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An Analysis of U.S. Aggregate Output Response by Farm Size

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ABSTRACT

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Past empirical evidence on supply response by size of farm in the U.S.A. provides no clear basis to conclude that supply elasticities vary systematically with farm size. In this paper, the central hypothesis that no systematic relationship exists between production response to price and size of farm is rejected. U.S. farms are disaggregated into nine economic size categories and own-price supply elasticities are measured for per farm and total agricultural output. Empirical results from this study suggest that supply response does vary systematically by farm size, with smaller farms exhibiting greater elasticities than mid-sized farms.

Introduction

Economic theory and conventional wisdom provide no clear basis to conclude that supply elasticities will be systematically higher for large or medium-size farms than for small farms. One traditional view is that small farmers are 'inners and outers', initiating production of an enterprise when the economic outlook appears to be favorable and exiting when the outlook appears to be unfavorable. This behavior implies a higher elasticity of supply for small farms than for large farms. Large farms also are more specialized, making for lower supply response to price. Marion (1985, p. 426) states that 'the industrialization of hog production is presumably reducing the downward flexibility of the supply response.'

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Another view is that large farms are most responsive to price. Large farms have higher proportions of cash operating inputs and lower fixed costs than small farms, making for a higher supply elasticity on large farms. Chapter 5 on Food and Agriculture of the Committee on Catholic Social Teaching and the U.S. Economy (1985) implies that large farms are responsive to economic conditions, and hence have higher supply elasticities than do small farms:

> Allowing (very large farms) to become the primary source of the country's food, however, would make our food system overly susceptible to fluctuations in the market for investment capital. This is particularly true in the case of nonfarm corporations that enter agriculture to get a high return on investment. If that return drops substantially or if it appears to stockholders and management that better returns can be obtained by investing the same capital in other sectors, they may cut back or even close down their operations without regard to the impact on the community or the food system.

A Congressional Budget Office report (1978, p. 14) states that small family farms 'have provided society with at least one important economic benefit – guaranteed continuity in agricultural output. Society will lose some of the continuity that has characterized farming as the U.S. increasingly moves away from small-scale production units.'

The above views are largely impressionistic. Empirical evidence on supply response by size of farm is sparse and inconclusive. Many studies in the past have estimated own-price supply elasticities for the U.S. agricultural output: Griliches (1959, 1960), Tweeten and Quance (1969), Morzuch et al. (1980), Chambers and Just (1981), Reed and Riggins (1981), Shumway (1983), Weaver (1983) and Antle (1984). None of these studies separated the effect of prices on output by farm size. Empirical studies in the U.S. have not estimated whether larger or smaller farms have greater supply response to price.

Sidhu and Baanante (1979) and de Janvry and Kumar (1981) estimated supply elasticities for Mexican wheat in India, dividing the farms studied into small and large farms. The study by de Janvry and Kumar (1981) generated output supply and input demand elasticities that were equal for both farm sizes. This indicated an identical pattern of production response to price movements on small and large farms (de Janvry and Kumar, 1981, p. 7). Sidhu and Baanante (1979, p. 461) also found that:

> . . . there are no differences in the technical and price efficiency parameters of small and large farms, that both classes of farms maximize profits, and that there exist constant returns to scale in wheat production in the Indian Punjab.

Objective

The objective of this study is to compare supply elasticity estimates by farm size. The hypothesis to be tested empirically is that relative supply response is not a function of farm size.

The model

The conceptual framework for estimating supply response has been formulated in detail by Nerlove and in numerous other studies listed in the references to this article. That framework is not repeated here to save space but some elaboration is required as it relates to size of farm. The model's functional form is specified based on our best judgment of the need to pool data among farm sizes to utilize as many observations as possible while minimizing the number of parameter estimates and variables to reduce multicollinearity and preserve degrees of freedom. The adaptive expectations-adjustment supply function is specified in logarithms because the error is expected to be proportional among sizes rather than the additive form associated with observations in original values.

U.S. farms are disaggregated into nine economic size categories ranging from farms with sales of under \$2,500 to farms with sales over \$500,000. The value of agricultural sales is the most common measure of farm business sizes used by the U.S. Department of Agriculture (U.S. Department of Agriculture, 1988, p. 31). The nine farm size used in this study are consistent with the classification used by the U.S. Department of Agriculture in reporting data by farm size categories. The implicit supply function for U.S. aggregate output used in this study is:

$$Q_{it} = f(\mathrm{RE}_t,\ S_i,\ T,\ D_i\,\mathrm{DA}_t,\ \mu_t)$$

where

Q_{it} is the total quantity of agricultural output produced by farm sales category i in year t (million 1969 dollars). This variable is represented by inflation-adjusted total gross farm income from cash sources for each sales category. The procedure used in this study for calculating the inflation-adjusted cash receipts is from Lin et al. (1980, pp. 34–38) as explained in the Appendix. The procedure adjusts for movement of farms into and out of each size class caused by changes in prices.

RE_t is an index of the expected future terms of trade – the index of prices received for crops and livestock divided by the index of prices paid by farmers for production items, including interest, taxes, and wage rates; 1969 = 100. It is assumed that expectations of future price are formed adaptively from past prices. More recent information is given a higher weight, i.e.

$RE_t = 0.5R_{t-1} + 0.3R_{t-2} + 0.2R_{t-3}$

where R_{t-n} is the actual parity ratio at time $t - n$; $n = 1, 2, 3$. (Other expectation forms, including a naive expectation model, were also considered. Estimation results will be discussed in the Elasticities of Supply Response section.)

S_i is the average farm size within each economic class as is represented by per-farm gross income from cash sources in 1969. Size classes $S_1, S_2, \ldots, S_9$ are shown later in Table 4.

T is the time trend (last two digits of current year) included to capture the effect of technology and other factors changing output at a constant amount annually.

D_i is a dummy variable with $D_i = 1$ for farm size i, zeros elsewhere. Size classes S_i's and dummy variables D_i's correspond. D_9 is omitted, and hence, the intercept applies to the smallest farms. When the largest and smallest farm size classes are excluded, D_8 is omitted, and its effect is part of the intercept.

DA_t is acreage diverted by government programs (million acres) in year t. Greater diversion is expected to reduce supply quantity, ceteris paribus.

μ_t is random error.

Variables RE, T, and DA are for all farms; the variables could not be uniquely specified for each farm size class.

The model was explicitly specified in a form to test the main hypothesis within the constraints of available data. Total output Q_{it} of size class i in year t is:

$Q_{it} = Q'_{it}N_{it}$

where Q'_{it} is output per farm and N_{it} is the inflation-adjusted number of farms (the procedure used for calculating the inflation-adjusted number of farms is explained in the Appendix). This distinction is made because increasing output per farm may be regarded as a more nearly true supply response than a change in number of farms in a size class. Changes in farm numbers in an economic class may come from economies of size and from other factors unrelated to a true supply response to price. Designating variables in natural logarithms as L, then:

$L\,Q_{it} = L\,Q'_{it} + L\,N_{it}$

The explicit supply function for N_{it} is:

$$N_{it} = b_0\, RE_t^{b_1 + b_2S_i + b_3S_i^2}\, DA_t^{b_4}\, e^{b_5T + \Sigma g_iD_i}\, e_t \quad (1)$$

and for Q'_{it} is:

$$Q'_{it} = a_0\, RE_t^{a_1 + a_2S_i + a_3S_i^2} N_{it}^{a_4}\, DA_t^{a_5}\, e^{a_6T + \Sigma d_iD_i} W_t \quad (2)$$

where e_t and w_t are random errors; other variables as defined above.

Equations (1) and (2) are estimated with variables in natural logarithms (designated L). The above equations constitute an interdependent system which recognizes that output per farm is determined jointly with number of farms (N and Q_i' are endogenous). More farms are expected to reduce Q_i', hence a_4 is expected to be negative.

A third specification combines equations (1) and (2) and is expressed as:

$$\text{L}\, Q_{it} = \text{L}\, g_0 + g_1 \,\text{L RE}_t + g_2(S_i \,\text{L RE}_t) + g_3(S_i^2 \,\text{L RE}_t) + g_4 \,\text{L}\, N_{it} + g_5 \,\text{L DA}_t + g_6 T + \Sigma\, h_i D_i + \text{L}\, m_t \quad (3)$$

From equation (1), the elasticity of response (E N) of N to expected price (RE) is:

$$\text{E}\, N_i = b_1 + b_2 S_i + b_3 S_i^2$$

and the elasticity of response (E Q') of Q' with respect to RE from (2) is:

$$\text{E}\, Q_i' = \frac{\partial \text{L}\, Q_i'}{\partial \text{L RE}} + \frac{\partial \text{L}\, Q_i'}{\partial \text{L}\, N_i} \frac{\text{dL}\, N_i}{\text{dL RE}}$$

or

$$\text{E}\, Q_i' = a_1 + a_2 S_i + a_3 S_i^2 + a_4 \,\text{E}\, N_i$$

where

$$\frac{\partial \text{L}\, Q_i'}{\partial \text{L RE}} = a_1 + a_2 S_i + a_3 S_i^2$$

$$\frac{\partial \text{L}\, Q_i'}{\partial \text{L}\, N_i} = a_4$$

and

$$\frac{\text{dL}\, N_i}{\text{dL RE}} = \text{E}N_i$$

The above are long-run elasticities. By construction, the short-run elasticities are one-half the long-run elasticities. This is because in the expected future terms of trade equations (RE_t), one-half of the weight is given to the actual parity ratio at time $t-1$ (R_{t-1}).

The supply elasticity is allowed to take a quadratic form in terms of farm size (S_i). If the constant is significant but the coefficients of the linear and squared terms are not significantly different from zero, the inference will be that the supply elasticity does not change systematically by farm size. If the coefficient of the linear term is significant, the inference will be that supply response is systematically lower (or higher) for smaller than for larger farms. And if the squared term for supply elasticity is significant, the inference will be that smaller and larger farms have larger (or smaller) supply elasticities than medium size farms – provided that inference applies in the relevant ranges of sizes considered. Allowing higher order supply elasticity response relationships among farm sizes was a priori judged to introduce undue multicollinearity and complicated interpretation.

With elasticities being a function of farm sizes, continuous transition of elasticities is assumed to take place as farm sizes change. That is, elasticities are continuously affected by farm sizes. Moreover, when reference is made to small-, large-, and mid-range farm sizes, no distinct division is implied. Rather, reference is made to a range of farms as one moves from the very small farms to the very large farms.

Data

The model was applied to U.S. aggregate annual data by economic class for the 1970 – 84 period. Data for total farm cash receipts, income per farm, and the number of farms in each sales category were from the U.S. Department of Agriculture (1986). Indices of prices received and prices paid by farmers were from the Council of Economic Advisors (1984). Data were further adjusted for inflation by the procedure described in Appendix. More specifically, data for Q_{it} (inflation-adjusted gross farm income) were obtained from the data developed in column M of Appendix Table A1. Similarly, data for N_{it} (inflation-adjusted farm numbers) were obtained from the data developed in column K of Appendix Table A1.

The U.S. Department of Agriculture annual data on economic class of farms are based on information from many sources which include periodic surveys such as the June Enumerative Survey (JES), special studies, the census of agriculture and other related information. The U.S. Department of Agriculture derives data by farm size from the annual estimates for all farms and the percentage distribution of farms by sales class. Aggregate data are collected annually. The percentage distribution of farms by sales class, are benchmarked to census data (gathered for years 1969, 1974, 1978, 1982) but are updated annually from the JES data. Although the JES economic class differs from the census of agriculture economic class in that it includes government payments and cash-related income, the JES provides sufficient additional information to make the adjusted number of observations well in excess of census year data (for a detailed description of data procedures and sources refer to U.S. Department of Agriculture, 1988). However, as an alternative, the model was also estimated using only the farm census years.

In terms of commodity composition in aggregate data, national annual estimates for cash receipts by the U.S. Department of Agriculture incorporate separate estimates for approximately 120 crop and livestock commodities. Most estimates are calculated at the state level and then summed to derive the national estimates (U.S. Department of Agriculture, 1988, p. 31).

Results

Table 1 shows statistical results for estimation of equation (1) for farm numbers. The coefficient of the variable L DA was not significant in any equation and the variable was excluded to reduce multicollinearity. In equation (1A) including all nine farm classes and the years within the observation period, 1970 – 84 (n = 135), the first-order autoregressive coefficient was – 0.724 and statistically significant, hence the equation was estimated with

TABLE 1

Autoregressive least squares regression results for farm numbers L N by economic class of farms, U.S., 1970 – 84

Variable	Equation (1A)		Equation (1B)		Equation (1C)[a]	
	Parameter estimate	t ratio	Parameter estimate	t ratio	Parameter estimate	t ratio
Intercept	2.54	0.15	– 17.86	– 1.60	– 14.16	– 0.60
L RE	1.16	2.83	1.02	3.78	1.06	1.44
S L RE	– 1.79 E-5	– 6.18	– 1.38 E-5	– 9.53	– 1.79 E-5	– 4.47
S^2L RE	8.72 E-12	5.91	–	–	–	–
T	1.73 E-3	0.21	0.01	2.12	0.01	0.85
D_1	– 3.44	– 15.77	–	–	–	–
D_2	– 2.88	– 13.40	– 2.80	– 26.80	– 2.87	– 14.94
D_3	– 1.88	– 8.71	– 1.73	– 16.77	– 1.69	– 10.45
D_4	– 0.85	– 4.02	– 0.64	– 6.40	– 0.53	– 3.45
D_5	– 0.68	– 3.28	– 0.53	– 5.32	– 0.50	– 3.24
D_6	– 0.19	– 0.93	– 0.05	– 0.49	– 0.10	– 0.64
D_7	– 0.12	– 0.61	0.12	1.34	0.09	0.62
D_8	– 0.51	– 3.01	–	–	–	–
	R^2 =	0.980	R^2 =	0.990	R^2 =	0.980
	ϱ =	– 0.724	ϱ =	– 0.615	ϱ =	– 0.341
	n =	135	n =	105	D.W. =	2.676
					n =	28

[a] Equation estimated by ordinary least squares for years 1969, 1974, 1978, and 1982.

autoregressive least squares (Cochrane – Orcutt method). The R^2 was 0.980 and the coefficient of each expected price variable L RE was highly significant. The coefficients indicate that the elasticity of farm numbers with respect to price is largest for very small and very large farms (with per-farm gross incomes outside the range of data).

Farms are not homogeneous in enterprise structure among economic classes. The enterprise mix on the very largest and very smallest size classes is weighted more heavily by cattle and calves and by fruits and vegetables than on other farms (see Tweeten, 1986, p. 71). The enterprise mix is more homogeneous with the largest and smallest size classes excluded, making for more reliable estimates of supply response by size less confounded by differences in enterprise mix among farms.

Results of such estimation are shown in equation (1B). Again, because of a significant autoregressive coefficient ($\varrho = -0.615$), the equation was estimated by autoregressive least squares. The coefficient of the interaction between expected price and size squared (S^2 L RE) was not significant, hence the variable was dropped from equation (1B). Coefficients of L RE and S L RE were highly significant, and indicated that the elasticity of farm numbers with respect to price was lower for large than for smaller size classes within the range of farm sizes considered.

Equation (1C) (and subsequent C equations) were estimated for only the farm census years (1969, 1974, 1978, and 1982). Coefficient signs and magnitudes for L N in equation (1C) in Table 1 are similar to those for equation (1B) but statistical significance is poorer. Because the C equations were estimated based on only 4 years of data (28 observations), subsequent analysis of elasticities rely on the A and B equations.

Statistical results for supply response as measured by output per farm by economic class are shown in Table 2. Equations (2A) and (2B) are estimated by autoregressive recursive least squares with L N HAT being the predicted value of L N from equations (1A) and (1B) respectively. The R^2 in equation (2A) is 0.996 and all but the coefficient of D_8 are statistically significant at the 0.0001 level. Results indicate that the elasticity of output per farm to price is largest for very small and very large farms.

Dropping the largest and smallest farm size from the data set and estimating output per farm as a function of prices and other variables including the predicted value of L N from equation (1B) produced results shown in equation (2B). As with other equations estimated by ordinary least squares, the first order autoregressive coefficient was statistically significant so equation 2B was estimated by autoregressive least squares. Each of the ten coefficients was statistically significant at the 0.001 level or better. The variable measuring interaction between size squared and expected price (S^2 L RE) was dropped because its coefficient was statistically insignificant.

TABLE 2

Autoregressive recursive least squares results for production response per farm L Q' by economic class of farms, U.S., 1970–84.

Variable	Equation (2A)		Equation (2B)		Equation (2C)[a]	
	Parameter estimate	t ratio	Parameter estimate	t ratio	Parameter estimate	t ratio
Intercept	−3.37	−8.74	−2.51	−3.71	7.94	1.96
L RE	1.05	5.29	1.19	7.38	2.30	3.97
S L RE	−9.42 E-6	−4.44	−1.02 E-5	−4.83	−4.33 E-5	−3.44
S^2 L RE	4.38 E-12	4.14	–	–	–	–
L N HAT	−0.43	−6.54	−0.55	−4.76	−2.34	−3.39
D_1	4.60	20.41	–	–	–	–
D_2	3.67	18.59	3.15	9.57	−1.91	−0.96
D_3	3.26	24.50	2.89	14.02	−0.09	−0.08
D_4	2.87	33.77	2.62	26.45	1.75	4.62
D_5	2.22	26.81	1.95	21.06	1.18	3.33
D_6	1.57	20.23	1.34	18.46	1.30	11.59
D_7	0.84	10.83	0.68	10.23	0.94	8.55
D_8	0.10	1.29	–	–	–	–
	R^2 = 0.996		R^2 = 0.998		R^2 = 0.996	
	ϱ = −0.430		ϱ = −0.671		ϱ = −0.204	
	n = 135		n = 105		D.W. = 2.161	
					n = 28	

[a] Equation estimated by ordinary least squares with data for years 1969, 1974, 1978, and 1982.

Results indicate that the elasticity of output per farm to price is less for large farms than for small farms[1]. The coefficient of L N HAT indicates that each percent increase in predicted farm numbers reduces output per farm 0.55%. Equation (2C) with only 4 years of data gave parameter estimates broadly supportive of other results in Table 2.

In Table 3, the final set of statistical equations are the result of regressing the logarithm of output (L Q_i) on the same explanatory variables as in Table 2. The equations are estimated by autoregressive recursive least squares. Results are similar to those in Table 2, indicating in equation (3A) that the elasticity of output response to price is highest for very large and small farms. With a more restricted set of farm sizes in equation (3B), the relative

[1] If error in S_i is correlated with error in Q'_{it} coefficients will be biased. Such error correlation is likely to be small because S_i is for 1969 in A and B whereas Q'_{it} is annual for 1970 to 1984; also Q'_{it} is in logarithms and S_i in original values.

TABLE 3

Autoregressive recursive least squares regression results for production response L Q by economic class of farms, U.S., 1970–84

Variable	Equation (3A)		Equation (3B)		Equation (3C)[a]	
	Parameter estimate	t ratio	Parameter estimate	t ratio	Parameter estimate	t ratio
Intercept	−2.80	−6.49	−0.77	−0.73	−4.80	−4.84
L RE	1.08	4.95	1.35	5.45	0.93	1.89
S L RE	−9.64 E-6	−4.08	−1.32 E-5	−4.04	−4.39 E-6	−1.05
S^2 L RE	4.44 E-12	3.76	–	–	–	–
L N HAT	0.46	6.20	0.15	0.81	0.83	4.94
D_1	4.29	16.96	–	–	–	–
D_2	3.39	15.32	2.34	4.56	4.32	8.58
D_3	3.13	20.88	2.38	7.52	3.58	11.61
D_4	2.89	29.71	2.46	17.58	2.91	20.23
D_5	2.21	23.37	1.84	14.05	2.26	16.21
D_6	1.62	18.26	1.40	14.56	1.51	13.41
D_7	0.94	10.54	0.76	8.35	0.74	6.60
D_8	0.19	2.22	–	–	–	–
	R^2 = 0.987		R^2 = 0.976		R^2 = 0.973	
	ϱ = −0.464		ϱ = −0.565		ϱ = −0.433	
	n = 135		n = 105		D.W. = 2.802	
					n = 28	

[a] Equation (3C) estimated by ordinary least squares for years 1969, 1974, 1978, and 1982; with L N actual rather than predicted.

output response to price drops as farm size increases. Signs on the coefficients of L N HAT are opposite between equations in Tables 2 and 3 as expected. More farms in a size class increase total output but are related to less output per farm. Equation (3C) generally supports results of the other equations in Table 3 but statistical results are less favorable.

Elasticities of Supply Response

Elasticities of supply response estimated from previous tables are shown in Tables 4 and 5. The central hypothesis of this study was rejected from the equations estimated – supply response to price appears to differ systematically by farm size. Whereas strong evidence points to a lower supply elasticity for mid-size versus smaller farms, the exact magnitude (and appropriate way to measure that magnitude) remains a point of controversy so various options are presented.

The total elasticity of supply response per farm to price (E Q') is the sum of the partial response (farm numbers constant) and the interaction between output per farm and farm numbers (α_4 E N_i) which is positive for large farms and negative for small farms. However, a case can be made that the middle term in Table 4, the partial elasticity, is a more accurate measure of true supply response to price because it abstracts from (adjusts for) possible bias of farms being shifted into or out of a size classification because of real prices change. By that reasoning the best measures of long-run partial elasticities of supply ∂L $Q_i'/$ ∂L RE, are approximately unitary in the small- to mid-range of farm sizes in Table 4 – a number in line with previously estimated long-run supply elasticities reported in studies listed earlier. Elasticities for smaller farms are larger than for large farms. Elasticities are negative for a range of larger farm sizes. This seems anomalous, but we have carefully checked the results and found nothing wrong. Nevertheless negative elasticities should be interpreted with caution. However, elasticities calculated from equation (2) become large for very big farms with sales in the millions of dollars. The largest farm size S_i of approximately \$2 million gave a negative elasticity E Q_i' in Table 4. But extending S_i to a value of \$3,000,000, equation 2A estimated a value for E Q_i' of 1.09 and for an S_i of \$4,000,000 gave a value for E Q_i' of 3.81. Because these latter two estimates outside the range of data lack reliability, it is well to confine elasticity estimates to the available range of farm sizes as shown in Tables 4 and 5. It should be emphasized that the goal of this study is not so much to calculate absolute elasticities, but to compare elasticities by size of farm. In other words, we are testing the hypothesis whether there exists a systematic relationship between elasticities and farm sizes.

If one is interested in predicting actual real change in output within an economic class following a change in expected price RE, the best measure of the elasticity of response is E Q_i in Table 5. However, the partial elasticity ∂L Q_i/∂L RE in Table 5 may be the best measure because it more fully adjusts for changes in farm numbers. (The Appendix procedure provided farm classes adjusted for changes in the price level.) Again the results are consistent – the mid-size range of farms display elasticities nearly unitary. As before, elasticities are higher for small farms than for large farms. However, it should be noted that the supply response estimates for very large farms are predicted to be positive and larger than those for small farms – although that conclusion again is subject to the caveat of predicting outside the range of data.

The model was also estimated using the ordinary least squares method of estimation. The elasticity results were very similar to those obtained from

TABLE 4

Elasticities of long-run production response to price by farm size calculated from equations (2A) and 2B)[a]

Farm size			Equation (2A)			Equation (2B)		
	Mean	Sales range	$E\,Q'_i$ $\frac{dL\,Q'_i}{dL\,RE}$	$\alpha_1 + \alpha_2 S_i + \alpha_3 S_i^2$ $\frac{\partial L\,Q'_i}{\partial L\,RE}$	$\alpha_4\,E\,N_i$ $\frac{\partial L\,Q'_i}{\partial L\,N_i}\frac{dL\,N_i}{dL\,RE}$	$E\,Q'_i$ $\frac{dL\,Q'_i}{dL\,RE}$	$\alpha_1 + \alpha_2 S_i$ $\frac{\partial L\,Q'_i}{\partial L\,RE}$	$\alpha_4\,E\,N_i$ $\frac{\partial L\,Q'_i}{\partial L\,N_i}\frac{dL\,N_i}{dL\,RE}$
($1,000 1969)			Elasticity in percent					
S_1	$1,953.1	$500+	−0.42	−0.64	0.22	–	–	–
S_2	339.9	250–500	0.04	−1.65	1.69	−0.24	−2.27	2.03
S_3	160.2	100–250	0.29	−0.35	0.64	0.22	−0.44	0.66
S_4	72.0	40–100	0.42	0.39	0.03	0.44	0.45	−0.01
S_5	34.8	20– 40	0.48	0.72	−0.24	0.54	0.83	−0.29
S_6	18.4	10– 20	0.51	0.87	−0.36	0.58	1.00	−0.42
S_7	9.4	5– 10	0.52	0.95	−0.43	0.61	1.09	−0.48
S_8	4.9	2.5– 5	0.53	1.00	−0.47	0.62	1.14	−0.52
S_9	1.6	<2.5	0.54	1.03	−0.49	–	–	–

[a] Short-run elasticities are one-half the long-rund elasticities.

TABLE 5

Elasticities of long-run production response to price by farm size calculated from equations (3A) and 3B)[a]

Farm size		Equation (3A)			Equation (3B)		
		$\mathrm{E}\,Q_i$ $\frac{d\mathrm{L}\,Q_i}{d\mathrm{L}\,\mathrm{RE}}$	$\gamma_1 + \gamma_2 S_i + \gamma_3 S_i^2$ $\frac{\partial \mathrm{L}\,Q_i}{\partial \mathrm{L}\,\mathrm{RE}}$	$\gamma_4\ \mathrm{E}\,N_i$ $\frac{\partial \mathrm{L}\,Q_i}{\partial \mathrm{L}\,N_i}\frac{d\mathrm{L}\,N_i}{d\mathrm{L}\,\mathrm{RE}}$	$\mathrm{E}\,Q_i$ $\frac{d\mathrm{L}\,Q_i}{d\mathrm{L}\,\mathrm{RE}}$	$\gamma_1 + \gamma_2 S_i$ $\frac{\partial \mathrm{L}\,Q_i}{\partial \mathrm{L}\,\mathrm{RE}}$	$\gamma_4\ \mathrm{E}\,N_i$ $\frac{\partial \mathrm{L}\,Q_i}{\partial \mathrm{L}\,N_i}\frac{d\mathrm{L}\,N_i}{d\mathrm{L}\,\mathrm{RE}}$
($1,000)		Elasticity in Percent					
S_1	$500+	−1.04	−0.81	−0.23	–	–	–
S_2	250−500	−3.47	−1.68	−1.79	−3.66	−3.12	−0.54
S_3	100−250	−2.11	−1.43	−0.68	−0.94	−0.77	−0.17
S_4	40−100	0.38	0.42	−0.04	0.40	0.40	0.00
S_5	20− 40	1.01	0.76	0.25	0.97	0.89	0.08
S_6	10− 20	1.29	0.90	0.39	1.22	1.11	0.11
S_7	5− 10	1.45	0.99	0.46	1.35	1.22	0.13
S_8	2.5− 5	1.53	1.03	0.50	1.42	1.28	0.14
S_9	<2.5−	1.59	1.07	0.52	–	–	–

[a] Short-run elasticities are one-half the long-run elasticities. See earlier definition for RE; and see mean values for S_i in Table 4.

the autoregressive least squares method results which are reported in Tables 4 and 5.

Equations also were estimated with raw data for farm numbers and output volume by farm class uncorrected for price changes using the Appendix procedure. Results predicting real output, farm numbers, and output per farm gave the same pattern of response by farm size as shown in the foregoing tables, but elasticities were more erratic among sizes. Because the procedures noted in this paragraph were conceptually and empirically inferior to that used, results are not shown.

Moreover, the model was estimated assuming other expectation forms than the one specified earlier. Among other forms, a naive expectations model was considered. In the naive expectations model the expected future terms of trade (RE_t) is assumed to be a function of one lagged Parity ratio (R_{t-1}). Estimated elasticities from the naive expectations model were very similar in the pattern of change among farm sizes to elasticities in Tables 4 and 5. Even the magnitude of elasticities were fairly close.

Other versions of the model included substituting a productivity index for the time trend. Again, the pattern of change in elasticities as farm size changed was similar to the pattern represented in Tables 4 and 5. Results are not shown here to avoid repetition.

Summary and Conclusions

The objective of this study, to estimate supply response by size of farm, was accomplished with generally positive results. The close fit as indicated by the high R^2s suggests that additional variables would account for little more variation in output among farm sizes. The central hypothesis to be tested in this study is that no systematic relationship exists between production response to price and size of farm. Based on empirical evidence, we reject the null hypothesis. Statistical tests indicate that there is a very small probability of obtaining t-values as large as those found when sampling from a population in which the true values of α_2, α_3, β_2, β_3, γ_2, and γ_3 are zero. Supply response does seem to vary systematically by size of farm, with smaller farms exhibiting greater elasticities that did mid-sized farms. Some results suggest high supply elasticities on very large farms, but the evidence must be regarded as tentative because inferences are called for outside the range of data.

Several challenges were faced in working with the data. For lack of data on farm size as measured by assets, value added, or other possibly more suitable measured, we had to rely on size as classified by sales. The Appendix details the procedure for correcting size classes for inflation. To further reduce bias, a recursive simultaneous equation system was specified separating output per farm and number of farms so that results could be corrected for changes in farm numbers arising from price changes or other factors. Nonetheless, shortcomings of the data suggest caution in interpretation of results while awaiting further tests of hypotheses with more refined data.

Appendix

Procedure used for calculating inflation adjusted farm numbers

Total cash receipts for each farm size are obtained by multiplying the number of farms in each sales category by average (per-farm) income from cash sources. However, the 129% increase in prices received by farmers between 1969 and 1984 has caused changes in farm numbers in each sales category that are due to inflation. The purpose of this appendix is to explain the procedure used in this study to obtain the inflation adjusted farm numbers. The objective is to separate the changes in farm numbers in each sales category for each year that are due to real factors such as technological factors, commodity programs, etc., from the changes due to inflationary factors. The method used herein is from Lin, Coffmann and Penn (1980, pp. 34 – 37). The explanation in this appendix is for the 1984 and 1969 data, but this procedure was applied to each year to assemble data for this study.

In the first step, a polynomial function was estimated which specified the cumulative farm numbers as a function of sales receipts in 1984. The following function is used for this purpose:

$$\text{LN FN}(S_m) = B_0 + \Sigma_{n=1}^{4} B_n(\text{LN } S)^n + e \qquad \text{(A1)}$$

where $\text{FN}(S_m)$ is the cumulative farm numbers that produce sales receipts in excess of S_m (the minimum sales in each category), S is average sales receipts in each size category, i.e. per farm income by the value of sales class, n is the degree of the polynomial function (which is 4 in this study), B_n are the parameters of the distribution, and LN is natural logarithm.

In the estimation, S is sales receipts in 1984 in terms of 1969 dollars. The deflation factor is prices received by farmers in 1969 divided by prices received in 1984. A second estimation must then be made. Use Appendix equation (A1) again along with the same B's as found in the first estimation. For S, however, use the sales receipts in 1984 and in terms in 1984 dollars.

The following table illustrates the calculation of the inflation adjusted 1984 farm numbers in each sales category. In other words, this table shows the determination of farm numbers that have been shifted from one sales class to another only because of real factors and not as a result of inflation.

In Appendix Table A1, column A represents each sales category. Column B and C are actual farm numbers in each sales category in 1969 and 1984

TABLE A1

Calculation procedure of inflation-adjusted farm numbers and total cash receipts in each sales category

Annual sales ($1,000)	Farm numbers			Cumulative Distribution of 1984 farm numbers (predicted)		Change due to inflation			Change due to other factors	1984 inflation adjusted farm numbers	Sales per farm ($ 1969)	Total sales (cash receipts) after adjustment for inflation ($1,000)
	1969	1984	Actual change	($ 1969)	($ 1984)	Gain	Loss	Net				
A	B	C	D	E	F	G	H	I	J	K	L	M
500 and over	4	31	27	13.21	30.73	17.52	0.0	17.52	9.48	13.48	636,869	16,102
200 – 499	11	118	107	60.07	156.69	96.62	17.52	79.10	27.90	38.90	143,808	12,581
100 – 199	32	188	156	138.89	328.94	190.05	96.62	93.43	62.57	94.57	66,994	12,727
40 – 99	155	353	198	317.55	632.24	314.69	190.05	124.64	73.36	228.36	28,950	12,886
20 – 39	304	247	– 57	604.92	992.32	387.40	314.69	72.71	– 129.71	174.29	12,840	5,182
10 – 19	369	269	– 100	902.09	1273.79	371.70	387.40	– 15.70	– 84.30	284.70	6,525	3,430
5 – 9	381	314	– 67	1180.41	1494.32	313.91	371.70	– 57.79	– 9.21	371.79	3,436	1,971
2.5 – 4.9	368	275	– 93	1447.53	1727.63	280.10	313.91	– 33.81	– 59.19	308.81	1,652	815
less than 2.5	1,376	533	– 843	1793.12	2358.82	565.70	280.10	285:60	– 1,128.60	247.40	576	598

respectively. Data for these columns are obtained from U.S. Department of Agriculture (1986). Column D is the actual change in farm numbers from 1969 to 1984; it is obtained by subtracting the figures in Column B from the figures in Column C.

The figures in Columns E and F are the cumulative farm numbers predicted by the fourth-degree polynomial function (equation A1). Entries in these columns were generated by applying the relevant parameters for each column to average sales receipts using equation (A1).[2] For Column F, the current value of farm sales (the lower value of each sales category listed in Column A) is substituted for S. For calculating the figures in Column E, the deflated sales receipts instead of current values are used for the variable S in equation A1.

Column G measures the increase in the number of farms due to inflation. The figures in this column are calculated by subtracting the figures in Column E (the predicted cumulative distribution of 1984 farm numbers in 1969 dollars) from the figures in Column F (the predicted cumulative distribution of 1984 farm numbers in 1984 dollars). For example, in 1984 there are only 13.21 farms with sales of 500,000 constant (1969) dollars and more (Column E). However, there are 30.73 farms with sales of 500,000 current dollars and over. Therefore, the gain was 17.52 farms due to inflation (Column G). Because the $500,000 and over sales is the highest income category, no loss has occurred in the number of farms due to inflation (Column H) in this sales group. For other income groups, the loss due to inflation (Column H) is equal to the gain that has occured to the next upper sales category due to inflation (Column G), For example, the 17.52 farms that have moved to the sales category of $500,000 and over because of inflation are a loss to the income category of $200,000 – 499,999 due to inflation. Column I measures the net change due to inflation. It is calculated as the gain (Column G) minus the loss (Column H) due to inflation.

Column J measures the change in farm numbers from 1969 to 1984 due to real factors (other than inflation). It is calculated as the actual change in farm numbers from 1969 to 1984 (Column D) minus the net change due to inflation (Column I). Finally, the figures in Column K represent the number of farms in 1984 in each sales category after adjusting for the effect of inflation on farm numbers. The figures in this column can be calculated in two ways:

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[2] To obtain the relevant parameters (B's in Appendix equation 1) for Columns E and F, deflated values of average sales receipts in each size category are substituted for S in Appendix equation 1. The parameters are estimated for each year using data on FN and S for the nine farm size categories.

(1) By adding the change in the number of farms due to real factors (Column J) to farm numbers in 1969 (Column B).

(2) By subtracting the change in the number of farms due to inflation (Column I) from the 1984 farm numbers (Column C).

These two ways give exactly the same results.

Column L measures sales per farm in 1969 dollars. The sales per farm in current dollars is found in U.S. Department of Agriculture (1986). The value in current dollars is then multiplied by the ratio of prices received in 1969 to prices received in the current year to obtain sales per farm in 1969 dollars.

The inflation adjusted total sales (Column M) are calculated by multiplying the sales per farm (Column L) by the current farm numbers (Column C) and subtracting the gain due to inflation (Column G) times the minimum possible sales in the category converted to 1969 dollars (Column A) and then adding the loss due to inflation (Column H) times the maximum possible sales in the category also converted to 1969 dollars (Column A). For example, the inflation adjusted total sales in 1984 for the 20 – 39 annual sales category is: $(12{,}840 \times 247) - [387.40 \times 20{,}000\ (0.59/1.42)] + [314.69 \times 39{,}999 \times (0.59/1.42)] = \$5{,}182{,}169$.

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