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The Inefficiency of Interest-Rate Subsidies in Commodity Price Stabilization

Bruce L. Gardner and Ramón López

Interest-rate subsidies have been used to stimulate commodity stockholding, with the intention of stabilizing prices. However, reductions in price variability can be achieved at less government cost using a direct storage subsidy, and it is possible that an interest-rate subsidy will increase price variability even though the interest subsidy increases mean stocks held. These results are demonstrated using a stochastic dynamic programming model of optimal private storage, with parameter values relevant to agricultural commodity markets, and with particular reference to the U.S. soybean market.

Key words: commodity storage, inventories, 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; Glauber, Helmberger, and Miranda; Gardner, chap. 8; Williams and Wright, chap. 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 United States, below-market interest rates, and in some cases interest-free loans, have been provided to farmers who store grain under government programs.

The primary purpose of this paper is to show that interest-rate subsidies are an inefficient means of stabilizing commodity prices. We have two main findings: more stabilization can be achieved at less cost by means of a direct subsidy of storage as compared to a subsidized interest rate; and, it is possible that an interest-rate subsidy causes prices to become less stable than with no policy at all. The issues are examined empirically in the case of U.S. soybeans.

The analysis is carried out in three steps: first, we illustrate our findings about inefficiency in a simple two-state stochastic model of a commodity market with competitive storage; second, we examine the possibility of destabilizing interest-rate subsidies; and third, we elaborate the model to incorporate many-state stochastic output, and storage-cost and supply/demand parameters representative of the U.S. soybean market.

Two-State Model

Consider the simplest model of price stabilization via commodity storage: two random annual production states with nonstochastic demand and a constant cost of storage. Competitive storage equilibrium in this model is characterized by the complementary inequalities:

$$
\begin{aligned}
(1)\quad & \mathrm{E}(p_{t+1}) = (p_t + g_z)(1 + r), \; z_t > 0 \\
& \mathrm{E}(p_{t+1}) \le (p_t + g_z)(1 + r), \; z_t = 0
\end{aligned}
$$

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where $E(p_{t+1})$ is the expected value of price in year $t + 1$, p_t is the price in year t, r is the rate of interest, g_z is the (constant) marginal cost of storing a unit of output from t to $t + 1$, and z_t is the quantity of inventories stored from t to $t + 1$. Relations (1) are a rearrangement of Williams and Wright [equation (2.5), p. 26] and the model is essentially the same as introduced in Williams and Wright (chap. 2) and in Gardner (chap. 2).[1]

The model is closed by the contemporaneous supply-demand equilibrium for each year:

$$(2) \quad z_t = \bar{y}_t - x_t + z_{t-1} + \varepsilon_t, \qquad \varepsilon_t = \pm\varepsilon$$

$$(3) \quad x_t = D(p_t)$$

where $\bar{y}_t$ is expected production, x_t is total use (consumption and exports), $D(p_t)$ is the demand function, and ε is a two-state random error which makes production stochastic.[2]

Even in this simple model it is not possible to solve algebraically for inventories as a function of price or of exogenous variables. We follow Gustafson, and Williams and Wright by specifying $D(p_t)$, g_z, and the frequency distribution of ε numerically and finding z_t as a function of supply ($= y_t + z_{t-1} + \varepsilon_t$) using stochastic dynamic programming. Once z_t is known for given y_t, z_{t-1}, and ε_t, we can calculate x_t from equation (2), then p_t from equation (3), and then $E(p_{t+1})$ from equation (1). A Monte Carlo simulation of ε_t is then carried out over many "years" to estimate price variability.

Consider the following numerical specification: the commodity demand function is $D(p_t) = Ap_t^{-0.9}$, (constant elasticity of demand of -0.9) with A chosen to give $p = 100$ at mean consumption; $y_t = 1{,}000 + \varepsilon_t$, $\varepsilon_t = \pm120$, each sign with probability 1/2; $g_z = 3$ (3% of the price at which mean production of 1,000 is consumed), and $r = 0.10$.

Competitive equilibrium inventory levels as a function of supply available (derived by a DP algorithm available from the authors) are shown in figure 1a, with the implied total demand function (including demand for inventories) in figure 1b.[3] Using this storage rule and inventory demand, a 1,000-year Monte Carlo simulation generated the results shown in table 1. Mean production is 1,000.8—showing that our 1,000 trials did not yield exactly 500 ε_t values of +120 and 500 of −120. Mean carryover stocks are 6.3, which is 0.6% of mean production. Mean price is 101.3 and the variance of price is 161.7.

Now consider price stabilization by means of a subsidy paid to inventory holders. Suppose the government covers all of the (noninterest) costs of storage, so $g_z = 0$ instead of $g_z = 3$. The competitive equilibrium now results in the storage rule and total demand function labeled as "storage-cost subsidy" in figure 1. The 1,000-year production sequence now generates the results shown in the third line of table 1. Mean stocks are 22.6, that is, 2.26% of mean production, more than triple the no-subsidy level. The variance of price is reduced to 124.5. The mean annual cost of the subsidy is 3 × 22.6 = 67.8, which is 0.07% of the mean value of the crop.

Suppose a subsidy of an equal amount per bushel was given in the form of an interest-rate buy-down. This is accomplished with an interest-rate subsidy of 3%, making the interest rate facing inventory holders 7% instead of 10%. The average storage-cost reduction is 100 × 0.03 = 3, per unit stored, the same as for the direct storage-cost subsidy. This policy generates the storage rule and inventory demand labeled "interest subsidy" in figure 1. The 1,000-year production sequence now gives the results shown in the second line of table 1. Mean stocks are 19.9, or 12% less than with the storage-cost subsidy. The variance of price is 129.8. The reduction in price variability is 20% less using the interest-rate subsidy than using the storage-cost subsidy. In this sense, the storage-cost subsidy is a more efficient means of stabilizing prices.

Although the direct storage-cost and interest-rate subsidies cost the same per unit stored, the former results in larger average stocks and therefore has higher annual budget costs. In order to compare the cost-effectiveness of the policies more directly, line 4 of table 1 shows

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[1] Note that there is no risk premium. This can be justified either by assuming storers are risk neutral, or (preferably) that futures markets permit price risks in storage to be eliminated.

[2] While production is perfectly inelastic with respect to price, we will relax this (and other) assumptions later. The additive ε_t means that the same model would apply to fixed supply with stochastic demand.

[3] The "total demand function" expresses p_t as a function of total supply available in period t—production plus beginning stocks—and it incorporate the effects of both current consumption demand and competitive speculative storage. This function is called the "equilibrium price function" in Salant, who makes it, rather than the storage function, the focus of analysis.

Table 1. Competitive Equilibrium in a Simulated Stochastic Market with Inventories

A. Two-State Production with Constant Storage Cost[a]

	Mean Production	Mean Price	Mean Carryover Stocks	Variance of Price	Subsidy per Unit Stored	Mean Gov't Cost of Subsidy
1. Base case (no subsidy)	1000.8	101.3	06.3	161.7	0.0	0
2. Interest-rate subsidy	1000.8	101.0	19.9	129.8	3.0	60
3. Storage-cost subsidy	1000.8	101.0	22.6	124.5	3.0	68
4. Adjusted storage subsidy[b]	1000.8	101.0	19.8	129.8	2.5	49

[a] In all the simulations the two production states are ±12% of mean random, exogenous output, constant-elasticity demand of –0.9. The interest rate is 0.10 in the base case and 0.07 with subsidy. Marginal storage costs are $g_z = 3$.

[b] Storage subsidy reduced such that the variance of price is the same as under the interest-rate subsidy.

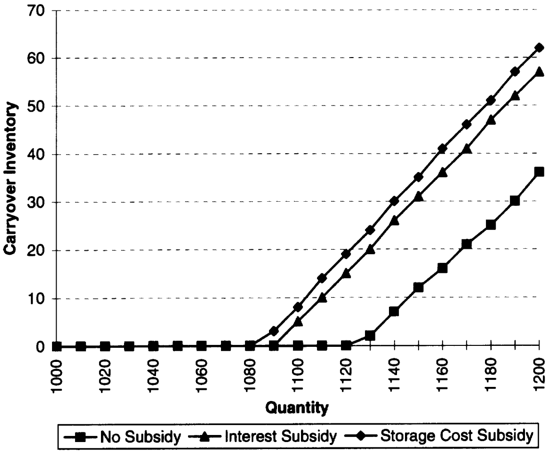

Figure 1a. Storage functions

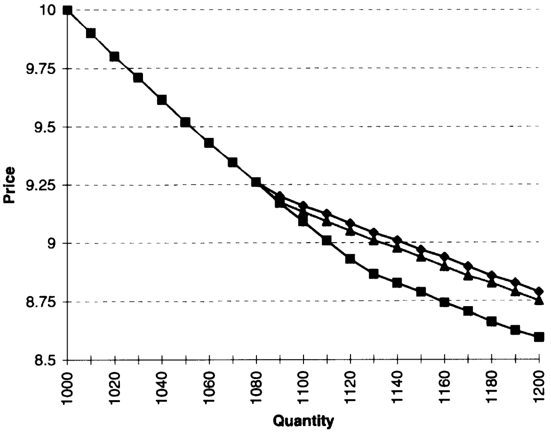

Figure 1b. Total demand

the results of a direct storage-cost subsidy that generates the same price stabilization as the interest-rate subsidy. Thus, line 4 shows the same variance of price as line 2. The subsidy per unit required in line 4 is 2.49, and the government's subsidy expenditure is 49; thus, the same price stabilization is achieved at a 22% higher cost when the interest-rate subsidy is used (comparing lines 2 and 4).

Thus, the direct storage-cost subsidy is about 20% more efficient than the interest-rate subsidy in two senses: obtaining more reduction in price instability for the same per unit subsidy, or obtaining the same reduction in price instability for less budgetary outlay.

Is the inefficiency of interest-rate subsidies a general result or only an artifact of the particular example chosen? Given the lack of an algebraic specification of the model's equilibrium and the consequent lack of analytical results for the variance of price, we cannot provide a proof in the context of the dynamic programming model (even though the result holds in all of many simulations we have carried out).[4] A heuristic argument for the generality of the finding is as follows.

Interest costs for a given quantity of inventories, unlike direct storage costs, increase with the commodity's price. This has two consequences for inventory behavior. First, for a given level of average subsidy, an interest subsidy provides less incentive to acquire stocks in low-price years. Thus, less is placed in inventories in abundant years than under the storage-

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[4] We have derived analytical results for the issues addressed in this paper, including sufficient conditions for an interest-rate subsidy to be price destabilizing in a model of inventories held in continuous time with unexpected shocks in current prices and certainty about future prices (Gardner and López).

cost subsidy (as figure 1 shows). Second, when a price-increasing shock occurs, a high interest rate automatically increases the cost of storage and increases the incentive to release stocks. An interest-rate subsidy blunts this incentive. Thus, while both an interest-rate and storage-cost subsidy increase the demand for inventories, as in the bottom panel of figure 1, a storage-cost subsidy shifts inventory demand further to the right and makes it (slightly) more elastic.

Destabilizing Subsidies

The main departures of the preceding simulations from actual commodity markets are the low average level of carryover stocks and the high frequency of stockouts (carryover levels of zero). Stockouts are a consequence of our assumption that g_z, the marginal cost of storage, is constant and positive, so that carryover stocks are held only when prices are expected to rise.

The convenience-yield theory of negative storage cost implies a more complex marginal storage-cost function. The marginal cost of storage rises with z ($g_{zz} > 0$), but there is a range of low values of z_t over which $g_z < 0$. Also, g_z increases at a decreasing rate ($g_{zzz} < 0$) at low inventory levels but at an increasing rate ($g_{zzz} > 0$) at higher inventory levels (figure 2). It is widely observed that storage occurs when price declines are expected, so convenience yield in some sense exists; but the economic reason for convenience yield is a contentious issue. It makes sense that with stockouts costly, farms would keep inventories for insurance purposes so long as transactions costs in buying from others are not negligible. At the industry level, spatial and temporal heterogeneity in harvests result in substantial stocks existing somewhere in the system even if every firm at some point gets very low on stocks (see, for example, Brennan, Williams, and Wright).

Consider the simplest modification of the two-state model with convenience yield that precludes stockouts, a linear marginal storage-cost function that has a sufficiently large negative value at $z = 0$. Let all the parameter values that generated table 1 remain the same, except that the constant marginal storage cost, $g_z = 3$, is replaced by the linear function, $g_z = -20 + 0.25z_t$. This implies $g_{zz} = 0.25$ and $g_{zzz} = 0$.

Panel A of table 2 shows the effects of the same interest-rate subsidy simulated in table 1. It turns out that indeed the subsidy (slightly) increases the variance of price, even though the subsidy increases mean stocks substantially (by 25% from 4.4 to 5.5% of mean production). This is a surprising result. How can larger average stocks fail to reduce price variability? The reason is that, unlike the table 1 case, convenience yield causes stocks to be held in all states of the market, and holding more stocks on average does not necessarily move us to a more elastic portion of the total demand curve. The total demand curve in figure 1 is more elastic at lower prices because the demand for carryover stocks becomes zero at all prices near or above the mean price. With convenience yield, stocks are held even at prices above the mean price, and what happens to the elasticity of demand depends on the functional form of the inventory demand function. For reasons discussed earlier, a rise in interest rates will tend to increase the elasticity of inventory demand. Thus, an interest-rate subsidy will make the total demand curve less elastic and this will increase the price instability caused by a given series of supply shocks unless marginal storage costs have a functional form that causes the total demand for inventories to become more elastic when inventory levels increase.

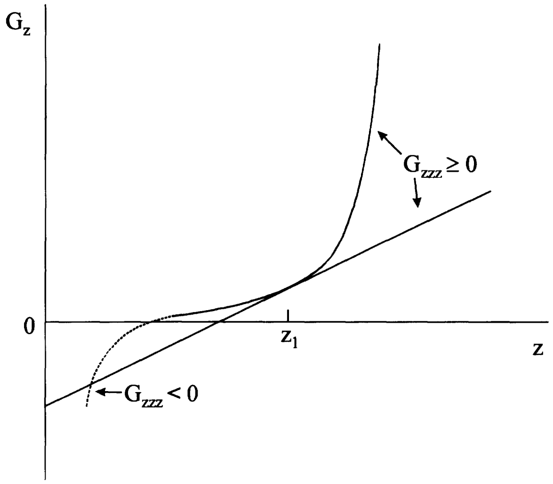

Figure 2. Storage cost function

The most straightforward way to analyze the effects of the storage-cost functional form is to consider marginal cost functions which are everywhere convex or concave rather than linear. In all cases $g_{zz} > 0$; i.e., the marginal cost of storage increases. If g_z increases at an increasing rate, $g_{zzz} > 0$. A specific example is a quadratic marginal cost function, $g_z = -20 + 0.005\, z_t^2$, where $g_{zz} = 0.01 z_t$ and $g_{zzz} = 0.01$. The

Table 2. Price Stabilization Effects of Interest-Rate Subsidies

	Mean Carryover Stocks	Variance of Price
A. Linear storage cost, $g_z = -20 + 0.25z$; $g_{zz} > 0$, $g_{zzz} = 0$		
No subsidy	44.5	73.1
Interest-rate subsidy	54.7	73.5
B. Quadratic storage cost, $g_z = -20 + 0.005z^2$; $g_{zz} > 0$, $g_{zzz} > 0$		
No subsidy	43.5	85.0
Interest-rate subsidy	50.1	88.3
C. Square root storage cost, $g_z = -20 + 5z^{0.5}$; $g_{zz} > 0$, $g_{zzz} < 0$		
No subsidy	9.0	104.9
Interest-rate subsidy	11.3	101.2

results of the 3% interest-rate subsidy are shown in panel B of table 2. With quadratic marginal storage costs, the subsidy causes a substantial increase in price variability. The reason why is apparent from the top diagram of figure 3. The subsidy shifts the total demand curve to the right, but makes it less elastic.

On the other hand, consider the opposite departure from linearity, where $g_{zzz} < 0$. An example is $g_z = -20 + 5z_t^{0.5}$, where $g_{zz} = 2.5z_t^{-0.5}$ and $g_{zzz} = -1.25$. The results of the 3% interest-rate subsidy are shown in panel C of table 2. Even though the interest-rate subsidy increases mean stocks less than in panels A and B, the subsidy has the effect we normally associate with increased storage—a decrease in price variability. The reason for the difference is apparent from the bottom diagram of figure 3. The subsidy shifts the demand for inventories further to the right at low price levels, making total demand more elastic as a result of the subsidy. The only difference between the top and bottom diagrams of figure 3 is the functional form of marginal storage costs.

The type of storage-cost function typically used in the empirical literature is as shown in figure 2, with $g_{zzz} < 0$ at low stock (high price) levels and $g_{zzz} > 0$ at high stock (low price) levels. In order to explore empirically both the inefficiency of an interest-rate subsidy and the possibility that an interest-rate subsidy might actually be destabilizing, we next consider storage cost and other characteristics of the U.S. soybean market.

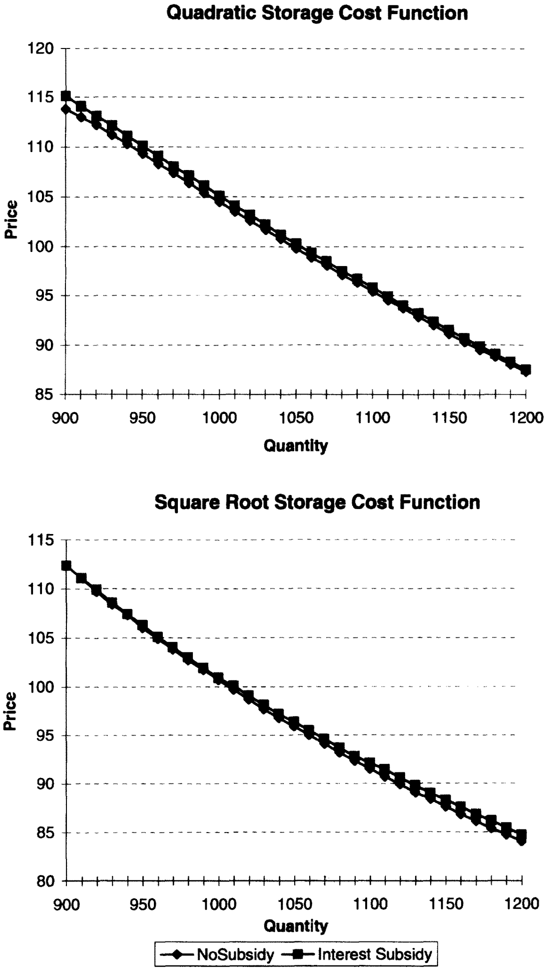

Figure 3. Total demand with alternative storage cost functions

Simulation Using U.S. Soybeans

Expansions of the two-state model to investigate conditions in the U.S. soybean market are as follows: (*a*) a data-based cost of storage function; (*b*) an empirical frequency distribution of production and demand deviations from trend values instead of two production states; (*c*) empirically relevant soybean current-use demand elasticity and interest rate; and, (*d*) instead of perfectly inelastic supply, an estimate of soybean supply response to expected price.

Our previous analysis indicates that the functional form of the storage-cost function is important. Evidence on rental rates for storing soybeans in commercial elevators exists, but is insufficient for our purposes. It seems clear that inventories are held when expected returns to storage are negative, and that for purposes of price stabilization this behavior should be taken into account. We observe substantial carryover stocks in years when new-crop futures prices are at or below old-crop prices. Applying equilibrium condition (1) with $z_t > 0$, assuming that futures prices measure expected market price, we rearrange equation (1) to obtain

$$(4) \qquad m_t - r_t p_t = g_z(z_t)$$

where m_t are year-over-year spreads in future prices as a measure of expected capital gains. We normalize the level of inventories as $\bar{z}_t = z_t / \bar{y}_t$, where $\bar{y}_t$ is the trend level of production. Data (from Chicago Board of Trade *Yearbooks*) are available for m_t and p_t from 1968 through 1992. In the early years, twelve-month ahead futures contracts were not traded. The widest old-crop, new-crop spread continually available is eight months, from July to the following March. We measure this spread using the difference between the March futures price and the preceding July futures price as observed in the last week in June of each year. This measure of m_t ranges from –\$4.97 (in 1973) to \$0.79 (in 1981), with ten of twenty-five years having a negative spread.

To get the dependent variable for equation (4), we use the six-month U.S. Treasury Bond rate for each year in calculating $m_t - r_t p_t$. The resulting adjusted eight-month price spreads between old-crop and new-crop futures are plotted in figure 4. The pattern is very similar to the standard one, e.g., as in Miranda and Glauber (p. 464); but the question arises with respect to these data, as is often the case in agricultural commodities, of why so much storage takes place in the face of apparently negative expected gains.

To estimate the functional form of $g_z(z)$, we fit linear, quadratic, cubic, and higher-order polynomials. The F-tests on the residuals indicate significant improvements in fit through the fifth degree polynomial. However, a problem that arises with all the polynomials is that they contain ranges of z over which g_z is falling. Since a falling marginal cost of storage, i.e., increasing returns to scale over a limited range of z, is counterintuitive and not called for by the data of figure 4, we estimated spline functions that maintain $g_{zz} > 0$. The best fit is a cubic specification from $z = 0$ up to $z = 0.15$ where $\hat{g}_z$ takes on its maximum value of \$0.1064, with $\hat{g}_z$ constant at \$0.1064 for $z > 0.15$. The cubic equation is

$$(5)$$

$$\begin{array}{llllll} \hat{g}_z = & -6.9 + & 120z_t - & 659\, z_t^2 + & 1{,}136\, z_t^3, & z \leq 0.15 \\ & (3.9) & (2.9) & (2.3) & (1.9) & \end{array}$$

where $\hat{g}_z = m_t - r_t p_t$, and t-statistics are in parenthesis. This is plotted in figure 4.

Note that the cubic specification implies

$$(6) \qquad \hat{g}_{zz} = 120 - 1{,}318z + 3{,}408z^2$$

$$(7) \qquad \hat{g}_{zzz} = -1{,}318 + 6{,}816z.$$

Thus, $g_{zzz} < 0$ when $z < 0.193$, which covers the range of z (0 to 0.15) for which the cubic equation is used. The functional form thus has the qualitative characteristics $g_{zzz} < 0$ as in panel C of table 2—that is, most favorable to the effectiveness of an interest-rate subsidy for stabilization purposes.

Turning to other features of the U.S. soybean situation, using deviations of yield and export demand around trend in 1968–92 data, we find a coefficient of variation of excess supply (supply shock minus demand shock divided by trend production) of 0.084. Using either the chi-square or Komolgorov-Smirnoff test, normality is accepted at the 5% level, so we assume that the annual shocks are normally distributed. We also assume that shocks are serially independent.

With respect to soybean demand and supply elasticities, econometric evidence indicates that U.S. soybeans are less elastic in short-run (annual) demand and more elastic in supply than in the table 1 simulations. We use the recent estimates of Miranda and Glauber of an elasticity of demand of –0.5 and of supply (in response to expected price) of 0.5.

The dynamic programming algorithm used earlier can be easily modified to incorporate the normal distribution of shocks and an elasticity of demand of –0.5. Incorporating supply response is more complicated, because supply responds to expected price and thus interacts with stockholding behavior in a more complex way. (The algorithm used here is available from the authors).

The results of simulations of competitive storage under the U.S. soybean parameter values are shown in table 3. The coefficient of variation of production is slightly different from the direct effect of random shocks because production adjusts to expected price—falling after low-price, high-carryover years, and rising

Table 3. Simulated U.S. Soybean Market with Competitive Storage, 1,000 Harvests

	Mean Carryover Stock as % of Prod.	Mean Cost of Subsidy	Variance of Market Price	Elasticity of Stock Demand
A. Base case[a]	0.113	0.0	123.0	-2.30
Storage subsidy (3.0)	0.130	3.92	97.9	-2.69
Interest subsidy (0.030)	0.129	3.88	100.4	-2.56
Interest subsidy	0.132	4.35	97.9	-2.62
B. Less-elastic case[b]	0.144	0.0	256.7	-2.38
Storage subsidy (3.0)	0.158	4.74	190.7	-2.65
Interest subsidy (0.0334)	0.160	5.34	190.7	-2.59
C. Storage capacity case[c]	0.102	0.0	154.6	-1.93
Interest subsidy (0.030)	0.107	3.4	156.2	-1.80
Storage subsidy (3.0)	0.107	3.21	154.5	-1.80
D. Linear demand[d]	0.106	0.0	121.7	-2.18
Storage subsidy (3.0)	0.118	3.55	102.4	-2.49
Interest subsidy (0.034)	0.119	4.05	102.4	-2.44

[a] Demand elasticity, –0.5; supply elasticity 0.5; interest rate 0.08; c.v. of random shocks, 0.084.

[b] Demand elasticity, –0.3, supply elasticity, 0.4; c.v. of shocks, 0.090.

[c] Parameters the same as in panel A, but marginal storage-cost function modified such that $g_{zzz} > 0$, at $z > 0.13$.

[d] Parameters the same as in panel A, but consumption demand is linear, with elasticity of –0.5 only at mean.

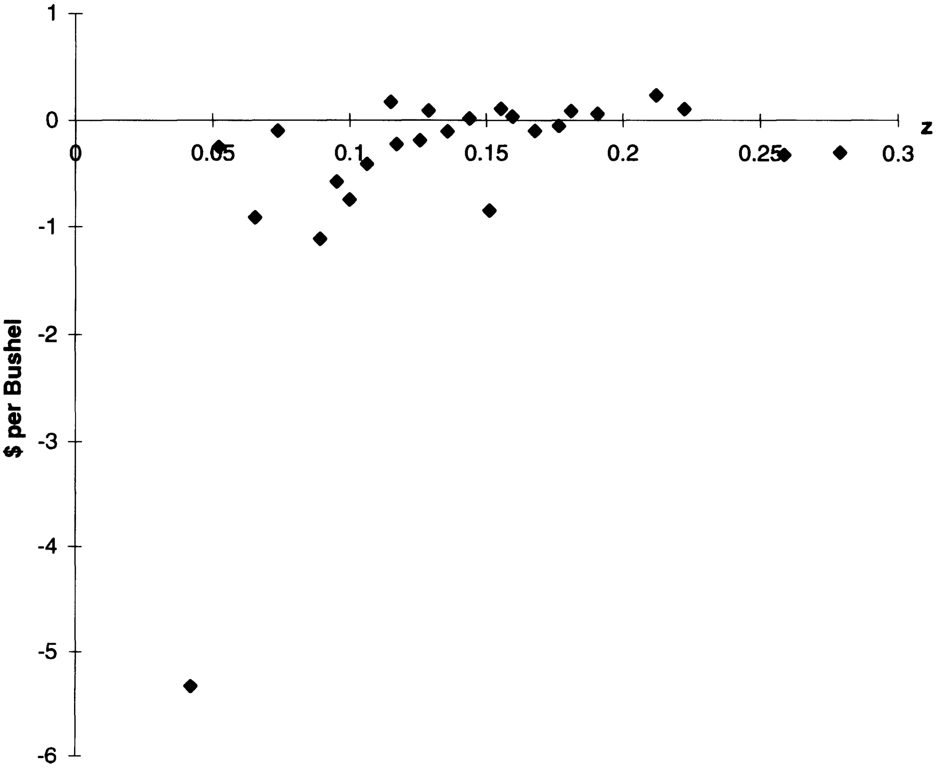

Figure 4. Adjusted soybean futures spreads

after high-price, low-carryover years. The mean carryover level is increased by either an interest-rate or direct storage-cost subsidy, but the increase is slightly larger for the direct subsidy. The variance of price is reduced by the interest-rate subsidy, but is reduced more by a direct subsidy (as shown in the third line of panel A), than by an interest-rate subsidy that averages the same amount (3% of mean price). The underlying reason for this, as shown in the right-hand column of table 3, is while both subsidies increase the elasticity of demand for carryover stocks as a function of current price, the interest-rate subsidy increases the elasticity by a smaller amount. To estimate the inefficiency of the interest-rate subsidy, the fourth line of panel A increases the interest-rate subsidy sufficiently to achieve the same variance of price as the direct storage subsidy. The subsidy-required 3.3% involves average government subsidy costs 11% higher than the direct subsidy (4.35 compared to 3.92). Thus we can say that, given the U.S. soybean market parameters, a direct storage subsidy is 11% more efficient than an interest-rate subsidy in the sense that a given reduction in price can be achieved at 11% less government cost when the storage subsidy is used.

Actual U.S. soybean stocks during 1968–92 averaged 14% of trend production, while the actual coefficient of variation (c.v.) of the U.S. soybean price in this period was 0.25. The simulated "base case" mean stocks are fairly close to the actual mean, but the actual c.v. of price is about twice the simulated price variability (i.e., a c.v. of 0.11). To obtain more price variability in the simulations, demand and supply can be less elastic, and random shocks can be larger. For purposes of comparison with the base case, panel B of table 3 shows results for a supply elasticity of 0.4, demand elasticity of –0.3, and coefficient of variation of excess supply of 0.09. These changes make a substantial difference in the variance of price, bringing it much closer to its observed values. The relative inefficiency of an interest-rate subsidy is similar, however. A direct storage-cost subsidy equal to 3% of the mean market price reduces the variance of price from 256.7 to 190.7. An interest-rate subsidy to achieve the same reduction in price variance costs 13% more.

The simulations do not permit investigation of the interesting case where $g_{zzz} > 0$ because the figure 4 soybean data do not indicate g_z rising at an increasing rate as carryover stocks become large. It is nonetheless plausible that there exists an upper limit on storage capacity, or at least more rapidly increasing storage costs at some high level of stocks. To explore this possibility, we modified the storage-cost function to let g_z rise according to a quadratic function above a stock level of 13% of mean production. This generates a storage-cost function of the same shape as figure 2, roughly tuned to the U.S. soybean situation. The results, keeping all other parameters the same as in the base case of panel A, are shown in panel C of table 3. Here we do have a case where an interest-rate subsidy makes the demand for carryover stocks less elastic, and increases the variability of market price. (Note that the direct storage subsidy is also ineffective in this case.) This illustrates again that the effects of price stabilization policies are quite sensitive to the functional form ($g_{zzz} \gtrless 0$) of the storage-cost function.[5] But the interest-rate subsidy is an inefficient stabilization mechanism, relative to a direct storage-cost subsidy, in all cases.

Since the functional form of storage costs is so important, it may be that the functional form of demand for current consumption also makes a difference. To explore this possibility, the base case of panel A in table 3 was reestimated, replacing the constant-elasticity demand function with a linear demand function having the same elasticity at mean production. The results are shown in panel D. Linear demand causes slightly less stocks to be held in all scenarios, probably because the prospects for high prices under short crops are not so great (since the elasticity of demand increases with price under linear demand). The relative inefficiency of the interest rate as a stabilization tool remains about the same, however. The second and third lines of panel D indicate that it costs 14% more to achieve the variance of price of 102.4 using an interest-rate subsidy, compared to a direct storage-cost subsidy.

Conclusions

The literature on competitive storage and on optimal public policy for price stabilization has found that public buffer-stock and related inventory management programs tend to be inefficient, and that subsidizing private storage is a more promising approach. We find, however,

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[5] The fact that storage capacity constraints are inimical to price stabilization through either interest-rate or storage-cost subsidies suggests that subsidies for building storage facilities (which the United States has had in the past) might be more efficient than either storage-cost or interest subsidies. However, the data for U.S. soybeans shows no evidence of a storage capacity constraint.

that it makes a difference whether such a subsidy is directly paid on storage costs or takes the form of subsidized interest rates for inventory holders (as it has in the United States and other countries). We find that, for purposes of stabilizing market prices, not only is an interest-rate subsidy less efficient, but it can even destabilize prices. The effects of interest rates on inventory behavior turn out to depend importantly on the form of the storage-cost function, in particular on whether the rate of increase in the marginal storage-cost function is increasing or decreasing with the inventory level ($g_{zzz} \gtrless 0$ in our notation).[6] In simulations intended to be representative of the U.S. soybean market, an interest-rate subsidy is stabilizing, but less so than a direct storage subsidy of equal cost.

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[6] In the circumstances under which an interest-rate subsidy destabilizes price, it is nonetheless true that the subsidy increases the mean level of stocks held. In this sense the subsidy increases speculative activities in the market. The question arises as to how this result bears on the longstanding issue of whether profitable speculative activity is price stabilizing. The literature on this issue focuses on comparing markets having speculative activity with the same markets in the absence of speculative activity (e.g., Hart and Kreps). Our results indicate that more speculation (in the sense of more stockholding) can generate less stabilization than less speculation, but this does not imply that subsidized storage can generate less-stable prices than no storage. The reason we find more stocks causing less stabilization under an interest-rate subsidy is that the lower interest rate causes stocks to be managed less flexibly in response to price changes. With no stocks, their management is, by construction, perfectly inflexible; so our results could not imply that stockholding caused by an interest subsidy would generate less stability than no stocks.