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FUTURES MARKETS, SPECULATION AND MONOPOLY PRICING

by

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Abstract

The possibility for a futures market to exist when the underlying commodity (called the cash good) is monopolized has been studied only recently after a long period of neglect, possibly due to the implicit assumption that, since futures markets are typically competitive, the corresponding cash markets are also competitive.

In the present paper we study a monopoly model of a storable good in a dynamic framework. The influence of the monopolist's futures position on his intertemporal pricing and production policy and the reciprocal influence of the latter on the equilibrium of the futures market are analyzed. The possibility of taking a short position increases the monopolist's output and reduces the expected variability of the cash price. Contract curves for futures positions are derived under the condition that the monopolist and the speculators have different prior beliefs. Our analysis highlights the essential role played by different prior beliefs in determining the size of the futures position, the futures price and speculative inventories.

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This paper is an attempt to study the influence of futures trading on the monopolist's intertemporal pricing and production plan. A futures contract can be interpreted as a commitment for future actions. Our interest is to analyze the influence that such a commitment can have on future and "present" production and prices. Interestingly enough, the existence of a futures market modifies the intertemporal discrimination rule due to the influence that the financial market exerts on the marginal revenue of the extractor or producer. For the case of an exhaustible resource we consequently characterize the effect that futures trading has on Hotelling's rule. Even though our model stresses the role played by speculators, the qualitative result about the path of prices would be similar if the hedging component was explicitly introduced.

The working of futures markets for monopolized cash goods has been studied only recently after a long period of neglect, possibly due to the irrealistic assumption that, since futures markets are perfectly competitive (a most debatable assumption itself), the corresponding cash markets are also perfectly competitive. Casual observation shows that cash markets are often dominated by a few large producers who can and do manipulate the futures market (see the papers in Anderson (1984) and Anderson and Gilbert (1986)). Three papers are of particular interest. Newbery (1984) compares the competitive equilibrium of a futures market for a nonstorable commodity with the equilibrium that arises when there is a risk-neutral dominant producer, facing a risk-averse competitive fringe, who acts as a big speculator. Any departure from the competitive futures price is interpreted as market manipulation by the dominant producer. Futures markets are seen as reducing risk for the competitive fringe, by providing the opportunity to hedge. The existence of futures markets therefore induces a supply increase of the cash good. The big speculator counteracts this by reducing the bias between the cash and the futures price. The reduction of fringe supply increases the expected cash price and thereby increases the expected profits of the dominant producer on the cash market. Newbery (1987) refines this analysis by allowing the dominant producer also to be risk-averse and discusses the conditions under which this producer may wish to suppress the futures market. Anderson and Sundaresan (1984) present a static analysis of a monopolist who can trade in futures at time 1 and produces a perishable good at time 2, the maturity date. They also find that futures trading increases supply. However, here it is the monopolist who produces more (at time 2) if it has sold futures (at time 1). Again, hedging is essential : futures trading is possible only if the futures market is viewed by the monopolist as a hedging instrument. No trade takes place if the futures market is purely speculative in a rational expectations equilibrium.

Yet, in real life purely speculative futures trading does appear in markets where the cash good is more or less monopolized. It seems worthwhile, therefore, to investigate whether another approach could account for this observation and to derive a purely speculative equilibrium under monopoly or oligopoly. In this paper we concentrate on the monopoly case in order to come to grips with the problem. We depart from the Newbery approach by excluding hedging and abandoning the competitive equilibrium as a standard of reference. Instead, we define manipulation in terms of the power a monopolist has to determine not only the current cash price but also the cash price to prevail in the future (to an extent determined by the degree of uncertainty about market demand). We depart from the Anderson-Sundaresan approach , not only because we need a dynamic model to account for this sort of manipulation, but also because we abandon the standard capital asset pricing model with its combined assumption of rational expectations and identical prior beliefs. Theses assumptions seem rather unrealistic and inappropriate, especially for a speculative market in which some traders have market power. Futures positions will be derived with the help of contract curves based on different priors. Differences in opinion will thus play a central role, as in the approach advocated by Varian (1987). As for the futures prices, these will be determined using bargaining theory.

In order to work out the monopolist's intertemporal pricing and production (or extraction) plan, we need a dynamic model with at least two periods during which the commodity can be produced (or extracted). This in turn allows for the possibility that the commodity may be stored by the monopolist (or by nature).

Our analysis proceeds in two steps. In a first step, the monopolist determines the time path of the production rate, the sales rate and the cash price, given its futures position and the current futures price. It is shown how the futures position affects the current cash price and the cash price planned at the maturity date. In a second step, the possibility for a purely speculative market to exist is examined. We find that contract curves can exist when the monopolist's expectations about market demand differ sufficiently from those of the speculators. Speculative futures positions and the futures price can then be determined under certain realistic informational assumptions.

Section I starts with the simpler case where a natural resource is monopolized. The possibility of taking a futures position is seen to affect Hotelling's rule. Section 1.2 develops the full model of a reproducible and storable commodity. The results are illustrated with the help of quadratic specifications. Section II then examines the expected profits that can be earned on the futures market, given that the monopolist is on its optimal extraction or production path. The sum of these gains can be positive at equilibrium, although the futures market is purely speculative. Section III shows under what conditions speculative stocks of the natural resource can be carried in the framework of our model.

I. THE CASH MARKET

1.1. The case of an Exhaustible Resource

Suppose a natural resource is monopolized. Before the production decisions are made, there is a futures market for this cash good on which the monopolist can enter a futures position f at the futures price p^f. In period 2, the futures price is equal to the cash price p_2, determined by the monopolist, since $t = 2$ is the maturity date. The monopolist faces an instantaneous demand curve $p_t = p_t(q_t)$, where q_t is the rate of extraction and p_t is the cash price net of a constant cost of extraction $(t = 1, 2)$. Nature has provided an initial stock s_0 to be sold over the two periods or

$$s_0 = q_1 + q_2. \tag{1}$$

Any quantity extracted is immediately consumed. In particular, there are no speculative stocks carried from period 1 to period 2.

In period 1 the monopolist maximizes the profit function

$$\left(\frac{1}{1+r}\right)[p_2(q_2)\cdot q_2 - fp_2(q_2)] + p_1(q_1)\cdot q_1 + fp^f, \tag{2}$$

with respect to q_1 and q_2, subject to constraint (1). The real rate of interest is represented by r. p^f and f are supposed to be predetermined. Their determination is the subject of Section II. A short position implies $f > 0$; a long position implies $f < 0$. Maximization of the Lagrangian gives

$$p_1(q_1) + q_1\frac{dp_1(q_1)}{dq_1} = \left(\frac{1}{1+r}\right)\left[p_2(q_2) + q_2\frac{dp_2(q_2)}{dq_2} - f\frac{dp_2(q_2)}{dq_2}\right] = \lambda \tag{3}$$

together with (1). This is a modified Hotelling rule. Instead of equalizing discounted marginal revenues over time, the monopolist must correct the second period's marginal revenue to take his futures position into account.

How this affects the extraction and pricing policy can be illustrated with an algebraic example. Suppose $p_t(q_t) = \alpha/\beta - (1/\beta)q_t$. Using (1), and (3), we find the linear extraction rules

$$q_1 = \frac{1}{2(2+r)}(\alpha r + 2s_0 - f)$$
$$q_2 = \frac{1}{2(2+r)}[-\alpha r + 2(1+r)s_0 + f]. \tag{4}$$

If the monopolist has taken a short position ($f > 0$), it will plan to extract more in period 2 and less in period 1 than if it had no futures position. With $r = 0$, this difference is equal to $f/4$. Clearly, the purpose is to decrease p_2 below and to increase p_1 above the level they would take in the absence of a futures market. Indeed, the cash prices are

$$p_1 = \frac{1}{2\beta(2+r)}[(4+r)\alpha - 2s_0 + f]$$

$$p_2 = \frac{1}{2\beta(2+r)}[(4+3r)\alpha - 2(1+r)s_0 - f].$$

With $r = 0$, the reduction in the price variation $\Delta p = p_2 - p_1$ is equal to $-f/2\beta$ or $\frac{1}{2}f\,dp_2(q_2)/dq_2$. The larger is r, the smaller is this reduction. The same is true for β.

In what follows, we put $r = 0$ to simplify the presentation and to facilitate the interpretation. Under that assumption, the optimal plan is

$$q_1 = \hat{q} - \frac{f}{4} \tag{5.1}$$

$$p_1 = \hat{p} + \mu f \tag{5.2}$$

$$q_2 = \hat{q} + \frac{f}{4} \tag{5.3}$$

$$p_2 = \hat{p} - \mu f \tag{5.4}$$

where $\hat{q} = s_0/2$ is the quantity extracted (in both periods) in the absence of a futures market, $\hat{p} = \alpha/\beta - s_0/2\beta$ is the cash price (in both periods) in the absence of a futures market and $\mu = 1/4\beta > 0$.

1.2. The Case of a Reproducible and Storable Commodity

We now generalize the preceding model by allowing for the possibility that the cash good is produced at a rate x_t and reinterpreting q_t as the rate at which it is sold and p_t as the cash price. The monopolist has a strictly convex cost of production $K(x_t)$ and a strictly convex cost of storage $C(s_t)$, where s_t is his inventory level at the end of period t. $C(s_t)$ has a minimum at $\bar{s} > 0$. The initial and terminal inventory level is $\bar{s}$, so that

$$\begin{aligned} s_1 &= \bar{s} + x_1 - q_1 \\ s_2 &= s_1 + x_2 - q_2 = \bar{s}. \end{aligned} \tag{6}$$

Neither the buyers of the cash good nor the speculators carry any inventory, so that there is no resale trading.

The monopolist maximizes the Lagrangian

$$\begin{aligned} p_1(q_1)q_1 + p_2(q_2)q_2 - K(x_1) - K(x_2) - C(\bar{s} + x_1 - q_1) \\ + [p^f - p_2(q_2)]f - \lambda(q_1 + q_2 - x_1 - x_2) \end{aligned} \tag{7}$$

with respect to q_1, q_2, x_1, x_2 and λ. The first-order conditions are

$$p_1(q_1) + q_1 \frac{dp_1(q_1)}{dq_1} + \frac{dC(s_1)}{ds_1} = p_2(q_2) + (q_2 - f)\frac{dp_2(q_2)}{dq_2} = \lambda \tag{8}$$

$$\frac{dK(x_1)}{dx_1} + \frac{dC(s_1)}{ds_1} = \frac{dK(x_2)}{dx_2} = \lambda \tag{9}$$

$$x_1 + x_2 = q_1 + q_2. \tag{10}$$

With f nonzero, marginal revenue differs from marginal production cost by the quantity $f dp_2(q_2)/dq_2$ at period 2. Equation (9) is the well-known condition - see Phlips and Thisse (1981) - that the rate of production is governed by the equality of the marginal cost of storage and the change in the marginal cost of production. According to equation (8), the rate of sales must be such that the marginal cost of storage is equal to the change in marginal revenue, corrected for $-f dp_2(q_2)/dq_2$. And the price change $\Delta p = p_2 - p_1$ is

$$\Delta p = \frac{dC}{ds_1} - \Delta(p\eta) + f\frac{dp_2}{dq_2}, \tag{11}$$

so that ***a short position*** ($f > 0$) ***is seen to reduce the variation of the cash price.*** (The converse is true if the monopolist takes a long position). η designates the elasticity of the instantaneous demand function for the cash good. Since $\Delta(p\eta)$ is positive when p is rising, the price increase is smaller than the marginal cost of storage.

The working of the model is again better understood if we specify the demand, cost of production and cost of storage functions. (These specifications will be used in Section II below). Let the instantaneous demand function be $\alpha/\beta - (1/\beta)q_t$, the same in both periods. Specify $K(x_t)$ as

$$K(x_t) = kx_t + \ell x_t^2$$

with $k, \ell > 0$, and let $C(s_t)$ be

$$C(s_t) = j + ms_t + ns_t^2$$

with $m < 0, n, j > 0$ and $\bar{s}$ defined by $C'(s_t) = 0$ or $\bar{s} = -m/2n > 0$. The negative slope coefficient reflects the "convenience yield" (see Brennan (1958)) so that $\bar{s}$ can be interpreted as a buffer stock held to satisfy unexpected orders.

Conditions (7) to (11) then have the following solution :

$$q_1 = q_1^* - \frac{2\beta\ell^2}{\theta}f \tag{12.1}$$

$$x_1 = x_1^* + \frac{\ell}{\theta}f \tag{12.2}$$

$$q_2 = q_2^* + \frac{\gamma + \ell + \beta\ell^2}{\theta}f \tag{12.3}$$

$$x_2 = x_2^* + \frac{\gamma}{\theta}f \tag{12.4}$$

where

$$\gamma = \ell + n(1 + \beta\ell)$$
$$\theta = \delta(1 + \beta\ell)$$
$$\delta = 4\ell + 2n(1 + \beta\ell)$$

and $q_1^* = q_2^* = x_1^* = x_2^* = (\alpha - \beta k)/2(1 + \beta\ell)$ is the quantity produced and sold in the two periods in the absence of a futures market. All coefficients are positive, except m.

When the monopolist takes a short position ($f > 0$) in period 1, both x_1 and x_2 are larger than in the absence of a futures market : total production is increased, and so are total sales (since $x_1 + x_2 = q_1 + q_2$). However, there is a shift of sales from the first to the second period, so that the price variation is reduced (as in the case of a natural resource).

II. THE FUTURES MARKET

Suppose that a futures market is set up for the cash good and offers a contract (p^f, f) to a risk-neutral monopolist and a risk-neutral representative speculator. (Market equilibrium requires that the speculators together take a position that matches the position taken by the monopolist.) Under what conditions will both sides accept such a contract ?

Under rational expectations such a contract is not possible. The No Trade theorem by Kreps (1977) and Tirole (1982) shows that risk-averse traders do not trade and that risk-neutral traders cannot expect any gain from trade : "speculation relies on inconsistent plans and is ruled out by rational expectations" (Tirole, 1982, p. 1163). In addition, the No Trade theorem by Milgrom and Stokey (1982), known as the Groucho Marx theorem, shows that private information cannot create an incentive to trade in the absence of an insurance motive for trading because "the mere willingness of the other traders to accept their parts of the bet is evidence to at least one trader that his own part is unfavorable. Hence no trade can be found that is acceptable to all traders. This no-trade result depends crucially on the rational expectations assumption that it is ***common knowledge*** when a trade is carried out that the trade is feasible and that it is mutually acceptable to all of the participants" (Milgrom and Stokey, 1982, p. 18).

To get around the Kreps-Tirole theorem, we shall depart from the Bayesian assumption that priors are identical. (Alternative routes are to introduce a non-rational trader or hedging). To get around the Milgrom-Stokey theorem, we shall suppose that, although the contract curve and the underlying beliefs are common knowledge, the traders do not make full use of this information. Differences in prior beliefs are thus ***not*** based on private information but on differences in "opinion", in the terminology of Varian (1987). Such differences in opinion result from the fact that a trader inteprets the beliefs of other traders as being noncredible and refuses to update his beliefs.

The information structure is then as follows. The monopolist's production and inventory technology and the form of the demand function for the cash good are common knowledge. Both the monopolist and the speculator are uncertain about the level of demand (α) for the cash good in periods 1 and 2 and have different expectations about its potential realizations. The monopolist determines its futures position before any production or sales decision is taken. If the speculator takes the matching (opposite) futures position, the monopolist can infer from this that the speculator's demand expectation is different from his. The speculator can in turn infer that their expectations differ and even what the monopolist's demand expectation is (by observing the period 1 price set by the monopolist for the cash good). Both are convinced, therefore, that the other party errs. Having discovered the true value of α, the monopolist revises the cash price in period 2 (given the observed q_1). Ex post, p_2 is thus different from what both parties expected it to be when they accepted contract (p^f, f) and their realized profits are different from what they expected.

The risk-neutral speculator is active on the futures market only and maximizes the expected value of

$$\phi = [p_2(q_2) - p^f]f. \tag{13}$$

This speculator buys f (takes a long position $f > 0$) if the expected cash price $Ep_2 > p^f$. However, this expected price depends on the monopolist's optimal production and sales policy for the cash good. And the futures position f is non zero and finite to the extent that the monopolist accepts only a finite matching position.

The monopolist maximizes its expected gain on the futures market, given the first-order conditions on the cash market and subject to the condition that the speculator's gain is nonnegative. This problem can be handled using the dynamic programming solutions worked out above for the cash market, if the quadratic specifications are accepted as valid approximations. Indeed, the certainty equivalence principle - see Simon (1956) - allows us to reinterpret the first-order conditions as maximizing the monopolist's expected profit. Being risk-neutral, the monopolist acts as a speculator on the futures market.

The argument to be developed in this section can be summarized as follows. Substitution of the optimal values for the cash market into the monopolist's intertemporal profit function makes it possible to separate the monopolist's expected gain in the absence of a futures position from the expected gain on the futures market. Adding up the speculator's and the monopolist's expected profits on the futures market, their sum turns out not to be zero. If they both had the same demand expectations, then this sum would be negative and no trade in futures would be possible. However, ***when the demand expectations are different, then the sum of their expected profits on the futures market can be positive. There exist contract curves and contracts (p^f, f) located on them are accepted by both parties.***

Let us examine this more closely, first in the case of an exhaustible resource and then in the case of a storable and reproducible commodity.

2.1. The Case of an Exhaustible Resource

Take the exhaustible resource model as specified in Section 1.1 and suppose α is a random variable whose realization is uncertain. All other coefficients are fixed and common knowledge. The specifications used are also common knowledge. Insert the equilibrium values of Equations (5) into the monopolist's profit function (2), with $r = 0$. The result is

$$\Pi_m = \hat{p}s_0 + (p^f - \hat{p})f + \frac{\mu}{2}f^2. \tag{14}$$

The expected profit in the absence of a futures position is $\hat{p}s_0$, the expected market value of the stock (net of extraction costs), since $\hat{p}$ is a function of the expected value of α. The monopolist's expected gain due to the futures position is

$$\psi = (p^f - \hat{p})f + \frac{\mu}{2}f^2. \tag{15}$$

If the speculator has the same expectation about α, his expected gain is

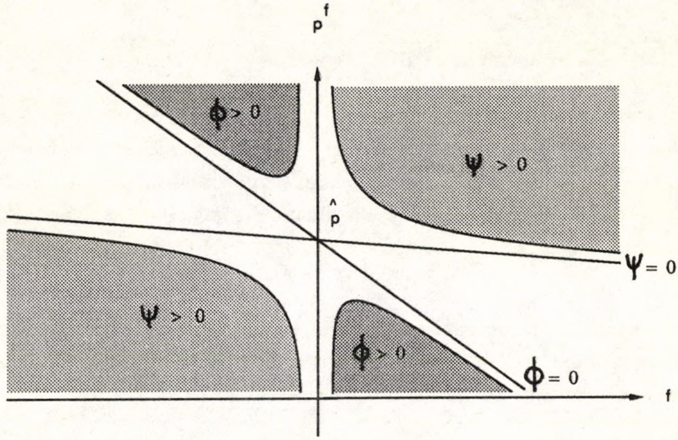
$$\phi = (\hat{p} - p^f)f - \mu f^2 \tag{16}$$

since he would use the same expected value of p_2 (as given in Equation (5.4)) to evaluate ϕ. Clearly the futures market is a zero-sum game and risk-neutral agents would take any position.[1] Nevertheless in this model the equilibrium futures quantity is zero because the action taken on the futures market influences the monopolist's profit on the cash market. By entering a futures position different from zero the monopolist deviates from the optimal cash quantities and therefore the profit is reduced. For our linear example the loss is equal to $\mu f^2/2$. If no profit is realized on the futures market, the monopolist does not trade futures contracts. Stated differently: the sum $\psi + \phi = -\mu f^2/2$ is negative and there can be no trade in futures.[2]

Indeed, the monopolist takes a futures position only if $\psi \geq 0$. $\psi = 0$ for $f = 0$ or for $p^f = \hat{p} - \frac{\mu}{2}f$. On the other hand, $\psi > 0$ for $p^f = \hat{p} + \frac{\psi}{f} - \frac{\mu}{2}f$, a rectangular hyperbola in the (p^f, f) plane. The speculator wants $\phi \geq 0$. $\phi = 0$ for $f = 0$ or for $p^f = \hat{p} - \mu f$, while $\phi > 0$ for $p^f = \hat{p} - \frac{\phi}{f} - \mu f$. The situation is as depicted in Figure 1. The only value on which they can agree is $f = 0$.

[1]It is important to note the distinction between the profit realized on the futures market and the profit derived from futures transactions. For the speculator both are identical because he is only active on the futures market. The monopolist is also active on the cash market and equation (15) combines the direct and the indirect consequences of futures trading.

[2]The same result would be obtained if α were known with certainty in both periods by both parties.



= = 0

Figure 1. Same expectations

The situation is very different when expectations about α differ. Suppose the monopolist expects α to be α_m while the speculator expects α to be α_s. The monopolist's (certainty equivalent) plans are then given by Equations (5.1) - (5.4) where $\hat{p}$ is replaced by

$$\hat{p}_m = 4\mu(\alpha_m - \frac{1}{2}s_0).$$

Hence the monopolist's expected gain due to futures trading is

$$\psi_m = (p^f - \hat{p}_m)f + \frac{\mu}{2}f^2. \tag{17}$$

The speculator expects instead $\hat{p}$ to be

$$\hat{p}_s = 4\mu(\alpha_s - \frac{1}{2}s_0)$$

so that his expected gain is

$$\phi_s = (\hat{p}_s - p^f)f - \mu f^2. \tag{18}$$

We note that

$$\psi_m + \phi_s = (\hat{p}_s - \hat{p}_m)f - \frac{\mu}{2}f^2 = 4\mu(\alpha_s - \alpha_m)f - \frac{\mu}{2}f^2 \tag{19}$$

so that ***trade in futures can take place if*** $\alpha_s \neq \alpha_m$. Two cases are to be distinguished depending on whether $\alpha_s > \alpha_m$ or $\alpha_m > \alpha_s$.

If the speculator is more optimistic than the monopolist about demand ($\alpha_s > \alpha_m$), then a contract is possible only for $f > 0$. $\psi_m = 0$ for $p^f = \hat{p}_m - \frac{\mu}{2} f$ and $\phi_s = 0$ for $p^f = \hat{p}_s - \mu f$ and these straight lines intersect for $\bar{f} = 2(\hat{p}s - \hat{p}_m)/\mu = 8(\alpha_s - \alpha_m) > 0$ (see Figure 2). Trade in futures can take place inside the triangle area.

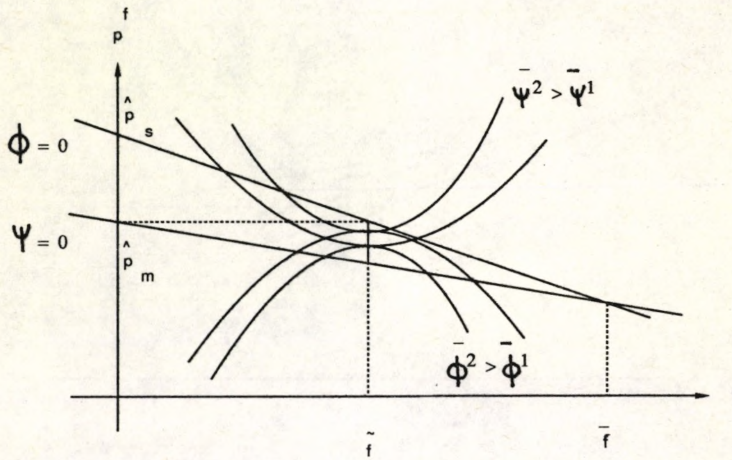


Figure 2. The speculator is more optimistic

In order to find the equilibrium values of f and p^f we maximize the monopolist's profit function for futures subject to the condition that $\phi = \phi_0 \geq 0$ or the Lagrangian

$$L = (p^f - \hat{p}_m)f + \frac{\mu}{2}f^2 + \lambda[(\hat{p}_s - p^f)f - \mu f^2 - \phi_0] \tag{20}$$

with respect to f and p^f.

We find

$$\tilde{f} = (\hat{p}_s - \hat{p}_m)/\mu = 4(\alpha_s - \alpha_m) \tag{21}$$

or $\tilde{f} = \frac{1}{2}\overline{f}$ while

$$\tilde{p}^f = \hat{p}_s - \mu\tilde{f} - \frac{\phi_0}{\tilde{f}} = \hat{p}_m - \frac{\mu\phi_0}{\hat{p}_s - \hat{p}_m}.$$

If instead the monopolist is more optimistic than the speculator ($\alpha_m > \alpha_s$), then a contract is possible only for $f < 0$ (the monopolist takes a long position, that is, buys futures). The straight lines $p^f = \hat{p}_m - \frac{\mu}{2} f$ and $p^f = \hat{p}_s - \mu f$ intersect for $\underline{f} = 8(\alpha_s - \alpha_m) < 0$ (see Figure 3) and trade in futures can take place inside the triangle area. The equilibrium value is given by $\tilde{f} = \frac{1}{2}\underline{f}$.

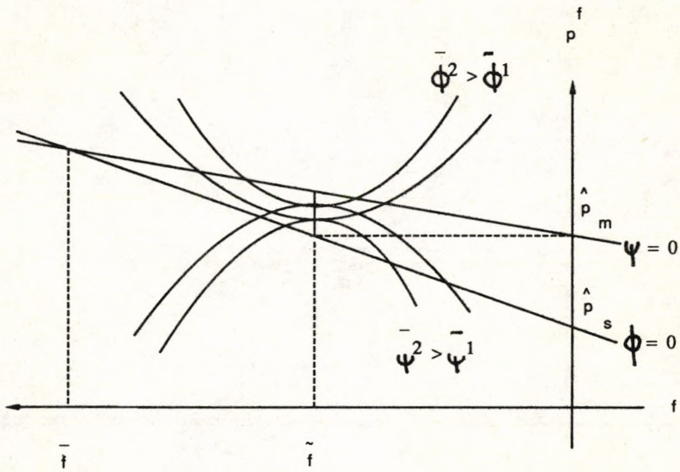


Figure 3. The monopolist is more optimistic

The reader may wonder how a monopolist could possibly take a long position, which calls for delivery in period 2 by the speculators (who then are short). In fact, this objection is not valid. Two interpretations are possible (see Anderson and Sundaresan (1984), p. 77 and note 4). One can imagine that all futures positions can be closed out in period 2, the difference between p^f and the realized p_2 being paid out to the party with the better forecast. It is also conceivable that the futures market does not call for delivery at all but only for a cash settlement in period 2. (Some existing stock market index futures illustrate this second interpretation).

The monopolist's (short or long) equilibrium position $\tilde{f}$ is independent of p^f and appears therefore as a vertical line segment in Figures 2 and 3. The equilibrium price $\tilde{p}^f$ corresponding to $\tilde{f}$ is anywhere on the vertical segments. It is in the monopolist's interest that $\tilde{p}^f$ be as close as possible to $\hat{p}_m$ (the profit maximizing second period cash price in the absence of a futures market), that is, as high as possible when the speculator is more optimistic (Figure 2) and as low as possible when the reverse is true (Figure 3).

Since the speculator has the opposite interest, a bargaining situation arises with respect to the futures price. A unique price can be determined if one is ready to accept one of the available bargaining solutions. We suggest the Nash bargaining point.[3]

The Nash solution implies the maximization of the product of ψ_m and ϕ_s with respect to p^f or

$$\frac{\partial \psi_m}{\partial p^f}\phi_s - \frac{\partial \phi_s}{\partial p^f}\psi_m = 0.$$

Since $\partial\psi_m/\partial p^f = \partial\phi_s/\partial p^f$, this boils down to solving $\phi_s = \psi_m$ for p^f so that

$$p^f = \frac{\hat{p}_s + \hat{p}_m}{2} - \frac{3\mu}{4}f. \tag{22}$$

On the other hand, since $\psi_m = \phi_s$ at equilibrium, it suffices to maximize

$$\begin{aligned}\psi_m &= \left(\frac{\hat{p}_s + \hat{p}_m}{2} - \frac{3\mu}{4}f - \hat{p}_m\right)f + \frac{\mu}{2}f^2\\ &= \left(\frac{\hat{p}_s - \hat{p}_m}{2}\right)f - \frac{\mu}{4}f^2\end{aligned}$$

with respect to f to find the equilibrium futures position

$$\tilde{f} = \frac{(\hat{p}_s - \hat{p}_m)}{\mu}$$

which is the same as the one derived in Equation (21). The Nash equilibrium futures price is

$$\begin{aligned}\overset{\approx}{p}{}^f &= \frac{\hat{p}_s + \hat{p}_m}{2} - \frac{3}{4}(\hat{p}_s - \hat{p}_m)\\ &= \hat{p}_m + \frac{1}{4}(\hat{p}_m - \hat{p}_s),\end{aligned} \tag{23}$$

a point on the vertical segments in Figures 2 and 3. The futures price is the lower with respect to the fifty-fifty point, the larger is the dispersion in opinion when the speculators are more optimistic than the monopolist. This solution can be interpreted as the perfect equilibrium of a two-stage game in which the quantities (the futures positions) are determined in the first stage and the prices in the second stage.

The same result can be obtained using a non-cooperative bargaining solution similar to Rubinstein's paradigm.[4] In our model, the expected profit is function of the futures quantities only. The futures price determine the proportion (of profit) that each participant receives

[3] We are grateful to Yves Richelle for working out this solution for us.

[4] See for example (1986).

if an agreement is achieved. Assume an artificial institution where the agents take turns to make a price proposal: at some fictious time 0 the first player proposes a price. Immidiately after, player two accepts or makes a new proposal to which player one reacts and so on. The payoff will be the share of profit received multiplied by a discount factor less than one (we assume that the discount factor is the same for both players).[5] It has been shown that if the time delay between proposals tends to zero then the partition is 1/2. In our model the maximum expected "profit" for the monopolist is obtained when $p^f = \hat{p}_m$ and is equal to $\psi_m = (\hat{p}_s - \hat{p}_m)^2/2$. The speculator realizes the same expected profit when $p^f = (3\hat{p}_m - \hat{p}_s)/2$. What we need to compute is the level of p^f such that the monopolist and the speculator receive 1/2 of the payoff. This value is:

$$p^f = \hat{p}_m + \frac{(\hat{p}_m - \hat{p}_s)}{4}$$

which gives the same result as for the previous bargaining concept.

2.2. The Case of a Reproducible and Storable Commodity

Using the fact that $\bar{s} = -m/2n$, the equilibrium values (12) of the model with a reproducible and storable commodity imply the equilibrium prices

$$p_1 = p^* + \frac{2\ell^2}{\theta} f \tag{24.1}$$

$$p_2 = p^* - \frac{\gamma + \ell + \beta\ell^2}{\beta\theta} f \tag{24.2}$$

where $p^* = (2\alpha\beta\ell + \alpha + \beta k)/2\beta(1 + \beta\ell)$. Insertion of this value of p_2 into the speculator's profit function gives

$$\phi = (p^* - p^f)f - \nu f^2 \tag{25}$$

where $\nu = (\beta\ell n + 2\ell + n + \beta\ell^2)/\delta\beta(1 + \beta\ell)$. Insertion of Equations (12) and (24) into the monopolist's profit function gives

$$\Pi_m = \Pi_* + (p^f - p^*)f + \frac{\nu}{2} f^2, \tag{26}$$

where Π_* is his profit in the absence of a futures market. *These results are of the same form as those obtained for the case of an exhaustible resource* (compare with (14) - (16)). As a result the analysis carried out in the previous section applies to the present case without modification.

[5]The discount factor is introduced in order to establish an incentive to reach an agreement.

III. SPECULATIVE INVENTORIES

3.1. Speculative Inventories: The cash market

In this section we analyze the model of exhaustible resources presented previously with the additional assumption that the speculator has the possibility of holding inventories for speculative motives. Alternatively, we could introduce a new type of agent, a so-called trader, the activity of whom would be to trade the good on the cash market exclusively. We continue to assume that the interest rate $r = 0$. All agents may have different expectations about the level of demand α in period two. These expectations are denoted by $\alpha_{2,i}$, where i is the index referring to the monopolist ($i = m$) or to the speculator ($i = s$). In period one the level of demand is known and is equal to α_1.

The profit function for the speculator holding speculative stocks as well as futures positions is

$$\Pi_s = (p_{2,s} - p_1)x - c(x) + (p_{2,s} - p^f)f \tag{27}$$

where $s_0 \geq x \geq 0$ represents the amount bought in period one, stored and sold in period two. $c(x)$ is the cost of carrying the stock from period one to period two. We assume that this cost function is quadratic and can be specified as

$$c(x) = \frac{\gamma}{2}x^2 \ , \ c'(x) = \gamma x$$

The optimal speculative stock is

$$x = \frac{E(p_{2,s}) - p_1}{\gamma} \tag{28}$$

This decision is made in period one simultaneously with the decision of extraction made by the monopolist.

The monopolist sells q_1 in period one to consumers that again do not participate in the futures market and to the speculator. The aggregate demand function obtained from the consumers' maximization of their utility function for period $t = 1, 2$ is:

$$q_{1,c} = q_1 - x = \alpha_1 - \beta p_1 .$$

Therefore the inverse demand function is:

$$p_1 = \frac{\alpha_1}{\beta} - \frac{1}{\beta}(q_1 - x)$$

In period two the monopolist sells $s_0 - q_1 = s_0 - q_{1,c} - x = q_2$. The consumers buy q_2 from the monopolist and x from the speculator.

The expected inverse demand function is[6]

$$p_2 = \frac{\alpha_2}{\beta} - \frac{1}{\beta}(q_2 + x)$$

The monopolist solves the following program

$$\max_{q_1, q_2} \Pi_m = p_1(q_1) + p_{2,m}(q_2) + (p^f - p_{2,m}(q_2))f$$
$$\text{s.t.} \quad q_1 + q_2 = s_0$$

Given x and f, the optimal quantities and prices are

$$q_1 = \frac{\alpha_1 - \alpha_{2,m}}{4} + \frac{s_0}{2} + \frac{x}{2} - \frac{f}{4} \tag{29.1}$$

$$q_2 = \frac{\alpha_{2,m} - \alpha_1}{4} + \frac{s_0}{2} - \frac{x}{2} + \frac{f}{4} \tag{29.2}$$

$$p_1 = \frac{3\alpha_1 + \alpha_{2,m}}{4\beta} - \frac{s_0}{2\beta} + \frac{x}{2\beta} + \frac{f}{4\beta} \tag{29.3}$$

$$p_{2,m} = \frac{3\alpha_{2,m} + \alpha_1}{4\beta} - \frac{s_0}{2\beta} - \frac{x}{2\beta} - \frac{f}{4\beta} \tag{29.4}$$

For positive speculative stock and a given futures position, the value of p_1 is higher and p_2 is lower if compared to a situation without speculation on the cash market. Speculation can therefore have a stabilizing impact on prices. This effect has the same type of impact as a short futures position entered by the monopolist. Consequently the presence of an active speculator (or trader) on the cash market and on the futures market (long position) might reinforce the overall stabilizing effect. A complete analysis of the question will be pursued after the equilibrium on the futures market is described.

We assume that the expectations held by the individuals are common knowledge. Therefore when the speculator determines his optimal stock he knows the monopolist's expected level of demand for period two and as a consequence knows that q_2 is a function of $\alpha_{2,m}$. His expected inverse demand function is

$$p_{2,s} = \frac{\alpha_{2,s}}{\beta} - \frac{1}{\beta}(q_2 + x) \tag{30}$$

[6]To simplify the notation we omit the symbol E for the expectation's operator.

where q_2 is the monopolist's optimal value (given x, f). Substituting q_2 we obtain

$$p_{2,s} = \frac{4\alpha_{2,s} - \alpha_{2,m} + \alpha_1}{4\beta} - \frac{s_0}{2\beta} - \frac{x}{2\beta} - \frac{f}{4\beta} \tag{31}$$

and the optimal speculative stock can be expressed as

$$x = \frac{2\alpha_{2,s} - \alpha_{2,m} - \alpha_1 - f}{2(1+\gamma\beta)} \tag{32}$$

The futures position that appears in x is the position entered by the monopolist. Even if expectations are the same for the two agents and identical to α_1, x can be positive for a given long futures position. This is not surprising if we consider the extraction model previously presented. With static demand we found that when the monopolist entered a short position the prices declined. This decline would have prevented any speculation on the cash market. Inversely for a long futures position the prices increased and hence speculative stocks could have existed. With demand shifting upward across time, stocks might be carried even with a short futures position. In other words, the speculator may hold inventories and simultaneously go long, that is, buy futures.

We also find

$$q_1 = \hat{q}_1 + \frac{x(f)}{2} - \frac{f}{4} \tag{33.1}$$

$$q_2 = \hat{q}_2 - \frac{x(f)}{2} + \frac{f}{4} \tag{33.2}$$

$$p_1 = \hat{p}_1 + \frac{x(f)}{2\beta} + \frac{f}{4\beta} \tag{33.3}$$

$$p_{2,m} = \hat{p}_{2,m} - \frac{x(f)}{2\beta} - \frac{f}{4\beta} \tag{33.4}$$

where $\hat{q}_1 = (\alpha_1 - \alpha_{2,m})/4 + s_0/2$, $\hat{q}_2 = (\alpha_{2,m} - \alpha_1)/4 + s_0/2$ are the quantities extracted in the absence of futures and speculative stocks, $\hat{p}_1 = (3\alpha_1 + \alpha_{2,m})/4\beta - s_0/2\beta$, $\hat{p}_{2,m} = (3\alpha_{2,m} + \alpha_1)/4\beta - s_0/2\beta$ are the cash prices in period one and the cash price expected by the monopolist in period two in the absence of futures and speculative stock, $x(f)$ is the speculative stock conditional on a futures position f. According to the speculator's beliefs, the second period expected price can be rewritten as

$$p_{2,s} = \hat{p}_{2,s} - \frac{x(f)}{2\beta} - \frac{f}{4\beta} \tag{34}$$

where $\hat{p}_{2,s} = (4\alpha_{2,s} - 2\alpha_{2,m} + 2\alpha_1)/4\beta - s_0/2\beta$.

3.2. The Futures Market Equilibrium

Inserting the equilibrium values of the previous subsection into the monopolist's profit function we obtain

$$\Pi_m = \hat{p}_1\hat{q}_1 + \hat{p}_{2,m}\hat{q}_2 + (\hat{p}_{2,m} - \hat{p}_1)(\frac{f}{4} - \frac{x(f)}{2}) + (\hat{q}_1 - \hat{q}_2)(\frac{f}{4\beta} - \frac{x(f)}{2\beta}) - \frac{f^2}{8\beta} + \frac{x(f)^2}{2\beta} + [p^f - \hat{p}_{2,m} + \frac{x(f)}{2\beta} + \frac{f}{4\beta}]f$$

The speculator's profit function becomes

$$\Pi\, s = [\hat{p}_{2,s} - \hat{p}_1 - \frac{f}{2\beta} - \frac{x(f)}{\beta}]x(f) - \frac{1}{2}\gamma x(f)^2 + [\hat{p}_{2,s} - \frac{f}{4\beta} - \frac{x(f)}{2\beta} - p^f]f$$

In order to find the equilibrium values for f and p^f we solve the following program

$$\max_{f,p^f} \Psi \quad \text{s.t.} \quad \Phi \geq \Phi_0$$

where Ψ is the expected gain from futures transactions:[7]

$$\Psi = (\hat{p}_{2,m} - \hat{p}_1)(\frac{f}{4} - \frac{x(f)}{2}) + (\hat{q}_1 - \hat{q}_2)(\frac{f}{4\beta} - \frac{x(f)}{2\beta}) - \frac{f^2}{8\beta} + \frac{x(f)^2}{2\beta} + [p^f - \hat{p}_{2,m} + \frac{x(f)}{2\beta} + \frac{f}{4\beta}]f.$$

This will enable us to write Π_m in term of the cash variable and the futures variable separately. (To lessen the complexity of the expression we did not decompose $x(f)$ into the cash and futures component.) Φ represents the profit for the speculator. The equilibrium futures position is

$$f = (\alpha_{2,s} - \alpha_{2,m})(\frac{2}{\beta\gamma} + 4) \tag{35}$$

Depending on the expectations formulated by the monopolist and the speculator, the resulting equilibrium (in terms of the monopolist's position) corresponds to a long or a short futures position. Interestingly, the value of f is equal to its value in the model without speculative stocks when γ tends to infinity:

$$\lim_{\gamma\to\infty} f = 4(\alpha_{2,s} - \alpha_{2,m}).$$

Up to now, the analysis did not explicitly incorporate the fact that the optimal value of x must be positive. Given the equilibrium on the futures market, we must determine the

[7]The correct expected gain from futures transaction requires to break down $x(f)$ into two parts, the cash part and the futures part.

condition on the parameters $\alpha_1, \alpha_{2,i}$ such that the constraint $x \geq 0$ is not violated. Using the equilibrium value of f in x we have

$$x = \frac{1}{2(1+\gamma\beta)}(\alpha_{2,s} - \alpha_1) - \left(\frac{2+3\gamma\beta}{\gamma\beta 2(1+\gamma\beta)}\right)(\alpha_{2,s} - \alpha_{2,m}). \tag{36}$$

$x > 0$ if

$$(\alpha_{2,s} - \alpha_1) > (\alpha_{2,s} - \alpha_{2,m})(\frac{2+3\gamma\beta}{\gamma\beta}) \tag{37}$$

When both agents expect an increase of the demand level and the speculator is more optimistic it is possible under condition (37) to have an equilibrium on the futures market with positive speculative stocks. If the monopolist is more optimistic, then the equilibrium futures quantity will correspond to a long position (for the monopolist) and the speculative stocks will be positive. The futures quantities exchanged are larger when compared to the case without speculative trading on the cash market.

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