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A STOCHASTIC THEORY OF PRICE SUPPORTS

Frederick I. Johnson

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A STOCHASTIC THEORY OF PRICE SUPPORTS *

Price supports have played a major role in U.S. agricultural policy since 1929. During World War II commodity price supports became commonplace, and have since remained a key policy instrument. The first part of this paper sets out a theoretical analysis of a price support program and its impact on production, market prices, and net producer prices. In particular, the analysis shows that, when price is stochastic, a support program will alter market equilibrium even when the support price is below the expected price. The second part of the paper measures the impact of price supports on the market for oats.

1. A Theory of Price Supports

It is well known that price supports encourage expanded production. Researchers have quantified the impact of price supports in several ways. The most common has been simply to include the support price as an explanatory variable in the supply relation. The (own) price determinants of supply are then (i) lagged own price and (ii) the announced support price. For a linear specification of supply this approach effectively treats expected price as a linear combination of lagged price and the support price.

If the price of a commodity is stochastic, supports will alter its distribution.[1] A support price simply prevents price from falling below a given level. Equivalently, it imposes a lower bound on the range of prices, which, *ceteris paribus*, raises expected price. This is illustrated in Figure 1, where

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the introduction of a support price (ϕ) increases the producer's expectation of the price which he will receive (EPP) to a level above the initial expected market-clearing price (EMP). The net impact of the support price on market price and production can be inferred by analyzing how this lower bound changes the equilibrium of anticipated supply and anticipated demand.

FIGURE 1

Because it takes time to grow and harvest crops, determination of how much to produce will depend on _expected_ price rather than actual price. Consequently, we use an _ex ante_ model of supply and demand to infer the impact of price supports on production: demand is _anticipated_ demand, supply is _anticipated_ supply. Equilibrium in this model is characterized by expected price and expected quantity. We assume that there is a reasonably efficient forward or futures market which generates a common expected market price for the commodity.

If only one producer is granted a price support, the impact of his expanded production on market equilibrium will be negligible. However, if all producers of the commodity receive the support, then we must take account of the change in equilibrium. For expositional purposes we first examine the single producer case in order to determine the basic relationship between the price the producer can expect to receive, the support price, and the expected market price. We then look at the case where all producers receive the support. The functional relationship between these three prices continues to hold, but the analysis is made more complex because of the simultaneous adjustment of these prices together with production.

a. Price Supports for a Single Producer

We take it as given that price is stochastic, and we envision the source of the randomness as uncertainty in the positions of the underlying supply and demand curves. This uncertainty may stem both from the unpredictabilty of certain events (such as rainfall, pestilence, and disease) and from imperfect estimates of the the supply and demand functions. Clearly, actual price will not be known in advance, but it can be assumed to follow some known distribution $f(\cdot)$. The <u>ex ante</u> market clearing price EMP is then the mean of the distribution $f(\cdot)$.[2] Formally,

$$(1) \quad EMP = \int_{-\infty}^{\infty} z\, f(z)\, dz$$

Now suppose that a <u>single</u> competitive agent is guaranteed a support price ϕ . Since the actions of a single agent are too insignificant to have any measurable impact on the market, the overall distribution of market price $f(\cdot)$ is unchanged, but the expected producer price EPP (the price, including support, which the agent expects to receive) is the mean of the distribution $f(.)$ truncated at the support price, and is given by:

$$(2) \quad EPP = \phi \int_{-\infty}^{\phi} f(z)\, dz \; + \; \int_{\phi}^{\infty} z\, f(z)\, dz$$

In particular, for $f(\cdot)$ normal with mean EMP and standard deviation σ :

$$\text{(3)} \quad EPP = EMP + (\phi - EMP)G\left(\frac{\phi - EMP}{\sigma}\right) + g\left(\frac{\phi - EMP}{\sigma}\right)$$

$$= T(EMP, \phi, \sigma)$$

where g(·) is the standard normal density and G(·) is the normal cumulative density function.3 The mean of the truncated distribution therefore can be computed from the moments of the underlying distribution and the value of the support price.

Notice that, as should be expected,

$$\text{(4)} \quad \frac{\partial EPP}{\partial \phi} = \int_{-\infty}^{\phi} f(z)\, dz > 0$$

so increasing the support price increases the expected producer price. This is true even when the support price is less than EMP. Also,

$$\text{(5)} \quad \lim_{\phi \to -\infty} EPP = EMP$$

so when there is no support EPP collapses to EMP. Finally, increasing the support price relative to EMP decreases the variance of the producer price. (The variance of the market price remains unchanged.)

In short, establishing a support price both raises expected producer price EPP and reduces the variance of the producer price. If the producer is risk-averse or risk-neutral, (and possibly even if he is a risk-seeker) the support price induces greater production. This holds even if the support price is less than the expected market price EMP (as is the case in Figure 1).

b. Price Supports for all Producers

Now consider the situation in which all producers of the commodity (call it x) face the support price ϕ. We have seen that the price support will lead a producer to expect a higher price for his output. In the aggregate, the response of all producers to the support price clearly must alter the market equilibrium. Just how this equilibrium changes will depend on how the support operations are carried out.

There are three basic ways in which prices can be supported. The first is essentially subsidization. The supporting agency pays the producer the support price but then releases the good back to the market. This depresses market price, and producers receive a higher price than consumers pay. Equivalently, the agency purchases surpluses but does not release them to the market immediately. If the market expects the agency to release the good eventually (and if agency stocks do not exceed what private stocks would have been), then the agency's inventories will simply displace private inventories. Again, producers will receive a higher price than consumers pay. Therefore, the timing of the release of agency stocks is immaterial.

The second type of policy is augmenting demand. Here, the supporting agency in effect creates an autonomous demand for the good. By purchasing the good and then disposing of it outside the "usual" market, through such programs as Food for Peace, P.L.480, and school lunches, the domestic price can be maintained at an artificially high level. Under this type of policy both buyers and producers face the same "high" price. (In practice, a demand augmenting program will likely displace some private sales, and therefore will have some effect on commercial markets, thereby driving a slight wedge between EMP and EPP.)

Third is a policy of supply reduction, and this is implemented through steps such as acreage restrictions and production quotas. Such a policy differs from a "pure" price support program in that it impacts production decisions through means other than net output price. As such, it is an adjunct to a price support program, and we defer consideration of it.

How, then, does the support price alter market equilibrium? Essentially, as the support price is introduced, producers face a higher expected price and consequently expand production. As production expands, the distribution of the market price f(•) shifts. We assume that the variance of the price is not affected by changes in the expected (mean) price. (The mean and the variance will be independent, for example, when quantity demanded and quantity supplied are both linear functions of price and of their respective error terms. If the error terms are normally distributed and independent of the exogenous variables, it follows that price is also normally distributed, and that while changes in exogenous variables will shift the mean, the variance will remain unchanged.) Formally, the relation between the initial and final price distributions is given by:

(6) $$f_{new}(z) = f_{old}(z-k)$$

for some constant k.

FIGURE 2

Market adjustment to a "subsidy" price support program is illustrated in Figure 2. The initial market equilibrium is given by (EMP_{old}, x_{old}). A price support program is now introduced. If only one producer receives the support, equilibrium is not affected (although the one producer would anticipate price EPP_{old}, based on the market price EMP_{old}, and expand his own production accordingly). However, when all producers are eligible for the support, production expands by enough to alter the equilibrium. The new equilibrium requires that:

(i) EMP_{new} lies on the demand curve;

(ii) EPP_{new} lies on the supply curve; and

(iii) the functional relation between EPP_{new} and EMP_{new}, given in equation (3), holds.

The difference between the two prices (EPP_{new} - EMP_{new}) is the per unit cost which the supporting agency can expect to bear: that is, it is the expected per unit subsidy.

The effect of a "demand augmentation" program is similar. The only difference is that consumers will pay more and purchase less. Because the agency is removing the good from the "usual" market, rather than reselling it at a lower price, a single price will prevail in the market, the price EPP_{new}. The total expected purchases under either the subsidy scheme or the demand augmentation scheme will be the same, but in the latter case some of the output (the difference between the quantity x_{new} and the quantity demanded at the price EPP_{new}) is permanently removed from the "usual" market. (In the subsidization case, all production x_{new} is sold on the usual market, at price EMP_{new}.)

This theory provides a basis for predicting how a market will respond to a change in a price support program. In the second part of this paper we will assess the impact that price supports have had on the oats market by projecting prices and production in the absence of price supports. We note that the support program is best characterized as "subsidization" rather than "demand augmentation." The effects of removing the supports can be inferred by working through Figure 2 (with the chronology reversed). Variables with the subscript "new" represent the equilibrium given the support program, which in this case is the initial situation. EMP_{new} and the support price are known, the variance can be calculated,[4] and EPP_{new} can be calculated in turn from equation (3). Estimates of demand and supply elasticities then enable us to infer the price (EMP_{old}) and production (x_{old}) which would have prevailed in the absence of price supports.

c. Implications for Policy

The primary implication of this theory of price supports is that establishing a support price will alter market equilibrium, even if the support price is less than the expected price (although clearly a very low support price will have a negligible effect). Production expands, the producer price rises, and market price may rise or fall according to the manner in which the supporting agency disposes of its acquisitions. This result contradicts the implications of the nonstochastic approach, which predicts that price supports will affect prices and production only when the realized price falls below the support price.

By extension, the resulting rise in production drives down the market price, requiring that support operations be carried out with a greater frequency than might have been anticipated on the basis of the pre-support price distribution. Consequently, a support program may prove to be more expensive than anticipated.

Finally, because the support price only comes into play when prices are low, payments to producers may be concentrated in those periods when they are most needed. However, since low prices are correlated with large crops, it is not clear that a price support program will, on balance, reduce fluctuations in farm income.

2. Market Impact of Price Supports for Oats

We now turn our attention to the effect that price supports have had on the price and production of a particular crop. We have selected oats for several reasons. First, oats are an important crop, accounting for some 5 percent of the feedgrain market. Second, while prices of all major feedgrains have been supported in the postwar period, acreage of all but oats has been restricted.[5] By choosing oats we hope to isolate the impact of "pure" price supports. And third, futures contracts in oats have been traded throughout the postwar years, and this allows a ready data source for expected market price (EMP).

Support operations for oats have been predominantly of the "subsidy" type. Overall, some 80 percent of disposals of CCC oats have been commercial dollar sales. This means that the expected producer price EPP will be higher than the expected market price EMP, as discussed above.

The impact of the price support program for oats can be measured by comparing actual prices and production with those which would have obtained absent price supports. Actual prices and production are, of course, known. Prices and production at the unsupported equilibrium can be inferred following the procedure outlined in Section 1b above. The first step is to calculate the spread between EPP and EMP. The next step is to use estimates of the price elasticities of supply and demand to infer what price would have prevailed and how much would have been produced in the absence of price supports.[6]

We use the futures price, adjusted for systematic bias,[7] as a measure of EMP. Since the price is supported through a "subsidy" support program, EMP and EPP diverge. As shown above, EPP can be computed directly from EMP, the support price, and the standard deviation.[8] (The standard deviation is estimated from the difference of the futures price and the spot price.[9])

TABLE 1

Values of EMP, the support price, and EPP are shown in Table 1. By construction, EPP is at least as great as EMP. As the support price increases relative to EMP, the divergence between EPP and EMP increases. The table shows that, on average, EPP exceeded EMP by approximately 8 percent during the period from 1946 through 1978.

These estimates of EMP and EPP, together with price elasticities of supply and demand, allow us to infer how production and prices would have differed had price not been supported. We simulated changes in EMP, EPP and production under the assumption that the elasticity of supply is between 0.2 and 0.3, and that the elasticity of demand is between 0.8 and 1.0.[10] The average change in each of these three variables (for the years 1945-1977) resulting from the removal of supports were:

EMP:	increased, by	1.3	to	2.1	percent
EPP:	decreased, by	5.7	to	6.5	percent
PRODUCTION:	decreased, by	1.2	to	1.7	percent

Two points should be stressed. First, these figures represent average changes for the entire period. In some years our simulations show expected production falling by as much as 5 percent, and in other years not changing at all. Second, these simulations are for the removal of the oat support program alone. Support programs for other crops undoubtedly have had a significant impact on the oats market. Cancellation of all support programs would presumably result in smaller changes in oat production than our results suggest.

3. Conclusions

The primary objective of this study was to assess the impact of price support policy on a single crop. To this end, we developed a theory of how price supports affect private expectations and market equilibrium. The primary implication of this theory was that price supports lead to expanded production even when the support price is below the anticipated market price. We then applied this theory to the post-war oats market. Our simulations suggested that there was a divergence of about 8 percent between the expected market price and the net price that farmers could expect. Because of the price supports, farmers received a price that was roughly 6 percent higher than they could otherwise have expected, and expanded their production 1 to 2 percent. Buyers paid 1 to 2 percent less than otherwise.

FOOTNOTES

1. Two articles, one by Gallagher and one by Just, recognize that price supports will alter the distribution of prices. Gallagher dichotomizes the market into "weak" and "strong" demand, in which the dominant price is, respectively, the support price and the lagged price. Whichever is the dominant price for that period is then used in the estimation of supply. Just circumvents the issue, arguing that "linearizing" price supports will not be "disastrous."

2. Strictly speaking, for the ex ante market clearing price to equal the expected price, two assumptions should be satisfied. First, all agents must have the same perception of $f(\cdot)$ if the concept of a common expectation is to be meaningful. Second, agents must be risk neutral.

3. For a derivation of equation (3), see Tobin.

4. The variance can be computed from var(EMP - P), where P is the price which actually obtains. This procedure requires the assumption that the variance (in real or nominal terms, as the case may be) is constant over time.

5. For more background on oats and their role in the agricultural economy, see Ryan and Abel, Mienken, and Womack.

6. In an earlier paper (Johnson) we estimated these elasticities by fitting the simultaneous model. While the supply estimates were quite satisfactory, the estimates of the inventory and demand relations were not convincing. Consequently, we use borrowed estimates of the elasticities in our simulations.

7. We assume that farmers form unbiased predictions of future price. We therefore ascribe any systematic bias to the difference between the local price and the Chicago price. We cannot compute the bias directly because the crop prices reported by the USDA include support payments to farmers. We therefore iterate our calculations of EPP for different values of bias (and hence of EMP) until we satisfy the condition that (SUM) EPP = (SUM) CROP PRICES.

8. $T(\cdot)$ is so defined under the assumption of normality. This assumption was not rejected by a Kolmogorov-Smirnov test at a 5 percent significance level.

9. σ^2 = var(Futures Price - Spot Price). Furtures prices are for September oats. The average Chicago closing price for the first four Mondays in March is used. Spot prices are average (weighted) prices for the crop year beginning in July (Minneapolis #2 white oats). All prices are deflated by the 1972 GNP deflator.

10. Womack (pp 86 and 45, respectively) cites a supply elasticity of 0.24 and demand elasticities of 0.8 and 0.9. Elsewhere (Johnson, pp 25-26) we have estimated a supply elasticity of 0.20. Mienken (pp 4, 29, 64) suggests that the elasticity of demand is close to 1.0.

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TABLE 1

EMP, EPP, and Support Price, 1946-1978 ($ 1972)

YEAR	EMP*	SUPPORT PRICE	EPP
1946	1.70	1.205	1.70
1947	1.49	1.268	1.50
1948	1.50	1.318	1.52
1949	1.05	1.312	1.32
1950	1.09	1.325	1.34
1951	1.39	1.257	1.43
1952	1.34	1.345	1.42
1953	1.21	1.358	1.39
1954	1.20	1.323	1.36
1955	1.00	1.000	1.08
1956	0.94	1.033	1.08
1957	0.92	0.938	1.02
1958	0.86	0.923	0.98
1959	0.85	0.741	0.89
1960	0.93	0.728	0.95
1961	0.90	0.895	0.98
1962	0.91	0.878	0.98
1963	0.87	0.908	0.97
1964	0.84	0.894	0.95
1965	0.81	0.808	0.89
1966	0.81	0.781	0.88
1967	0.85	0.797	0.91
1968	0.78	0.763	0.86
1969	0.65	0.727	0.78
1970	0.60	0.689	0.74
1971	0.65	0.563	0.70
1972	0.58	0.540	0.65
1973	0.69	0.511	0.69
1974	1.20	0.470	1.20
1975	0.95	0.430	0.95
1976	1.05	0.545	1.05
1977	1.04	0.737	1.04
1978	0.86	0.686	0.89

* EMP is set equal to the ~~support~~ futures price, less 9 cents. See footnotes 7 and 9.

FIGURE 1: SUPPORT PRICE RAISES EXPECTED PRICE FROM EMP TO EPP

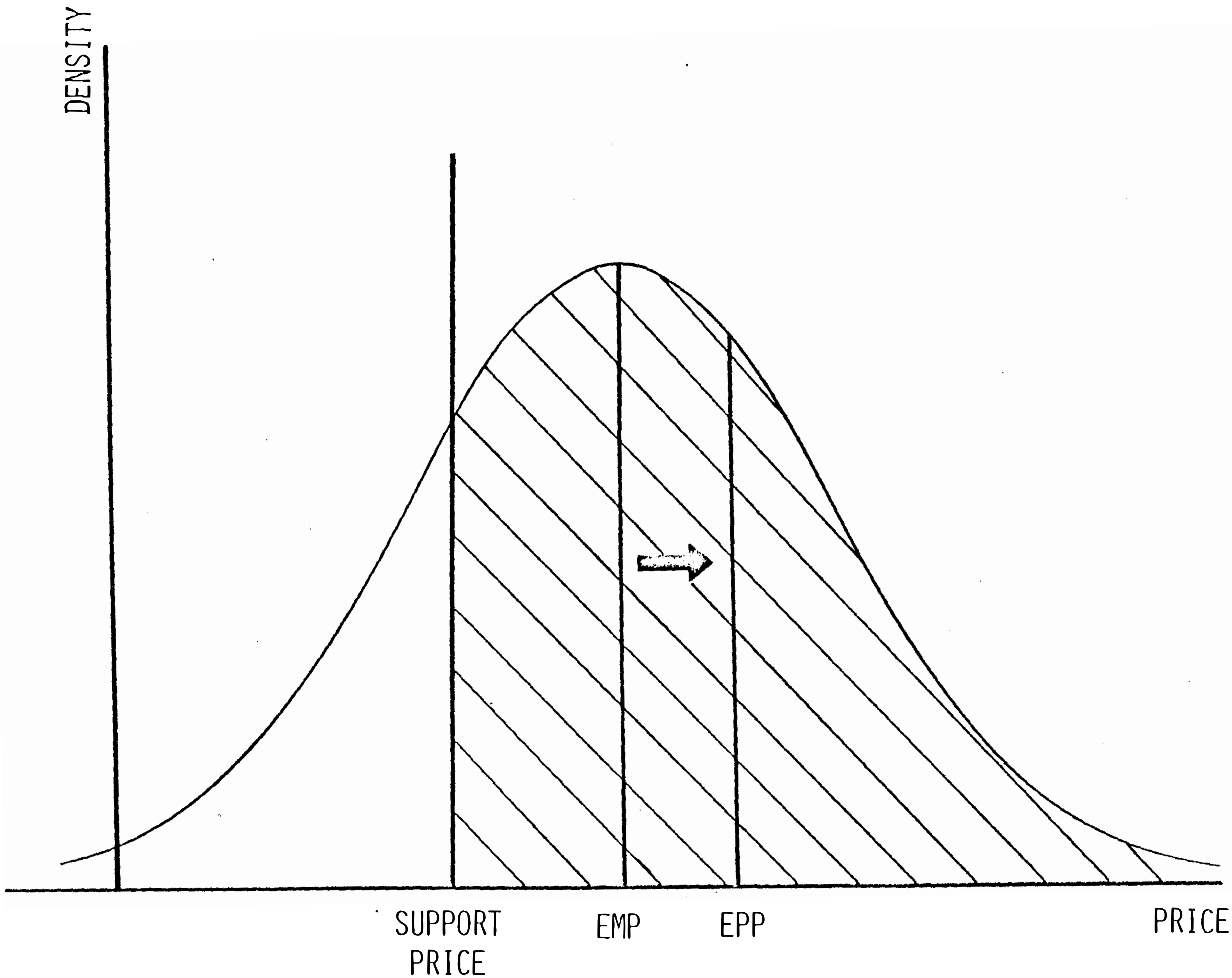

FIGURE 2: MARKET RESPONSE TO PRICE SUPPORTS