-1}(P^s))]\Big\}.$$

The contract price can be solved from the first-order condition and the market equilibrium condition to be:

$$(16) \qquad P^c = E\ P^s - \frac{\text{cov } (P^s,\ \hat{\Pi}^p + (b + \frac{\gamma}{\beta})\ \hat{\Pi}^b)}{(\frac{2}{\beta} + \frac{b}{\gamma})} \quad ,$$

while the spot price solves

$$(17) \qquad R\, Z'(\bar{Q}) = C'(\bar{Q}).$$

Again note that if the buyer is risk-neutral, the contract price and expected spot price are equal.

Given the expression for the contract price in equation (16) above, the equilibrium spot and contract volumes are

$$(18) \qquad Q^{s*} = R^{-1}(P^s) - Q^{c*}, \text{ and}$$

$$(19) \qquad Q^{c*} = \frac{b}{b\beta + 2\gamma} \left[\frac{\beta \operatorname{cov}(P^s, \hat{\Pi}^p) - \gamma \operatorname{cov}(P^s, \hat{\Pi}^b)}{\operatorname{var} P^s}\right].$$

Denoting the equilibrium fraction of trades carried out through contracts by α as before, we see that

$$(20) \qquad \alpha = \frac{b}{b\beta + 2\gamma} \left[\frac{\beta \operatorname{cov}(P^s, \hat{\Pi}^p) - \gamma \operatorname{cov}(P^s, \hat{\Pi}^b)}{(C'^{-1}(P^s))(\operatorname{var} P^s)}\right].$$

Again, α depends on the degree of risk aversion, the source of uncertainty, and the variance of the spot price, the higher is the variance of the spot price, the lower the fraction of trades carried out under contract.

Comparison of Competitive and Monopoly Outcomes

It is useful to compare the monopoly and competitive solutions under the two-price system. As long as the market can be described as "demand-shocks-only" or "supply-shocks-only," the relationship between the spot and contract prices is similar to that in the competitive case. As under competition, the contract and expected spot prices are equal when buyers are risk-neutral. That is not true, however, under seller risk neutrality; the monopolist does not provide "contract insurance" without additional compensation. Finally, using equations (12) and (19), we can compare the contract volumes under competition and monopoly. With seller risk neutrality, we obtain the usual result that the monopoly volume is half of the competitive volume.

The relationship between market structure and price flexibility has figured prominently in debates in industrial organization since Means's advancement of the "administered prices" hypothesis. Focusing on the polar cases of competition and monopoly, we can address in the context of our model whether, <u>ceteris paribus</u>, monopolists have stickier prices than competitors. The hypothesis of a positive relationship between industry concentration and price rigidity implies that α should be larger under monopoly. That is, holding constant across market structures the values of the risk aversion parameters and the covariances of buyer and seller profits with the spot price, contracting and price rigidity are more extensive under monopoly if

(21) $$\left(\frac{1}{\frac{2\gamma}{b} + \beta}\right)\left(\frac{1}{C'^{-1}(P_m^s)}\right) > \left(\frac{1}{\frac{\gamma}{b} + \beta}\right)\left(\frac{1}{C'^{-1}(P_c^s)}\right), \text{ or}$$

(22) $$\frac{C'^{-1}\ (P_c^s)}{C'^{-1}\ (P_m^s)} > \frac{2\gamma + b\beta}{\gamma + b\beta},$$

where P^s_c and P^s_m represent the prices corresponding to the equilibrium quantities where price equals marginal cost and marginal revenue equals marginal cost, respectively.

The value of the expression on the left-hand side of the inequality in (22) is at least unity, since total competitive production must exceed monopoly production. The expression on the right-hand side is bounded between one and two.

No unambiguous result can be delineated, but some special cases are illustrative. In the case wherein marginal cost curves and demand curves are linear, contracting (and price rigidity) is necessarily greater under monopoly only if buyers are risk-neutral. In general, the result depends on the slopes of the demand and marginal cost curves. Price flexibility will be relatively greater under monopoly the steeper is the marginal cost curve or the flatter is the demand curve. Associating changes in marginal cost with changes in capacity utilization, the former implies that a monopolist would be more likely to raise prices during booms in this case.

III. CONTRACTING AND PRICE ADJUSTMENT

Obtaining closed-form solutions for α and var P^s requires the specification of functional forms for the demand and marginal cost curves. In so doing, we chose a modeling framework that will also allow us to consider the impact of contracting on the "persistence" demand and supply shocks on prices. Turnovsky (1983) has considered the persistence effects of transitory shocks on prices in markets for storable commodities. Recent macroeconomic models of the influence of labor contracts on the behavior of wages and prices (e.g., Fischer, 1977; Taylor, 1979) have also focused on the "persistence" issue and have considered roles for stabilization policy in the presence of contracts.

If in the absence of storage, there were a single spot price for a given commodity, then transitory shocks could exert no persistence; there would only be a one-period change in the price. If the good were sold only through long-term contracts, the persistence of transitory fluctuations would be imbedded in the ability of contract provisions to adjust to market conditions. With trade on both spot and contract markets, shifts in the mix of spot and contract trades can alter the short-run and long-run impacts of shocks on prices.

To facilitate comparison with other studies, smoothing, we introduce speculative stockpiling by third parties, following Turnovsky.[10] We then examine the impact of a two-price system on market equilibrium in the presence of demand and supply disturbances. Both contracting and storability will affect not only the immediate impact of transitory shocks on current-period spot prices, but also persistence of that impact. Further, both the variance of the distribution of spot prices will be altered.

Total demand is the sum of consumption and inventory demands. Price-taking, risk-neutral speculators trade in inventories on the spot market in anticipation of changes in price. Speculators are assumed to

(23) $$\max_{I_t} E_t\{((1+\delta)^{-1} P^s_{t+1} - P^s_t) I_t - \frac{h}{2} I_t^2\} ,$$

where I represents the end-of-period stock level and δ is the discount rate (identical to that of the buyers and sellers). Holding stocks is assumed to be costly--in fact, increasingly costly--in the size of the stock due to payments to factors fixed in the short run (e.g., storage facilities). Thus changes in price expectations cannot be fully acted upon instantaneously. We model such costs as quadratic, the simplest specification of "diminishing returns;" these costs are indexed by the parameter h.[11]

Maximizing (23) with respect to I_t yields the following demand function for stocks:

$$(24) \qquad I_t = h^{-1}\left((1+\delta)^{-1} E_t P^s_{t+1} - P^s_t\right) .$$

As with most other studies since the original development by Muth (1961), speculative holdings are a function of the expected increase in price -- taking into account the cost of adjusting stock levels.

To obtain solutions for α and var P^s, we suppose that, in the absence of shocks, the demand function is linear and of the form

$$(25) \qquad Q^D_t = a-dP^s_t,$$

and that the cost function is such that

$$(26) \qquad C\ (Q_t) = F + \frac{1}{2}\, c\ Q_t^{\ 2}\ ,$$

so that

$$(27) \qquad C'(Q_t) = cQ.$$

Further suppose that the market is subject to additive demand and supply shocks ε_{Dt} and ε_{St}, respectively, that are identically and independently distributed with mean zero and variances σ_D^2 and σ_S^2 , respectively.

In the competitive case, buyers and sellers carry out planned spot purchases and sales equal to $(1-\alpha)(a-dP^s)$ and $(1-\alpha)c^{-1}P^s$, respectively, where α is an equilibrium parameter determined as before with respect to "normal sales" (excluding speculative stockpile movements). Inventory movements as well as demand and supply shocks are also absorbed on the spot market. For example, an interruption in contract supply ($\varepsilon_{St} < 0$) affects the market as follows. There is excess demand at the prevailing contract price, and the spot market functions to absorb disturbances. Given an optimal choice of α, equilibrium in the spot market requires that

$$(28)\quad (1-\alpha)\ c^{-1}\ P_t^s + \varepsilon_{St} = (1-\alpha)(a-dP_t^s)+\varepsilon_{Dt}+h^{-1}[E_tP_{t+1}^s-P_t^s - E_{t-1}P_t^s + P_{t-1}^s].$$

To facilitate the solution for the spot price, we first define lower-case p's as prices in deviation form. That is,

$$(29)\qquad p_t^s = P_t^s - \bar{P}^s,$$

where $\bar{P}^s$ is the long-run equilibrium price at which expectations are realized. We can then rewrite equation (28) as

$$(30)\qquad [(1-\alpha)\ (c^{-1}+d) + 2h^{-1}]\ p_t^s = \varepsilon_{Dt} - \varepsilon_{St} + h^{-1}p_{t-1}^s + h^{-1}E_tp_{t+1}^s\quad .$$

Under the assumption of rational expectations, we can solve the second-order inhomogeneous difference equation in (30) by standard methods to yield

$$(31) \qquad p_t^s = \psi\, p_{t-1}^s + \frac{\varepsilon_{Dt} - \varepsilon_{St}}{(1-\alpha)\,(c^{-1}+d) + h^{-1}(2-\psi)} ,$$

where ψ is the root within the unit circle of the quadratic equation $h^{-1}\psi^2 + \left((1-\alpha)\,(c^{-1}+d) + 2h^{-1}\right)\psi + h^{-1} = 0$.

Even transitory shocks exhibit persistence effects on the spot price, because of inventory behavior and because of the existence of contracts. Moreover, the variance of the spot price increases with ψ, since

$$(32) \qquad \text{var } P^s = \frac{\sigma_D^2 + \sigma_S^2}{\left((1-\alpha)\,(c^{-1}+d) + h^{-1}(2-\psi)\right)^2} .$$

Again, with transitory shocks, the variance of the spot price depends on α: $\partial \text{ var } P^s / \partial\alpha > 0$. While the use of long-term contracts is often seen as an instrument of price stability, this inequality indicates that maintenance of contract prices in the presence of fluctuating supply and demand increases variability in the spot market. Equations (13) and (32) constitute a pair of nonlinear relationships between α and var P^s. These nonlinearities can cause problems of nonuniqueness and nonexistence of rational expectations equilibria (see McCafferty and Driskill, 1980). Given our assumptions of linear demand and marginal cost curves and the results in equations (13) and (32), we can write the implicit expression for α as the solution to

$$(33)\quad \alpha = \left[\frac{\beta(\rho_{p^s,\ \hat{\Pi}^p})\,\sigma_{\hat{\Pi}^p} - \gamma(\rho_{p^s,\ \hat{\Pi}^b})\,\sigma_{\hat{\Pi}^b}}{C^{-1}(p^s)\,(\frac{\gamma}{b} + \frac{\beta}{s})}\right]^2 \quad \frac{[(1-\alpha)\,(\bar{c}^{-1} + d) + h\,(2-\psi)]^2}{\sigma_D^2 + \sigma_S^2}$$

It can be easily shown that the signs of the derivatives of α with respect to the underlying parameters--measures of risk aversion, the correlations of buyer and seller profits with spot price movements, the variability of profits in the absence of contracting, and the variances of supply and demand shocks--are exactly as in equation (13) before.

Three relationships between the persistence parameter ψ and the underlying structural parameters are of interest. First, since $d\psi/d\alpha > 0$, the larger is the fraction of trades carried out under contracts, the greater is the persistence. Second, $d\psi/dd < 0$, so that the greater is the demand response to a change in price, the smaller is the initial increase in price and the lower is the persistence. These two relationships imply that increasing the fraction of trades carried out under contracts will increase the variance of the spot price, while higher values of d will lead to a smaller variance of the spot price.[12] Third, since $d\psi/dh < 0$, the less costly is stock adjustment (and hence the greater the speculative response to expected price changes), the greater is the persistence effect on prices of a transitory shock.

Extension to Multiperiod Contracts

The expression for the spot price derived above can be used in the context of multiperiod contracts to motivate the sort of price adjustment model suggested by Taylor (1979). Consider a contract lasting T periods.[13] Discount rates for buyers and sellers are set equal to a common rate δ. We consider the competitive case below; the monopoly case is analogous.

The analogue to equation (9) for desired contract purchases is

$$(34) \qquad Q^{c*} = \frac{\left(E_0 \sum_{t=0}^{T} \Delta_t P_t^s\right) - P^c - \gamma \operatorname{cov}(P^s, \hat{\Pi}^b)}{\gamma \operatorname{var} P^s} ,$$

where the weights Δ_t are contructed so that $\Delta_t = (1+\delta)^{-t} / \sum_{t=0}^{T} (1+\delta)^{-i}$, $\sum_{t=0}^{T} \Delta_t = 1$. The sellers' case derives analogously. Equilibrium in spot and contract markets gives an optimal contract price of

$$(35) \qquad P^c = \left(E_0 \sum_{t=0}^{T} \Delta_t P_t^s\right) - \frac{\operatorname{cov}(P^s, s\hat{\Pi}^p + b\hat{\Pi}^b)}{\left(\frac{b}{\gamma} + \frac{s}{\beta}\right)} .$$

Equation (35) illustrates the importance of expectations of the spot price over the duration of the contract in determining the equilibrium contract price. When buyers or sellers are risk-neutral, the contract price is a weighted average of expected future spot prices. Hence expectations of future demand and supply shocks can influence the current contract price. In general, the difference between the contract price and the weighted average of expected future spot prices depends on sources of underlying disturbances, market structure, and the degree of risk aversion of trading parties.

Now consider the simple case of two-period contracts. When shocks are transitory, we can combine equations (31) and (35) to yield the following expression for adjustment of the contract price:

$$(36) \qquad P_t^c = (1-\psi)\,\bar{P}^s + \psi\,(\Delta_0\,P_{t-1}^s + \Delta_1\,P_t^s + \Delta_2\,E_t\,P_{t+1}^s) + \Delta_0\eta_t - \frac{\text{cov}\,(P^s,\ s\hat{\Pi}^p + b\hat{\Pi}^b)}{(\frac{b}{\gamma} + \frac{s}{\beta})}\ ,$$

where $\eta_t = (\varepsilon_{Dt} - \varepsilon_{St})/((1-\alpha)(c^{-1} + d) + h^{-1}(2-\psi))$.

Equation (36) provides a formal justification for the model of contract price adjustment suggested by Taylor (1979)--in which market participants consider lagged and expected future prices and the impact of current-period shocks--and can be considered in three parts. First, whether the contract price exceeds, equals, or is exceeded by the function of the spot price and market conditions embodied in the first two terms of (36) depends on buyer and seller risk aversion and the covariance of the spot price and profits in the absence of contracting. Second, in the first term of (36), the distribution of weight placed on the long-run mean spot price versus that placed on the weighted average of current, lagged, and expected future spot prices depends on the magnitude of the persistence parameter ψ. The greater is the persistence, the smaller is the weight placed on the long-run price. The weights on current, lagged, and expected future spot prices are a function of the discount rate. When $\delta = 0$, $\Delta_0 = \Delta_1 = \Delta_2 = \frac{1}{3}$, and equal weight is placed on the three spot prices. Finally, both current demand and supply shocks matter for the determination of the contract price in the current period.

Note that when $\psi=0$, equation (36) is exactly the expression for the contract price in the static model derived previously. The importance of ψ in (36) indicates the role of decisions about the use of long-term contracts and inventories in determining the sensitivity of the prices on newly signed contracts to current market conditions.

The dependence of contract prices on the persistence effects of shocks on the spot price suggests again the importance of the relationship among h, α, and ψ. The greater is the equilibrium fraction of trades carried out under contracts and the more sensitive is speculative stockpiling to expected price appreciation, the larger is the persistence parameter ψ, and the greater is the weight placed on the expected path of spot prices in determining the contract price. As shown earlier, the extent of contracting (as determined by α) is a function of the variance of the spot price and the covariances of buyer and seller profits with the spot price. The more important are demand shocks relative to supply shocks, the larger is α, and the more gradual is contract price adjustment to shocks.

IV. EXTENSIONS AND CONCLUSIONS

Considerable attention has been devoted by macroeconomists and industrial economists to the problem of "sticky" or inflexible prices, and its consequences for market equilibrium and the effectiveness of stabilization policy. The search for microeconomic foundations of non-Walrasian outcomes in labor and product markets has spawned many studies of contracting. Our purpose in this paper has been to emphasize the role of contracts in markets (for many raw materials and basic industrial commodities) in which long-term contractual arrangements and spot markets coexist. These markets provide a laboratory for studies of the behavior of prices in response to demand and supply fluctuations, studies that can help to explain recent failures in estimating econometric price equations.

Our analysis has been pursued with two goals in mind--(i) to explain the existence of contracts in product markets and their contribution to price stickiness, and (ii) to consider the impact of demand and supply shocks on spot prices when market trades also take place through long-term contracts. With respect to the first point, we find that the relative importance of contracting is endogenous, depending on, *inter alia*, the variance of the spot price and the sources of underlying fluctuations. Consistent with the findings of previous macroeconomic studies, we find that contracting and price rigidity are more likely the more important demand shocks are relative to supply shocks.

Second, we adapt our static model of the determination of contract prices and quantities to discuss the adjustment of contract prices. Introducing storage by speculators, we find that even transitory disturbances exhibit persistence effects on spot prices in the presence of contracts. Links between contracting and storage suggest a fruitful extension in merging two strands of the recent macroeconomics literature explaining "persistence"--that based on the role of inventories and that based on overlapping (labor) contracts. In general, the predicted adjustment of spot prices to transitory shocks depends on the use of contracts, the ease with which speculative stocks can be adjusted, and the source of the shocks.

Three extensions of our results seem particularly promising. The analysis of econometric models of price determination in commodity markets is an obvious application of the "two-price" model presented here. As noted earlier, many commodity markets have experienced multiple-price regimes, most notably copper and petroleum. Equation (31) for the spot price indicates that the intertemporal correlation of price changes depends on the importance of nominal contracting in the market. Moreover, the relationship between the contract price and expected future spot prices embodied in equation (35) depends on the same factors determining the importance of contracting (as measured by α). Hence we would expect that markets experiencing structural change in terms of the source of or variance of shocks should undergo changes in contracting structure. The change in contracting then alters the time-series properties of the effects of shocks on prices and the cross-sectional relationship between prices.

Nowhere is this pattern more apparent than in the oil market, where vertical integration was replaced by a two-price system in the 1970s, with contracts signed by newly-formed state-owned production companies. Through the first major oil shock (in 1973-74), contract trade was supplemented by a "thin" spot market (with about five percent of total world volume). Given the increased volatility of the market, almost half of all trades were carried out on the spot market by the time of the second shock in 1979-80. In the oil market of the mid-1980s, the vast majority of trades are effectively carried out on spot markets, with a dramatic reduction in the term of contracts still used.[14] Similarly, the two-price system in the copper market was replaced over the 1970s by spot trading on the London Metals Exchange.

These developments have important policy implications. Hubbard and Weiner (1984) have shown that the optimal public strategic stockpile responses to commodity price shocks depend on the persistence effects of price changes (ψ in equation (31)). Since persistence is an increasing function of the relative importance of contracting, the optimal stockpile policy and the effectiveness of any stockpile policy change with the contracting regime.

That is, the question of which price to observe is important; one implication of the two-price model outlined above is that the behavior of spot and contract prices may diverge substantially from that of "average" prices. Since α represents the optimal fraction of trades carried out under contracts, the weighted-average acquistion price P satisfies

$$(37) \qquad P = \alpha\, P^c + (1-\alpha)P^s.$$

To consider the effect on the volatility of average prices of changes in the volatility of demand and supply, note that since $\text{var } P = (1-\alpha)^2 \text{ var } P^s$,

$$(38) \qquad \frac{d \text{ var } P}{d\sigma^2} = (1-\alpha)^2 \frac{d \text{ var } P^s}{d\sigma^2} - 2(1-\alpha) \text{ var } P^s \frac{\partial\, \alpha}{\partial \text{ var } P^s} \frac{d \text{ var } P^s}{d\sigma^2}$$

$$= \left[(1-\alpha)^2 - 2(1-\alpha) \text{ var } P^s \frac{\partial\alpha}{\partial \text{ var } P^s} \right] \frac{d \text{ var } P^s}{d\sigma^2} \qquad ,$$

where $\sigma^2 = \sigma_D^2 + \sigma_S^2$. Since $\frac{\partial\alpha}{\partial \text{var } P^S} < 0$, the response of the variance of the composite price to a change in the volatility of underlying shocks may be greater or less than the response of the variance of the spot price to that same change, depending on the sensitivity of the contracting decision to the variance of the spot price (i.e., depending on the risk aversion of the transactors). That is, the relationship between the responses to changes in the variance the "spot" and "average" prices is likely to be unstable. Hence, price stabilization schemes facilitated by public stockpiles will in general be unable to stabilize "average" prices by focusing on spot prices.

Second, in the real world, we find indexed contracts with elements of both the contract and spot trades stylized in the previous sections. Hence, while we have structured the model to think about the optimal mix of <u>individual trades</u> carried out on auction markets and on nominal contracts, we can interpret the results in terms of the optimal degree of indexation of typical contracts in the industry. Indexation of contracts corresponds to a low value of α in the preceding section. We expect a higher degree of indexation when (i) most shocks come from the supply side and sellers' profits are more vulnerable (in the sense defined before) to spot price changes, and (ii) demand shocks are more important and buyers' profits are more vulnerable to spot price changes. If we again assume that sellers' <u>ex ante</u> profits should be more vulnerable to spot price fluctuations than buyer's profits, then indexation is likely to be more extensive the more important are cost shocks relative to demand shocks.

Two hypotheses can be readily tested using panel data on the different industries. First, cyclical price sensitivity should be greater as aggregate cost shocks become more important relative to aggregate demand shocks. Specifically, changes in input prices should be "passed through" more rapidly as cost shocks become more important. Second, since seller vulnerability to price fluctuations should be greatest early in the chain of production, price flexibility should be greatest in intermediate-goods industries whose output goes to another intermediate-goods industry rather than to final consumption.[15]

A third application of the two-price approach is to macroeconomic studies of aggregate price flexibility. An extension to a dynamic analysis of sticky prices is logical, as "contracting" is a manifestation of the notion that prices are in some sense "costly to adjust." This focus on costs of adjustment has appeared in Barro (1972), Sheshinski and Weiss (1977), and Rotemberg (1982). In this literature, such costs are hypothesized to be of two types. First, there is some (fixed) cost attached to changing prices, including, for example, any physical costs of changing list prices. The second cost relates to any negative effects of price changes on firms' "reputations." Our model provides an alternative explanation for price rigidity, and our use of nominal contracts does not rely on menu costs or on a group of agents' being non-maximizers. Our model is similar in many ways to the structure used by Rotemberg (1982), though, in our framework, the analogue to costs of adjustment (i.e., the determinants of α) differs across industries, so that treating such costs as identical across industries to facilitate aggregation for time-series studies may pose a serious difficulty.

While we have concentrated our attention on multiple-price regimes in individual markets for primary or industrial commodities, the approach has important implications for aggregate models of prices and quantities. If contractual arrangements in product markets are endogenous, then models of price adjustment designed to examine the impacts of demand and supply shocks on market equilibrium and the potential for effective policy intervention must go further than determining prices as a simple markup over standard unit input costs. Moreover, to the extent that price "rigidity" implied by contracting is the result of an optimizing process, profitable opportunities for policy intervention (to alter the variances of prices or output) may be lacking.

Footnotes

[1]Indeed, sticky product prices appear to antedate sticky wages (see the early discussions in Mills, 1927, and Tucker, 1938). Gordon (1981) provides a review of macroeconomic models of output and price adjustment.

[2]Implicit contract theory has been used to rationalize "Keynesian unemployment" (Okun, 1981; Harris and Holmstrom, 1983). Formal models of the influence of labor contracts on price flexibility can be found in Fischer (1977) and Taylor (1979). In such models, the predetermination of prices for some given period provides a role for stabilization policy. An alternative approach is suggested by Blanchard (1982)--namely that price adjustment in the aggregate appears gradual because individual price adjustments are desynchronized.

[3]The empirical model in Rotemberg (1982) offers a test of the importance of customer markets, justifying price stickiness because of costly price adjustment (in the sense of upsetting buyer-seller relationships).

[4]Price dispersion can occur for two other reasons: (i) imperfect information about prices, combined with costly search and heterogeneous buyers and sellers; and (ii) price discrimination. The first is likely to be important for differentiated retail goods (Pratt, Wise, and Zeckhauser, 1979), but less so for homogeneous commodities, whose prices are widely quoted. The second is illegal under U.S. antitrust law, unless cost differences can be demonstrated.

[5]Copper and petroleum are oft-cited examples here; others worth mention are coal, natural gas, aluminum, iron ore, and oil tanker services. A small literature has developed on the two-price system in the copper market (see Fisher, Cootner, and Baily, 1972; McNicol, 1975; Mackinnon and Olewiler, 1980; and DeKuijper, 1983). Although the most dramatic episodes of spot-contract price divergence has occurred in the oil market, analytical work has been scarce (see Nordhaus, 1980; Verleger, 1982; Bohi, 1983; Hubbard and Weiner, 1983).

[6]Stigler and Kindahl (1970) showed that many industrial commodities are purchased on contracts whose typical duration is at least a year.

[7]Carlton (1979a) considers this issue from the sellers' point of view in the context of the informational value of contracts. If all uncertainty exists on the demand side, price discounts for long-term contracts can be traced to this information role.

[8]In addition, as goods progress from raw materials to finished output, a progressively larger share of the total cost reflects labor cost. To the extent that wages are sticky, sellers' profits are more vulnerable to spot price risk than those of buyers.

[9] Given the symmetrical structure of the model, the monopsony case is analogous.

[10] In many markets, middlemen (e.g., petroleum refiners, grain processors) hold most of the inventory. In an empirical study of the copper market, Bresnahan and Suslow (1985) examined the impact of changes in the relationship between spot and contract prices on inventory behavior.

[11] For a more general intertemporal optimizing model of inventory behavior under uncertainty, see Hubbard and Weiner (1984).

[12] Extension of the model to consider serially correlated shocks amplifies the results presented here. For discussion of shocks following autoregressive processes, see Hubbard and Weiner (1984); a comparison to a one-price model can be made by seeing also Blinder (1982).

[13] We take the contract duration of T periods as given here. In general, the length of the contract is also a choice variable for the negotiating parties (see for example Roberts, 1980).

[14] For a more detailed discussion of the two-price system in the world oil market, see Hubbard (1984).

[15] Preliminary tests along these lines using panel data on manufacturing industries have produced results favorable to the predictions of the model; see Domowitz, Hubbard, and Petersen (1985).

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