Risk

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Abstract

A standard model of behaviour under uncertainty is used to suggest price interaction (risk) terms for use in a positive supply study. Linearity is assumed and O.L.S. used. The risk terms greatly improve the statistical fit of the Pinto bean supply response, are quantitatively important and a substantial bias occurs if they are neglected.

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Timothy J. Ryan is a graduate student in the Department of Agricultural and Applied Economics at the University of Minnesota. He graduated with a B. Agr. Sc. in 1969 and a M. Agr. Sc. in 1972 from Melbourne University, Australia. He was an Agricultural Economics Officer in the Victorian Department of Agriculture and was given leave in August 1975 to undertake a Ph.D. programme at the University of Minnesota. In 1974, he was awarded the Prize Essay competition by the Agricultural Economics Society (U.K.) for his article on a simulation model of a beef feedlot. At the University of Minnesota he is under the guidance of Professor James P. Houck.

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Introduction

This article demonstrates the empirical importance of price risk in an aggregate supply equation. Just (1975, p. 836) in a recent overview of risk response models, contends that the implications of risk for positive response studies have been seriously neglected. He (p. 840) further observes that risk has been shown to be of empirical importance only at relatively disaggregated levels. In this study a U.S. supply equation for Pinto beans is presented. The empirical results show that the omission of the risk variables would result in a serious bias in the supply elasticity.

The specifications of the risk variables are derived from a simple model of behaviour under uncertainty. This model reveals that interaction terms between prices, price variances and covariances of the crop of interest and competing crops should be included in the supply equation. The inclusion of these interaction terms stands in contrast to the traditional approach of specifying risk as the standard deviation of crop price. The equation was assumed linear in the variables and estimated with O.L.S. Behrman and Just (1974), two prominent workers in the incorporation of risk into supply response, both employed more computationally burdensome nonlinear estimation procedures.

The work of Behrman was concerned with the supply response of four major annual crops on small agricultural regions in Thailand. The equation of interest in the Behrman (p. 157) model related desired area planted to expected price, expected yield and to two arbitrarily specified risk variables. The two risk variables were intended to capture price risk and yield risk. The price risk variable was specified as the standard deviation of the price of the crop over the three preceding production periods relative to the standard deviation of the index of prices for alternative crops over the same period. The yield risk variable was specified as the standard deviation of actual yields of the crop of concern over the three preceding production periods. Three other equations, an adaptive expectations equation for price, a partial adjustment equation for acreage and a trend equation for yields completed the model.

The more recent work of Just (1974a) in crop reporting districts in California has provided a more general method of evaluating the response to changing risk. The Just model, termed an adaptive risk model, contains expectations on risk variables. The expectations are formed as geometric weightings of the variances and the covariances of the variables of interest (e.g., prices and yields). The procedure is analagous to the way a price expectations variable is formed as a geometric weighting of past prices. A rigorous justification of the adaptive risk model is presented in Just (1974b), while an intuitive justification is presented in Just (1974a). The estimation procedure is a one-dimensional or a rather cumbersome two-dimensional search procedure which is used to obtain maximum likelihood estimates.

The Theoretical Model

Assume that a decision maker's objective function may be represented as a quadratic expected utility function and that costs are constant or are known at the time the decision is made. The objective function may be expressed as

$$\max U^* = P'Mx - b/2\, x'Wx$$

where

U^* = expected utility

P' = a row vector of expected output prices p_i^* (strictly a price net of unit costs)

M = a diagonal matrix of expected enterprise yields with elements m_i

x = a column vector of enterprise levels (acreage)

b = a scalar risk coefficient

W = a covariance matrix of enterprise revenues.

The first order conditions for maximization of the expected utility function give

$$MP - b\,W\,x = 0$$

hence (A) $$1/b\, W^{-1}\, M\, P = x$$

To focus on the effects of price variability assume that yields are either known at the time that the planting decision is made or that the variability is negligible.[1] The variance and covariance of yields are assumed zero. Let the variance of the price of the ith product be σ_i^2 and the covariance with the jth product σ_{ij}. The diagonal and the off-diagonal elements of the W matrix are respectively[2]

$$w_{ii} = m_i^2 \sigma_i^2$$

and
$$w_{ij} = m_i m_j \sigma_{ij}$$

In the two alternatives case, the inverse W^{-1} can easily be derived and the equation A may be solved for x_1. Multiplying both sides by the yield, m_1, gives the following expression for the output of alternative 1.

$$x_1 m_1 = \frac{m_1^2 p_1^* w_{22}}{b(w_{11} w_{22} - w_{12}^2)} - \frac{m_1 m_2 p_2^* w_{12}}{b(w_{11} w_{22} - w_{12}^2)}$$

The numerators of each term may be divided into the denominators, canceling and separating each of the two terms to give

$$x_1 m_1 = \left(\frac{b w_{11}}{m_1^2 p_1^*} - \frac{b w_{12}^2}{m_1^2 p_1^* w_{22}}\right)^{-1} - \left(\frac{b w_{11} w_{22}}{m_1 m_2 p_2^* w_{12}} - \frac{b w_{12}}{m_1 m_2 p_2^*}\right)^{-1}$$

The w_{ij} terms may be substituted into the above expression and the yields in each of the terms cancel out leaving output as a function of four interaction terms between expected prices and variances and covariance of the prices, namely

$$x_1 m_1 = g\left(\frac{\sigma_1^2}{p_1^*}, \frac{\sigma_{12}^2}{p_1^* \sigma_2^2}, \frac{\sigma_1^2 \sigma_2^2}{p_2^* \sigma_{12}}, \frac{\sigma_{12}}{p_2^*}\right)$$

The first term shows that the effect of the crop price variance on the supply response may be modified by the level of the crop price. The second term shows that the effect of the covariance of prices between the crop and its alternative may be modified by the level of the crop price and the price variance of the alternative. The third term is somewhat less intuitive, but it and the fourth term show that the price level of the alternative crop acts as a modifier on the supply response. For ease of later use the four terms are referred to as IT1, IT2, IT3, and IT4 respectively.

The Empirical Model and the Results

A linear model of the general form

$$Q_t = \phi(P_t^*, C_t, R_t, W_t)$$

was used, where

Q_t is the annual U.S. production of Pinto beans

P_t^* is the supply inducing price of Pinto beans

C_t is the supply inducing price of the competing crop

R_t is a vector of risk variables and

W_t is a weather index.

Pinto beans are produced predominantly in the states of Colorado, Idaho and Nebraska and to a lesser extent in eight other states. The Pinto beans are characterized by cobweb-type fluctuations in prices and in production.[3] The price series (1950 onwards) exhibits considerable price fluctuations and exhibits changes in the variability of the fluctuations. In addition, a period-to-period price reversal pattern is apparent, especially in the post-1960s. Production, with the exception of the extraordinary years 1973 and 1974, moved regularly in the opposite direction to current price. Goodwin's extrapolative expectations model was chosen as a suitable model to use as the specification of the supply-inducing price. Goodwin's model is

$$P_t^* = P_{t-1} + \beta(P_{t-1} - P_{t-2}) \quad \text{where} \quad -1 < \beta < 1.$$

A negative β would be consistent with producers expecting a reversal pattern in the price series.

Sugar beets were eventually selected from a number of possible alternative crops as the competing crop. The relative stability in the sugar beet price series was deemed sufficient to permit lagged price to be used as the relevant price. As sugar beets had been under government quotas at times during the period investigated, attempts to incorporate actual quota acres in Colorado and Idaho or zero one dummy variables were tried. These were not successful and lagged sugar beet price alone was retained.

The price risk variables were constructed over the three preceding years from the variances and the covariance of Pinto bean prices and the competing crop prices. After some preliminary investigations using the variances, it was decided to continue the investigation using standard deviations. To permit more recent price variations to have a greater weight, but to avoid the estimation problems raised by the Just (1974) declining weights, the fixed weight lag scheme proposed by Fisher was used.[4] Let PSD_t be the value of the weighted standard deviation in year t. It is calculated as

$$PSD_t = [\sum_{k=1}^{3} w_k(x_{t-k} - \bar{x}_t)^2]^{1/2}$$

where

x_{t-k} is the price in year t-k

$\bar{x}_t$ is the average price over the preceding three years to year t

w_k is a Fisher lag of 1/2, 1/3 and 1/6 for k=1, 2 and 3 respectively.[5]

The covariance between Pinto bean prices and the competing crop price is similarly computed with the Fisher lag scheme. The interaction terms, which are suggested by the theoretical model, are readily calculated using the weighted standard deviations, the covariance and the average price around which the deviations were calculated as the expected price. The expected prices used in the interaction terms therefore are consistent within the risk variables. The weather variable is a June 1st pasture index.

The preferred equations estimated from 1953 through 1975 are presented in table 1. Equation 1 contains no risk variables. Equation 2 is an example of the traditional approach and contains the weighted standard deviation of the crop price as the risk variable. Equations 3, 4 and 5 contain variations on the interaction terms which were suggested by the theoretical model developed earlier.

The variables which are contained in the preferred equations are

LPP - the price of Pinto beans (f.o.b. Colorado, U.S. No. 1) lagged one year in dollars per 100 lbs.

DPP - the difference between the price of Pinto beans lagged one year and that lagged two years (i.e., $P_{t-1} - P_{t-2}$)

LSBP - the average farm price of sugar beets, including government supports, in Colorado and Idaho, lagged one year, dollars per ton

IND - the average of 1st June pasture index for Colorado and Idaho

DW1 - a dummy variable set equal to one in the "good" years 1961 and 1963 and zero in all others[6]

DW2 - a dummy variable set equal to one in the "poor" years 1956, 1964 and 1973 and zero in all others[6]

PSD - a weighted standard deviation of the preceding three years of Pinto bean prices around the preceding three-year average; the weights are 1/2, 1/3 and 1/6

CFV - a weighted coefficient of variation of Pinto bean prices determined by dividing the PSD variable by the preceding three-year average (a variation on the IT1 variable in the theoretical section)

IP1 - the absolute value of the covariance of Pinto bean and sugar beet prices divided by the preceding three-year average of Pinto bean prices and divided again by the standard deviation of sugar beet prices (a variation on the IT2 variable in the theoretical section)

IP1*2 - the square of the covariance of Pinto bean and sugar beet prices divided by the preceding three-year average Pinto bean price and divided again by the variance of the sugar beet price (a variation on the IT2 variable in the theoretical section)

The signs on the coefficients in all equations conform with _a priori_ expectations. Goodwin's β coefficient, which may be obtained by dividing the coefficient on DPP by the coefficient on LPP, is negative in all cases. The negative β indicates that the supply-inducing price is revised in the opposite direction to the recent price movement. Given the behaviour of the Pinto bean price series, the revision is in accordance with Goodwin's (p. 191) expectations. The magnitude of β is over one-half for equation 1, but is reduced to approximately one-third when a risk variable is included as in equations 2, 3 and 4 and declines further to 0.17 for equation 5.

The inclusion of a risk variable in an equation increases the $\bar{R}^2$ value and the coefficient on the LSBP variable becomes significant at the 5 percent level. The coefficient on the weather variable, IND, also declines. The risk variables have negative coefficients indicating that an increase in price variability has a depressing effect on the supply of Pinto beans. The specification of the coefficient of variation (CFV) variable permits a differential response to price variability. The supply-reducing response is modified at high recent prices and has a larger effect at low recent price levels. In contrast, the standard deviation (PSD) variable implies the same response to price variability irrespective of recent price levels. The IP1 and the IP1*2 variables of equations 4 and 5 permit an interaction between the covariance of the crop prices, the variability of sugar beet prices and the level of Pinto bean prices. High recent price levels of Pinto beans or increased variability of sugar beet prices will modify the supply-reducing response. Conversely, a *ceteris paribus* increased variability of Pinto bean prices as reflected in the covariance term will cause a greater supply-reducing response.

The other two interaction terms IT3 and IT4 suggested by the theoretical model were not empirically important in equations containing all four interaction terms. This result held when all four terms were specified in variance or in standard deviation form. There was a close (simple correlation coefficient of 0.98) association between IP1*2 and the IT4 variable specified as the covariance divided by the competing crop price. The equation (5) containing IP1*2 is reported in preference to the equation with IT4, as the IP1*2 equation had a slightly higher $\bar{R}^2$ and the IP1*2 variable incorporates the variability of the competing crop price as well as the covariance.[7]

The short-run price elasticity of supply of Pinto beans is not readily obtainable as lagged price enters the risk variables in a non-linear fashion. The sense of the elasticity response from the risk variables is that if the small change in price is perceived to be increasing the price riskiness, then the change will induce a smaller, less elastic price response given the negative sign on the risk coefficients. A less inelastic response may be expected to occur if the price change is perceived to be decreasing the price riskiness. The supply elasticities from all equations are presented in table 2. The no risk variable equation has a low elasticity due to the omitted risk variables. The use of the elasticity from that equation would result in a substantial underestimate of the supply response. The first derivatives of the risk variables were all positive for 1975. The supply response is accordingly more inelastic than if there were no response to risk. The response in other years will differ due to different price quantity combinations and due to different three-year price histories.

An indication of the quantitative importance of the risk variables may be gleaned from the projections for 1976. Table 3 sets out the response net of the risk variables and the magnitude of the effect of each risk variable. The 95 percent confidence interval (Kmenta, p. 404) for each equation is also given in table 3. The 1976 Pinto bean production is 5,716 thousand cwt. The 5,716 figure lies outside the PSD (equation 2) confidence interval, but falls within the confidence intervals for the other models. Equation 3 and equation 4 projections were very close to the actual production level.

Figure 1 shows a plot of the actual Pinto bean production levels and the estimated production levels from the no risk variable equation (1) and a risk variable equation (5). The equation containing the price risk variables is clearly superior to the no risk variable equation, particularly in the post-1972 period, the years of extreme price fluctuations. The decrease in production in 1976, which lies outside the historical period, is predicted by the risk variable equation but is missed by the no risk equation. The decrease in 1976 production is predicted by all risk equations (see table 3), although the PSD equation (2) apparently over-responded.

Concluding Comments

The intention of this study was to apply a risk model which could be easily estimated to the aggregate supply of Pinto beans. A simple model of producer behaviour under uncertainty was used to suggest variables which may appear in a supply response equation. The risk variables in the preferred equations have intuitive explanations and they suggest a plausible behavioural response on the part of producers. The study revealed that risk response was quantitatively important in Pinto bean supply and that omission of the risk response would involve a considerable bias in the supply response. Any policy initiatives undertaken to reduce the price fluctuations of Pinto beans should take into account the supply-increasing effects of such a reduction. Failure to do so would result in a lower, albeit more stable equilibrium price, than would be expected and perhaps larger price support payments.

FOOTNOTES

With the usual _caveat_, the author is indebted to James P. Houck, Vernon R. Eidman, Maury E. Bredahl, Paul Gallagher and the anonymous reviewers of the Western Journal of Agricultural Economics for inspiration and constructive comments.

[1]No yield data nor acreage data on Pinto beans are published. Only production data are given.

[2]See Hazell and Scandizzo (p. 237) for the more general case.

[3]All data were gleaned from official U.S.D.A. publications.

[4]The Fisher weights gave marginally better empirical results than an equal weighting scheme.

[5]Fisher lags over four- and five-year periods were tried. The three-year lag gave the most satisfactory results. The results were not highly sensitive to the length of lag and definitely not as sensitive as the results reported by Traill (p. 10) in his study on onion acreage risk response.

[6]In five years, as judged from crop conditions discussed in various monthly issues of the U.S.D.A. _Crop Production_, extreme weather conditions occurred which were not captured in the June 1st index.

[7]The consistency among the order of the interaction terms is not maintained in equation 5 in which CFV contains a standard deviation and IP1*2 contains variances and a covariance squared.

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Table 1. Supply Equations (1953-1975) for U.S. Pinto Bean Production ('000 cwt)

Eq.	Const.	LPP	DPP	LSBP	IND	DW1	DW2	PSD	CFV	IP1	IP1*2	$\bar{R}^2$	D.W.	d.f.
1.	1,026	255.4	-148.5	-129.1	40.58	867.0	-404.8					0.71	2.14	16
		(2.75)	(3.06)	(1.92)	(3.33)	(2.90)	(1.60)							
2.	508	426.6	-123.3	-86.38	27.66	661.0	-607.0	-525.9				0.91	1.91	15
		(7.41)	(4.60)	(2.33)	(3.97)	(3.97)	(4.29)	(6.23)						
3.	2,321	442.2	-153.2	-182.2	26.19	525.9	-694.0		-7,769.3			0.86	1.68	15
		(5.79)	(4.61)	(3.83)	(2.93)	(2.41)	(3.76)		(4.39)					
4.	2,077	476.2	-150.7	-202.9	29.18	533.3	-680.4		-5,790.4	-2,941.5		0.92	1.49	14
		(7.86)	(5.80)	(5.38)	(4.14)	(3.12)	(4.72)		(3.83)	(3.25)				
5.	1,293	394.6	-68.5	-134.8	31.00	633.7	-546.60		-4,917.3		-360.0	0.93	1.87	14
		(7.22)	(2.20)	(3.82)	(4.86)	(4.08)	(4.08)		(3.46)		(4.08)			

$|t|$ values in parentheses.

Table 2. Pinto Bean Short-Run Supply Elasticity 1975

Eqtn.	1	2	3	4	5
Elast.	0.47	1.19	1.02	1.03	1.15

Table 3. The Supply Response in 1976 ('000 cwt)

Eqtn.	Net of risk variables	Risk variables effect				Estimate	95% c.i.	
		PSD	CFV	IP1	IP1*2		Lower	Upper
1	6,466					6,466	5,303	7,629
2	8,868	-4,714				4,154	3,150	5,158
3	8,307		-2,460			5,839	4,993	6,685
4	8,251		-1,840	-590		5,821	5,162	6,478
5	7,345		-1,562		-378	5,405	4,767	6,041
Actual 1976						5,716		

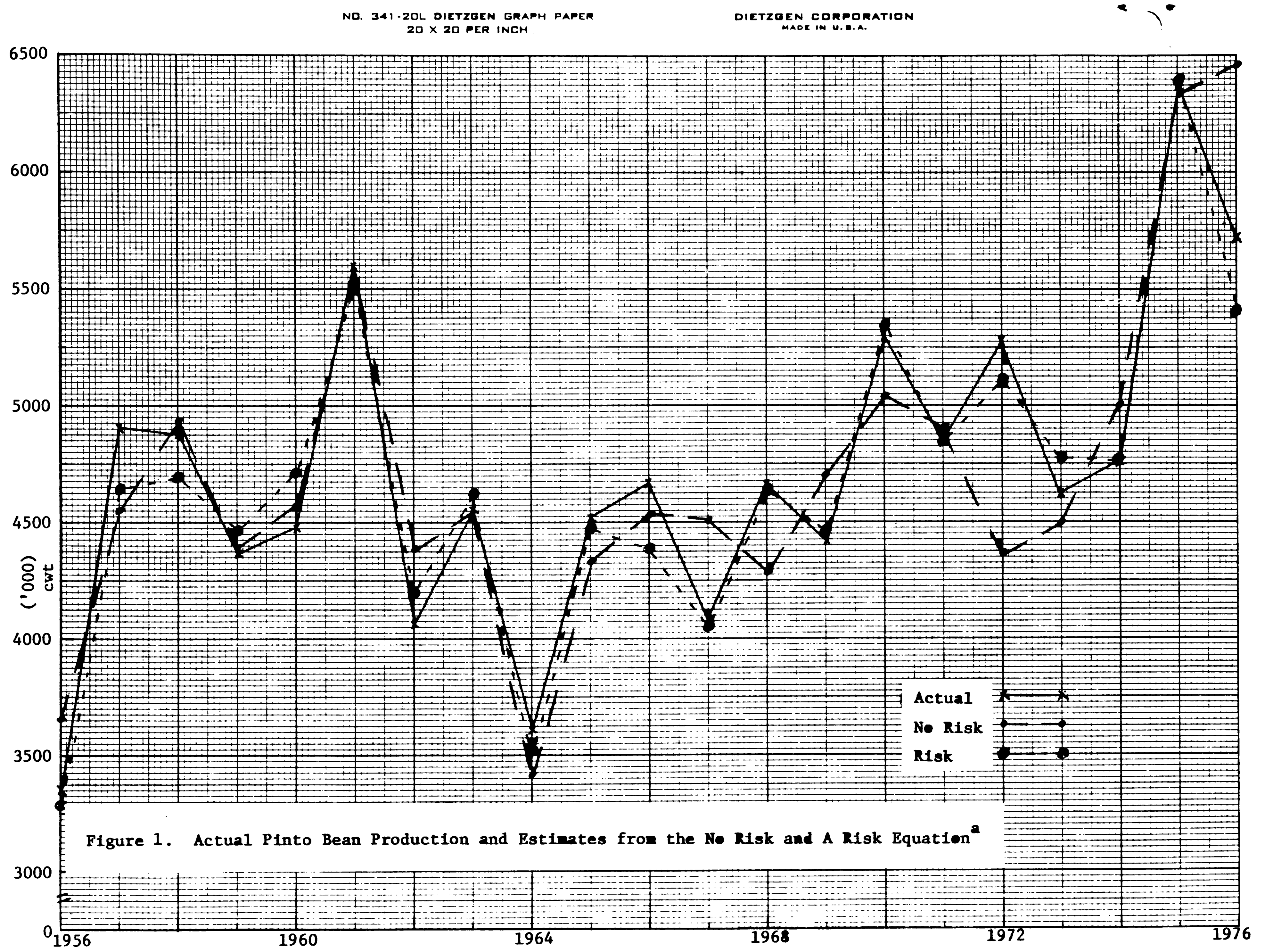

Figure 1. Actual Pinto Bean Production and Estimates from the No Risk and A Risk Equation[a]

[a]No risk, eqtn. 1, table 1; Risk, eqtn. 5, table 1.