DISCUSSION PAPER

COMMODITY RICE STABILIZATION IN IMPERFECT OR CARTELIZED MARKETS

by

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The views presented here are those of the author, and they should not be interpreted as reflecting those of the World Bank
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Most studies of commodity price stabilization assume that all agents behave competitively. However, many commodities suitable for stockpiling are produced by countries with a significant share of the world market, and commodity agreements themselves often result in cartelization of the market. The paper explores the consequences of market power for the choice of storage rule and the degree of price stabilization. It finds that with linear demand, dominant producers choose more stable prices than under perfect competition and price stability increases with their market share. With constant elastic demand the competitive degree of price stabilization is achieved.

1. INTRODUCTION

Most studies of commodity price stabilization either attempt to solve for the socially optimal level of storage or, less often, characterise the competitive level of storage. However, many primary commodities suitable for storage are produced by countries with a significant share in world trade in the commodity. Newbery [5], lists 8 commodities for which single countries supplied more than 50 percent of world trade between 1977-79, and a further 12 for which the share was more than 25 percent. Seven of the ten "core"
commodities identified by UNCTAD as suitable candidates for inclusion in the Integrated Program for Commodities (IPC) appear in this list, through Brazilian coffee (at 17 percent) is conspicuously absent, as are the large cocoa producers. Of course, it does not automatically follow that the country is the correct level of aggregation at which to measure market power, at least for agricultural commodities, which are typically produced by numerous small farmers, but since many countries intervene in the commodity market (via Marketing Boards, taxes and other controls) it is at least worth investigating whether they would benefit from exercising this market power, and whether it would influence their attitude to price stabilization.

In this context it is interesting to observe that until the early 1960s Brazil produced about half of the world's coffee but held between 80-90 percent of producer coffee stocks. By the mid 1970s Brazil's share of production was less than one third, but it still held half the total stocks. Recently, its shares of both production and stocks have dropped further. From the 1960s on, Brazil has followed a policy of reducing production to reduce stocks, and has also successfully reduced its ratio of stocks to production. Can such behaviour be explained by Brazil's market power? Under what circumstances would the ratio of stocks to production increase with market power? Would it pay a dominant producer to be the sole stocking agent?

Even if it is argued that individual countries have insufficient market power to prevent competitive outcomes, it is clear from the discussions in UNCTAD over the IPC that the primary producers wish to set up commodity agreements. To the extent that they are successful in setting up agreements which act in the producer's interest, they will be able to exercise considerable market power, and it is again worth asking whether and how this
will affect their attitudes to price stabilization. In this paper we ask
whether large producers will do more or less storage if they exercise market
power than if they behave competitively, and hence whether imperfectly
competitive markets exhibit more or less price stability than otherwise
identical but competitive markets. With one, arguably unimportant
qualification, we are able to show that imperfect competition will lead to as
much or greater price stability. This may explain why the producing countries
are anxious to set up commodity agreements to stabilise prices. Various
authors have argued that the private market will, if competitive, supply the
socially optimal level of storage, and hence that there is no case for any
public price stabilization schemes. Whilst Newbery and Stiglitz [8, 9, 10]
have demonstrated that this argument is fallacious in the absence of a
complete set of insurance markets, it also misses the point that producers are
more interested in their own welfare than in global welfare. If producers
benefit from a greater degree of price stability than the competitive market
would supply, then they may have an incentive to set up public buffer
stocks. The other point to make about commodity agreements is that
developing countries are concerned not just to stabilize the prices of their
commodity exports, but to raise them to levels which yield a "fair"
remuneration. The example which captured their imagination was that of the
OPEC cartel. Thus it is worth asking how a successful cartel of producers
would coordinate the price stabilization and price raising aspects of its
operations. Does the fact that average supply can also be controlled further
encourage storage and price stabilization or are the two aspects quite
separate?
The paper is organised as follows. The next section compares the competitive level of storage with the imperfectly competitive level, on the assumption that planned supply is insensitive to annual price variations (as, for example, may be reasonable for perennials, but would be inappropriate for annual crops). The conditions under which dominant producers prefer greater price stability are then investigated. The following section extends the analysis to deal with supply responses, and hence addresses the questions of price raising as opposed to price stabilization. The last section draws brief conclusions.

2. PRICE STABILIZATION BY DOMINANT PRODUCERS

In a competitive economy, if agents are risk-neutral and hold rational expectations they will continue to store until they have arbitrated the expected returns to current and future sales. In an imperfectly competitive economy, dominant agents will arbitrage expected marginal returns. If, in addition, agents face stable linear demand schedules and serially uncorrelated supply risk, it is possible to derive analytical solutions for the competitive storage rule, as shown in Newbery and Stiglitz [8, Ch. 30; 10]. Since linear demand schedules give rise to linear marginal revenue schedules, the same analytical techniques can be applied to derive the imperfectly competitive storage rule.

In this model it is therefore very easy to ask whether a dominant producer does more or less storage than he would if he behaved competitively and to show that he will do more storage, so prices are more stable. This raises the more general question of the circumstances under which dominant producers will do less stabilization than competitive producers, and, in these
cases, what the response will be by competitive consumers. If consumers find it profitable to arbitrage in such cases, what will be the effect of their behavior on the market power of the dominant producer? In short, what does the market equilibrium look like once we allow all agents (producers and consumers) to arbitrage price by storage?

The first step in this sequence of questions is to characterize the competitive stock rule for the linear demand case, and then show how to extend the analysis to imperfectly competitive markets.

2.1 Optimal Storage Rules

The analytically soluble model in Newbery and S'iglitz [8, 10] contains the following elements:

(i) There is a stock $S_{t-1}$ carried forward from the previous year.

(ii) To this is added a random harvest, $h_t$, so that at date $t$ the amount available for consumption, $C_t$, and for storage, $S_t$, is the total supply, $x_t$:

$$x_t = h_t + S_{t-1} = C_t + S_t.$$  

There are no storage losses, and for the moment planned production does not change for year to year. If weather and other random factors are serially uncorrelated, this implies that the harvest is also a serially uncorrelated, stationary random variable. We choose units so that the average harvest is one unit:

$$Eh_t = 1, \ Var(h_t) = \sigma^2, \ Cov(h_t, h_{t'}) = 0, \ t \neq t'.$$
Finally, we assume that demand is stationary, linear and non-stochastic, so that the market clearing price $p_t$ is a linear function of current consumption, $C_t$: $p_t = p(C_t)$. If, on average, consumption equals harvest, so that stocks neither continually increase nor decrease, and if the elasticity of demand at the pre-stabilization mean price, $\bar{p}$, is $\varepsilon$, then the (inverse) demand schedule can be written

$$p(C) = \bar{p} \left(1 + \frac{1}{\varepsilon} - \frac{C}{\bar{C}} \right), \quad EC = 1.$$

The (risk neutral) competitive equilibrium level of storage will be to store enough today to drive up today's price and drive down next year's expected price until there are no further arbitrage gains to be made on further storage:

$$p_t - k > \beta E p_{t+1} \quad \text{complementary inequalities.}$$

Here, $k$ is the constant unit annual storage cost excluding interest, while $\beta = 1/(1+r)$ is the discount factor to apply to next year's sale when the interest rate is $r$. At least one of the equations must be satisfied with an equality, and reflects the fact that stocks cannot be negative, but may be drawn down to zero if the current price is high enough. Simple arguments set out in [8, 10] show that the competitive storage rule (and hence consumption, which are functions of total supply only:

$$S_t = f(x_t) > 0, \quad C_t = x_t - f(x_t),$$
and the problem reduces to finding a function \( f \) which solves the arbitrage rule of equation (4):

\[
\begin{align*}
\text{(6)} \quad p(x_t - f(x_t)) + k &> \beta E[p_{t+1} + f(x_t)] - f(x_t) - p(x_t) + f(x_t) \\
&\text{comp.} \\
f(x_t) > 0
\end{align*}
\]

Since stocks must be non-negative, there is a critical value of supply, \( x_0 \), below which \( f(x) = 0 \), for which

\[
\text{(7)} \quad p(x_0) + k = \beta E[p - f(h)].
\]

For the linear demand function of equation (3) and (6) can be rearranged to yield

\[
\begin{align*}
\text{(8)} \quad f(x) = & \begin{cases} 
\frac{1}{1 + \beta} [x - a + \beta E[p + f(x)]), & x > x_0, \\
0, & x < x_0
\end{cases}
\end{align*}
\]

where \( x_0 \) is defined by (7) and \( a \) is a constant:

\[
\text{(9)} \quad a = 1 + \epsilon(1 - \beta + k/p) = 1 + \epsilon(c + r), \quad c \equiv k/p^*.
\]

Here \( c \) is the total annual storage cost per $ stored excluding interest and \( C + r \) is the total cost including interest.

In [10] we show how to solve equation (8) for the special case of the two point distribution

\[
\begin{align*}
\text{(10)} \quad h = & \begin{cases} 
1 + \gamma & \text{with Prob } \rho, \\
1 - \gamma & \text{with Prob } 1 - \rho
\end{cases}
\end{align*}
\]

\[\gamma = \frac{\rho}{1 - \rho}.\]
so that

\[ \hat{H} = 1, \ \text{Var} \ h = \gamma u^2 = \sigma^2. \]

In this case the competitive stocking rule is linear beyond \( x_0 \):

\[ f(x) = \alpha(x - x_0), \quad x_0 < x < x_m, \]

where

\[ \alpha = \frac{1 + \beta - \sqrt{(1 + \beta^2) - 4\beta \rho}}{2\beta \rho}, \]

\[ x_0 = \frac{a - a \beta \rho (1 + u)}{1 - a \beta \rho}, \quad x_m = \frac{1 + u - \alpha x_0}{1 - \alpha}. \]

\( x_m \) is the maximum level of \( x \) achieved after an infinite run of good harvests provided the parameters lie in a certain range:

\[ 1 - \gamma u + \alpha(x_m - x_0) < x_0 < 1 + u. \]

That this is the solution to (9) can be checked by substitution and will be further illustrated below in the calculations for the dominant producer. The intuitive reason for both the linearity (beyond \( x_0 \)) and the constraints of (15) is that it must be the case that if the harvest is high \((1 + u)\) then positive stocking is undertaken, even if current stocks are zero, whilst if the harvest is low \((1 - \gamma u)\) then there is no carry forward, even if current stocks are high \((e.g. \leq \text{their maximum value, } S_m = \alpha(x_m - x_0)\). Then the current state of the system is essentially determined by the current harvest, which can only take two values. For a more complete derivation of
and characterization of the solution, see [10]. Hence to check that the parameters are such that equation (12) is the solution, once $\beta$, $\epsilon$, $k/p$, $u$, and $p$ have been specified, $a$, $x_0$ and $x_m$ can be computed from (13) and (14) and checked to see if (15) is satisfied.

So far we have derived the competitive rule, but unfortunately the dominant producer stockin. rule now follows immediately, for the dominant producer is interested in arbitraging marginal revenue, rather than price. Since for a linear demand schedule the marginal revenue is also linear, the dominant producer's problem is isomorphic to the competitive problem. Instead of the arbitrage rule of equation (4) we have

$$\begin{align*}
mt + k &> BEm_{t+1} \\
S_t &> 0
\end{align*}$$

(16) complimentarily

where $m_t$ is the marginal revenue at date $t$. Suppose that all producers face perfectly correlated supply risk $\beta$ and initially that the dominant producer does all the storage. Let his average production be a fraction $\mu$ of the total, and his current supply $y_t$:

$$y_t = S_{t-1} + \mu h_t, \quad C_t = h_t - S_t.$$  

(17)

The dominant producer's marginal revenue from increasing his current sales now by one unit when the price is given by (3), is

$$m_t = \overline{p} \left[ 1 + \frac{1}{\epsilon} - \frac{1}{\epsilon} \left\{ (1 - \mu)h_t + 2(y_t - S_t) \right\} \right].$$

(18)
We need a state variable, \( x_t \), which describes the current state of the system, and which determines the dominant producer's optimal storage, \( S_t = f(x_t) \). Now, from (17) and (18), if

\[
\begin{align*}
\text{(19)} & \quad x_t = \frac{1}{2} (1 + \mu) h_t + S_{t-1}, \\
\text{then} & \quad m_t = \mu [1 + \frac{1}{\epsilon} - \frac{2}{\epsilon} (x_t - f(x_t))]
\end{align*}
\]

is completely described by \( x_t \), as required, whilst the arbitrage equation (16) can be written

\[
\begin{align*}
\text{(21)} & \quad f(x) = \frac{1}{1+\beta} [x - A + \beta E[f \left( \frac{1}{2} (1 + \mu) h + f(x) \right)]], \quad x > x_0,
\end{align*}
\]

where

\[
\begin{align*}
\text{(22)} & \quad A = \frac{1}{2} (a + \beta u) = \frac{1}{2} [1 + \epsilon (1 - \beta + k/p) + \beta u], \\
\text{(23)} & \quad x_0 = A - \beta E[f \left( \frac{1}{2} (1 + \mu) h \right)].
\end{align*}
\]

Evidently this has the same structural form as the competitive storage rule described by (8) and (9), which suggests looking for a solution of the form given by equation (12). On the assumption (to be checked) that storage only occurs in years of high output, when \( h = 1 + u \) with probability \( p \), equation (23) gives

\[
\begin{align*}
\text{(24)} & \quad x_0 = \frac{a + u \beta - a \beta p (1+\mu)(1+u)}{2(1-a\beta p)},
\end{align*}
\]
whilst the parameter $\alpha$ in the stocking rule if found by equating coefficients of $x$ on each side of equation (21) when the harvest is high: $\alpha(1+\beta) = 1 + \beta \alpha^2$
or

$$\alpha = \frac{4\beta - \sqrt{(1+\beta)^2 - 4\beta \rho}}{2\beta \rho},$$

exactly as for the competitive rule of equation (13). It remains to check the assumption of storage if and only if the harvest is high. This requires first a calculation of the maximum available supply $x_m$, generated by the maximum available stock, $S_m = \alpha(x_m - x_o)$:

$$x_m = \frac{1}{2} (1+\mu)(1+u) + \alpha(x_m - x_o) = \frac{\frac{1}{2} (1+\mu)(1+u) - \alpha x_o}{1 - \alpha}.$$

The counterpart to equation (15) which ensures that there is no carryforward in bad years and always carry-forward in good years is then

$$\frac{1}{2} (1+\mu)(1+u) + \alpha(x_m - x_o) < x_o < \frac{1}{2} (1+\mu)(1+u).$$

This can be checked directly, but as it is interesting to study the effect of the market share, $u$, on the stocking rule, it is useful to define new

variables

$$z_o \equiv \frac{x_o}{\frac{1}{2} (1+\mu)} = x_o \frac{\mu(\alpha - \beta)}{(1+\mu)(1-\alpha\beta)},$$

where $x_o^c$ is the competitive value of $x_o$, given by (13). Similarly

$$z_m \equiv \frac{x_m}{\frac{1}{2} (1+\mu)} = \frac{1 + u - \alpha z_o}{1 - \alpha}.$$
With this change of variable condition (27) can be written

\[ 1 - \gamma u + \alpha (z_m - z_o) < z_o < 1 + u \]

which has the same form as (15). It is clear from (28) that \( z_o \) decreases with \( \mu \), and so the most rigorous test of whether there exist sets of parameters which satisfy both (15) and (30) is to try \( \mu = 1 \).

The following example demonstrates that this is possible.

**Numerical Example**

If \( \rho = 0.75 \) (Bad harvests once every four years)

\( u = 0.20 \) (Harvests 1.2 or 0.4, coefficient of variation (CV) of output 35%)

\( \varepsilon = 2.5 \) (elasticity, unstabilized CV of price = 13.9%)

\( \beta = 0.95 \) (5% interest rate)

\( k/p = 3\% \) (non interest storage costs per $ stored)

then \( a = 1.2, \ alpha = 0.6835 \) and the competitive rule is

\[ f^C(x) = 0.6835(x - 1.2), \ x > 1.2; \]

which, since harvests never exceed 1.2, implies that there is never any storage, so it is not profitable to stabilize prices any further. The extreme case of a dominant producer is that of a monopolist, whose market share, \( \mu \), is 1. Then from (23-26), \( A = 1.075, x_o = 0.9563, x_m = 1.7263, S_m = 0.5263 \), and the monopoly storage rule is

\[ f^M(x) = 0.6835(x - 0.9563), \ x > 0.9563. \]
This stocking rule implies average stocks of 25.6 per cent of average harvest, which is substantial. Moreover, it reduces the CV of consumption from 35 per cent to 22 per cent and lowers the CV of prices from 14 per cent to 9 per cent. The effect of stockpiling in this example is to substantially improve monopoly profits and reduce average consumer surplus relative to the no stabilization monopoly equilibrium. The extra loss of consumer surplus averages about 9 per cent of (riskless) consumer expenditure on the crop. (These calculations make use of various formulae derived and discussed in [10].)

It is clear from equation (24) and this numerical example that a monopolist will always store more than a competitive market, and hence will arbitrage prices beyond the point at which other risk neutral agents would find it profitable to store. Hence the assumption that only the monopolist stores is valid. It is also clear from (28) that a dominant producer will proportionately more than a comparably sized competitive sector, but it is not obvious that his total storage will be enough to eliminate competitive storage by other agents. However, it is easy to check this, by asking whether the maximum amount the dominant producer would ever store exceeds that which a competitive economy would store. For this

\[ s^d = \gamma (x^d - y^d) > s^c = \gamma (x^c - y^c) \]

where superscripts d, c, refer to the dominant producer or competitive case respectively. After some manipulation this reduces to

(33)  \[ \mu > \frac{1+ u - a}{1 + u - \beta} \]
This formula is quite intuitive, for if \( a = 1 + u \), then there is never any storage under competition, and hence no matter how small is \( u \), the only storage would be done by the dominant producer. If, however, there would normally be competitive storage (i.e. if \( a < 1 + u \)) then if the dominant producer is smaller than a critical size, he would undertake insufficient arbitrage to eliminate competitively profitable arbitrage opportunities. Providing other storage operators can monitor total current storage (or, equivalently, provided that they can forecast the future expected price) they will then undertake more storage so that in equilibrium the market will be competitively arbitragged. In such cases, the dominant producer would face neutral incentives to store, for if he reduced his storage by one unit, competitive stockholders would increase their storage by exactly one unit, and there would be no net impact on expected arbitrage profits. Since these will have been driven to zero in competitive equilibrium, there is no gain or loss to the dominant producer in storing, and he might just as well not store. These conclusions can be summarized as follows.

**PROPOSITION 1.** With correlated supply risk, a stable linear demand schedule, and no choice of supply, a dominant producer will either do more price stabilization than is competitively profitable, or, if he is sufficiently small and storage is competitively profitable, the market will achieve the competitive level of storage.

Provided the parameters satisfy equations (15) and (30) the stocking rule will be as shown in Figure 1. Here \( z \) is defined in terms of the harvest, \( h \), and past carryover, \( S_{-1} \), by

\[
(34) \quad z = \frac{x}{\frac{1}{2} (1+u)} = h + \frac{2S_{-1}}{1+u},
\]
and storage $S$ satisfies $S = \frac{1}{2} (1+\mu) f(z)$. As $\mu$ rises from zero to one, the location of the trigger value of $z$, $z^d_o$, given by (28) falls from the competitive level $z^c_o = x^o_o$, to the monopoly level given by (29).

It is interesting to ask whether a dominant producer would choose to store on average more than he produced, since for competitive producers the ratio of storage to production is typically rather low. Average stocks for a competitive industry are readily shown to be

$$\overline{S}^c = \frac{\alpha \phi}{1 - \alpha \phi} (1 + u - x_o) = \frac{\alpha \phi}{1 - \alpha \phi} \left( \frac{1 + u - a}{1 - \alpha \beta} \right),$$

([10, eq. 25]). The ratio of average stocks to average supply, $\mu$, for a dominant producer is

$$\frac{\overline{S}^d}{\mu} = \frac{1}{2 \mu} \frac{\alpha \phi}{1 - \alpha \phi} (1 + u - z_o) = \frac{1 + u}{2 \mu} \overline{S}^c + \frac{\alpha \phi (a - \beta)}{2(1 - \alpha \phi)(1 - \alpha \beta \phi)},$$

substituting for $z_o$ from (28). As $\mu$ tends to zero, it might appear that this ratio tends to infinity, but (33) shows that either $\mu$ is bounded away from zero or $\overline{S}^c$ is zero. The maximum value (35) can reach allowing (33) to hold with equality is

$$\text{Max} \frac{\overline{S}^d}{\mu} = \frac{\alpha \phi (1 + u)}{(1 - \alpha \phi)(1 - \alpha \beta \phi)} > 1,$$

and hence small dominant producers will typically store on average more than they produce.

We have shown, therefore, that with linear demand schedules dominant producers will store more than competitive producers, and, if they are large
enough, will do all the storage, and ensure that prices are more stable than under perfect competition. The intuitive reason for this is immediate from the Figure 2.

Supply fluctuations (described by a density function in Figure 2) induce price fluctuations as shown, and, since the marginal revenue schedule is steeper than the demand schedule, induce much larger fluctuations in marginal revenue, providing a monopolist with a much larger incentive to store. However, this is quite clearly a special property of the demand schedule and it is therefore important to ask under what circumstances monopolists (and therefore, to some extent, dominant producers) have a comparative advantage in storage over competitive agents (whether producers, specialist stockholders, or consumers).

Consider a situation in which, with a given level of current supply, it is just not worth a competitive market storing, so that

\[(37) \quad p(Q_0) + k = \beta Ep(\bar{Q}_1) ,\]

where period 0 is today, and period 1 is the next period. In such cases it will pay a monopolist to store if \(dR(Q_0)/dQ_0 + k < \beta E dR(\bar{Q}_1)/dQ_1\), where \(R(Q)\) is revenue from the sale of \(Q\). This can be rewritten as

\[(38) \quad p(Q_0)(1 - \frac{1}{\varepsilon_0}) + k < \beta Ep(\bar{Q}_1)(1 - \frac{1}{\varepsilon_1}) \equiv \beta (1 - \frac{1}{\bar{\varepsilon}})Ep, \quad \bar{\varepsilon} = \frac{Ep}{Ep/\varepsilon} ,\]

where \(\varepsilon_1 = \varepsilon(Q_1)\) is the elasticity of demand when sales are \(Q_1\), and \(\bar{\varepsilon}\) is an average price elasticity. Substituting from (37), the monopolist will store more if
where \( r \) is the rate of interest. The accumulated proportional storage cost, 
\[
(1 + r)\frac{k}{p},
\]
takes values between 1.3 per cent and 5.1 per cent for the six core commodities considered by Newbery and Stiglitz [8, Table 20.7, p. 195].

Equation (39) demonstrates immediately that if the demand schedule has constant elasticity the monopolist will do less stabilization than a competitive market, but this result is very sensitive to the shape of the demand schedule. A slight fall in price elasticity at lower prices (by, e.g., 5-10 per cent) will induce the monopolist to undertake more stabilization.

With a linear demand schedule (for which the elasticity falls rapidly) this tendency can be quite pronounced, as was shown in Figure 2.

If monopolists (and, ipso facto dominant producers), have an incentive to arbitrage less than other competitive agents, then the latter will undertake all the profitable arbitrage. It remains to check that the resulting equilibrium cannot be manipulated by dominant producers. The effect of competitive storage is to increase demand (for storage) in low price states and reduce it (by drawing down stocks) in high price states. Hence it tends to increase the price elasticity at low prices, making it even less attractive for the dominant producer to store then. The results of this section can be summarized as follows.

**Proposition 2.** Provided potential stockholders face no higher storage costs than the dominant producer, prices will either be more stable in imperfectly competitive markets (if the price elasticity falls fast enough with price) than in perfectly competitive markets, or, at worst, no less stable.
3. EXTENSIONS

The model described in the last section was designed to see whether and when dominant producers had a comparative advantage in storage, and thus whether imperfectly competitive markets would be more or less stable than perfectly competitive markets. However, it was silent on supply, and hence less suitable for modelling the behaviour of a producers' cartel, which would obviously restrict supply. Again, it is straightforward to extend the competitive analysis of storage with a supply response provided in [10, Appendix 2] to the case of a pure monopolist. The details are provided in Newbery [6]) which shows that the effect of the supply response is to increase \(x_0\) (and hence, other things equal, reduce the amount of storage) and, at least for some parameters, to increase \(\alpha\) (which tends to increase the amount of storage). If we use the same parameters as the previous numerical example, together with a linear supply schedule whose elasticity at \(p=1\) is 0.625, then the storage rule is

\[
(40) \quad f(x) = 0.741(x - 0.9791), \quad x > 0.9791,
\]

(compare equation (32).) Planned production varies between \([q_s, q_o]\), where \(q_s\) is planned when the current supply is at its maximum carryover \(s_m\):

\[
q_s = 0.9569, \quad q_o = 1.0505, \quad s_m = 0.5172, \quad x_m = 1.6741.
\]

The net effect of the supply response on storage appears ambiguous, as Figure 3 shows. If current supply (production plus carryover) is less than \(x^*\), then the supply response leads to less storage than no supply response, and conversely if supply exceeds \(x^*\). In the present case \(x^* = 1.2356\), which means that if there was no carryover from last period, current supply will be less than \(x^*\), but if there
was a positive carryover last period then current supply will exceed $x^*$ in good years (when there is any storage to do). The chances of storage with $x > x^*$ are thus $p$, the chance of a good harvest last period, 75 per cent, and it would seem that allowing for a positive supply response can increase the average level of storage. However, in other cases, storage might be less, and the maximum amount ever stored in the present example is less with the supply response. The range of values taken by consumption, $C = x - f(x)$, is $[0.4050, 1.1361]$ with the supply response, and $[0.4, 1.2]$ without suggesting that prices are more stable if supply as well as demand can respond. The harvest will, of course, be more unstable, since it varies because of the weather and because of variations in planned supply which depend on past weather. These two sources of variability are therefore uncorrelated and thus additive.

What conclusions can we draw from this analysis? If the demand schedule is linear, then we have shown that the supply response does not change the conclusion that a monopolist will choose more stable prices than a competitive industry, for the supply response does not alter the arbitrage conditions for marginal revenue -- it merely provides an alternative to storage for achieving it. Indeed, in the numerical example provided, if supply conditions were such that the competitive industry would supply as much as the cartel (i.e. if their costs were sufficiently higher) then they would do no storage, whereas the cartel chooses to store a considerable amount. It follows that a producers' cartel will stabilize the price more than competitive agents (stockholders or consumers) would choose. Cartelization would thus lead to a transfer of some storage functions from the consumers or intermediate stockholders to the cartel.
If, however, the demand schedule has constant or rising elasticity as price falls, then the analysis of Section 2 demonstrated that competitive agents would have a comparative advantage in storing, and the cartel would, in such cases, do no storage. As a result, the effective demand schedule facing the cartel (for consumption plus additions to stock or minus stock drawdown) will have a kink at the point in which the current harvest is large enough to ensure a positive carryover, as in Figure 4 below. This kink will introduce a discontinuity into the marginal revenue schedule facing the cartel and raises the possibility that the cartel may produce more at lower prices than at higher prices. If so (and the two potential solutions A and B in Figure 4 will need to be compared to see which yields higher profit) then the cartel will tend to act in a more stabilizing way than a competitive industry, and will reduce the need for storage (though whether it will also increase price stability needs checking). Unfortunately, this non-convexity induced in the cartel’s revenue function by the actions of competitive storage makes the problem analytically intractible. There is even the possibility that the cartel might choose to destabilize supply if faced with such a demand schedule, as Newbery [4] demonstrated in another context (though this might in turn alter the form of the effective demand schedule facing the cartel).

If the producers’ cartel is not monolithic, but faces a fringe of competitive producers, then, by analogy with the results of Section 2, we would expect that the cartel would still tend to store enough to stabilize the price more than a competitive industry (though characterising the solution becomes more difficult as the supply response affects the slope parameter $\alpha$). However, there is an additional factor which might offset this stabilizing tendency. If the fringe producers are risk averse, their
production plans will be affected by the price instability. If the cartel arbitrages to reduce the risk facing the fringe, then their supply response will tend to harm the cartel. In such cases it may pay the cartel to further destabilize prices in order to discourage the fringe and hence raise average prices. Elsewhere Newbery [6] shows that this is theoretically possible provided the fringe is more risk averse than some critical level, but that this level is implausibly high. Thus the incentive for the cartel to destabilize instead of stabilize appears to be quantitatively negligible.

Moreover, the costs of destabilizing (or not adequately stabilizing) to the cartel increase with the degree of destabilization at the same rate as do the benefits (of the higher price though the lower fringe supply), so it is not true that a little bit of destabilization is worthwhile.

4. CONCLUSIONS

Whether or not dominant producers will stabilize prices more than the competitive level depends on the way the elasticity of demand varies with price, since this will determine the shape of the marginal revenue schedule relative to the demand schedule. If demand is linear, then dominant producers will undertake significantly more storage than is competitively justified, and, if they have a small enough share of the market, they may store several times their average level of output. Price stability will increase with the market share of the dominant producers. If producers are successful at forming a producers' cartel, then one would expect storage activities to shift from consumers and intermediaries to the cartel. On the other hand, if demand has constant or rising elasticity as price falls then dominant producers will leave storage and arbitrage to competitive intermediaries. Their production
decisions may, however, increase the extent of price arbitrage, and hence reduce price instability. Whilst dominant producers would in theory benefit from destabilizing the market and hence reducing the supply of more risk averse competitors, the costs of so doing appear to be out of all proportions to the gains. Hence the main conclusion of the paper is that the presence of imperfect competition tends to reduce price instability, or, at worst, leave it unchanged.

The other important conclusion is that care must be taken in designing rules for the operation of International Buffer Stock schemes if their intention is to stabilize prices, for the conventional rule proposed is particularly susceptible to manipulation by dominant producers. Efficient storage rules are not only cheaper and more cost effective than the conventional Bandwidth rule, but are not vulnerable to manipulation. Since seven out of the ten "core" commodities proposed for international price stabilization have potentially quite concentrated market structures, it is a matter of some importance to reconsider the design of these stabilization schemes.

REFERENCES


FOOTNOTES

1/ The research described in this paper was undertaken whilst I was working in the Development Research Department of the World Bank. I am grateful to the Bank for providing a stimulating research environment, but the views expressed in the paper are those of the author alone, and do not necessarily reflect those of the World Bank.
2/ Rarely do writers enquire into the relationship between the two, and hence most work in this area is seriously flawed. For a critique of this literature see Newbery and Stiglitz [7, 8]. Exceptions to these strictures include Gustafson [3], Goreux [2], Gardner [1], and Wright and Williams [11].

3/ The assumption of perfect correlation allows us to use the two state competitive model described above and hence derive analytical solutions. If the model is to be applied to observed data, then the role of the analytical model is to provide a first approximation to the numerical solution, which can be approximated as described in [10, Appendix]. There is no intrinsic difficulty in allowing for any specified correlation between the dominant producer's supply and that of the rest of the world.

4/ It is tedious, rather than difficult, to solve for the market equilibrium with a competitive fringe, at least for the linear model analyzed in [6].
FIGURE 1 - Storage as a Function of Market Share and Supply

FIGURE 2 - Probability Distribution of Price and Marginal Revenue
FIGURE 3 - The Effect of Supply Response on Storage

FIGURE 4 - The Effect of Competitive Storage on the Cartel's Supply Decision