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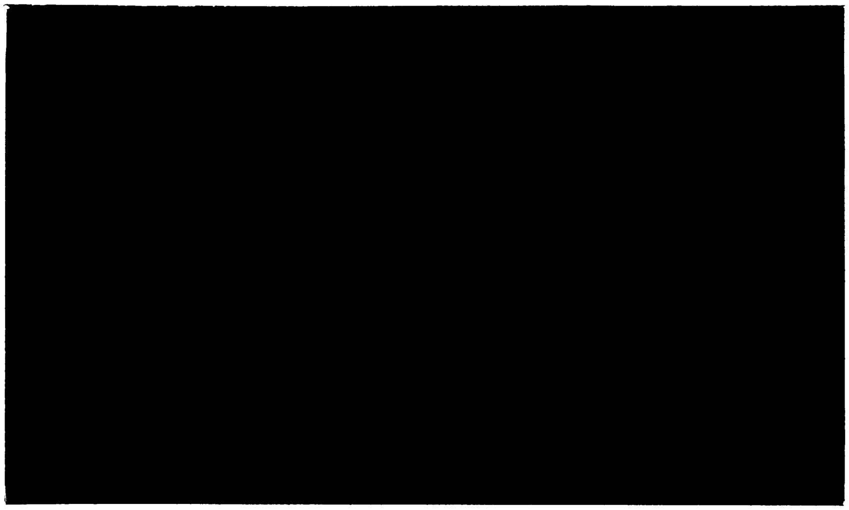

The Inefficiency of Interest Rate Subsidies

in Commodity Price Stabilization

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The Inefficiency of Interest Rate Subsidies in Commodity Price Stabilization

Governments in both developing and industrial countries have sought to stabilize commodity prices by means of stockpiling schemes. However, the use of nationally or internationally managed buffer stocks for this purpose has been widely criticized in recent years. Subsidization of privately owned stockholding is argued to be preferable (Newbery and Stiglitz, Williams and Wright, Ch. 15). The idea is that with lower costs of storage, more stocks will be available to buffer unanticipated shocks to the commodity markets. Since one of the main costs of holding stocks is the foregone interest earnings on funds invested in them, these subsidies can take the form of interest rate subsidies. Such subsidies have been used in the 1980s in several Latin American countries and in the U.S. grains programs. In Colombia and Brazil several hundred million dollars annually are spent on them. In the U.S., below-market interest rates, and in some cases interest-free loans, have been provided to farmers who store grain under government programs.

The purpose of this paper is to show that, counter to the usual expectations, an interest rate subsidy can cause prices to become <u>less</u> stable. In general, interest-rate subsidies are an inefficient means of stabilizing commodity prices, in that more stabilization can be achieved at less cost by means of a direct subsidy of storage. The issues are examined empirically in the case of U.S. soybeans, where governmental intervention for stabilization purposes has been minimal but fluctuations in 1968-92 permit an assessment of how private stockholding and price variability respond to interest rates.

The Model

Two approaches to inventory theory have been developed. The first applies dynamic optimization to the profit maximization problem given continuous production with random shocks in demand or supply. The second applies dynamic programming to determine optimal stockholding given future shocks that will be encountered randomly according to a known probability density function. We consider the effect of interest rates on price stability using both approaches.

Continuous Production, Firm-level optimization: Consider a competitive representative farm that both produces and stores a commodity. The farmer's problem is to maximize intertemporal profits:

$$(1) \qquad \max_{s_t,\, y_t} \int_0^\infty [P_t\, s_t - c(Y_t, w_t) - G(Z_t)]\, e^{-rt}\, dt$$

$$\text{s.t.} \qquad \text{(i)} \qquad \dot{Z}_t = y_t - s_t$$

$$\text{(ii)} \qquad Z_0 = \bar{Z}; \quad s_t \geq 0,\ y_t \geq 0$$

where p_t is the expected market price of the product at time t, s_t is the level of sales at time t, y_t is the level of production at time t, w_t are factor prices or other exogenous variables affecting the cost of production c(·), r is the discount rate, Z_t is the level of inventories and $\dot{Z}_t$ is inventory change at time t. The function $G(Z_t)$ is a net inventory cost function. This function is assumed U-shaped—marginal inventory costs are negative low inventory levels but become positive at some level of Z. The negative marginal costs are with low inventories due to "convenience yield"—the fact that inventories generate benefits by reducing transaction costs. At low inventory levels, increasing stocks lead to transaction cost savings greater than the marginal physical costs of carrying inventories. The convenience yield at very low inventory levels is assumed sufficiently large that inventories never fall to zero.

To solve the problem, define a co-state variable q_t and maximize equation (1) using the current-value Hamiltonian:

$$(2) \qquad H_t = p_t s_t - c(y_t, w_t) - G(Z_t) + q_t(y_t - s_t)$$

subject to the constraints $s_t \geq 0$, $y_t \geq 0$ and initial conditions. Note that q_t is the current value shadow price of inventories. Necessary conditions, assuming an interior solution for y_t, are:

(3) (i) $p_t - q_t \leq 0;\ s_t(p_t - q_t) = 0,\ s_t \geq 0$

(ii) $q_t - c_y(y_t, w_t) = 0$

(iii) $\dot{q}_t = rq_t + G_z(Z_t)$

(iv) $\dot{Z}_t = y_t - s_t;\quad Z(0) = \bar{Z}$

(v) $\lim_{t \to \infty} q_t e^{-rt} = 0$

Condition 3(i) indicates that if the firm has positive sales then the market price of the commodity must be equal to its shadow price, q_t. If the market price is less than the shadow price then there are no sales. If we assume that at every point in time consumption and sales occur, and that inventory levels are never zero, then $p_t = q_t$, yielding from 3(ii) the classical marginal cost condition $c_y(y, w_t) = p_t$. Under these conditions 3(iii) becomes:

$$(4) \qquad \dot{p}_t = rp_t + G_z(Z_t)$$

where $G_z(Z_t)$ is the marginal cost of holding inventory level Z_t.

<u>Market equilibrium</u>: The volume of sales is undetermined at the level of the representative firm. Sales are determined by final demand conditions. Each point in time $s_t = D(p_t) + \varepsilon_t$ where $D(p_t) + \varepsilon_t$ is the consumers' demand at time t, and ε_t is an exogenous demand shock. It is assumed that the slope of the demand function, $D'(p)$, is negative. Equation (4) is a continuous time representation the intertemporal market equilibrium condition for a storable commodity.

Using the temporary equilibrium equality of sales and final demand we can use condition 3(i) to write the short-run market equilibrium as:

(5) $$\dot{Z}(t) = y_t(p_t, w_t) - D(p_t) - \varepsilon_t$$

where $y_t(p_t, w_t)$ solves 3(ii). Note that ε_t can alternatively be interpreted as an additive supply shock.

Finally, long-run equilibrium or steady state requires that:

(6) (i) $y(p^*, w) - D(p^*) - \varepsilon^* = 0$

(ii) $rp^* + G_z(Z^*) = 0$

where p^* and Z^* is the combination of market price and stock level that allows both the stock market and flow market to be in long-run equilibrium and ε^* is a permanent demand or supply shifter. At the long-run equilibrium $\dot{Z} = \dot{p} = 0$, i.e., neither the inventory level nor the market price changes. The second order conditions of this problem require the marginal storage costs to be increasing, that is $G_{zz}(Z_t) > 0$.

The inventory model summarized by equations (2) to (6) can be used to analyze the effects of a given shock (ε_t) on both the temporary equilibrium and the steady state, and the effect of a change in the interest rate on the responsiveness of Z_t and P_t to such a shock. It can be shown using equation (4) that the necessary and sufficient condition for an interest rate rise to increase the responsiveness of Z_t to a shock, and thus to be stabilizing in the sense of decreasing the responsiveness of P_t to a shock is

(7) $$P_t\, G_{zzz}/G_{zz} > -G_{zz}/r.$$

By the second-order condition G_{zz} is positive, i.e., marginal storage cost is rising over the range of z. With $G_{zz} > 0$, the sufficient condition for inequality (7) is $G_{zzz} \geq 0$, which means marginal cost rises at a non-decreasing rate over the relevant range of Z. A linear marginal storage cost function meets this criterion, as does a function that has rising marginal cost as storage capacity is reached. These assumptions imply

$$\frac{\partial(\partial P_t/\partial \varepsilon_t)}{\partial r} < 0,$$

i.e., that the price effect of a shock is smaller, the higher the interest rate. If $G_{zzz} < 0$, however, the net effect is ambiguous.

The intuition behind this is as follows: An increase in r has two effects, namely, (1) increases the sensitivity of the opportunity cost (rp) to price fluctuations; (2) decreases the level of inventories held. Effect (1) is always stabilizing because inventory holders will respond more promptly to commodity price changes by releasing or purchasing inventories thus cushioning the price fluctuations. The opportunity cost of holding inventories is more sensitive to price fluctuations the higher is the interest rate and because this more a gile response of inventory to time changes. Effect (2) is ambiguous. If lower inventories imply that the slope of the marginal cost of inventories becomes flatter (i.e., if G_{zz} becomes smaller), then the marginal cost of inventory adjustment declines and stockholders become more prone to adjust inventories, thus increasing price stability.[1] This, of course, happens if $G_{zzz} > 0$, in which case the inventory reduction effect caused by a higher r is also stabilizing. The net effect of a higher r is therefore stabilizing. If, however $G_{zzz} > 0$, then effect (2) is destabilizing because a reduced level of inventories causes an increase in the marginal cost of inventory adjustment. In this case the net effect of a higher r is ambiguous. See Lopez for more details.

[1] Note that the marginal cost of inventory adjustment is not the same as the marginal cost of inventories. Indeed, the former is the slope of the latter (G_{zz}).

Discrete Time, Stochastic Model

The preceding model assumes continuous production and is deterministic in the sense that buyers and sellers know ε_t before making their decisions, that they ignore the consequences of future shocks, and that no stockouts ($Z_t = 0$) occur. An alternative model often used for agricultural commodities relaxes these assumptions. It assumes production takes place at a particular time, the "harvest", and stocks are the quantity not consumed before the next harvest (Gustafson; Gardner; Newbery and Stiglitz; Williams and Wright). A random shock in either supply or demand occurs each year. Economic agents know the probability density function of the future shocks and all the structural parameters. In this sense the model embodies rational expectations.

The optimization problem for a competitive production and storage industry can be solved by stochastic dynamic programming. See Gustafson, Gardner, or Williams and Wright. The resulting competitive equilibrium is characterized by

(7) $$E(P_{t+1}) = (1 + r)P_t + G_z(Z_t)$$

and

(8) $$Z_t = y_t - D(p_t) + Z_{t-1} + \varepsilon_t$$

Equations (7) and (8) are discrete-time versions of equations (4) and (5), showing that despite their differences the essential economics of the models are the same. The discrete-time model is recursive in that production, y_t, is pre-determined at harvest time t, being a function of the expectation of p_t and observed factor prices during the preceding year. This model never arrives at a steady state, since ε_t generates new disturbances each year, but in expected value over a long period of time if $E(\varepsilon_t) = 0$ and $E(Z_t - Z_{t-1}) = 0$,[1] then $E(P_t - P_{t-1}) = 0$. The mean price equates mean production and consumption.

The temporary equilibria of the discrete-time model can be depicted in terms of the supply and demand for stocks. $D(P_t)$ in Figure 1 is a stationary component of consumption demand. S_t is the total supply available, including current production, inventories carried from the preceding crop, and the effects of temporary additive shocks ε_t in both supply and demand. It is perfectly inelastic with respect to P_t because neither current production nor the previous period's carryover depends on current price. The horizontal difference between S_t and $D(P_t)$ is the inventory level Z_t as given by equation (8). Since equation (7) is simultaneously determined with (8), and contains two endogenous variables P_t and P_{t+1}, it is not immediately clear that a unique equilibrium exists; for proof that the competitive equilibrium exists and is unique, see Samuelson (1971).

The optimal Z_t depends on expectations concerning ε_t. If the expected future value of all shocks is zero, then the model reduces to a discrete-time version of the deterministic model of equations (1) to (6). But apart from unique, one-time shocks, agents form expectations about future shocks and this affects their inventory holdings. The expected value (mean) of future shocks is assumed to be zero, but agents know that shocks will occur, and know the probability density function of them. The larger and more frequent the shocks, the larger is Z_t for a given P_t (Gustafson), so that the certainty-equivalence approach of substituting the expected value of shocks in the model of equations (1) to (6) is inappropriate.

The size and frequency of shocks is the exogenous cause of price variability. Inventories buffer the price effects of the shocks. However, holding larger inventories does not in itself increase the buffering effect. As in the continuous time model, the issue for price stability is the <u>change</u> in stocks caused by a given shock. Larger changes in stocks and smaller price changes occur, the more elastic is D_t. But bigger stocks do not necessarily move us to a more elastic range of this function. If in Figure 1, D_t is shifted to the right for a given $D(P_t)$ function, so that $E(Z_t)$ increases, this also increases $E(S_t)$ by the same amount.

The interest rate is not the only determinant of the elasticity of the inventory demand function. The elasticity also depends on characteristics of the storage cost function, the consumption demand function, and the frequency distribution of expected future shocks. As in the continuous case, a sufficient condition for an interest rate rise to increase the elasticity of the inventory demand function, and so to be price stabilizing, is that $G_{zz} > 0$ and $G_{zzz} \geq 0$ over the range of Z. However, the functional forms that give $G_{zzz} \geq 0$ do not rule out the total depletion of stocks. To maintain the idea of "pipeline" stocks at low inventory levels, we need a marginal storage cost function to be concave at levels of inventories below a certain critical point, z^* in Figure 2. That is, $G_{zzz} < 0$ for $z < z^*$ and $G_{zzz} > 0$ for $z > z^*$. Even if $z < z^*$, the condition for an interest rate increase to be stabilizing may still hold, but this will depend on parameter values. If $z > z^*$ the condition holds unambigously.

Empirical Investigation: U.S. Soybeans

With the typical storage cost functions that have $G_{zzz} < 0$ over part of their range, it is an empirical question whether an interest rise will increase or decrease the slope of the inventory demand function and hence the stability of price. Moreover, the empirical question cannot be settled analytically in the stochastic case even when the parameters of the G(Z) function are known, because we cannot find the probability density function of Z analytically. We follow two methods of empirical investigation here: simulation via dynamic programming and econometric estimation of the effect of the interest rate on price variability.

Competitive Soybean Carryover and Price Stabilization

Samuelson (1971) analyzes the time path of stochastic speculative price in a competitive market for a storable commodity. The problem is to transform a sequence of randomly generated shocks (the ε_t) to a sequence of corresponding prices, P_t, when the market participants take into account all current information and the probabilities of future shocks at each future date. Samuelson shows that the price path can be found by dynamic programming. Williams and Wright (1991) provide a solution algorithm for the discrete, annual grain production-and-storage problem where production is a random variable, responsive to expected price. The solution generates P_t and Z_t for each possible value of ε_t and lagged stocks Z_{t-1}. A sequence of ε_t following the stochastic process assumed in the dynamic programming problem is then generated to simulate a time series of prices. The variance of the simulated time series of prices at alternative interest rates measures the effect of r on price instability.

For the U.S. soybean case we have the following, based on 1968-92 data. The deviations of yield and export demand around trend imply a coefficient of variation of excess supply (supply shock minus demand shock divided by trend production) of .084. Using either the Chi-square or Komolgorov-Smirnoff test, normality is accepted at the 5 percent level so we assume that the annual shocks are normally distributed. We also assume that shocks are serially independent.

A price arbitrage equation such as (4) would suggest the following empirical relationship expressed in discrete rather than continuous form,

(9) $$m_t = \alpha_0 + \alpha_1 z^1_{t-1} \; \alpha_2 z^2_{t-1} + \alpha_3 z^3_{t-1} + \alpha_4 p_{t-1} \, ,$$

where m_t are the annual November-to-November spreads in future prices as a measure of expected capital gains. We normalize the level of inventories as $z_t = \frac{Z_t}{\bar{y}}$, where $\bar{y}$ is the level of trend production. The right-hand terms associated with z can be interpreted as the marginal storage cost while the last right-hand term would capture the opportunity cost of holding inventory as well as errors of using m_t as a proxy for expected capital gains. These errors are likely to be correlated with the price level and thus the coefficient α_4 cannot be regarded as an unbiased estimate of the discout rate, r.

Table 1 presents the estimated coefficients of (9). As can be seen, the coefficient α_4 is negative, and cannot therefore be interpreted as the discount factor. As discussed above this coefficient is likely to be a biased estimate of the discount rate. In any case our interest is with the other coefficients which provide some idea regarding the shape of the marginal storage cost function. Based on the arbitrage condition we can interpret the first four right-hand-side terms in (9) as G_z. Thus using the estimates from Table 1 we have that,

$$G_{zz} = 119.22 - 1317\ z_{t-1} + 3373.65\ z_{t-1}^2$$

$$G_{zzz} = -1317 + 6747.3\ z_{t-1}.$$

This implies that $G_{zzz} > 0$ for all $z_t > 0.195$. Thus, for periods where inventory levels are above approximately 19% of annual production, the marginal cost of adjusting inventories is increasing with z and, hence, a higher interest rate necessarily plays a stabilizing effect (remember that the other effect, the opportunity cost effect, is always stabilizing). For periods where inventories are below 19% of the annual production the effect of r is ambigous. It is worthwhile noting that over the last 25 years the average inventory levels have been above or about the 19% level in 7 years (or about 30%) of the observations).

Table 1. OLS estimates of the price spreads equation

	Coefficient value	T-statistics
α_0	-5.99	-3.79
α_1	119.22	3.31
α_2	-658.56	-2.63
α_3	1124.55	2.16
α_4	-0.11	-1.25
$R^2 = 0.58$; $\bar{R}^2 = 0.50$		

Figure 3 shows the demand for stocks generated by competitive storage behavior given the storage cost and yield variability conditions just discussed, with an elasticity of product demand for soybeans of -0.6 and an interest rate of 5 percent. With an elasticity of intended production with respect to expected price of 0.3, the implied mean stocks are 10.5 percent of mean production. The implied variability of price is estimated by simulating a series of 1000 "years", giving a coefficient of variation of price of .123 — the expected departure of a particular year's price from the mean price is 12.3 percent.

Now consider what happens if the interest rate is reduced to zero, e.g., the government provides interest-free loans on stored commodities as was done in the U.S. Farmer-Owned Reserve Program. Competitive stock demand is increased as shown in the r = 0 curve in figure 3. Mean stocks are 10.5 when r = .05 and rise to 12.3 when r = 0. For stabilization purposes, however, the important point is that the slope of the stock demand curve is also increased by the interest-rate subsidy. The arc elasticity of stock demand is -2.3 when r = .05, and this elasticity rises to -2.8 when r = 0. This is not a large increase but it is sufficient to reduce the coefficient of variation of price from .123 to .117.

What if the government's subsidy had been a direct storage cost subsidy rather than an interest rate subsidy? With a mean price of \$5.00 per bushel, a 25-cent per bushel storage subsidy would cost the government the same as the 5 percentage point interest subsidy that was simulated. The storage subsidy results in essentially the same increase in mean stocks but increases the elasticity of demand for stocks more than the interest rate subsidy does. In the present case the 25-cent storage subsidy increases the elasticity of demand for stocks over the range used above to -3.0. The simulated coefficient of variation of price falls to .1147.

In sum, in the simulated soybean example, a given subsidy payment is about 25 percent more effective in reducing price variability (i.e., reduces the coefficient of variation 25 percent more) when made as a storage payment rather than an interest-rate subsidy. This result is qualitatively robust to alternative assumptions about the elasticity of consumption demand for soybeans, the elasticity of supply and the variability of yields. In all cases the direct subsidy generates more price stabilization per dollar spent than an interest rate subsidy.[2]

Historical U.S. Price Stability

Soybeans have the least governmental intervention in pricing and stockholding of the major U.S. crops, and the soybean price experienced large fluctuations in the 1970s and 1980s. Privately held carryover stocks (measured at the end of each marketing year, on September 1) have during the past 20 years been as low as 60 million bushels or 5 percent of normal production (in 1973) and as high as 26 percent of production (in 1986). The question to be investigated is whether the variability of the soybean price during this period has been influenced by changes in interest rates.

We have monthly data on soybean prices from January 1968 through June 1992 and estimates of stocks at four dates during the year: January 1, April 1, July 1, and September 1.

The last two "quarters" of the year contain two months (July-August) and four months (September-December) because the U.S. soybean marketing year established by the U.S. Department of Agriculture begins on September 1. Thus the September 1 stocks are the carryover from one crop year to the next.

The stocks at the beginning of each quarter constitute the supply available for use within that quarter. The change in the price of soybeans from quarter to quarter is determined by supply changes and by changes in demand conditions. The flexibility of stockholding determines the size of the price effect that a demand shift will cause, and this flexibility as influenced by interest rates is what we want to investigate.

To analyze interest rates effects without attempting to estimate the full structure of the soybean market, which has proven very difficult in past econometric studies, we use the following two-step regression procedure. First we regress quarterly soybean prices on quarterly dummies and time, to remove seasonal effects and trend:

$$P_t = \gamma + \sum_{i=1}^{3} \alpha_i D_i + \gamma_1 T + \gamma_2 T^2 + \varepsilon_t \tag{10}$$

where the D_i are dummies, and T is time in quarters. Because the errors of an OLS regression are serially correlated, with a Durbin-Watson statistic of .89, equation (10) is estimated by GLS using an autocorrelation coefficient of .55.

Second, the absolute values of residuals from equation (10) are regressed on the quarterly stock level and the interest rate on six-month U.S. Treasury bills, along with quarterly dummies and the price:

$$|\hat{\varepsilon}_t| = \beta_0 + \sum_{i=1}^{3} \alpha_i D_i S_t + \beta_1 P_t + \beta_2 R_t + \beta_3 S_t + V_t \tag{11}$$

where $\hat{\varepsilon}$ is the residual from equation (10), R_t is the rate of interest on 6-month U.S. Treasury bills, and S_t is the supply of soybeans at the beginning of the quarter — the inventory carried over from the preceding quarter plus production. Production and inventory data are from the U.S. Department of Agriculture. They assume that a year's production becomes available on September 1 of each year.

Equation (11) is intended to identify effects of interest rates and inventories on price stability, with stability defined as the standard deviation of prices around (seasonally adjusted) trend. The larger the inventories, the less price instability is expected, so β_3 is expected to be negative. For a given level of inventories, we expect a lower interest rate to result in more price instability, so β_2 is expected to be negative. Lower interest rates could have a net effect of reduced price instability if they cause inventory levels to increase sufficiently to offset the effect on the responsiveness of inventories to price changes.

Table 2 shows the estimates of equations (10) and (11) using the quarterly 1968-92 U.S. soybean data. In equation (10), explaining quarterly soybean prices, the estimated quarterly seasonal effects on price are non-significant, but their estimated value indicate lower prices in the three quarters from September through June, with the highest prices in the base period of July-August, which is the end of the marketing year. There is significant quadratic trend in soybean prices—rising in the middle years of the 1968-92 period relative to either end, and with an overall upward trend (prices are not deflated).

Equation (11), explaining the absolute values of the residuals from equation (10), generated a Durbin-Watson statistic of .67 when estimated by ordinary least squares. Accordingly, equation (11) is also estimated using generalized least squares. The results, shown in table 1, indicate that larger inventories reduce price instability, as expected.

As to whether an interest rate subsidy would reduce price instability, the results imply the following. The estimated effect of an interest rate increase is to reduce price variability,

Table 2. GLS Regression coefficients (t ratios) explaining the variability of monthly U.S. soybean prices

Independent variable	Dependent variable: Soybean price (eqn. 10)		Absolute deviation of soybean price from (10) (eqn. 11)	
Intercept	1.80	(4.79)[a]	.395	(1.00)
Sept. - Dec.	-.26	(0.88)	.07	(1.91)
Jan. - March	-.23	(0.75)	.06	(1.70)
April - June	-.12	(0.40)	.04	(1.70)
Inventories			-.09	(1.83)
Time	.16	(10.77)		
$(\text{Time})^2$	-.0013	(8.8)		
Soybean price			.23	(4.67)
Interest rate			-.048	(1.52)
R^2	.618		.474	
df.	91		90	

[a] Absolute value of "t" rates in parentheses.

suggesting that bringing down interest rates would be destabilizing. But the t stochastic is too low to reject the hypothesis of a zero effect. Moreover, there is a complication because of the inventory level. Suppose the interest rate is reduced by .01 (one percentage point). According to the estimate of β_2, this would increase the average deviation of soybean price from trend by 4.8 cents per bushel, ceteris paribus (holding stock levels constant). But the reduction in interest rate would also increase the level of stocks. If stocks increase 100 million bushels, the β_3 coefficient implies the average deviation of soybean price is reduced by 0.9 cents per bushel. Thus, it would require about a 500 million bushel increase in stocks to offset the direct interest-rate effects so that an interest-rate subsidy would stabilize prices. Since mean stocks are about 1 billion bushels, this is a 50 percent increase in stockholding. This is a larger effect than we could reasonably expect an interest rate subsidy to have—in wheat the U.S. paid much larger interest rate subsidies without achieving such a large increase in inventories. Therefore, these regressions indicate an interest rate subsidy might well be destabilizing for U.S. soybean prices. But the statistical evidence is too weak to establish this result against the null hyopthesis of a zero effect.

Conclusions

A higher interest contributes to price stability by increasing the rise in the cost of holding stocks caused by a price rise. Thus, when a price-increasing shocks occurs, more stocks are released, the higher the interest rate. However, it is also the case that more stocks will be released the larger the inventories available, and that higher interest rates reduce the average level of stocks; so we cannot be certain that higher interest rates will reduce price instability. What we can be sure of is that a per-unit subsidy of stockholding will reduce price instability by more than an interest rate subsidy that reduces the cost of stockholding by the same amount. The reason is that the subsidy increases average stocks held without the potentially offsetting reduction in the responsiveness of stockholding that an interest rate decline causes.

Empirical evidence on U.S. soybeans indicates that an interest-rate subsidy would be stabilizing, but a per unit subsidy could reduce the year-to-year standard deviation of price about 25 percent more at the same cost to the government. Statistical evidence on quarterly soybean prices suggests it is possible that higher interest rates have in fact reduced the price effects of random shocks upon the U.S. soybean market.

Footnotes

1. $E(z_t - z_{t-1} = 0)$ means stocks are not expected to accumulate or decumulate indefinitely.

2. The results are more sensitive to alternative assumptions about the storage cost function. In the case of a linear marginal storage cost function, we have $G_{zzz} = 0$; and the demand for stocks, which in this case is almost linear, shifts to the right when the interest rate falls. But stock demand increases more at high prices than at low prices, so stock demand becomes less responsive to price, not more responsive. This generates the result that subsidizing interest rates increases price instability. However, the soybean data do not yield a storage cost function that gives this result.

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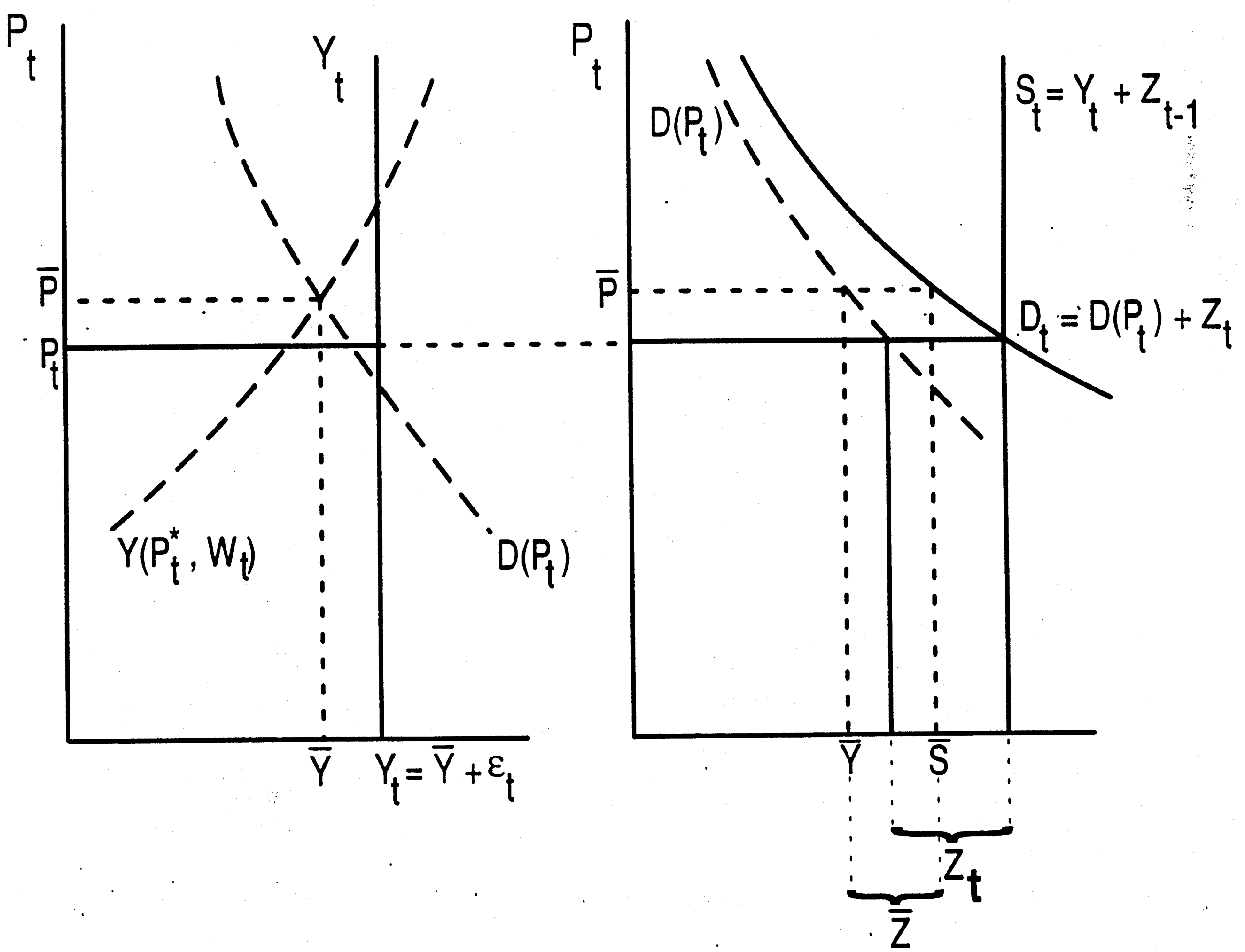
Figure 1.



Annual Consumption and Production Flows

Annual Flows Plus Inventories

Figure 2.

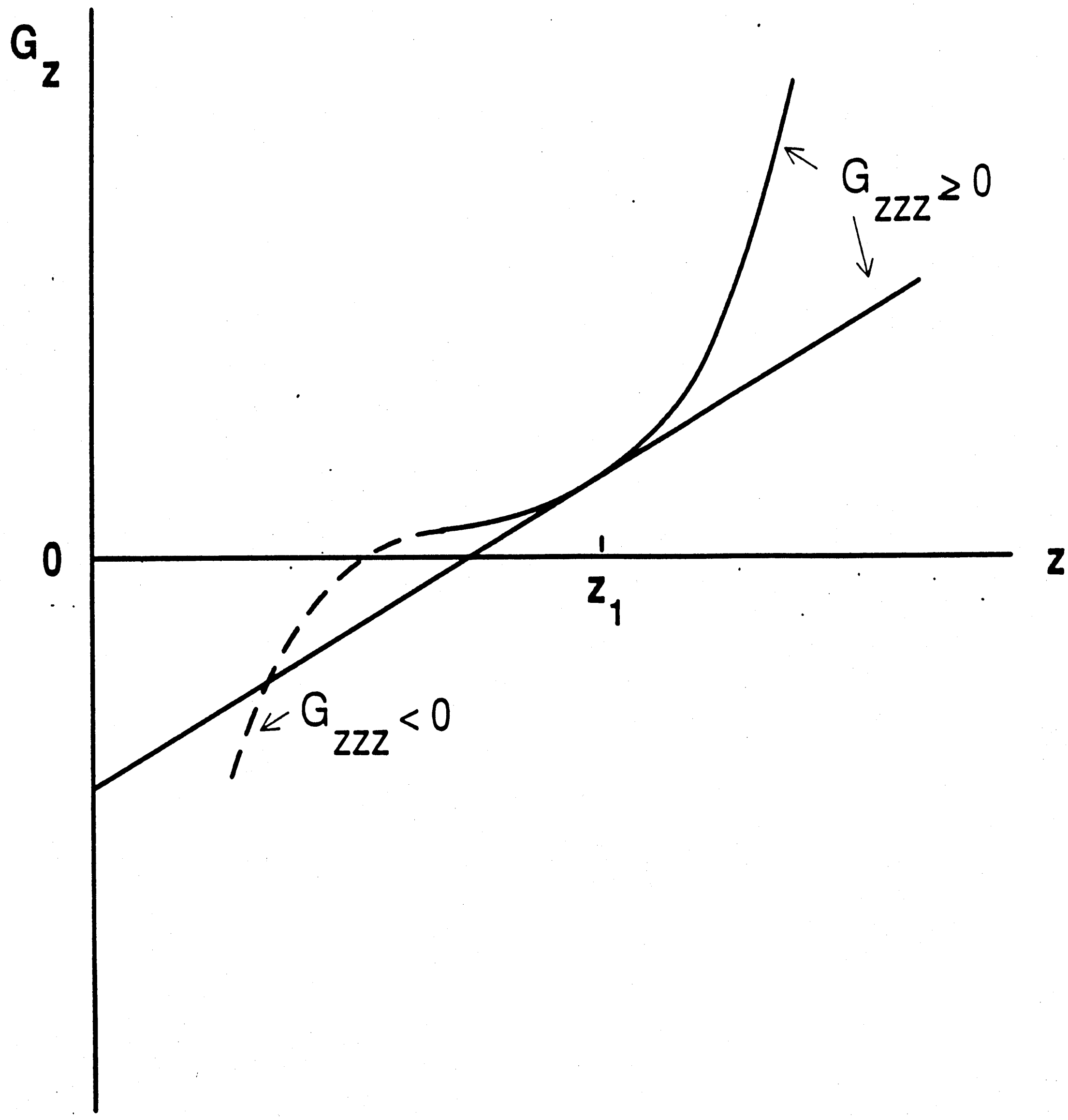


Figure 3. U.S. Soybean Inventory
(Ending Stock Demand)