# Price Stabilization Policies and Futures Markets

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## CONTENTS

## ABSTRACT

Because of the short-term nature of existing futures contracts, farmers are subject to intertemporal income uncertainty, yet price stabilization may be detrimental because it negates the benefits of (intertemporal) production flexibility. Multiyear futures, if they existed, would be preferred to price stabilization, but they would not provide perfect hedging opportunities because the risk faced by farmers is nonlinear in price. This means that options may be useful hedging devices, and that there may be scope for government intervention, even when long-term futures exist. The optimal price policy is not price stabilization, however, but it requires the support price to be positively correlated to the futures price that prevails when production decisions are made.

# PRICE STABILIZATION POLICIES AND FUTURES MARKETS

The perceived need to stabilize agricultural markets has for a long time provided a motivation for agricultural policies in many developed countries, and much research has concentrated on the analysis of price stabilization.[1] A crucial element of this research is that the (potential) benefits from stabilization arise because of the market failure assumption of incomplete risk markets. It is a fact, however, that some markets that deal directly with risk associated with agricultural prices do exist. Farmers can engage in forward contracting that locks in a price before planting time. More generally, futures markets in many countries allow farmers to manage price uncertainty. When this is recognized, the rationale for government intervention is diminished (McKinnon 1967; Newbery and Stiglitz 1981; Gilbert 1985). However, because the existence of futures markets for some commodities does not complete the set of markets in an Arrow-Debreu sense, the rationale for price stabilization remains. In particular, it has been suggested that, because of their limited time horizon, existing futures markets are useful in hedging intrayear price variability but are not very useful in eliminating interyear price variability (Gardner 1989). Whether this lack of complete futures markets provides a basis for government intervention is an open question.

This paper analyzes the desirability of price stabilization policies when (one-year) futures markets exist. A distinctive feature of the analysis is that we provide an explicit multiperiod framework. This allows us to compare price stabilization with the use of rollovers of one-year futures, and with the potential effects of multiyear futures markets. To concentrate on the multiperiod features of the analysis, we abstract from basis risk and production risk. It is well known that, if agricultural production is subject to uncertainty, then price stabilization may be undesirable. Specifically, the (typical) inverse correlation between market price and yields provides a "natural" hedge that partly stabilizes farm income. In a sense, therefore, assuming no production uncertainty provides the most favorable case for price stabilization. Furthermore, we assume throughout that the distribution of price is unaffected by farmers' decisions. The results, therefore, are relevant to a small open economy that is exposed to world price uncertainty.

We consider a farmer facing a one-period lag in output production. If no futures market exists, the short-term (one-period) price uncertainty cannot be hedged and the farmer is exposed to income risk. If one-period futures markets exist (as they do for most commodities), then the short-term price uncertainty can be hedged via these markets. Assuming no basis or production risk, production occurs where marginal cost equals the futures price,[2] and the farmer's income in that period depends upon the prevailing futures price. However, the farmer still faces income uncertainty in an intertemporal context unless this one-period futures price is constant across periods. Given risk aversion, this unhedged income uncertainty may correspond to an inefficient allocation of risk bearing, and thus may provide a rationale for government intervention.

Before proceeding with this analysis, three observations are in order. First, in any period the farmer retains the possibility of responding optimally to the prevailing one-period futures price. Hence, (future) income is a strictly convex function of futures price, and stabilizing price at its mean reduces expected income, as well as income variability. Thus, it is not tautological that interyear price stability is desirable.[3] Second, even complete futures markets (for all relevant future dates) would not provide perfect income insurance because future income is a nonlinear (convex) function of future price. What is needed to eliminate all income uncertainty is an insurance mechanism that provides the farmer with a payoff that is nonlinear in price. Thus, we analyze the risk reduction role of commodity options (which allow the construction of payoffs that are nonlinear in price), in addition to the role of multiyear futures and/or price stabilization. Finally, the lack of complete futures (and insurance) markets may affect long-term resource allocation decisions. If the farmer makes investments that are productive over many future periods, the absence of complete risk-bearing markets will affect current investment decisions. In this paper, we neglect this issue and focus only on the income uncertainty present in an intertemporal model due to the absence of complete risk-bearing markets.[4]

This paper is organized as follows. First, the main features of the model are outlined. The use of one-period futures, including rollover hedging, is then illustrated and compared with a price stabilization policy. Next, multiyear futures are considered, and the hedging role of options in this dynamic context is analyzed. Finally, some properties of an optimal second-best stabilizing price policy are derived.

## The Model

The essence of the problem can be captured with a three-period model with a one-period time lag in production. If periods are denoted by $t$, production decisions occur at $t$ and the corresponding output is realized at $t + 1$ ($t = 1, 2$). Let $q_t$ denote the farmer's output at $t$, $p_t$ denote realized price at time $t$, and $C(q_t)$ denote the farmer's cost function (which implicitly embodies the interest rate to the extent that certain costs are incurred before output is sold). Moreover, let ~ denote a random variable. The farmer's realized income from production in period $t$ is thus written as

$$\tilde{I}_t = \tilde{p}_t q_t - C(q_t) \qquad t = 2, 3. \tag{1}$$

In addition to production decisions, the farmer makes hedging decisions. It should be emphasized that in this setting it is income instability, not price instability per se, that is the problem. Given a complete set of markets, the risk-averse producer will choose to eliminate all income risk. Although a complete set of markets cannot be assumed, one-period futures markets exist, and in what follows they are assumed to be always available to the farmer.

The hedging decision at $t = 2$ involves choosing the number of future sales with delivery date at $t = 3$. The decision at $t = 1$ is more complex because the one-period futures market may be used not only to hedge next period's output, but also as a rollover hedge to insure against movements in period 2 futures prices (Gardner 1989). Thus, let ${}_t y_{t+1}$ represent the number of futures contracts sold at $t$ ($t = 1, 2$) with a delivery date at $t + 1$, and let ${}_t f_{t+1}$ represent the price at $t$ of a futures contract with delivery date at $t + 1$. Throughout the analysis, we assume that futures prices are unbiased, and therefore ${}_t f_{t+1} = E_t \tilde{p}_{t+1}$, where $E$ denotes the mathematical expectation operator, and the subscript to $E$ is the time index of the relevant information set. Because futures prices are assumed to be unbiased forecasts of future spot prices, we can write

$$\tilde{p}_{t+1} = {}_t f_{t+1} + \tilde{\epsilon}_{t+1} \qquad t = 1, 2\ , \tag{2}$$

$${}_2\tilde{f}_3 = E_1 \tilde{p}_3 + \tilde{\theta}_2\ , \tag{3}$$

where $E_t \tilde{\epsilon}_{t+1} = 0$ and $E_1 \tilde{\theta}_2 = 0$. Note that the one-period futures price for period 3 prevailing in period 2 is not known in period 1, and thus ${}_2\tilde{f}_3$ is a random variable in period 1.

To emphasize the production features of the problem, we abstract from consumption decisions by assuming that the risk-averse farmer maximizes the expected utility of terminal wealth, an approach adopted in similar circumstances by Mossin (1968), Anderson and Danthine (1983), and Karp (1988). From the preceding section, the farmer's terminal wealth is given by

$$\tilde{W} = \{[\tilde{p}_3 q_3 - C(q_3)] + (1 + r)[\tilde{p}_2 q_2 - C(q_2)]\} + \{(1 + r)[{}_1y_2 \cdot (-\tilde{\epsilon}_2)] + {}_2y_3 \cdot (-\tilde{\epsilon}_3)\}\ , \tag{4}$$

where $r$ denotes the one-period interest rate, the terms in the first set of braces denote income from production, and the terms in the second set of braces denote payoffs from hedging decisions.

Because of the separation principle associated with the existence of one-period futures markets, production decisions are straightforward. Output in each period is chosen so that marginal cost equals current one-period futures price. Hence, the production problem is summarized by the profit function $\pi(.)$, which is defined as

$$\pi({}_tf_{t+1}) = \underset{q_{t+1}}{\text{Max}} \ \{{}_tf_{t+1} \cdot q_{t+1} - C(q_{t+1})\} \qquad t = 1, 2. \tag{5}$$

Furthermore, in period 2 the farmer completely hedges his output (${}_2y_3 = q_3^*$), whereas in period 1 hedging via the one-period futures market need not equal next period output because of the rollover possibility. Specifically, let $x_1 \equiv {}_1y_2 - q_2^*$ represent the rollover hedge. Using this and (5), the farmer's terminal wealth with one-period futures can be rewritten as

$$\widetilde{W}_F = \pi({}_2\widetilde{f}_3) + (1 + r) \cdot \pi({}_1f_2) + (1 + r)[x_1 \cdot (-\widetilde{\epsilon}_2)] \ . \tag{6}$$

## One-Period Futures Markets

When only the one-period futures market exists, (6) indicates that long-term price uncertainty remains because, at $t = 1$, ${}_2f_3$ is uncertain. In this setting, the only way to hedge this long-term risk is through rollover hedging (through the correlation between $\widetilde{\epsilon}_2$ and ${}_2\widetilde{f}_3$, that is, between the cash price at time 2 and the time 2 futures price for delivery at time 3). The magnitude of the rollover hedge can be determined by maximizing, over $x_1$, expected utility of terminal wealth as given in (6). This yields the first-order condition (FOC)

$$E[U'(\widetilde{W}_F)(-\widetilde{\epsilon}_2)] = 0 \ , \tag{7}$$

where superscripted primes denote the order of differentiation. Thus, it is apparent that

$$x_1^* \ \gtreqless \ 0 \ \text{ as } \operatorname{Cov}[U'(\widetilde{W}_F),(-\widetilde{\epsilon}_2)] \ \gtreqless \ 0 \ , \tag{8}$$

where Cov(.,.) denotes the covariance operator and $\widetilde{W}_F$ is evaluated at $x_1 = 0$. If $\widetilde{\theta}_2$ and $\widetilde{\epsilon}_2$ are independently distributed (i.e., the realized value of $\widetilde{p}_2$ has no impact on the expected price for period 3), then the optimal rollover hedge is zero. However, if there are any long-term (stochastic) factors affecting price (as is likely not only because of serial correlation in demand patterns or weather conditions, but also through inventories), then $\widetilde{\theta}_2$ and $\widetilde{\epsilon}_2$ are likely to be correlated (typically they will be positively correlated, in which case the optimal rollover hedge is likely to be positive).

In general, no analytic solution for $x_1^*$ is possible. To gain some insight note that a Taylor-series approximation of (10) around $\theta_2 = \epsilon_2 = 0$ yields

$$x_1^* \simeq [{}_1\overline{q}_3/(1 + r)] \cdot [\mathrm{Cov}(\widetilde{\theta}_2,\widetilde{\epsilon}_2)/\mathrm{Var}(\widetilde{\epsilon}_2)] \ , \tag{9}$$

where Var(.) denotes the variance operator, and ${}_1\overline{q}_3 \equiv \pi'(E_1\widetilde{p}_3)$ is the period 3 output that would be induced by a futures price at time 2 equal to its current expectation. In what follows, ${}_1\overline{q}_3$ will be referred to as the "anticipated output" for period 3.[5] Clearly, (9) is just an approximation (and does not reflect, as it should, risk attitudes or the price responsiveness of supply), but it holds for "small risk" and illustrates the importance of the persistence of price shocks, as reflected in the covariance term, as well as the impact of unforeseen movements in $p_2$ that are strictly transitory.

**Price Stabilization**

We can now ask how price stabilization affects the farmer, given that one-period futures markets exist. Clearly, given the presence of one-period futures markets, stabilization for $t = 2$ is irrelevant. What is important is long-term price variability, reflected in (6) via ${}_2\widetilde{f}_3$. Thus, stabilization entails choosing a stabilized price ($p_s$) for period 3. Hence, under stabilization, terminal wealth is nonstochastic and is given by

$$W_S = \pi(p_s) + (1 + r) \cdot \pi({}_1f_2) \ . \tag{10}$$

No definitive comparison of price stabilization with one-period futures is possible. Insight into the critical factors affecting this comparison can be obtained, however, through an approximation. The (normalized) difference in expected utility under the two regimes can be defined as

$$\Delta \equiv \{E[U(\widetilde{W}_F)] - U(W_S)\}/U'(W_S) \ . \tag{11}$$

If the stabilization program is budget neutral (in an expected value sense), then $p_s$ must equal the current expectation of future price.[6] Hence, assume $p_s = E_1\widetilde{p}_3$. Then, a second-order Taylor-series approximation around $\theta_2 = \epsilon_2 = 0$, together with the (approximate) optimal rollover hedge in (9), yields

$$\Delta \simeq \tfrac{1}{2}\, \mathrm{Var}(\widetilde{\theta}_2)[\pi'' - \beta \cdot (\pi')^2 \cdot (1 - \rho^2)] \ , \tag{12}$$

where $\beta \equiv (-U''/U')$ is the measure of absolute risk aversion (evaluated at $p_s$), $\rho^2$ is the (squared) correlation coefficient between $\theta_2$ and $\epsilon_2$, and $\pi'$and $\pi''$ denote the first and second derivatives of the profit function (reflecting output supply and the slope of supply, respectively, both evaluated at $p_s$).

The expression in (12) reflects the usual result that price variability is most beneficial when supply is quite price responsive ($\pi''$ is large) and risk aversion is relatively small ($\beta$ is small) (Gilbert 1985; Schmitz, Shalit, and Turnovsky 1981). The additional insight concerns the role of rollover hedges captured by the term $(1 - \rho^2)$, which indicates that, if prices are highly serially correlated, then price stabilization is less likely to be beneficial because of the implicit long-term hedging available through short-term markets. Finally, note that the magnitude of the variance of price is not instrumental in ranking the two regimes.

**Multiperiod Futures Markets**

Now suppose that multiyear futures markets exist. Hence, ${}_1f_3$ represents the price at $t = 1$ of a futures contract with a delivery date at $t = 3$, and ${}_1y_3$ is the number of these two-period futures that the farmer sells forward at $t = 1$. Assuming that futures prices are unbiased means that ${}_1f_3 = E_1\tilde{p}_3$ and that (3) can be equivalently expressed as ${}_2\tilde{f}_3 = {}_1f_3 + \tilde{\theta}_2$. Then, the terminal wealth with multiyear futures markets can be written as

$$\tilde{W}_M = \pi({}_2\tilde{f}_3) + (1 + r)\pi({}_1f_2) + (1 + r)[x_1 \cdot (-\tilde{\epsilon}_2) + {}_1y_3 \cdot (-\tilde{\theta}_2)] \ . \tag{13}$$

Note that, if $\theta_2 \equiv 0$ so that no event before $(t - 1)$ affects expectations of period $t$ prices, the absence of multiperiod futures markets is irrelevant. The FOCs for the optimal choice of $x_1$ and ${}_1y_3$ are given by

$$E[U'(\tilde{W}_M) \cdot (-\tilde{\epsilon}_2)] = 0 \ , \tag{14}$$

$$E[U'(\tilde{W}_M) \cdot (-\tilde{\theta}_2)] = 0 \ . \tag{15}$$

If $\{\tilde{\theta}_2,\tilde{\epsilon}_2\}$ are independently distributed, it is clear that $x_1^* = 0$, whereas ${}_1y_3^*$ must be positive (because $\mathrm{Cov}[U',(-\theta_2)]$ is positive at ${}_1y_3 = 0$). However, because the two-period futures market is not a perfect hedging device (provided $\pi'' > 0$; i.e., there is some supply response), we cannot conclude that it is generally undesirable to use rollover hedges for any joint distribution of $\{\tilde{\theta}_2,\tilde{\epsilon}_2\}$. In particular, if the relationship between $\{\tilde{\theta}_2,\tilde{\epsilon}_2\}$ is nonlinear, then using rollover hedges may be desirable. If, however, the conditional expectation of $\tilde{\epsilon}_2$ is linear in $\tilde{\theta}_2$ (for example, they are jointly normally distributed), then using rollover hedges will only add noise to the portfolio without providing additional hedging power.

A comparison between expected utility under price stabilization and that under multiperiod futures shows that the positive effects of price variability on expected income (the convexity of the profit function) are dominant, although income is still random. For example, suppose that ${}_1y_3 = \pi'({}_1f_3)/(1 + r)$ and $x_1 = 0$, meaning the farmer hedges by selling forward the amount that would be produced under price stabilization (discounted by the interest rate), and uses no rollover hedge. Then the difference in terminal wealth between the two regimes is

$$\tilde{W}_M - W_S = [\pi({}_2\tilde{f}_3) - \pi({}_1f_3) + \pi'({}_1f_3) \cdot ({}_1f_3 - {}_2\tilde{f}_3)] \,, \tag{16}$$

which equals zero at ${}_2f_3 = {}_1f_3$ and is strictly positive elsewhere because of the strict convexity of the profit function. Thus:

> **Proposition 1.** With multiperiod futures markets, the farmer will always prefer that price be allowed to fluctuate rather than having it stabilized.

Finally, it is important to note that, even if long-term futures markets exist, income cannot be perfectly stabilized via these markets because of the strict convexity of the profit function.

## The Hedging Role of Options

Because income for period 3 is a nonlinear function of the random price (${}_2\tilde{f}_3$), the farmer will benefit by having access to a financial instrument whose payoff is nonlinear in price. Hence, commodity options can be useful. Lapan, Moschini, and Hanson (1991) have shown that there is little hedging value from using an option once production decisions are made (because, given output, income is linear in price). Thus, the only potential value of options occurs for hedging, in period 1, the income that will occur in period 3. From a hedging standpoint, if futures markets exist, it makes little difference whether the farmer is assumed to use calls or puts.[7] Analytically, however, it is convenient to consider the use of a combination of these two instruments, or a *straddle* (Lapan, Moschini, and Hanson 1991).[8]

Because we are concerned with the use of options in period 1 only (in period 2 there is no residual need to hedge, given the optimal use of one-period futures), we assume that the straddle expires in period 2 and that the deliverable instrument is the one-period futures contract then being traded. Thus, at time 1 the buyer of such a straddle has the option of buying or selling, at $t = 2$, one future contract expiring at $t = 3$, at a predetermined strike price. Furthermore, we assume that the strike price is equal to ${}_1f_3$, which is the period 1 expectation of ${}_2\tilde{f}_3$. The value at $t = 2$ of the expiring straddle is given by

$$| {}_2\tilde{f}_3 - {}_1f_3 | = | \tilde{\theta}_2 | . \tag{17}$$

If the straddle price is unbiased, its price (compounded at $t = 2$) is[9]

$$\phi = E_1 | \tilde{\theta}_2 | . \tag{18}$$

Furthermore, for simplicity, we assume straddles are available at only this strike price.[10]

Let $z_1$ denote the number of straddles sold by the farmer at $t = 1$. When the straddle is allowed, along with multiyear futures and rollover hedging, the terminal wealth expression is given by

$$\begin{aligned} \tilde{W}_O = {} & \pi({}_2\tilde{f}_3) + (1 + r) \cdot \pi({}_1f_2) \\ & + (1 + r)[x_1 \cdot (-\tilde{\epsilon}_2) + {}_1y_3 \cdot (-\tilde{\theta}_2) + z_1 \cdot (\phi - | \tilde{\theta}_2 | )] . \end{aligned} \tag{19}$$

The FOCs for the optimal choice of $x_1$, ${}_1y_3$, and $z_1$ are

$$E[U'(\tilde{W}_O) \cdot (-\tilde{\epsilon}_2)] = 0 , \tag{20}$$

$$E[U'(\tilde{W}_O) \cdot (-\tilde{\theta}_2)] = 0 , \tag{21}$$

$$E[U'(\widetilde{W}_0) \cdot (\phi - \mid \widetilde{\theta}_2 \mid )] = 0 \,. \tag{22}$$

Assuming that the conditional expectation of $\widetilde{\epsilon}_2$ is linear in $\widetilde{\theta}_2$ (e.g., they are jointly normally distributed), we know that $x_1^* = 0$. To simplify the analysis further, assume that $\widetilde{\theta}_2$ is symmetrically distributed around zero with density function $g(\theta_2)$, so that $g(\theta_2) = g(-\theta_2)$ and, for any function $h(\theta_2)$,

$$\int_{\theta_2<0} h(\theta_2)\, g(\theta_2)\, d\theta_2 = \int_{\theta_2\geq 0} h(-\theta_2)\, g(\theta_2)\, d\theta_2 \,. \tag{23}$$

Then, the FOCs for the optimal levels of ${}_1y_3$ and $z_1$ can be rewritten in terms of the realizations $\theta_2 \geq 0$ only

$$\int_{\theta_2\geq 0} [U'(B) - U'(A)]\theta_2 g(\theta_2)d\theta_2 = 0 \tag{24}$$

$$\int_{\theta_2\geq 0} [U'(B) + U'(A)](\phi - \theta_2)g(\theta_2)d\theta_2 = 0 \,, \tag{25}$$

where:

$$A \equiv \pi({}_1f_3 + \widetilde{\theta}_2) + (1 + r) \cdot \pi({}_1f_2) + (1 + r) \cdot [-{}_1y_3 \cdot \widetilde{\theta}_2 + z_1 \cdot (\phi - \widetilde{\theta}_2)] \tag{26}$$

$$B \equiv \pi({}_1f_3 - \widetilde{\theta}_2) + (1 + r) \cdot \pi({}_1f_2) + (1 + r) \cdot [{}_1y_3 \cdot \widetilde{\theta}_2 + z_1 \cdot (\phi - \widetilde{\theta}_2)] \tag{27}$$

From (24), it is clear that $(A - B)$ cannot always be of the same sign; i.e., either $A \equiv B$ everywhere or $(A - B)$ changes sign. Expanding each around $\theta_2 = 0$ yields

$$(A - B) = 2[\pi'({}_1f_3) - (1 + r) \cdot {}_1y_3]\widetilde{\theta}_2 + \frac{1}{6}\, [\pi'''(f_0) + \pi'''(f_{00})] \cdot \widetilde{\theta}_2^3 \tag{28}$$

where $\pi6'''$ is the third derivative of the profit function (the curvature of the supply curve). Note that (28) holds exactly for some $f_0 \in [0, {}_1f_3 + \theta_2]$, $f_{00} \in [0, {}_1f_3 - \theta_2]$. Hence,

**Proposition 2.** If the forecast error in the period 2 futures price is symmetrically distributed, the optimal multiperiod hedge satisfies:

$$ {}_1y_3^* \gtreqless \pi'({}_1f_3)/(1 + r) \quad \text{as} \quad \pi''' \gtreqless 0 $$

In particular, with a quadratic profit function (linear supply function), the optimal multiperiod hedge is equal to the expected output $\pi'({}_1f_3) = {}_1\overline{q}_3$ discounted by the interest rate.

Furthermore, if the profit function is quadratic, then, given the optimal futures hedge, $A \equiv B$ for all $\theta_2$ and both $A$ and $B$ are increasing functions of $\theta_2$ for $z_1 = 0$. It follows immediately that the integral in (25), evaluated at $z_1 = 0$ is strictly positive because $\text{Cov}\{U'[A(\tilde{\theta}_2)],(\phi - \tilde{\theta}_2)\} > 0$ at $z_1 = 0$. Given the second-order conditions, we must have $z_1^* > 0$ to satisfy the FOC. Hence,

**Proposition 3.** With symmetrically distributed $\tilde{\theta}_2$ and a quadratic profit function, optimal hedging in period 1 includes short straddles (in addition to a futures hedge).

A hedging role for options (straddles) arises because of the nonlinearity of the farmer's price risk. Unless an infinite set of such straddles is available, however, options cannot provide farmers with complete insurance and thus there is still scope (potentially) for government intervention. The policy required, however, is not price stabilization at $p_s$, which is dominated by multiyear futures (with or without options).

## Optimal Government Price Policy

One-period futures markets are clearly not sufficient to hedge the income risk arising from price uncertainty in a multiperiod framework. The analysis, however, also shows that price stabilization is unlikely to provide much improvement. Price stabilization is inferior to multiperiod futures markets and may not be desirable, even when only one-period futures are available. This finding is in apparent contradiction with the claim that, in the absence of complete insurance (or state-contingent) markets, some form of government price intervention is likely to be part of a second-best solution, despite its distortionary effects on production. The problem is with the specific form of government intervention that was analyzed (stabilization at a fixed price $p_s$). As we will show, the optimal second-best price policy will be positively correlated with market price. Moreover, there is (potentially) a scope for this government price policy, even if multiyear futures markets exist.

Assume that the government adopts a policy rule that sets, at the time production decisions are made, the price farmers will receive for their output (one period later). This pricing policy may be made contingent upon all available information. In particular, this information set will include the one-period futures price. Hence, define

$$p_g = F({}_2f_3)\ , \tag{29}$$

where $p_g$ is the government set price to be paid to farmers, ${}_2f_3$ is the futures price, and $F(.)$ is the functional relationship (to be determined) between the government-determined price and the futures price. The difference $\{p_g - {}_2f_3\}$ reflects the subsidy (deficiency) payment made to farmers, except that it is based upon the forward price prevailing when planting decisions are made and not upon the realized market price.[11] Note that price stabilization as considered earlier corresponds to $F'(.) \equiv 0$, whereas a price floor program [such as that considered by Innes (1990)] corresponds to $F'(.) = 0$ for all ${}_2f_3$ below some (policy-determined) level.[12]

The choice of such a price program is constrained by its expected budgetary cost $(BC)$

$$E[(\tilde{p}_g - \tilde{p}_3) \cdot q_3(\tilde{p}_g)] = E[(\tilde{p}_g - {}_2\tilde{f}_3) \cdot q_3(\tilde{p}_g)] \leq BC\ , \tag{30}$$

where $\tilde{p}_g = F({}_2\tilde{f}_3)$. Note that (expected) budget neutrality would set $BC = 0$. The government objective is to choose the price rule $F({}_2f_3)$ to maximize the expected utility of farmers, subject to the budget constraint in (30). Terminal wealth is

$$\tilde{W}_G = \pi(\tilde{p}_g) + (1 + r)[\pi({}_1f_2) - {}_1y_3 \cdot \tilde{\theta}_2]\ , \tag{31}$$

where ${}_1y_3$ is the multiperiod hedge and, for simplicity, we assume that no straddles or rollover hedges are used by the farmer.

Optimizing expected utility of farmers' terminal wealth subject to the government budget constraint results in a standard nonlinear programming problem with (30) as a constraint if the distribution of ${}_2f_3$ is discrete, and in a control problem with (30) as an isoperimetric constraint, if the distribution of ${}_2f_3$ is continuous. From either problem, choosing $p_g$ for each ${}_2f_3$ yields

$$J \equiv U'(W_G)q_3 - \lambda\,[q_3 + (p_g - {}_2f_3) \cdot q_3'] = 0 \qquad \text{for all } {}_2f_3\,, \tag{32}$$

where $\{p_g - {}_2f_3\}$ is the actual subsidy (which is contingent on the actual realization of ${}_2\tilde{f}_3$), $\lambda$ is the Lagrange multiplier corresponding to the constraint of (30) (which is constant for all ${}_2f_3$), $q_3 \equiv \pi'(p_g)$ is output, and $q_3' \equiv \pi''(p_g)$ is the slope of the supply curve.

From (32), it is clear that a policy of price stabilization ($p_g = p_s$ for all ${}_2f_3$) *cannot* solve (32) unless $q_3' \equiv 0$ (no price responsiveness of supply) because, under such a plan, $W$, $q_3$, and $q_3'$ would be independent of ${}_2f_3$, whereas the subsidy $(p_g - {}_2f_3)$ would be inversely related to ${}_2f_3$. Hence, $p_g$ will vary with ${}_2f_3$ (and so will $q_3$). The important remaining question is how the optimal government price will covary with the futures price. Implicitly differentiating (32) yields $dp_g/d({}_2f_3) = -[\partial J/\partial({}_2f_3)]/[\partial J/\partial p_g]$. Because the second-order conditions of the government problem require $[\partial J/\partial p_g] < 0$, it follows that sign $[dp_g/d({}_2f_3)]$ = sign $[\partial J/\partial({}_2f_3)]$.

To find the sign of $[\partial J/\partial({}_2f_3)]$, first note that the multiperiod hedge ${}_1y_3$ is constant along the optimal path, similarly to the multiplier $\lambda$, because farmers will choose ${}_1y_3$ conditional on the government policy rule $p_g = F({}_2f_3)$. Alternatively, because the government acts as an agent for the farmer in our model, one can think of ${}_1y_3$ as being chosen by the government jointly with the policy rule $F({}_2f_3)$. Hence, ${}_1y_3^*$ is constant for any given distribution of ${}_2\tilde{f}_3$, and so is the rule $F({}_2f_3)$, although

$p_g$ will clearly covary with ${}_2f_3$.[13] Differentiating the FOC of (32), holding $\lambda$ and ${}_1y_3$ constant, one finds that $[\partial J/\partial({}_2f_3)] = \lambda q_3' - U'' q_3 \cdot (1 + r)_1 y_3$. Hence, a sufficient condition for $[\partial J/\partial({}_2f_3)] \geq 0$ is that ${}_1y_3 \geq 0$ (the multiperiod hedge is short). Hence,

> **Proposition 4.** Stabilization at a fixed price is never an optimal price policy rule. The optimal policy requires that the support be responsive to market conditions. In particular, the support price should be positively correlated with the one-period futures price.

In general, no analytic solution to (32) is available. However, to illustrate the characteristic of a solution, assume that

$$U(W) = \ln(W) \quad \text{and} \quad W = ap_g^2 . \tag{33}$$

Under these assumptions, the solution for the optimal support price $p_g$ is

$$p_g = ({}_2f_3/4) + [\gamma + ({}_2f_3/4)^2]^{1/2} , \tag{34}$$

where $\gamma$ ($>0$) is determined from (30). Note that $p_g$ is a *strictly convex* function of ${}_2f_3$, with slope $[dp_g/d({}_2f_3)] \in \{1/4, 1/2\}$.

In summary, although some price intervention can be beneficial because of incomplete insurance markets, optimal intervention will not involve the typical policies of price stabilization or price floors. Rather, optimal intervention will make the price received by farmers positively correlated with the futures (or market) price, thereby taking advantage of the potential price responsiveness of supply. Furthermore, the optimal intervention scheme itself will be influenced by the existence of multiperiod futures markets.

## Conclusion

The rationale for price stabilization has long rested on the premise that farmers are risk averse and that risk is not appropriately allocated among different economic agents. Given that futures markets exist and provide opportunities for farmers to hedge risk, the residual rationale for such intervention relies on the fact that futures markets are incomplete and hence farmers face long-term income (price) uncertainty. As shown again in this paper, however, price stabilization may be detrimental if output is price responsive.

We have also shown that adding complete futures markets still does not provide perfect income insurance, although it is superior to price stabilization. Hence, there may be scope for additional risk-sharing markets, such as (long-term) commodity options. Alternatively, lacking these markets, the residual intertemporal income uncertainty of producers may provide the rationale for government intervention. Government programs, however, should be designed to mimic the effects of missing markets. In particular, if government policy is restricted to price policy, it should allow for some responsiveness between market price and the price paid to farmers. In other words, common price stabilization policies, such as those implemented in U.S. farm support legislation, are dominated by alternative price policies.

The analysis conducted corresponds to a small open economy facing price uncertainty from world price variability. Within this context, although there may be a scope for government price intervention, border measures such as import tariffs or import quotas are inefficient policies because they not only affect farmers, but also harm consumers. Policies to stabilize farm income should, more appropriately, be internal policies (such as price supports and deficiency payments) that maintain linkages between domestic prices and world prices. If border measures are to be the means of intervention, the optimal policy that is likely to emerge is not import quotas or variable levies, which sever the link between domestic prices and world prices, but rather policies permitting domestic prices to respond to world prices. Because this analysis has shown that the rate of change of internal prices with respect to world prices should be less than unity, the corresponding border policy would entail a fixed specific tariff, plus an ad valorem import subsidy less than one.[14] Such a policy change would benefit not only domestic producers, but should also help foreign exporters.

## ENDNOTES

1. A useful summary of earlier work is found in Turnovsky (1978). The book by Newbery and Stiglitz (1981) provides an extensive analysis of many relevant issues. Additional discussion of instability as rationale for government programs in agriculture is given by Myers and Oehmke (1988).

2. This is the separation result of Danthine (1978); Feder, Just, and Schmitz (1980); and Holthausen (1979).

3. A risk-neutral farmer will prefer price instability as long as output has some price responsiveness, as originally shown by Oi (1961). When the farmer is risk averse, then the concavity of the utility functions counters the convexity of the profit function, and the ranking of price instability/stabilization is ambiguous [see, among others, Schmitz, Shalit, and Turnovsky (1981)].

4. An analysis of the resource allocation effects of options hedging when wealth is nonlinear in price is provided by Moschini and Lapan (1991).

5. Note that this anticipated output will equal the mathematical expectation of output only if the supply curve $\pi'$ is linear.

6. If there were more than two future time periods, and if current expectations of prices for each of these time periods varied, the government could still "stabilize" prices by setting the price for each period at its current expectation. In other words, stabilization in this context does not mean eliminating predictable variations in yearly income; this variation will lead to no market failure, provided capital markets function properly. The objective is to eliminate the uncertainty, which is accomplished by such a scheme. Of course, if current expectations for all future prices are the same, no such issue arises. Also, note that full elimination of uncertainty, from the farmer's perspective, means that the government cannot revise the stabilized price in response to new information.

7. A call can be constructed using a futures and a put, and a put can be constructed using a futures and a call. In other words, one of the three instruments (futures, put, and call) is redundant, a fact that is dual to the put-call parity of option pricing.

8. A short straddle, which consists of one short call and one short put with the same strike price, will "make" money when the realized price is near the strike price of the option, but lose money for extreme (large or small) price realizations.

9. Because funds to buy straddles are required in period 1 but the revenue is not received until period 2, the straddle price at $t = 1$ will be $\phi/(1 + r)$.

10. In reality, options are available at a number of strike prices. Furthermore, it would be beneficial for the farmer to use options at different strike prices because this would enable him/her to more effectively hedge the nonlinear income risk. For simplicity, however, we assume only one strike price is traded or used.

11. Alternatively, $p_g$ could be made contingent upon the realized market price, $p_3$. Note, however, that this would be inferior to the current formulation (unless $p_g$ were a linear function of $p_3$) because the farmer could not use the one-period futures market to hedge all short-term risk.

12. For a closed economy, this government program, through its impact on production decisions, would influence the distribution of realized price ($p_3$) and hence the current value of ${}_2f_3$. This analysis is for a (small) open economy in which ${}_2f_3$ reflects current estimates of next period's world price. The policy rule $p_g$ could be supported in a number of ways, including border measures such as tariffs or quotas. Such border measures, however, are inferior to the program described here because they distort consumption decisions.

13. This result should be carefully distinguished from the effects of a change in the distribution of ${}_2\tilde{f}_3$, which will affect both the optimal policy rule and the optimal multiperiod hedge.

14. By contrast, for example, the variable import levy used by the European Community to support domestic farm prices can be seen as an ad valorem import subsidy equal to one because the tariff declines by one unit for each one-unit rise in world price.

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