An Economic Investigation Into Inflation Passthrough to the Farm Sector

Luther G. Tweeten

The purpose of this study is to estimate the impact of general inflation on prices paid and received by farmers. Specific objectives are: (1) to test the hypothesis that the farm commodity domestic demand function at the farm level is homogeneous of degree zero in prices and income; and (2), conditional on not rejecting the hypothesis in (1), to test the hypothesis that general inflation changes the ratio of prices received to prices paid by farmers because it impacts unevenly on prices and income in the demand function versus the supply function for farm output. Empirical results provided no basis to reject the hypothesis that economic functions determining demand for output at the farm level are homogenous of degree zero in income and prices. A truly general increment in overall price level appears to increase nominal prices received and farm demand in proportion to the general price level but leaves real farm demand and hence real demand price unchanged. This hypothesis could not be rejected based on the domestic components of demand for farm output examined in this study. Given demand and supply functions homogeneous of degree zero in all prices and income, the second hypothesis that general inflation impacts evenly on all prices and income was rejected for the 1963-77 period. In that period, national inflation moved upward the supply curve through prices paid by farmers proportionately more than it moved upward the demand curve and prices received by farmers, contributing to a cost-price squeeze.

Inflation is often defined as an increase in the general price level. In reality, all prices do not rise in concert and the economic impact can be uneven among sectors of the economy. In a 1976 study, Tweeten and Griffin found that national inflation as measured by the implicit price deflator of the Gross National Product was more fully and quickly apparent in prices paid by farmers than in prices received by farmers.

The purpose of this study is to estimate the impact of general inflation on prices paid and received by farmers using more recent data and different conceptual models than used previously. Specific objectives are: (1) to test the hypothesis that the farm commodity domestic demand function at the farm level is homogeneous of degree zero in prices and income, and (2) conditional on not rejecting the hypothesis in (1) to test the hypothesis that general inflation changes the ratio of prices received to prices paid by farmers because it impacts unevenly on prices and income in the demand function versus the supply function for farm output.

The conceptual framework presented in the next section is followed by the empirical results presented in the third section. Results are summarized and conclusions drawn in the final section. Parameters estimated herein indicate considerably greater passthrough of general inflation to prices received by farmers than found by Tweeten and Griffin. However, evidence continues to support the hypothesis that general inflation contributes to the "cost-price" squeeze, a term widely used to refer to a declining ratio of prices received to prices paid by farmers.

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Conceptual Framework

The impact on prices of inflation is illustrated graphically for food in Figure 1 with retail supply SR and demand DR as well as farm level supply SF and demand DF in equilibrium at quantity QF of farm-produced food ingredients and farm commodity price PF and retail price PR. Inflation, characterized by a rise in the general price level originated by federal deficit spending or other inflationary pressures validated by an increase in the money supply, raises nominal consumer income and prices for nonfood items. This raises retail demand to DR′ and derived demand at the farm level to DF′. Because the marketing margin is DR′-DF′, the extent to which DF′ exceeds DF clearly depends on the response of the marketing margin to inflation.

Supply at retail SR is supply at the farm level SF plus the marketing margin. Inflation as defined above increases prices paid by farmers and hence shifts SF upward. With inflation, supply at the retail level is the new farm level supply SF′ plus the marketing margin. *If* supply and demand functions depicted in Figure 1 are homogeneous of degree zero in all prices (and income) and *if* each nominal price is increased at the same rate by inflation, then the nominal upward shifts in supply and in demand are equal to each other and to the increase in the general price level. The proportional gain in PF′ over PF and of PR′ over PR is the inflation rate; and real demand, supply and quantity QF remain unchanged by inflation. If these theoretical, "textbook" homogeneity and equiproportional change conditions do not hold, real price and quantity effects may occur, even abstracting from any real balance effect.

Algebraic Model of Structural Equations

The foregoing graphical model is modified and presented as an algebraic model suitable for subsequent testing of hypotheses.

Utility maximization under a budget constraint gives demand functions homogeneous of degree zero in prices and income for individual consumers [Henderson and Quandt, p. 24]. In reality, market demand functions formed by aggregating are not necessarily homogeneous of degree zero in prices and income because of externalities, time lags, imperfect information and a host of other factors. However, the demand function for food at the retail level is hypothesized to be of the following general form:

$$QRt = QR[(PR/PG)t, (Y/PG)t, (PN/PG)t] \quad (1)$$

where QR is quantity demanded, PG is the general price level as measured by the implicit deflator of the Gross National Product or by the Consumer Price Index, Y is income, PN is the composite price of food substitutes and complements and t refers to the current year. Food and non food items must be net substitutes in this "two-commodity" world, hence the coefficient of PN is positive in theory.

If QR is invariant to the general price level PG, the elasticity of QR with respect to PG, defined as E(QRPG), is equal to zero, or

$$E(QRPG) = E(QRPR) \cdot E(PRPG) + E(QRY) \cdot E(YPG) + E(QRPN) \cdot E(PNPG) = 0 \quad (2)$$

where E(QRPR) is the elasticity of QR with respect to PR and other elasticities are defined similarly. If the demand function is homogeneous of degree zero in prices and income and inflation is truly general so that

$$E(PRPG) = E(YPG) = E(PNPG) = 1 \quad (3)$$

it follows that elasticities of QR with respect to PR, Y or PN are in theory unchanged whether the equation is estimated with current or with deflated values of PR, Y and PN. The advantage of the conventional deflated time series econometric estimates of (1) is reduced multicollinearity by removing the effect of PG. However, if (3) does not hold,

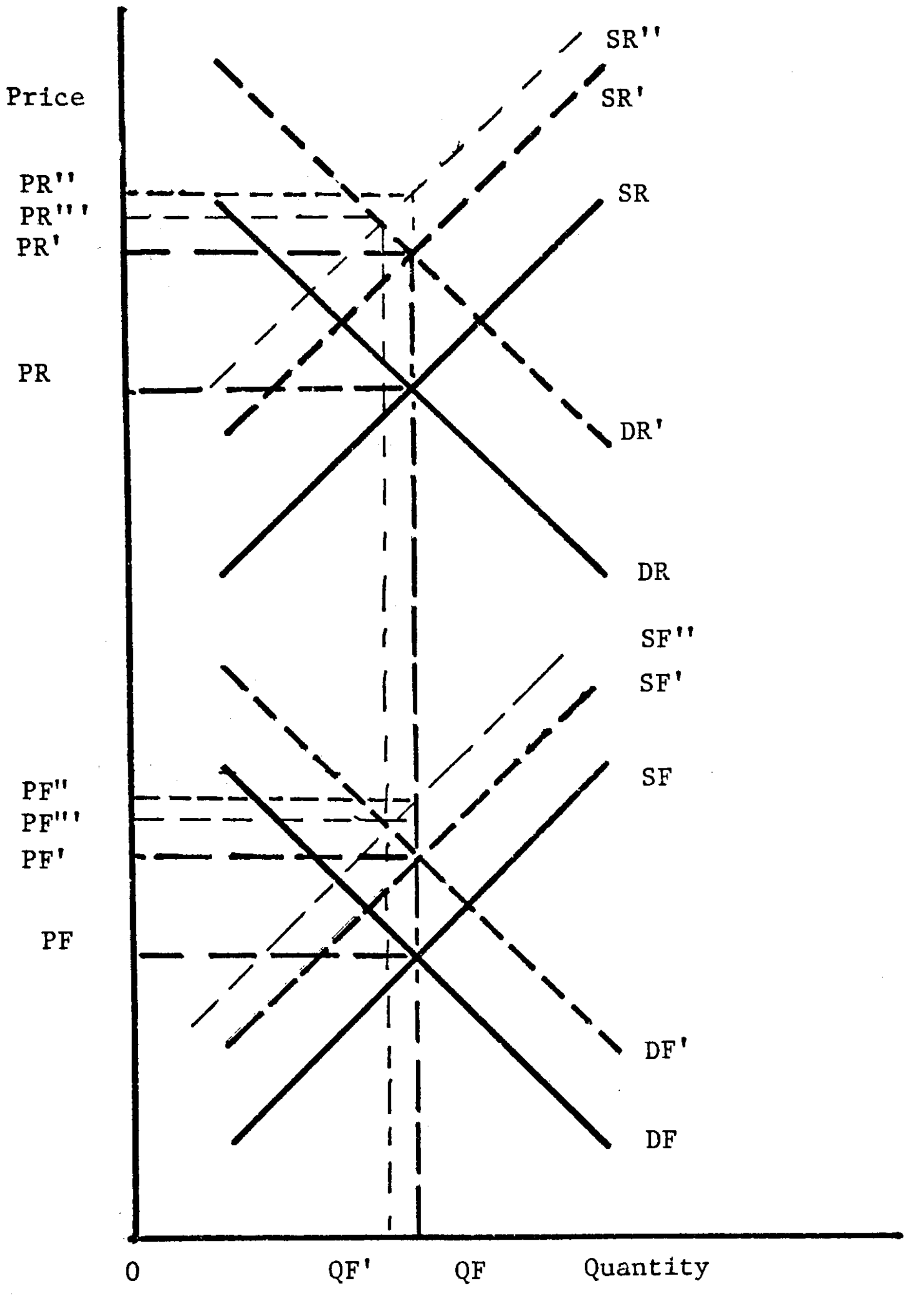

Figure 1. Graphic Illustration of the Impact of Inflation on Food Demand D and Supply S at Farm F and Retail R Levels

specification error is introduced. Inflation can shift real demand and quantity demanded either because (3) does not hold or because the demand function is not homogeneous of degree zero in current values of PR, Y and PN.

The basic form of the retail level demand equation estimated empirically in this study is

$$\text{(4)} \qquad PRt = PR(QRt, Yt, PNt)$$

where prices and income are in current rather than deflated dollars and QR is retail quantity of food including farm ingredients QF, imported foods and marketing services.[1] Separating each component of QR would complicate empirical estimates — the assumption is that the response of PR to QR is the same whether the quantity is from foreign or domestic sources.

Price is dependent in retail demand equation (4) because: (1) quantity in (4) is considered to be predetermined by past prices in the retail food supply equation, and (2) the theoretical model calls for prediction of retail price — the latter is predicted with greater precision, other things equal, when price rather than quantity is the dependent variable around which error is minimized.

Estimating the impact of inflation on demand for marketing services is complicated by joint determination of marketing services by elements of supply and demand. Marketing sector supply and demand are specified as follows:

$$\text{(5)} \qquad PMt = PM(QMt, Yt, Xt) \text{ Demand}$$

$$\text{(6)} \qquad QMt = QM(PMt, PLt, Zt) \text{ Supply}$$

[1]Shifting terms, (2.1) can be expressed as $(PR/PG)t = QR^{-1}[QRt, (Y/PG)t, (PN/PG)t]$
or
$PRt = QR^{-1}[QRt, (Y/PG)t, (PN/PG)t]PGt$
thus PR, the dependent variable, becomes homogeneous of degree 1.0 in PG. PG is factored out of the right side of the above equation to derive equation 2.4.

where price PM and quantity QM of marketing service are jointly determined; Y is income and PL is the price of labor. X is other factors influencing demand and Z is other factors such as the price of energy affecting the supply of marketing services. Single equation demand, supply and reduced form variants of the system were also estimated with results reported later.

Static economic theory suggests the hypothesis that the demand for and supply of marketing services are homogeneous of degree zero in prices and income. Real quantity QM is invariant to PG. The analytical basis for this hypothesis is similar to that for demand at the retail level and is not reviewed here.

Marketing margins as measured by DR-DF may decline as the quantity of farm ingredients increases, hence QF may be included in the specification of marketing margins. Because farm level demand is a derived demand, it is estimated indirectly from retail and marketing sector empirical estimates. For a given demand quantity, the farm level price PF is retail price PR less marketing margins PM as in Figure 1, or

$$\text{(7)} \qquad PFt = PRt - PMt.$$

The percentage change in PF associated with a one percent increase in the general price level PG is

$$\text{(8)} \quad E(PFPG) = E(PRPG)\left(\frac{PM}{PF} + 1\right) - E(PMPG)\frac{PM}{PF}$$

where E(PFPG) refers to the elasticity of price at the farm level with respect to the general price level and other terms beginning with E are interpreted similarly. If inflation is fully passed to retail price, i.e. $E(PRPG) = 1$, and to marketing margins, i.e. $E(PMPG) = 1$, then $E(PFPG) = 1$. That is, if retail demand price and the marketing margin in the food basket increase 1 percent, farm price PF also increases 1 percent. This implied 100 percent passthrough of inflation to the farm sector need not hold in practice — the actual degree of passthrough of inflation to the farm level is estimated in the Empirical Results section of this article.

The real price effect of inflation on the farming industry is defined in terms of PF/PP where PP is prices paid by farmers. The real price effect may be expressed as

$$(9) \qquad E[(PF/PP)PG] = E(PFPG) - E(PPPG).$$

If the elasticity of the farm terms of trade PF/PP with respect to PG is negative, the farm sector experiences a cost-price squeeze from general inflation. Real price effects may originate in (9) either from demand and supply functions that are not homogeneous of degree zero in prices and income or because inflation impacts prices unevenly, e.g. PP responds more than do other prices and income to PG.

The model is formulated such that the short-run elasticity E(PFPG) and the elasticity of the shift in the nominal demand curve with respect to PG are identical; similarly, the short-run elasticity E(PPPG) and the elasticity of the nominal supply curve with respect to PG are identical. The latter is apparent from the supply function of the form $QF = f(\frac{PF}{PP})$. An increase in PP by a given percentage due to PP must be accompanied by an equal percentage rise in PF to leave QF unchanged. This required rise in PF is the upward shift in the supply curve at a given QF.

Inflation Transmission Equations

The responses of PR and PM to Y, PN, PL and other predetermined variables were estimated by structural demand and, in some instances for PM, supply equations. The relationship of income and selected prices to the general price level was estimated by inflation transmission equations of the form

$$(10) \qquad Pit = P(PGt,\ T,\ Ut)$$

where Pit refers to respective current price and income variables in the structural equations, PG is the implicit price deflator of the Gross National Product, T is time and U is the national unemployment rate. The time variable is included to adjust for changes in technology, tastes and other factors which cause systematic digression of Pi from PG over time, and U is included because greater unemployment is expected to result in less cost-push inflation and differing responses to PG, other things equal. Several variants of (10) and the structural equations were estimated, including distributed lags to separate short- and long-run impacts. Empirical modifications that improved results are reported later.

Alternative Forms of the General Model

The general conceptual model given above can be estimated in various forms. Equation (4) can be estimated with PG as an independent variable in conjunction with deflated value of Y and PN (see footnote 1). Then E(PRPG) can be computed directly from the coefficient of PG in the empirical counterpart of equation (4). A shortcoming is that much of the information on the components of E(PRPG) shown in equation (3) is lost by the procedure. If inflation passthrough to income and prices of non-food items were complete so that E(YPG) = E(PNPG) = 1, the impact of PG on PR would be computed directly from the empirical version of equation (4) as E(PRPG) = E(PRY) + E(PRPN). Such simplicity is not necessarily possible, however. To provide more information, the model is estimated by stages: (a) structural equations, (b) inflation transmission equations for Y, PN, PL and the price of energy, PE, and (c) combined results from the first two steps to compute equations (8) and (9).

Computing equation (9) requires an estimate of E(PPPG). The supply equation for farm output may be specified with output QF a function of the ratio of lagged prices received PF to current or lagged prices paid by farmers PP. Thus an increase in PG shifts the output supply curve upward through PP. An equation relating PP to PG can be specified as an input supply equation where supply price is a function of technology and costs incurred by input suppliers. Because quantity of QF in the input supply equation is expected to have little impact on price PP within the range of variation in QF considered, i.e. input supply is highly elastic, the equation relating PP to PG omits QF and takes the form of the price transmission equation (10) with PP dependent.

Empirical Results

Empirical results are presented in three subsections: (a) structural equations for retail demand and marketing services, (b) inflation price transmission equations, and (c) elasticities of price response to inflation.

Structural Equations

Variables defined in Table 1 were used to estimate demand equations for food at retail in Table 2. Annual U.S. data for the equations were divided into two 15-year periods — 1948-62 and 1963-77. This procedure was chosen as a compromise between a longer

TABLE 1. Summary of Variables Used in Empirical Model

Code		Description and Source
PR	:	Retail cost, market basket originating on U.S. farms, 1967=100, [USDA, March 1979, p. 5; and earlier issues].
PM	:	Farm-retail spread, market basket originating on U.S. farms, 1967=100, [USDA, March 1979, p. 5; and earlier issues].
PF	:	Farm value, market basket originating on U.S. farms, 1967=100, [USDA, March 1979, p. 5; and earlier issues].
QR	:	Index of total food consumption, 1967=100, [USDA, March 1978, p.9].
QM	:	Quantity of marketing services as measured by marketing bill [USDA, March 1977, p. 25; and earlier issues] deflated by wholesale price index [USDA, March 1978, p. 10], in billion 1967 dollars.
QF	:	Quantity of farm food services as measured by the farm value of food [USDA, March 1975, p. 25; and earlier issues] deflated by the index of prices received by farmers for crops and livestock [Council of Economic Advisors, p. 365], in billion 1967 dollars.
Y	:	Disposable personal income, 1972=100 [USDA, March 1978, p. 4]. Y/N is Y divided by population [USDA, March 1978, p. 4].
PN	:	Consumer price index, all items less food, 1967=100 [Council of Economic Advisors, p. 314].
PG	:	Implicit price deflator of Gross National Product, 1972=100 [USDA, March 1978, p. 13].
PL	:	Hourly earnings of production employees in food manufacturing and nonsupervisory employees in wholesale and retail trade, 1967=100 [USDA, March 1979, p. 15; and earlier issues].
PE	:	Wholesale price index for industrial fuels, related products and power, 1967=100 [Council of Economic Advisors, p. 319]
PP	:	Prices paid by farmers for all items, including interest, taxes and wage rates, 1967=100 [Council of Economic Advisors, p. 365].
T	:	Time, recorded as last two digits of current year (T is in original values in all equations, including those in which other variables are logarithms).
U	:	Unemployment rate, males age 20 and over, as a percent of all males age 20 and over [Council of Economic Advisors, p. 291].

TABLE 2. Demand Equations for Food at the Retail Level Estimated by Ordinary Least Squares from Annual U.S. Data in Logarithms for 1948-62 and 1963-77, with PRt Dependent[a]

Equation Number	Period	d[b]	R^2		Equation: Intercept	QRt	Yt	PNt
(11)	1963-77	1.55	.987	Coef.	10.8279**	−2.4190**	.9404**	.2091
				s. e.	2.5804	.5538	.2535	.3155
(11)	1948-62	2.19	.926	Coef.	5.5525*	−1.7127**	.3111	1.2159**
				s. e.	2.1164	.3898	.2513	.40147
(12)	1963-77	1.67	.986	Coef.	12.0698**	−2.6238**	1.0989**	
				s. e.	1.7324	.4487	.0822	
(12)	1948-62	2.013	.864	Coef.	11.0520**	−2.2784**	.9673**	
				s. e.	1.3703	.4410	.1605	

[a]See Table 1 for definition of variables.

[b]Durbin-Watson d statistic. The d statistic is used to test the null hypothesis of zero positive autocorrelation in the residuals. For this test as well as the t-test for zero values of multiple regression coefficients, the following notation is used:
* Significant at .05 probability level.
** Significant at .01 probability level.
s.e. Refers to standard error of regression coefficient.

period to provide more degrees of freedom and a shorter period to provide a more homogeneous market structure within each period. Parameter estimates for equations with the same specification but with different years of data permit observation of structural change between the two time periods.

Nominal demand equations are estimated with prices and income in current rather than constant dollars. All variables (except time variable T) in all empirical equations are in logarithms, hence the coefficients are price and income flexibilities or elasticities. Despite the large apparent differences in coefficients in (11) between periods, an F-test of the null hypothesis that the coefficients of equation (11) were equal for the 1948-62 and 1963-77 periods was highly insignificant. Elimination of PN (because it has generally been less significant than Y in previous studies of demand cited in the references) reduced multicollinearity (see Appendix Table 1 for simple correlation coefficients) and attendant instability of coefficients. The obvious similarity of coefficients between the two time periods in equation (12) affirms the above F-test giving no basis to reject the null hypothesis of similar demand structures (coefficients) for 1948-62 and 1963-77.

Similar trends in movement of income Y and PN over time precluded precise empirical separation of income and substitution effects. Omitting PN in equation (12) results in the coefficient of Y containing both income and substitution effects. Results indicate that a 1 percent increase in current income increased retail demand price by .97 in the 1948-62 period and by 1.10 percent in the 1963-77 period. Coefficients in equation (12) are significantly different from zero at the .01 probability level or better. But in the case of Y, the test of interest is whether its coefficient differs from 1.0. With a standard error (s.e.) on the coefficient of Y of .082 for the 1963-77 period and of .160 for the 1948-62 period, no basis exists to reject the null hypothesis that the elasticity of PR with respect to nominal income Y is 1.0. The inference also implies inability to reject the null hypotheses that nominal demand for food increases in direct proportion to inflation (assuming inflation of 1 percent raises Y by 1 percent), that the retail demand equation is homogeneous of degree zero in prices and income, and that real demand for food at the retail level is unaffected by inflation.

Illustrating with equation (11) for 1963-77, the nominal income elasticity of retail demand E(QRY) is − E(PRY) ÷ E(PRQR) or .39, the cross price elasticity of demand E(QRPN) is − E(PRPN) ÷ (PRQR) or .09 and the own price elasticity of demand is 1/E(PRQR) or − .41. If marketing margins are constant and price at the farm level is 39 percent of price at retail (the actual 1963-77 average), then the price elasticity of demand at the farm level is estimated to be − .16. Despite model differences, these results are broadly in line with results from Brandow, George and King, Hiemstra, Mann and St. George, Tweeten and Waugh.

Several variants of equations (11) and (12) were estimated: variables in original values rather than logarithms, the Consumer Price Index for all food instead of PR, quantity QR as the dependent variable; Y and PN were deflated and PG included as an independent variable to control for inflation, a lagged dependent variable was inserted to account for lagged effects, and quantity and income were divided by population to estimate per capita demand; and data were combined for 1948-77. Because no variant improved the equations, results are not shown.

The economic behavior of marketing services under inflation may be characterized by joint determination of marketing sector price and quantity in supply and demand equations. Appendix Table 2 contains equations estimated simultaneously by three-stage least squares with PM and QM jointly determined. Coefficients of the variables possessed expected signs and all were significantly different from zero at the .01 level in the demand and supply equations for the 1963-77 period. The variables in Appendix equations (A-1) and (A-2) performed better in estimating the economic structure of marketing services for the 1963-77 period than for the 1948-62 period. The supply equations gave statistically satisfactory results with the price of energy PE a predetermined variable but performed poorly with inclusion of the price of labor PL in the supply equation — the coefficient of PL was positive. The coefficient of PL was expected to be negative and more significant than that of PE because labor is a much greater component of marketing costs than is energy.

This ambiguity and failure to improve on results in Appendix Table 2 with alternative specifications of the simultaneous system prompted attention to ordinary least squares, which produced parameter estimates shown in Table 3 with PM dependent. Correlation between Y and PL (see Appendix Table 1) advised against including both variables in "reduced form" equations for PM in Table 3.[2] According to demand equation (13), a 1 percent increase in Y increased PM by .47 percent in the 1948-62 period and .71 percent in the 1963-77 period. In the latter period, the impact of Y was distributed over time as indicated by the significant coefficient on the lagged value of PM in equation (14). That equation indicated that a 1 percent increase in Y increased PM by .39 percent in the short run and by .81 percent in the long run. Comparing demand equation (15) with "reduced form" equation (16), the response of PM is somewhat greater to PL than to Y. The coefficient of PL tends to reflect the influence of Y as well as wage rates.

The quantity of food ingredients QF supplied by farmers is introduced in equations (15) and (16) to control for the influence of QF on PM. The results indicate that PM was negatively and significantly influenced by greater demand quantity QF in the 1963-77 period. That is, marketing margins appear not to be constant but to be greater when farm quantity QF is smaller.

Modifications such as estimation in original observations (as opposed to logarithms), additional prices (PN,PE, interest rates), pro-

[2]The term "reduced form" here refers to a regression of an endogenous variable on predetermined variables in the system — the term is used in quotes because the equations in Table 3 include an independent variable QM which may be viewed as endogenous.

TABLE 3. Demand and Reduced Form Equations for Food Marketing Services Estimated by Ordinary Least Squares from Annual U.S Data in Logarithms for 1948-62 and 1963-77, with PMt Dependent[a]

Equation Number	Period	d or h[b]	R^2		Equation: Intercept	QMt	Yt	PLt	QFt	PMt−1
(13)	1963-77	1.44	.969	Coef.	4.8504**	−.7901**	.7074**			
				s. e.	.7068	.2005	.0424			
(13)	1948-62	1.69	.967	Coef.	2.9190**	−.0506	.4747**			
				s. e.	.2222	.1565	.1063			
(14)	1963-77	− .59	.986	Coef.	2.5601**	−.4882**	.3866**			.5256**
				s. e.	.8027	.1638	.0931			.1445
(14)	1948-62	− .54	.974	Coef.	2.1281**	−.1720	.3777**			.3598
				s. e.	.5127	.1626	.1145			.2134
(15)	1963-77	1.20	.980	Coef.	4.7709**	−.7601**	.9800**		−.3483**	
				s. e.	.3286	.1153	.1180		.1178	
(15)	1948-62	1.70	.967	Coef.	2.9298**	−.0523	.4771**		−.0043	
				s. e.	.3595	.1691	.1267		.1103	
(16)	1963-77	1.98	.986	Coef.	3.4684**	−.8323**		1.1823**	−.2741	
				s. e.	.4729	.1549		.1499	.1290	
(16)	1948-62	1.51	.961	Coef.	2.4052**	−.1843		.6469**	.0096	
				s. e.	.2894	.2400		.2045	.1211	

[a]See Tables 1 and 2 for definitions.

[b]Durbin-Watson d statistic or h statistic, the latter used to test for first order autocorrelation in the residuals in equations containing a lagged dependent variable.

ductivity variables, QM dependent, per capita equations, and deflated values of prices and income in equations that included PG did not improve results over those in Table 3.

Inability to reject the hypothesis that the coefficients of Y in equation (15) and of PL in equation (16) are unitary for the 1963-77 period is equivalent to not rejecting the hypothesis that marketing margin as represented by PM is homogeneous of degree zero in income Y in (15) and price PL in (16). And this conclusion is equivalent to not rejecting the hypothesis that a 1 percent increase in the general price level increases nominal demand for marketing services 1 percent and real demand not at all.

Inflation Transmission Equations

Inflation transmission equations are shown for key variables in Table 4. In each case, the dependent variable was regressed on PG and unemployment rate, time and the lagged dependent variable. Several variables with insignificant coefficients or high intercorrelations were dropped.

Although the estimated elasticity of PN with respect to PG obviously is much closer to unity than the elasticity of Y/N with respect to PG for 1963-77, statistical inference indicates that the probability that the *true* elasticity of PN with respect to PG falls short of unity is greater than the probability that the true elasticity of Y/N with respect to PG falls short of unity. The coefficient of PG for 1963-77, .8029 in equation (18), is significantly different from 1.00 at the .09 probability level. The coefficient for PG in equation (19) for the same period is significantly different from unity at the .005 probability level. The long-run coefficient of PN is $.6995 \div (1 - .3011) = 1.0$ for the 1963-77 period according to equation (20).

On the whole there is insufficient evidence to reject the null hypothesis that E(Y/N PG) and E(PNPG) equal unity, i.e. that national inflation as measured by PG is fully imparted to the demand variables Y/N and PN based on 1963-77 results. This conclusion is strengthened by the argument that the coefficients are probably biased downward by error in PG.

Inflation transmission equations for the price of labor PL specified exactly the same for the 1948-62 period and the 1963-77 period resulted in unrealistic coefficients in one or the other period. So different specifications are shown for each period in equation (21) to (24). An increase in the response of PL to inflation over time is evidenced by the generally larger coefficients for PG in the 1963-77 period than in the 1948-62 period.

Elasticity Estimates

The foregoing results supply the foundation to estimate the effect of inflation on prices received by farmers. The procedure is to estimate the response of PF to PG, proceeding step-by-step from retail to farm level demand.

The elasticity of retail food prices with respect to inflation E(PRPG) is the product of the elasticity of retail price with respect to income E(PRY) and the elasticity of income with respect to inflation E(YPG)[3] or

(26) $$E(PRPG) = E(PRY) \cdot E(YPG)$$

$$.8823 = 1.0989 \cdot .8029$$

(1963-77 from equations (12) and (18)

$$.7233 = .9673 \cdot .7477$$

(1948-62 from equations (12) and (18)).

The elasticity of PM with respect to general inflation E(PMPG) can be estimated from various equations. Based on demand equations with only Y affected by inflation, the elasticity is

[3]Equation (18) can be written $\ln Y = \alpha_0 + \alpha_1 \ln PG + \alpha_2 \ln U + \alpha_3 T - \ln N$. It follows that the elasticity of Y or Y/N with respect to PG is α_1. Y/N rather than Y was used in equation (18) because of fewer multicollinearity problems with the former.

TABLE 4. Inflation Transmission Equations Estimated By Ordinary Least Squares From Annual U.S. Data In Logarithms For 1948-62 AND 1963-77[a]

					Equation				
Equation Number & Dependent Var.	Period	d or h[b]	R^2		Intercept	PGt	Ut	T	Lagged Dependent Variable
(18) (Y/N)	1963-77	1.73	.999	Coef.	−1.5319**	.8029**	−.0346*	.0346**	
				s. e.	.1320	.1042	.0140	.0049	
(18) (Y/N)	1948-62	1.53	.996	Coef.	− .3616	.7477*	−.0431*	.0120*	
				s. e.	.9261	.3196	.0150	.0074	
(19) (PN)	1963-77	.84*	.998	Coef.	.4045**	.9622**			
				s. e.	.0506	.0111			
(19) (PN)	1948-62	.86*	.988	Coef.	.7612**	.8807**			
				s. e.	.1108	.0269			
(20) (PN)	1963-77	1.49	.999	Coef.	.1731	.6995**			.3011**
				s. e.	.0891	.0906			.1033
(20) (PN)	1948-62	1.75	.994	Coef.	.6247**	.6069**			.2896**
				s. e.	.0889	.0792			.0811
(21) (PL)	1963-77	2.00	.999	Coef.	− .5646**	.7558**		.0280**	
				s. e.	.0655	.0545		.0030	
(22) (PL)	1963-77	−3.20*	.999	Coef.	− .4115**	.4577**		.0208**	.3568
				s. e.	.0965	.1572		.0044	.1788
(23) (PL)	1948-62	1.12	.990	Coef.	−4.0886**	1.9679**	.0547*		
				s. e.	.2519	.0634	.0204		
(24) (PL)	1948-62	− .98	.996	Coef.	−1.2549*	.6497**			.6607**
				s. e.	.5013	.2223			.1050
(25) (PE)	1963-77	.60*	.920	Coef.	−2.4029**	1.5440**	.2054		
				s. e.	.7944	.1948	.1256		
(25) (PE)	1948-62	1.89	.882	Coef.	.9255	1.0910**		− .0161*	
				s. e.	.9020	.3102		.0070	

[a]See Table 1 for definitions and sources of variables; Table 2 for meaning of asterisk.
[b]Durbin-Watson d statistic or h statistic, the latter used to test for first order autocorrelation in equations containing lagged dependent variables.

(27) $E(PMPG) = E(PMY) \cdot E(YPG)$

$.7868 = .9800 \cdot .8029$
(1963-77 from equations (15) and (18))

$.3104 = .3866 \cdot .8029$
(1963-77 short run from equations (14) and (18))

$.6543 = .8149 \cdot .8029$
(1963-77 long run from equations (14) and (18))

$.3567 = .4771 \cdot .7477$
(1946-62 from equations (15) and (18)

$.2824 = .3777 \cdot .7477$
(1946-62 short run from equations (15) and (18))

$.7611 = 1.0179 \cdot .7477$
(1946-62 long run from equations (14) and (18))

The elasticity of PM with respect to PG was also computed as E(PMPG) = E(PMPL)·E(PLPG) from equations (16) and (21) ((23) instead of (21) for 1948-62) and as E(PMPG) = E(PMPE)·E(PEPG) from the simultaneous equation system in Appendix Table 2 and equation (25). These latter estimates from the simultaneous system and from the reduced form equations containing PL gave slightly higher estimates of E(PMPG) than the foregoing estimates from Y.

The next step is to compute the elasticity of farm price with respect to PG. This will be expressed from the foregoing estimates (26) and (27) using the equation (8) derived earlier.

$$(8) \quad E(PFPG) = E(PRPG)\left(\frac{PM}{PF} + 1\right) - E(PMPG)\frac{PM}{PF}$$

$1.0292 = .8823\ (2.5381) - .7868\ (1.5381)$
(1963-77)

$1.7619 = .8823\ (2.5381) - .3104\ (1.5381)$
(1963-77 short run)

$1.2330 = .8823\ (2.5381) - .6543\ (1.5381)$
(1963-77 long run)

$1.2450 = .7233\ (2.4231) - .3567\ (1.4231)$
(1948-62)

$1.3507 = .7233\ (2.4231) - .2824\ (1.4231)$
(1948-62 short run)

$.6695 = .7233\ (2.4231) - .7611\ (1.4231)$
(1948-62 long run)

Equations which distinguish length of run are considered to be less reliable because of multicollinearity introduced by the lagged dependent variable. The foregoing elasticities, particularly the estimates which do not distinguish length of run, provide no basis to reject the null hypothesis that national inflation is fully passed to nominal demand at the farm level, i.e. that each 1 percent increase in PG raises prices received by farmers by 1 percent, other things equal.

Real Price Impact

We have already observed that the elasticity of demand at the farm level with respect to PG is approximately unity. If the same holds for supply, inflation influences neither quantity QF nor real price PF/PP.

Following the same procedure for farm supply as followed above for demand requires estimates of the degree of homogeneity of the supply function with respect to prices. Previously estimated supply functions (see Tweeten and Quance) express output as a function of PF/PP and are homogeneous of degree zero in prices. If inflation transmission to prices paid by farmers is unitary, i.e. E(PPPG) = 1, it follows that the nominal supply curve shifts upward 1 percent with a 1 percent increase in general inflation.

Empirical estimates of E(PPPG) are available from equations in Table 5, estimated with a specification similar to the price transmission equations in Table 4. The supply of purchased farming inputs is considered to be perfectly elastic — prices paid by farmers are assumed to be unaffected by the quantity demanded.

As apparent in Table 5, a different set of variables accounted for the variation in PP from 1948 to 1962 and from 1963 to 1977. The time trend and unemployment rate were prominent in the 1963-77 period (equation (29) whereas a distributed lag in response of

TABLE 5. Impact of Inflation on Prices Paid by Farmers as Estimated by Ordinary Least Squares from Annual U.S. Data in Logarithms for 1948-62 and 1963-77, with PP Dependent[a]

Equation Number	Period	d or h[b]	R^2		Equation: Intercept	PGt	Ut	T	PFt	PPt−1
(28)	1963-77	.84	.994	Coef.	−1.7733**	2.2108**	−.0768*	−.0481**		
				s. e.	.3130	.2471	.0332	.0115		
(28)	1948-62	1.31	.992	Coef.	.8524	.9861	−.0342	−.0083		
				s. e.	1.4894	.5141	.0241	.0119		
(29)	1963-77	1.1	.999	Coef.	−1.4514**	1.7748**	−.0560**	−.0387**	.2004**	
				s. e.	.1408	.1218	.0144	.0051	.0282	
(30)	1963-77	.60*	.998	Coef.	−1.0129**	1.4189**		−.0244**	.2226**	
				s. e.	.1264	.1207		.0053	.0416	
(31)	1963-77	c	.992	Coef.	− .8645*	1.1163		−.0145		.3394
				s. e.	.3967	.6742		.0173		.3366
(32)	1948-62	1.27	.974	Coef.	.1261	.7200**			.2863**	
				s. e.	.3017	.0353			.0418	
(33)	1948-62	− .51	.987	Coef.	− .3859	.5896**			.3020**	2222**
				s. e.	.2746	.0480			.0316	.0683

[a]See Table 1 for definitions and sources of variables; see Table 2 for meaning of asterisks.
[b]Durbin-Watson d statistic or h statistic, the latter used in equations containing lagged dependent variables.
[c]The h statistic cannot be computed, but the first order autocorrelation coefficient is estimated to be .4373.

PP to PG was prominent in the 1948-62 period as evidenced by the highly significant coefficient of PPt-1 in equation (33). The index of prices paid by farmers contains some price components for purchased livestock, seed and feed that are also part of prices received by farmers. To control for this distortion, PF is included as an independent variable in several equations. The point estimate of E(PPPG) as measured by the coefficient of equation (30) for 1963-77 is 1.4189 and significantly exceeds unity. With a standard error of .1207, the coefficient also statistically exceeds at the .01 probability level the estimate E(PFPG) = 1.0292 derived above. Thus, statistical evidence indicates that the farm level supply curve rises proportionately more than the demand curve with inflation, other things equal.

The final step in the analysis is to compute the impact of the general price level on real farm price PF/PP where PF is prices received and PP prices paid by farmers. As defined earlier in equation (9), the elasticity of real farm price with respect to PG is E(PFPG) less E(PPPG).

Based on the foregoing coefficients, the elasticity of real farm prices with respect to PG is 1.0292 − 1.4189 = −.3897, indicating that based on 1963-77 data, national inflation imposed a cost-price squeeze on the farm sector. It is cautioned that this and related estimates of E[(PF/PP)PG] can be interpreted as no more than the "most likely" values because lack of a standard error for the parameter precludes a statistical test of hypothesis. Inflation passthrough defined as the percentage increase in prices received by farmers (upward shift in demand in Figure 1) in relation to the percentage increase in prices paid by farmers (upward shift in supply in Figure 1) was 1.0292 ÷ 1.4189 = .725 or 72 percent based on the 1963-77 structure and particular coefficients selected to illustrate results — with quantity QF constant.[4]

The principal source of the squeeze was not demand or supply functions homogeneous of degree other than zero nor failure of prices and income to raise nominal demand at the farm level at the rate of inflation, but rather was prices paid by farmers increasing considerably faster than the inflation rate. The hypothesis E(PFPG) = 1 was not rejected whereas the hypothesis E(PPPG) = 1 was rejected in favor of a larger value. Evidence of the impact was apparent as the general price level increased 87 percent while prices paid by farmers increased 122 percent from 1963 to 1977 (see Table 1 for data sources).

The mix of inputs used by farmers helps to explain the different rates of increase in PP and PG. Farming is capital intensive, and nominal capital price as measured by interest rates increased 425 percent from 1963 to 1977. Farmers have more real property per capita than others, and property taxes per acre increased 153 percent during the same period. Farm wage rates and machinery prices also increased faster than the general price level. The price index of all farm production items with nonfarm origin increased 137 percent and with farm origin increased 91 percent from 1965 to 1977 [U.S. Department of Agriculture, June 1978, p. 23] (earlier data unavailable).

General inflation appeared to have a less unfavorable impact on PF/PP in the 1948- 62 period than in later years. The relative impact on prices received as indicated by E(PFPG) shown earlier seemed no less than in 1963-77 but E(PPPG) appeared to be lower. For the earlier period the significant coefficient on PPt-1 in equations (32) and (33) in Table 5 suggests a difference between

[4]With output constant at QF in Figure 1, product price at the farm level would need to rise to PF″ to retain the pre-inflation ratio of prices received to prices paid by farmers. With output at QF in the shortrun, prices received rise only to PF′. In time, the reduced ratio of prices received to prices paid induces restraint on use of inputs and hence in production of output to QF′. The equilibrium result is higher prices (PF″′ in Figure 1) than the price PF′ following inflation but less than PF″. This process is described and quantified by Tweeten and Griffin. The "long-run" impacts estimated empirically in this study do not account for the output adjustments which dampen real price effects.

short- and long-term responses. Based on equation (33), E(PPPG) is .59 in the short run and .76 in the long run. The implication is that a 1 percent increase in PG increased PF/PP by $1.35-.59=.76$ percent in the short run and by $.67-.76= -.09$ percent in the long run based on the 1948-62 market structure.

Summary and Conclusions

The overall objective of this study was to estimate the impact of general inflation on prices paid and received by farmers. This objective was analyzed with two component hypotheses:

(1) The first is that economic functions determining demand for output at the farm level are homogeneous of degree zero in income and prices, so that a truly general increment in overall price level increases nominal prices received and farm demand in proportion to the general price level but leaves real farm demand and hence real demand price unchanged. This hypothesis could not be rejected based on the domestic components of demand for farm output examined in this study. While it has been long recognized that national inflation strongly influences prices paid by farmers and hence the nominal supply of farm output, a major finding of this study is that passthrough of national inflation to nominal demand for farm output at the farm level is full and complete in one year.

(2) Further statistical analysis focused on the impact of inflation on prices paid by farmers and the supply of farm output. Statistical results provided evidence to reject the null hypothesis that a 1 percent increase in the general price level increased prices paid by farmers and the supply curve by 1 percent and instead supported a higher value. Although a standard error could not be computed to test differences between responses of farm prices paid and received to inflation, the evidence for the 1963-77 period indicated that national inflation raised prices paid by farmers and nominal supply of farm output more than it raised prices received by farmers and nominal demand for farm output.

At issue is whether this cost-price squeeze is structurally (causally) related to general inflation or is a statistical artifact of the 1963-77 period. Although the procedure employed in this study was designed to control for variables to obtain the net effect of inflation, such precision is in fact not easily accomplished. Some deductive inferences suggest that the greater impact of inflation on the supply curve (prices paid) than on the demand curve (prices received) is expected with inflation. Interest rates and property taxes increased faster than the general price level and farmers, because of their heavy capital and real estate intensity, were influenced more than other parts of the economy. If inflation is associated with inadequate investment, savings and aggregate supply of capital, continued inflation may in the future generate a cost-price squeeze to farmers because of high capital intensity of farming. The question of whether E(PPPG) will, in the future, approach unity and hence relieve farm cost-price pressures is obviously a candidate for future study.

This study had several limitations:

(1) Inflation has cost-push, demand-pull and structural sources. It is not possible to separate the impact of each of these on the farming economy. But is important to recognize that the impact on farm terms of trade and income is much more favorable if inflationary pressures come from a shortage of food and fiber rather than a shortage of energy. Subsequent analysis could estimate inflation passthrough associated with cost-push versus demand-pull inflation, for example.

(2) Inflation is expected to work its way through the economic system with a distributed lag. Distributed lag equations herein provided erratic results in part because of reliance on annual data. In some equations, lag may be several months but less than one year. Monthly and quarterly data would add to this study by revealing a cost-price squeeze or gain associated with demand and

supply influenced unevenly by general inflation over a few months or quarters.

(3) Use of current rather than deflated price and income resulted in substantial multicollinearity. Even discounting the high R^2 arising from strong trends in the data, statistical properties of the equations were in general reasonably satisfactory in relation to those found in other econometric investigations. The use of current rather than deflated time series was necessary to test the hypotheses of this study and implicit assumptions underlying traditional deflation procedures. This study, for the most part, validates and recommends the use of *deflated* series in subsequent demand analysis.

(4) The model was substantially more elaborate than a simple regression relating the ratio of prices received to prices paid by farmers to the general price level so that the effects of productivity, real income and other factors not related to inflation could be controlled and eliminated. While it would be presumptuous to argue that these efforts were fully successful, it is well to note that failure to correct should have been apparent in an elasticity of E(PFPG) well below unity — a result not found in this study. The impact of failure to correct for productivity would not be large on E(PPPG), yet this parameter was found to be the source of the cost-price squeeze.

(5) Lack of time and resources precluded making additional modifications in the econometric model. Suggested additions or changes include disaggregation of farm and food output by commodity, region and type of farming, along with integration of supply and demand equations into a simultaneous econometric system. Emphasis in this study was on demand for farm output at the domestic level. More attention needs to be given domestic inventory and to foreign components of demand and to domestic supply at the farm level.

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APPENDIX TABLE 1. Simple Correlation Coefficients between Variables Used in Econometric Models. Coefficients Above and to Right of Diagonal for 1948-62; Coefficients Below and to Left of Diagonal for 1963-77[a]

	Variable														
	T	PR	QR	Y	Y/N	PN	PG	PM	QM	PL	PE	U	PP	PF	QF
T	1.00	.73	.99	.99	.99	.99	.99	.98	.99	.99	.87	.44	.90	−.64	.78
PR	.96	1.00	.67	.75	.76	.80	.79	.81	.66	.74	.75	.06	.92	−.01	.90
QR	.98	.88	1.00	.99	.99	.98	.98	.97	.99	.99	.86	.41	.88	−.69	.73
Y	.99	.98	.96	1.00	.99	.99	.99	.98	.98	.99	.89	.37	.92	−.62	.79
Y/N	.99	.98	.96	.99	1.00	.99	.99	.98	.96	.99	.90	.34	.93	−.60	.79
PN	.98	.98	.93	.99	.99	1.00	.99	.99	.96	.99	.89	.35	.95	−.57	.81
PG	.98	.99	.93	.99	.99	.99	1.00	.99	.97	.99	.91	.37	.93	−.58	.81
PM	.95	.99	.88	.96	.97	.99	.99	1.00	.96	.98	.88	.35	.94	−.57	.78
QM	.71	.50	.83	.68	.66	.61	.61	.51	1.00	.98	.83	.49	.85	−.70	.73
PL	.99	.98	.95	.99	.99	.99	.99	.97	.66	1.00	.87	.44	.91	−.63	.78
PE	.89	.97	.78	.91	.92	.95	.95	.98	.37	.92	1.00	.20	.84	−.50	.78
U	.53	.64	.43	.56	.57	.65	.64	.69	.14	.59	.71	1.00	.15	−.99	.15
PP	.96	.99	.89	.98	.98	.99	.99	.99	.52	.98	.97	.65	1.00	−.29	.90
PF	.91	.97	.82	.93	.93	.92	.94	.94	.40	.93	.92	.59	.96	1.00	−.06
QF	.97	.98	.92	.98	.98	.96	.97	.95	.56	.97	.91	.53	.97	.98	1.00

[a]See Table 1 for definitions and sources of variables.

APPENDIX TABLE 2. Demand and Supply Equations for Food Marketing Services Estimated by Three-stage Least Squares from Annual U.S. Data in Logarithms for 1948-62 and 1963-77[a]

Equation Number		Dependent Variable		Equation[a]				
				Intercept	QMt	PMt	Yt	PEt
				(Model 1963-77)				
(A-1)	(Demand)	PMt	Coef.	6.4013**	−1.2391**		.7717**	
			s. e.	1.0224	.2920		.0559	
(A-2)	(Supply)	QMt	Coef.	.0554		1.7158**		−.8523**
			s. e.	.6399		.2904		.1581
				(Model 1948-62)				
(A-1)	(Demand)	PMt	Coef.	2.8533**	−.0007		.4417	
			s. e.	.5382	.4037		.2684	
(A-2)	(Supply)	QMt	Coef.	− .7147		1.7655**		−.7537
			s. e.	2.4042		.3060		.7796

[a]See Table 1 for sources and definitions of variables, see Table 2 for definition of asterisks.