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ON THE USE OF PRICE RATIO IN SUPPLY RESPONSE

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SUPPLY RESPONSE

Jean-Paul Chavas

Abstract

Because of a lack of data or multicollinearity problems, it is fairly common to include only a subset of the relevant prices in econometric model of supply response. This paper provides some evidence on the validity of using price ratios in this situation. A model of the U.S. poultry and egg industry where feed cost and output price are the only economic variables considered suggests that the use of price ratios would be inappropriate. If careful attention is given to model specification, it appears that homogeneity restrictions should not be imposed on supply response models unless the excluded prices are known to have little influence on production decisions.

ON THE USE OF PRICE RATIO IN SUPPLY RESPONSE

The modeling of supply response has a long history in agricultural economics. The specification and estimation of input-output relationships or supply-demand relationships has received considerable attention. Economic theory has helped providing a basis for the specification of economic models. One of its contributions has been that prices should be interpreted only in relative terms. This proposition has had a profound influence on agricultural economics. It has led a number of economists to avoid the use of absolute prices in economic analysis. For this reason, numerous models of the agricultural sector use price ratios as explanatory variables. Similarly, data on "feed cost to price" ratios are regularly published for a number of livestock activities. However, in empirical work, it is often difficult to obtain data on all prices involved in a given economic sector, implying that only a subset of the relevant prices are included in econometric models of supply response. For example, feed cost is frequently the only cost of production considered in models of livestock activities. In this situation, it is reasonable to question whether or not the use of price ratios is always appropriate in model building.

The objective of this paper is to provide some evidence on the validity of the use of price ratios in supply response when some of the relevant prices are not included in the model. The issue is approached from a theoretical point of view in section 1. It is shown that the homogeneity of degree zero in prices of supply functions holds in general only in a partial equilibrium framework where all relevant prices are included. In section 2, a model of the U.S. poultry and egg industry in which feed cost and output price are the only economic variables considered is presented. The model provides some empirical evidence supporting the theoretical results. This suggests that the homogeneity restrictions (the use of price ratios) should not be systematically imposed on supply response models.

1 - Price Homogeneity

Consider an industry constituted of competitive firms. The i^{th} firm produces an output Y_i from two inputs X_{1i} and X_{2i} according to the production function[1/]

$$Y_i = f_i\,(X_{1i}\ ,\ X_{2i}) \qquad ;\ i = 1, \ldots, m \qquad (1)$$

where m is the number of firms in the industry. In a competitive market, all prices P, r_1 and r_2 are exogenous to the firm, P denoting output price and r_j the price of the j^{th} input (j = 1,2). The i^{th} firm is presumed to maximize the profit function $\pi_i = P\ Y_i - r_1\ X_{1i} - r_2\ X_{2i}$. Under appropriate assumptions about the production process, the profit maximizing input and output levels for the i^{th} firm are

$$X_{ij}^D = X_{ij}\left\{\frac{r_1}{P}, \frac{r_2}{P}\right\} \qquad ;\ j = 1, 2;\ i = 1, \ldots, m \qquad (2)$$

and

$$Y_i^S = Y_i\left\{\frac{r_1}{P}, \frac{r_2}{P}\right\} \qquad ;\ i = 1, \ldots, m \qquad (3)$$

Equations (2) and (3) represent respectively the firm input demand and output supply functions. They are homogeneous of degree zero in prices, that is a proportionate change in all prices does not affect the optimal factor use or the optimal production level. The short-run industry input demand or output supply function is simply the sum of (2) or (3) over all firms, i.e.

$$X_j^D = \sum_{i=1}^{m} X_{ij}\left\{\frac{r_1}{P}, \frac{r_2}{P}\right\} = X_j^D\left\{\frac{r_1}{P}, \frac{r_2}{P}\right\} \quad ;\ j = 1, 2 \qquad (4)$$

and

$$Y^s = \sum_{i=1}^{m} Y_i \left\{\frac{r_1}{P}, \frac{r_2}{P}\right\} = Y_p^s \left\{\frac{r_1}{P}, \frac{r_2}{P}\right\} . \qquad (5)$$

Expressions (4) and (5) are the partial equilibrium industry input demand and output supply functions. It is clear that they are homogeneous of degree zero in prices. These results may be alternatively expressed in elasticity form. From (5), production elasticities with respect to output price and input prices are respectively

$$\frac{\partial Y_p^s}{\partial P} \frac{P}{Y_p^s} = - \frac{1}{PY_p^s} \sum_{j=1}^{2} (h_j \; r_j) \qquad (6)$$

and

$$\frac{\partial Y_p^s}{\partial r_i} \frac{r_i}{Y_p^s} = \frac{1}{PY_p^s} \; h_i \; r_i \qquad (7)$$

where $h_i = \dfrac{\partial Y_p^s}{\partial (r_i/P)}$. From (6) and (7), it follows that homogeneity of degree zero in prices implies

$$\frac{\partial Y_p^s}{\partial P} \frac{P}{Y_p^s} = - \frac{\partial Y_p^s}{\partial r_1} \frac{r_1}{Y_p^s} - \frac{\partial Y_p^s}{\partial r_2} \frac{r_2}{Y_p^s} \qquad (8)$$

This is a classical result of production theory: in the short run and in a partial equilibrium framework, homogeneity implies that the aggregate production elasticity with respect to output price (or supply elasticity) is entirely determined by the production elasticities with respect to input prices.

Now consider that the industry is facing the input supply curve for X_2

$$X_2^s = X_2^s \; (r_2) \qquad (9)$$

Using (9) and the demand function for X_2 (equation (4)), we can solve for the equilibrium price level $r_2 = r_2(r_1, P)$. Substituting this expression into (5) yields

$$Y^s = Y^s_P \left\{\frac{r_1}{P}, \frac{r_2(r_1, P)}{P}\right\} = Y^s_G\ (r_1, P) \tag{10}$$

Equation (10) is a supply function that takes into consideration the adjustments of the input price r_2 as the other prices (r_1 and P) fluctuate. It is not a partial equilibrium function since it takes into account the equilibrium conditions in the market for X_2. This interaction among related commodity markets is crucial in the investigation of supply response (Gardner, 1979). Note the difference between the partial equilibrium supply function (5) and equation (10). The former includes all prices involved in the production process and is homogeneous of degree zero in these prices. The latter includes all prices except the price r_2 that adjusts to other price fluctuations. It is shown in the appendix that equation (10) is homogeneous of degree zero in prices only if the supply curve for X_2 is perfectly inelastic, i.e. if X_2 is a fixed input. However, if the supply for X_2 has a positive but finite slope, then expression (10) is not homogeneous of degree zero. In this case, it can be shown that (see Appendix)

$$\frac{\partial Y^s_G}{\partial P} \frac{P}{Y^s_G} > - \frac{\partial Y^s_G}{\partial r_1} \frac{r_1}{Y^s_G} \tag{11}$$

Thus, partial equilibrium supply (or demand) functions in which all output and input prices are included (equation (5)) are homogeneous of degree zero in prices. The implication for empirical work is that the use of price ratios in econometric modeling is fully justified in this context.

However, it is fairly common in the literature to find models of supply response that do not include all relevant prices. This may be justified because of the unavailability of data or multicollinearity problems. In this case, one or more of the prices are excluded (equation (10)). Of course, equation (10) is a misspecification of a partial equilibrium model (equation (5)). However this is not a very interesting case. Rather, we can consider equation (10) as a correct specification of a model in which the excluded prices are allowed to adjust through the supply-demand relationships. In this context, we have just shown that the homogeneity restrictions may not be satisfied. Thus, economic theory suggests that price ratios should not be systematically used in the specification of supply response models when at least one input price is not included in the model.

In order to illustrate this point, the next section presents the specification and estimation of supply functions for the poultry and egg industry.

2 - Supply Response for the U.S. Poultry Industry

The production process for broilers, turkeys and eggs involves a sequence of different stages at which key functions are performed. Coming from the primary breeder flock, chicks (poults) are introduced into the hatchery supply flock. For broilers and turkeys, the hatchery supply flock in turn produces the chicks (poults) that are fed and sold for human consumption. For egg-type chickens, the hatchery supply flock is used to produce chicks that are then introduced in the laying flock. It is the laying flock that produces the eggs for human consumption.

In an econometric model, the production decisions in the U.S. poultry industry are investigated at four levels. First, placement refers to the placement of just hatched chicks or poults in the hatchery supply flock. Second, testing refers to testing for the detection of Pullorum-Typhoid disease, done by official State agencies. Testing is performed on young females before they start producing eggs that will be hatched. This test is made because young chicks (poults) hatched from the eggs laid by pullorum infected breeder hens are likely to die within a few days. Testing occurs at about five months of age for chickens and six months for turkeys. Finally, hatching of eggs from the hatchery supply flock precedes the production stage.

The functions "placement", "testing", "hatching" and "production" are performed in sequence. Thus, the decisions made about each function depend on the current economic situation and on the decisions made at an earlier stage. The influence of previous stages involves technical or biological input-output relationships as well as production lags.

Knowledge of the technology characterizing the production process is therefore crucial in the specification of the sequential decisions. For example, egg production follows a cycle characterized by a low laying rate, then a production peak after a few weeks followed by a slow decline in productivity. The length of the cycle is about ten months for broiler-type chickens and six to seven months for turkeys. For egg-type chickens, the cycle lasts from six to ten months in the hatchery supply flock and usually twelve to fourteen months in the laying flock. Such relationships are taken into consideration in the specification of the model of supply response for broilers, turkeys and eggs.

The influence of economic variables on supply response involves output price as well as input cost. Cost of production studies show that feed cost is the single most important cost of production for poultry and eggs (USDA, 1978). Given possible multicollinearity problems and the difficulty of finding information on other costs of production such as wages, cost of capital, . . . , feed cost is the only cost introduced in the model. Thus the supply response is specified according to equation (10) where some input prices are excluded. Also, given the extent of vertical integration in the poultry industry, wholesale price is used since farm prices are often formula prices that tend to lag behind the wholesale price (Chavas, 1978). Finally, a choice had to be made between using nominal prices or real prices (deflated by some price index). It is clear that, in a partial equilibrium framework (equation (5)), nominal and deflated prices have the same effect because of the homogeneity restriction.[2/] However, this may not be the case for the supply functions (9) and (10). Indeed, in general (10) is not homogeneous of degree zero in price and the choice between nominal and deflated prices does matter.[3/]

Since it seems more reasonable to assume that the supply of input (9) responds to real prices rather than nominal prices, deflated prices may give a better specification in both equations (9) and (10). For this reason, all prices used in the poultry model are deflated prices.[4/]

Since the supply for poultry and eggs takes several months to adjust to changing conditions, a quarterly observation period has been chosen. The period covered and data used to estimate the model is from 1965 to 1975. Table 1 identifies the variables.

Broiler Model

The supply response for broiler is investigated at three levels: placement, hatching and production. The placement equation is specified as

B1 = f(PBL2, PBL3, Z1L2, Z1L3, B1L4)

where B1 is placement in hatchery supply flock, Z1L2 and Z1L3 the feed cost lagged two and three quarters, PBL2 and PBL3 the wholesale price of broiler lagged two and three quarters, and B1L4 placement lagged four quarters. The cost and price variables were introduced to measure the impact of profitability for broilers on placement. The lags were chosen mostly on the basis of preliminary tests in the absence of *a priori* information on the adjustment process. Placement lagged four quarters accounts for dynamic adjustments in the broiler industry.

Hatching measures the number of chicks produced by commercial hatcheries. The hatching equation is

B3 = f(B2L1, B2L2, B2L3, Z1L1, PBL1)

where B3 is broiler hatching, B2 broiler testing,[5/] Z1 feed cost, and PB broiler wholesale price. The lags for testing, B2L1, B2L2 and B2L3, are consistent with the technology governing the production process. Hatching begins about two months after the testing of a hen in the hatchery supply flock and lasts for about nine months. The specifications for feed cost and wholesale price assume a one quarter lagged response to a changing broiler profitability.

Chicks hatched are fed and produce marketable broilers after about eight weeks. The equation describing production is

$$B4 = f(B3L1, Z1L1, PBL1)$$

where B4 is broiler production (pound, ready-to-cook), B3 hatching, Z1 feed cost, and PB broiler wholesale price. Hatching is lagged one period because of the two month production period after hatching for maturing the birds. Feed cost and broiler wholesale price are lagged one quarter assuming a one quarter lagged response to a changing broiler profitability.

Turkey Model

In the production component of the turkey model, there are three equations: testing, hatching and production. The testing variable is used due to the absence of data on placement of turkeys in the hatchery supply flock. Thus the testing equation is the first equation in the sequence describing the production process, i.e.,

$$T1 = f(PTL2, Z1L2, T1L4)$$

where T1 is testing of turkeys, PT the wholesale price of turkeys, and Z1 feed cost. As with the broiler model the symbol (Lj) indicates that a variable is lagged j quarters. Cost and price variables are introduced to measure the impact of turkey profitability on testing. The lag structure was chosen on the basis of preliminary tests.

Hatching measures the number of poults hatched in commercial hatcheries. The hatching equation is

$$T2 = f(T1L1, T2L2, Z1L1, PTL1)$$

where T2 is turkey hatching, T1 turkey testing, Z1 the feed cost, and PT the turkey wholesale price. The lags for testing are consistent with the production technology. Hatching begins about two months after testing and lasts for about six months. Feed cost and wholesale price are lagged one quarter, assuming a one quarter lagged response to a changing turkey profitability.

The poults hatched are fed to produce marketable turkeys after 17 to 21 weeks. The turkey <u>production equation</u> is

T3 = f(T2L2, Z1L1, PTL1)

where T3 is turkey production (pounds, ready-to-cook), T2 turkey hatching, Z1 the feed cost, and PT the wholesale price of turkeys. Again, feed cost and turkey wholesale price are lagged one quarter.

Egg Model

The supply response for eggs is investigated at three levels: testing, hatching and production. The <u>testing equation</u> is specified as

E1 = f(PEL3, PEL4, Z2L3, Z2L4, E1L4)

where E1 is Pullorum-Typhoid testing on egg-type chickens, PE the wholesale price of shell eggs and Z2 the feed cost. As with turkeys, the feed cost and wholesale price are introduced to measure the impact of egg profitability on testing. The lag structure was chosen on the basis of preliminary tests. The use of the testing variable (E1L4) lagged four quarters accounts for dynamic adjustments in the egg industry. The <u>hatching equation</u> is

E2 = f(E1L1, E1L2, Z2L1, PEL1, LP)

where E2 is the number of egg-type chicks hatched, E1 testing of egg-type chickens, Z2 the feed cost, PE the wholesale price of shell eggs, and LP is average layer yield (eggs produced per month by 100 layers). The lags for the testing variable are consistent with the current production technology. Hatching starts about two months after testing and lasts for about seven months. The feed cost and the wholesale price are lagged one quarter to reflect the delay in response to changes in egg profitability. The layer yield variable accounts for technological change.

The <u>production equation</u> is

$$E3 = f(E2L2, E2L3, E2L4, E2L5, Z2L1, PEL1, LP)$$

where E3 is egg production, E2 hatching of egg-type chicks, Z2 the feed cost, PE the wholesale price of shell eggs, and LP is layer yield. The lag structure for hatching is consistent with the physical production process. Laying starts at about five months of age and lasts for about twelve months. Feed cost and the wholesale price are lagged one quarter due to the adjustment process. Layer yield accounts for technological progress.

<u>Estimated Structure</u>:

The structure for the model is linear. This simple specification is rationalized on the basis that there is in general little <u>a priori</u> information available concerning alternative functional forms. As feed cost (defined here as a weighted average of corn price and soybean meal price) constitutes only about 50 percent of the total cost of production (USDA, 1978) it appears unrealistic to assume that other input costs (labor cost, fuel cost, etc.) have no impact on the production decisions. Similarly, labor or fuel are typically variable inputs in poultry and egg production, implying that their industry supply functions are not perfectly inelastic. Based on the theoretical arguments of section 1, it follows that the output supply functions are not homogeneous of degree zero in prices. Thus, the price and feed cost variables are specified in a linear form rather than a ratio form in the model. The structural equations are recursive and estimated by least-squares methods. The first equation of each sub-sector (broiler placement, turkey testing and egg testing) is specified as a partial adjustment model and estimated by non-linear regression (NLS) using the Marquardt Algorithm.[6/] Broiler, turkey and egg hatching are each separated from the previous stage (testing) by a laying cycle. Similarly, there is a laying cycle between egg hatching and egg production. Thus we would expect the lag structure for testing in the hatching equations and for hatching in the egg production equation to follow the shape of a typical laying cycle. For this reason, the shape of an average laying cycle has been imposed as exact restrictions on the lag structure of the broiler hatching, turkey hatching, egg hatching and production equations which are estimated by restricted least-squares (RLS).[7/] Finally, broiler testing, broiler production and turkey production are estimated by ordinary least-squares (OLS). Dummy variables are introduced in the model to allow for seasonal effects. A time trend variable is used as a proxy for structural change. The estimated structural model is presented in Table 2. All the structural estimates have the expected sign and appear to give a reasonable representation of the production process. This suggests that the model has a good structural integrity.[8/]

3 - Empirical Implications

Since the estimated structural model does not include contemporaneous endogenous variables on the right hand side of any equation, it is also the reduced form of the model. It provides a basis for investigating economic adjustments in the poultry and egg industry. Estimates of the output elasticities with respect to output price lagged one quarter and feed cost lagged one quarter at different stages of the production process are presented in Table 3. These elasticities are higher at early stages, decrease during the production period and approach zero at the last stage of the production process. This pattern corresponds to the theory of "putty-clay" investment: it suggests that any production decision at a particular stage reduces the possibilities of economic adjustment at later stages. All output elasticities with respect to price and cost have the expected sign. Also, in all cases but one, output elasticity with respect to price is larger than output elasticity with respect to feed cost. This provides some evidence in favor of the theoretical results presented in section 1 (equation (11)). The only exception is for egg production (E3) where both elasticities are close to zero. On the average, the supply elasticity with respect to output price is about twice as large (in absolute value) as the output elasticity with respect to feed cost (Table 3). If price ratio had been used in the supply equations, it would impose the restriction that these two elasticities are equal. Thus, results in Table 3 suggest that the use of price ratios would involve a misspecification of the model. The use of price ratios under the homogeneity assumption might be justified either if excluded production costs have no impact on industry output or if the supply curves of these excluded inputs are perfectly inelastic. In the former case, the supply function (10) becomes the correct specification of a partial equilibrium model. In the latter case, it was shown in section 1 that excluding the price of fixed inputs in the output supply function preserves the homogeneity condition of equation (10). It appears that neither case is supported by *a priori* knowledge about the production process for poultry and eggs. Note that multicollinearity problems may also lead the model builder to use price ratios, thus reducing the number of explanatory variables. In this situation using price ratios could be justified if the reduction in variance obtained from imposing (theoretically incorrect) homogeneity restrictions more than compensates for the increase in bias of the estimators. As the specification of supply response in our model shows no serious multicollinearity problem, the use of price ratios would be inappropriate since it would impose unjustified restrictions on the model.

However, the use of feed cost to price ratio has been fairly widespread in econometric models. For example, in the modeling of the poultry and egg industry, Gerra (1959), Rahn (1973) and Chen (1976) have used feed cost to price ratios in their specification of supply response, excluding other production costs. Also, Hein (1976) used price ratios but included both feed cost and wage rate in the specification of poultry production equations. Finally, feed cost to price ratios are regularly published in statistical bulletins (USDA, 1976). Given our results, it appears that the use of price ratios in economic analysis may be misleading since they do not necessarily reflect a particular economic situation when some of the relevant prices are excluded.

4 - Concluding Remarks

The objective of a model builder is to obtain a good approximation of the economic system he intends to analyze by including as much information as possible in the model specification (Johnson and Rausser, 1977). In the case of the investigation of aggregate supply response, this information may come from the knowledge of the technology and market structure underlying the production process and from economic theory. In partial equilibrium, economic theory suggests that supply functions are homogeneous of degree zero in prices. However, this assumes that all input and output prices are included in the response function. If, either because of a lack of data or because of multicollinearity problems, the model builder decides to exclude some relevant prices from the model, then the homogeneity restriction may not hold. In this context the results of this paper suggest that homogeneity restrictions should not be systematically imposed on supply response models.

Table 1. Description And Source Of The Data Set

Variable		Description	Unit	Source[a]
Exogenous Variables	DV_2	Dummy variable for the second quarter		
	DV_3	Dummy variable for the third quarter		
	DV_4	Dummy variable for the fourth quarter		
		$Z_1 = (\frac{70}{.56}\ PCD) + (\frac{30}{20}\ PSD)$ = feed cost for broilers and turkeys[b/]	1976 \$/100 lb.	
		$Z_2 = (\frac{85}{.56}\ PCD) + (\frac{15}{20}\ PSD)$ = feed cost for eggs[b/]	1976 \$/100 lb.	
	TT	Time trend (1=first quarter 1965)		
	PS	Price of Soybean meal, 44 percent, Decatur	\$/ton	PES
	PC	Price of Corn, Chicago No. 2 yellow	\$/bu.	PES
	CPI	Consumer Price Index	(1967=100)	NBER
	PSD	PS/CPI = deflated soybean meal price	1967 \$/20 lb.	
	PCD	PC/CPI = deflated corn price	1967 \$/(.01) bu.	
Endogenous Variables -turkey-	T1	Turkeys in flocks tested for pullorum-typhoid	million	PES
	T2	Poults hatched	million	PES
	T3	Turkey production	thousand lbs.	PES
	TP	Wholesale price of turkeys, New York frozen, ready-to-cook, hens	cts./lb.	PES
	PT	TP/CPI = deflated turkey wholesale price	1967 \$/lb.	

Table 1. Continued

Variable		Description	Unit	Source[a/]
-broiler-	B1	Broiler-type placements in hatchery supply flock	million	PES
	B2	Broiler-type chickens in flocks tested for pullorum-typhoid	thousand	PES
	B3	Hatching of broiler-type chicks in commercial hatcheries	thousand	PES
	B4	Broiler production	thousand lbs.	PES
	BP	Wholesale price of broilers-nine city average	cts/lb	PES
	PB	BP/CPI = deflated wholesale price of broilers	1967 $/lb	
-eggs-	E1	Egg-type chickens in flocks tested for pullorum-typhoid	thousands	PES
	E2	Hatching of egg-type chicks in commercial hatcheries	millions	PES
	E3	Egg production	million dozs.	PES
	EP	Wholesale price of shell eggs, New York, grade A, large white	cts./doz.	PES
	PE	EP/CPI = deflated wholesale price for shell eggs	1967 $/doz.	
	LP	Layer productivity	eggs/layer	PES

a/ PES and NBER stand for Poultry and Egg Situation published regularly by ERS-USDA, and National Bureau of Economic Research, respectively.

b/ Feed cost is defined as the cost of a ration composed of 70 percent corn/30 percent soybean meal for broiler and turkey, and 85 percent corn/15 percent soybean meal for eggs. Although perhaps overestimating feed costs, the use of fixed weights in the computation helps avoid multicollinearity problems, and saves degrees of freedom.

Table 2. Estimates of the Structural Model[a/]

Broiler Placement (NLS)

$$\begin{array}{llll} B1 = \lambda\,[.9446 & +\ 2.1064\ DV2 & +\ .3067\ DV3 & -\ .0643\ DV4 \\ \quad (1.6086) & (.3811) & (.3330) & (.3117) \end{array}$$

$$\begin{array}{lll} +\ 36.512\ PBL2 & +\ 13.551\ PBL3 & -\ .8420\ Z1L2 \\ (8.318) & (6.429) & (.325) \\ [1.101] & [.4092] & [-.3077] \end{array}$$

$$\begin{array}{l} -\ 1.023\ Z1L3] + (1 - \lambda)\ B1L4 \\ (.329) \\ [-.3739] \end{array}$$

with $\lambda = .6475$, $R^2 = .8905$,
$(.0947)$

Broiler Hatching (RLS)

$$\begin{array}{llll} B3 = 269118 & +\ 14.978\ B2L1 & +\ 12.060\ B2L2 & +\ 9.142\ B2L3 \\ \quad (80230) & (3.791) & (2.247) & (1.704) \\ & [.125] & [.100] & [.076] \end{array}$$

$$\begin{array}{llll} -\ 31729\ Z1L1 & +\ 849379\ PBL1 & +\ 31000\ DV2 & -\ 52629\ DV3 \\ (8561) & (215019) & (12227) & (11791) \\ [-.132] & [.291] & & \end{array}$$

$$\begin{array}{ll} -\ 77137\ DV4 & +\ 6770\ TT \\ (12616) & (642) \end{array}$$

Broiler Production (OLS)

$$\begin{array}{llll} B4 = 112781 & +\ 1.9603\ B3L1 & -\ 20728\ Z1L1 & +\ 629835\ PBL1 \\ \quad (106250) & (.1441) & (10210) & (236130) \\ & [.796] & [-.035] & [.087] \end{array}$$

$$\begin{array}{llll} +\ 52458\ DV2 & -\ 51575\ DV3 & -\ 27129\ DV4 & +\ 7290\ TT \\ (16215) & (21897) & (15213) & (788) \end{array}$$

with $R^2 = .9811$

Turkey Testing (NLS)

$$\begin{array}{lll} T1 = \lambda\,(-527.055 & -\ 344.095\ DV2 & +\ 226.386\ DV3 \\ \quad (419.536) & (140.547) & (137.279) \end{array}$$

$$\begin{array}{lll} +\ 1081.521\ DV4 & +\ 4411.930\ PTL2 & -\ 167.755\ Z1L2) \\ (138.376) & (1455.421) & (77.179) \\ & [1.910] & [-.6254] \end{array}$$

$$+\ (1 - \lambda)\ T1L4$$

with $R^2 = .9543$, and $\lambda = .4339$.
$(.1039)$

Table 2. Continued

<u>Turkey Hatching</u> (RLS)

$$\begin{array}{llllllll}
T2 = & -4.407 & + .0127\ T1L1 & + .01027\ T1L2 & - 1.0950\ Z1L1 \\
 & (4.293) & (.00146) & (.00118) & (.6164) \\
 & & [.330] & [.2667] & [-.106]
\end{array}$$

$$\begin{array}{llll}
+ 22.2669\ PTL1 & + 26.8073\ DV2 & + 2.6018\ DV3 \\
(8.6355) & (1.075) & (2.561) \\
[.250] & &
\end{array}$$

$$\begin{array}{ll}
- 8.966\ DV4 & + .3257\ TT \\
(2.205) & (.0433)
\end{array}$$

<u>Turkey Production</u> (OLS)

$$\begin{array}{lllll}
T3 = & -197707 & +14617\ T2L2 & - 21518\ Z1L1 & + 265611\ PTL1 \\
 & (40551) & (1225) & (8157) & (110068) \\
 & & [1.069] & [-.1524] & [.2185]
\end{array}$$

$$\begin{array}{llll}
+ 221772\ DV2 & + 254305\ DV3 & + 1313\ DV4 & + 906\ TT \\
(15760) & (26294) & (51146) & (475)
\end{array}$$

with $R^2 = .9928$

<u>Egg Testing</u> (NLS)

$$\begin{array}{llll}
E1 = \lambda\ [& -426.252 & - 760.76\ DV2 & - 1222.30\ DV3 \\
 & (846.581) & (355.98) & (345.48)
\end{array}$$

$$\begin{array}{lll}
- 916.124\ DV4 & + 7197.55\ PEL3 & + 4831.98\ PEL4 \\
(363.91) & (2998.96) & (2389.70) \\
 & [1.7137] & [1.1504]
\end{array}$$

$$\begin{array}{lll}
- 436.04\ Z2L3 & - 300.08\ Z2L4] & + (1 - \lambda)\ E1L4 \\
(290.75) & (287.58) & \\
[-.7934] & [-.5460] &
\end{array}$$

with $R^2 = .9520$ and $\lambda = \underset{(.0609)}{.2477}$.

<u>Egg Hatching</u> (RLS)

$$\begin{array}{lllll}
E2 = & -63.5228 & + .0263\ E1L1 & + .0263\ E1L2 & - 10.869\ Z2L1 \\
 & (102.283) & (.0034) & (.0034) & (2.916) \\
 & & [.315] & [.315] & [-.237]
\end{array}$$

$$\begin{array}{llll}
+ 188.90\ PEL1 & + 16.388\ DV2 & + .1422\ DV3 & - .4704\ DV4 \\
(26.414) & (5.311) & (4.282) & (4.631)
\end{array}$$

$$\begin{array}{ll}
+ .8759\ TT & + .0251\ LP \\
(.2787) & (.0587)
\end{array}$$

Egg Production Equation (RLS)

$$
\begin{array}{llllll}
E3 = & 476.98 & + .8805\ E2L2 & + 1.245\ E2L3 & + 1.154\ E2L4 & \\
 & (323.73) & (.1003) & (.1418) & (.1314) & \\
 & & [.0807] & [.1142] & [.1058] & \\
 & + 1.063\ E2L5 & - 44.691\ Z2L1 & + 118.54\ PEL1 & + 4.460\ DV2 & \\
 & (.1210) & (8.192) & (78.126) & (14.269) & \\
 & [.0975] & [-.0894] & [.031] & & \\
 & - 6.819\ DV3 & + 27.100\ DV4 & - .1863\ TT & + .2473\ LP & \\
 & (11.038) & (10.080) & (.499) & (.1597) &
\end{array}
$$

---

a/ Structural estimates are accompanied by their standard error (in parenthesis) and elasticities evaluated at mean levels (in brackets).

Table 3.

Output Elasticities With Respect To Wholesale Price and Feed Cost a/

Output Variable	Elasticity of output w.r.t Wholesale Price	Feed Cost
Broiler		
B1	.9778	-.4413
B3	.291	-.132
B4	.087	-.035
Turkey		
T1	.8287	-.2714
T2	.250	-.106
T3	.2185	-.1524
Egg		
E1	.7094	-.3317
E2	.539	-.237
E3	.0310	-.0894

a/ elasticities evaluated at the mean values of the relevant variables.

Appendix

The homogeneity of degree zero of (5) implies

$$\frac{\delta Y_P^s}{\delta P} P + \frac{\delta Y_P^s}{\delta r_1} r_1 + \frac{\delta Y_P^s}{\delta r_2} r_2 = 0 \qquad \text{(A1)}$$

From (10), we have

$$\frac{\delta Y_G^s}{\delta r_1} = \frac{\delta Y_P^s}{\delta r_1} + \frac{\delta Y_P^s}{\delta r_2} \frac{\delta r_2}{\delta r_1} \qquad \text{(A2)}$$

and

$$\frac{\delta Y_G^s}{\delta P} = \frac{\delta Y_P^s}{\delta P} + \frac{\delta Y_P^s}{\delta r_2} \frac{\delta r_2}{\delta P} \qquad \text{(A3)}$$

Substituting (A2) and (A3) into (A1) yields

$$\frac{\delta Y_G^s}{\delta P} P + \frac{\delta Y_G^s}{\delta r_1} r_1 = \frac{\delta Y_P^s}{\delta r_2} \left\{ \frac{\delta r_2}{\delta P} P + \frac{\delta r_2}{\delta r_1} r_1 - r_2 \right\} \qquad \text{(A4)}$$

Clearly, Y_G^s is homogeneous of degree zero in the prices P and r_1 only if $r_2 = \frac{\delta r_2}{\delta P} P + \frac{\delta r_2}{\delta r_1} r_1$, i.e. . if $r_2(r_1, P)$ is a function homogeneous of degree one.

Now, note that the function $r_2(r_1, P)$ is obtained from solving the equilibrium conditions in the market for X_2, $X_2^D \left\{ \frac{r_1}{P}, \frac{r_2}{P} \right\} = X_2^s\ (r_2)$.

From the implicit function rule we have

$$\frac{\delta r_2}{\delta P} = \frac{\delta X_2^D / \delta P}{\delta X_2^s / \delta r_2 - \delta X_2^D / \delta r_2} \qquad \text{(A5)}$$

and

$$\frac{\delta r_2}{\delta r_1} = \frac{\delta X_2^D / \delta r_1}{\delta X_2^s / \delta r_2 - \delta X_2^D / \delta r_2} \qquad \text{(A6)}$$

Also, the homogeneity of $X_2^D \left\{ \frac{r_1}{P}, \frac{r_2}{P} \right\}$ implies that

$$\frac{\delta X_2^D}{\delta P} P + \frac{\delta X_2^D}{\delta r_1} r_1 = - \frac{\delta X_2^D}{\delta r_2} r_2 \tag{A7}$$

Using (A5), (A6) and (A7), we have

$$\frac{\delta r_2}{\delta P} P + \frac{\delta r_2}{\delta r_1} r_1 - r_2 = - \frac{\left\{ \delta X_2^s / \delta r_2 \right\} r_2}{\delta X_2^s / \delta r_2 - \delta X_2^D / \delta r_2} \tag{A8}$$

Thus, $r_2 = \frac{\delta r_2}{\delta P} P + \frac{\delta r_2}{\delta r_1} r_1$ only if $\frac{\delta X_2^s}{\delta r_2} = 0$, i.e. if the supply curve for X_2 is perfectly inelastic.

If X_2 is a variable input ($\partial X_2^s / \partial r_2 > 0$), then

$$\frac{\delta r_2}{\delta P} P + \frac{\delta r_2}{\delta r_1} r_1 - r_2 < 0 \tag{A9}$$

From (A4), it follows that

$$\frac{\delta Y_G^s}{\delta P} P + \frac{\delta Y_G^s}{\delta r_1} r_1 > 0 \tag{A10}$$

or, in elasticity form

$$\frac{\delta Y_G^s}{\delta P} \frac{P}{Y_G^s} + \frac{\delta Y_G^s}{\delta r_1} \frac{r_1}{Y_G^s} > 0 \tag{A11}$$

Thus if the supply curve for X_2 has a positive but finite slope, Y_G^s (r_1, P) is not homogeneous of degree zero in prices and the corresponding supply elasticity plus the corresponding elasticity of output with respect to r_1 is greater than zero.

FOOTNOTES

1/ X_1 and X_2 are considered as variable inputs throughout the paper.

2/ Denoting the price index by I, equation (5) expressed in real terms becomes $Y_s = Y_P^S \left\{ \frac{r_{1/I}}{P/I}, \frac{r_{2/I}}{P/I} \right\}$ which is equivalent to (5).

3/ Using deflated prices, equation (10) becomes $Y^S = Y_G^S \left\{ \frac{r_1}{I}, \frac{P}{I} \right\}$ where I is the price index. In a small sector situation where a change in a particular price does not have a significant impact on the price index, it follows that $\frac{\delta Y_G^S}{\delta P} \frac{P}{Y_G^S} = \frac{\delta Y_G^S}{\delta (P/I)} \frac{P/I}{Y_G^S}$: the elasticity of supply with respect to a nominal price is approximately equal to the elasticity of supply with respect to the corresponding real price. In this context, since the homogeneity restriction can be expressed in elasticity from (such as in equation (8)), the use of deflated prices in supply response does not insure by itself the homogeneity of supply or demand functions with respect to either nominal or real prices. Thus, it still makes sense to investigate the validity of price ratios in supply response even if deflated prices are used. Although this argument strictly holds only for a small sector, it appears to be approximately valid for most econometric modeling of agricultural production.

4/ One issue raised here is the specification of the general price level (inflation) in the supply function (10). The choice of a price deflator could affect the estimates of separate parameters, implying that there is a chance that the estimated coefficients may be distorted. However, they should not affect the price ratio results.

5/ No economic adjustments were assumed between placement and testing. For this reason, the testing function is not included in the broiler model.

6/ Non-linear least squares was used in order to obtain a standard error for each parameter of the partial adjustment model.

7/ The information about the average shape of a laying cycle for broilers, egg-type chickens and turkeys has been provided by Mr. W. Russell, Poultry Department, University of Missouri-Columbia.

8/ The predictive performance of the model outside of the estimation period has been investigated in Chavas (1978). It gives further evidence on the validity of the representation.

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