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Economic Factors Determining Changes in Dressed Weights of Live Cattle and Hogs

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Livestock dressed weights have experienced significant trends and volatility which affect wholesale production of red meats. An econometric model was used to estimate the impact of relative prices and technology on cattle and hog average dressed weights. For fed steers and heifers, the economic incentives affecting placement weights and weight added in feedlots were considered. Results indicate quarterly dressed weights of steers and heifers respond to contemporaneous profitability ratios and to lagged feeder prices, the effects being highly inelastic. Cow dressed weights also responded while hog dressed weights did not respond to profitability ratios. Technology changes may have accounted for about 83% of dressed weight growth for steers and about 62% for hogs from 1980–97.

Key words: dressed weights, elasticities, placement weight, profitability ratios, weight added

Introduction

Quantities of beef and pork produced depend upon animals slaughtered and dressed (carcass) weights. Carcass weights are an increasingly important factor in determining red meat supplies as dressed weights trend upward. Greater carcass weights are largely the result of changes in animal genetics and feed nutrition (Brester, Schroeder, and Mintert). These technologies have resulted in heavier carcasses and higher carcass yields, suggesting that beef and pork supplies are now more dependent upon livestock productivity than previously.[1]

Increasing dressed weights can significantly affect market prices due to changes in wholesale meat tonnage. An example is the sharp price decline experienced in the beef cattle sector from 1994 to 1996. Oklahoma City, 500–550 pound feeder calf prices declined from about $99 per cwt the first quarter of 1994 to about $64 per cwt by the third quarter of 1996. Economists attributed much of the decline to increased wholesale production of red meat and poultry, as well as increasing feed prices [U.S. Department of Agriculture (USDA) 1996]. Beef production, however, not only reflected increasing slaughter, but also the cumulative effects of increasing dressed weights since the early

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[1]In the beef sector, productivity is viewed as pounds produced per breeding cow. Often it is measured as liveweight pounds of weaning calves, but reference here is to carcass weight pounds when offspring are slaughtered. The same refers to the sow herd in the pork sector, i.e., carcass weight pounds of barrow and gilt slaughter.

1990s. Specifically, from 1990 to 1994, commercial cattle slaughter increased from 33.2 to 34.2 million head, while average cattle dressed weights increased from 680 to 710 pounds (USDA 1997). Dressed weights declined slightly from 1994 to 1996, but were still historically high and contributed to record large 1997 beef supplies.

The purpose of this study is to quantify the economic factors that determine average dressed weights of live cattle and hogs. Dressed weights in these two sectors have not only demonstrated strong trends over the past 15 years, but also significant variations. A systems econometric model is used to estimate quarterly dressed weights for the livestock classes of steers, heifers, cows, and barrows and gilts. Supply elasticities are estimated, which, given expected changes in input and output prices, are useful information for predicting the effects of dressed weights on beef and pork supplies. While considerable work has been conducted in estimating supply relationships specific to livestock numbers (Antonovitz and Green; Brester and Marsh; Marsh; McGivern and Kerr; Nelson and Spreen; Rosen, Murphy, and Scheinkman; Rucker, Burt, and LaFrance; Tryfos), other work has emphasized total pounds produced (Arzac and Wilkinson; Dean and Heady; Hayenga and Hacklander; Kulshreshtha and Reimer). Considerably less attention has been directed, however, toward estimating average live or dressed weights in supply analysis (Kulshreshtha and Reimer; Whipple and Menkhaus).

Dressed Weight Statistics

Table 1 provides summary statistics for quarterly dressed weights of the livestock classes from 1980–97. The null hypothesis that dressed weights are normally distributed could not be rejected based on the Jarque-Bera (JB) statistic at the $\alpha = 0.05$ significance level (Pindyck and Rubinfeld, p. 41). There is substantial variation in the dressed weights, with the sample standard deviations being 28.4, 38.9, 17.6, and 6.5 pounds for steers, heifers, cows, and barrows and gilts, respectively. Dressed weight volatility can imply a substantial change in wholesale meat production. Consider beef, for example. In the fourth quarter of 1997, a total of 4.0, 2.8, and 1.8 million head of steers, heifers, and cows were slaughtered, respectively; multiplied by their corresponding standard deviations (of dressed weights), this amounts to a total of 252 million pounds of beef for one quarter.

The maximum and minimum values of dressed weights suggest positive trends in carcass weights since the minimum values were observed in the early 1980s. The smallest weight increase in the beef sector occurs for cows, which might be expected since cull cows are not normally targeted for finishing profitability, but rather are sold for salvage purposes.[2] On an annual basis from 1980 through 1997, average dressed weights for steers, heifers, cows, and hogs increased by 55, 98, 20, and 17 pounds, respectively. Genetic changes (i.e., British-Continental cross-breeding) have permitted finishing weights of heifers to increase more than those of steers without reducing yield grade.

[2] Some producers feed cull cows on hay, silage, and grain rations to add weight and grade, taking advantage of price seasonality, i.e., lower cull prices in the fall and higher cow prices in early spring. Cost of feed relative to cull cow prices may influence feeding decisions.

Table 1. Summary Statistics for Quarterly Average Dressed Weights of Livestock, 1980–97

	Average Dressed Weights (lbs.)			
Statistics	Steers	Heifers	Cows	Hogs
Mean	735.15	658.63	527.00	172.08
Maximum	788.00	719.00	560.00	187.00
Minimum	686.00	589.00	484.00	161.00
Standard Deviation	28.40	38.93	17.61	6.52
Jarque-Bera[a]	4.40	5.35	2.73	3.24

[a] Under the null hypothesis of a normal distribution, the Jarque-Bera test statistic has a χ^2 distribution with two degrees of freedom. For a significance level of $\alpha = 0.05$, the critical value is 5.99.

Theoretical Model

Modeling of dressed weights for cattle and hogs should exploit the theoretical supply relationships of livestock. That is, relative output and input prices should be important variables in determining weight adjustments. Kulshreshtha and Reimer, in estimating annual weights of Canadian cattle and calves, specified feed price, feed supplies, and trend as the primary explanatory variables. Whipple and Menkhaus, in estimating annual live weights of lamb, specified the price of lamb and the price of protein supplement as the major independent variables. Anderson and Trapp, in a nonlinear break-even analysis of feeder cattle, indicate slaughter cattle and corn prices are important determinants of beginning and ending weights in cattle finishing. Managers of livestock firms, whether they be farms or specialized finishing units, normally make production decisions involving numbers produced, quality standards, and weight produced per head. In a short period such as one quarter, livestock numbers produced (slaughtered) are a result of previous resource commitments and biological factors. Weight per head, given genetic traits, feed conversion, health, etc., depends upon price expectations and quality goals such as grades.

A simple profit function for a livestock-producing firm allows derivation of the relevant functions/variables for econometric estimation of dressed weights. It is based on a cattle feedlot (firm) that purchases feeder cattle, feed, and other inputs to produce fed cattle that are sold to a meat packer on a liveweight basis. The firm is assumed to be a price taker and the objective is to maximize profits. Though many management decisions must be made, it is assumed the important decision variables are placement weights of purchased feeder cattle and weight added to the placement inventories.[3] The short-run production function, with assumed Leontief technology, is given as

[3] Extensive custom finishing occurs in the cattle feeding industry, but in this example the feedlot owns the cattle so as to emphasize the economic importance of the demand for different placement weights.

$$Q \cdot W = f(Q_p, Q_c, Q_k; T), \tag{1}$$

where Q = total number of fed cattle produced, W = average slaughter weight of fed cattle, Q_p = total quantity of feeder placement weight purchased, Q_c = total quantity of feed inputs used, and Q_k = total quantity of nonfeed inputs used. Equation (1) indicates that the input-output relationships are defined given the firm's state of technology (T). Furthermore, let total placement weight and feed used be defined as

$$Q_p = W_f Q \tag{1a}$$

and

$$Q_c = W_a Q \alpha, \tag{1b}$$

where W_f = average placement weight of feeder cattle, Q = number of feeder cattle placed, W_a = average weight added to feeder cattle (for finishing), and α is a feed conversion factor that indicates pounds of feed required to yield one pound of gain. The other inputs (Q_k) in equation (1) include all nonfeed factors (i.e., labor, capital), and the technology variable (T) may include breeding genetics (implicit in the feeders purchased), nutrition management, firm organization, etc.

Introducing input and output prices specific to equation (1) and utilizing equations (1a) and (1b), the firm's unconstrained profit function (π) is written (omitting Q_k) as follows:

$$\pi = P_s f(Q_p, Q_c; T) - (P_f W_f + P_c W_a \alpha) Q, \tag{2}$$

where P_s is the slaughter (output) price, P_f is the feeder cattle (input) price, and P_c is the feed (input) price. In this analysis, corn is the major feed grain used, and thus P_c is the price of corn. Nonfeed inputs (Q_k) of equation (1) are omitted here to shorten the notation, but also its economic analysis is not of interest. Equation (2) describes the firm's profits as liveweight revenue less cost of feeder placements and cost of corn consumed. For any nonzero value of π, the returns are allocated to Q_k and other fixed factors of production. First-order conditions for profit maximization are with respect to the choice variables, W_f and W_a, and are given by

$$\frac{\partial \pi}{\partial W_f} = P_s f_1 Q - P_f Q = 0 \tag{3}$$

and

$$\frac{\partial \pi}{\partial W_a} = P_s f_2 Q - P_c Q \alpha = 0, \tag{4}$$

with the terms f_1 and f_2 representing the first-order partials of $f(\cdot)$ with respect to W_f and W_a, respectively. The solution of the first-order conditions for profit maximization [equations (3) and (4)] allows derivation of the demand and supply functions for W_f and W_a, respectively:

$$(W_f, W_a) = W^*(P_f, P_c, P_s; Q, T), \tag{5}$$

which says that a firm's optimal decision (W^*) in demanding feeder placement weights (W_f) and in supplying finishing weight (W_a), given Q and T, depends upon the input price of feeder cattle, the input price of corn, and the output price of slaughter cattle.

The average slaughter weight (W) shown in the dependent variable of equation (1) is a linear combination of beginning and added weights, given as

$$W = W_f + W_a. \tag{6}$$

Consequently, the theoretical relationship for average liveweight (W) depends upon the arguments in equation (5). In establishing the theoretical impacts of prices on W, the assumption of Hotelling's lemma of derivative properties for W_f and W_a is invoked (Varian, pp. 30–31):

$$W_f(P_f, P_c, P_s; Q, T) = -\frac{\partial\pi(P_f, P_c, P_s; Q, T)}{\partial(P_f)} \tag{7}$$

and

$$W_a(P_f, P_c, P_s; Q, T) = \frac{\partial\pi(P_f, P_c, P_s; Q, T)}{\partial(P_s)}, \tag{8}$$

stating that the demand for beginning weight in equation (7) and the supply of added weight in equation (8) are expressed as first-order derivatives of the indirect profit function (assuming the derivatives exist and all prices > 0).

The second-order derivatives of the indirect π function permit deriving the marginal impacts of output and input prices on slaughter weight (Varian, pp. 33–34). Assuming π is convex, they are specified as follows:

$$\frac{\partial W_f(\cdot)}{\partial P_f} = \frac{-\partial^2\pi(\cdot)}{\partial P_f^2}; \quad \frac{\partial W_f(\cdot)}{\partial P_s} = \frac{-\partial^2\pi(\cdot)}{\partial P_f \partial P_s}; \quad \frac{\partial W_f(\cdot)}{\partial P_c} = \frac{\partial^2\pi(\cdot)}{\partial P_f \partial P_c} \tag{9}$$

and

$$\frac{\partial W_a(\cdot)}{\partial P_s} = \frac{\partial^2\pi(\cdot)}{\partial P_s^2}; \quad \frac{\partial W_a(\cdot)}{\partial P_f} = \frac{\partial^2\pi(\cdot)}{\partial P_s \partial P_f}; \quad \frac{\partial W_a(\cdot)}{\partial P_c} = \frac{-\partial^2\pi(\cdot)}{\partial P_s \partial P_c}. \tag{10}$$

The terms $W_f(\cdot)$, $W_a(\cdot)$, and $\pi(\cdot)$ refer to the functional arguments in equations (7) and (8). Signs assigned to the demand for placement weight of equation (9) are negative for the first term since demand slopes downward, and positive for the last term, corn price. The latter, for example, indicates that if corn price increases, the beginning weight increases as it is cheaper to buy more weight and add less in the feedlot (Anderson and Trapp). The second term regarding slaughter price is somewhat nebulous; however, with the firm as a profit maximizer, an increase in slaughter price could reduce beginning weight in order to increase profits. Signs assigned to the supply of weight added in equation (10) are positive for the first term since supply slopes upward, and negative for the last term, corn price. The latter indicates an increase in corn price would decrease weight added since marginal costs of finishing increase. The second term regarding feeder price is also nebulous. However, it is conceivable that increases in

feeder price could increase W_a since the firm is a profit maximizer. That is, increasing feeder price increases placement costs, and therefore more finishing weight is added to compensate.

Given equation (6) and equations (9) and (10), the marginal relationships for W can be summarized as follows:

$$\frac{\partial W}{\partial P_s} = \frac{\partial W_f}{\partial P_s} < 0 + \frac{\partial W_a}{\partial P_s} > 0, \tag{11}$$

$$\frac{\partial W}{\partial P_f} = \frac{\partial W_f}{\partial P_f} < 0 + \frac{\partial W_a}{\partial P_f} > 0, \tag{12}$$

$$\frac{\partial W}{\partial P_c} = \frac{\partial W_f}{\partial P_c} > 0 + \frac{\partial W_a}{\partial P_c} < 0, \tag{13}$$

which says that the effects of market output and input prices on average liveweight (W) depend upon their theoretical effects on beginning weight (W_f) and added weight (W_c). The signs of the partials correspond to the theoretical signs assigned in equations (9) and (10). It is difficult, however, to state a priori which marginal effects dominate in equations (11)–(13). It is left to the empirical results to determine the balance of the impacts.

The theoretical arguments for average liveweights of cows and hogs are similar to those of steers and heifers (though not developed here). However, placement weights are not considered—only weight added. A priori, based on the supply arguments of equation (10), slaughter price and corn price should demonstrate positive and negative impacts, respectively, on weight added, and hence average slaughter weights.

The transition to the market level for W involves aggregating the micro relations of equation (5), also considering marketings (Q), technology (T), and seasonality (quarterly weights). Given equations (5) and (6), average liveweight at the market level is therefore specified as

$$W = \ell(P_f, P_c, P_s, S, Q, T), \tag{14}$$

where the variable S (seasonality) represents quarterly intercept shifts, Q is the number of livestock marketed, and T is the trend variable (technology) as given in equation (1). In the aggregate function, Q would not be constant and is included on the right-hand side so that the estimated input and output price effects (on average weights) account for levels of livestock marketed. Trend is included since technology changes have impacted livestock weights through breeding genetics, feed nutrition, and management (Brester, Schroeder, and Mintert). Trend and seasonality were also included in placement weight and slaughter weight equations of Anderson and Trapp. The focus of the model is on average *dressed* weights. Consequently, their behavior is a direct function of the average liveweights in structural equation (14), or

$$ADW = g\left[\ell(P_f, P_c, P_s, S, Q, T)\right], \tag{15}$$

where ADW is average dressed weight. Since the latter's relationship to average liveweight is a technical one, i.e., a dressing percentage, from a behavioral standpoint the economic incentives that determine W_f and W_a should also determine average dressed weight.

Empirical Specification

Equation (15) and its theoretical underpinnings serve as the basis to specify the empirical model. The following general equation, specified with livestock-corn price ratios and in dynamic form, represents the set of four dressed weight equations to be estimated:

$$(16) \qquad ADW_{j,\tau} = f\left[\left(P_{SL_j}/P_{CN}\right)_{\tau,\tau-1}, \left(P_{fd_i}\right)_{\tau-1}, Q_{j,\tau}, S_2, S_3, S_4, T, ADW_{j,\tau-1}, U_{j,\tau}\right],$$

$$j = 1,2,3,4; \qquad i = 1,2; \qquad \tau = 1,2,\ldots,T.$$

In the empirical model, ADW_j represents the four dependent variables, $ADWS$, $ADWH$, $ADWC$, and $ADWG$, which are, respectively, average dressed weights of steers, heifers, cows, and barrows and gilts under federal inspection (pounds). The independent variables include the four slaughter prices, P_{SL_j}, which are: the price of Choice 2–4 slaughter steers, 1,100–1,300 pounds, Nebraska direct (specific to the $ADWS$ equation); the price of Choice 2–4 slaughter heifers, 1,000–1,200 pounds, Nebraska direct (specific to the $ADWH$ equation); the price of slaughter cows, boning utility, Sioux Falls (specific to the $ADWC$ equation); and the price of barrows and gilts, U.S. 1–3, 230–250 pounds, Iowa/S. Minnesota (specific to the $ADWG$ equation). P_{CN} is the price of #2 yellow corn, Central Illinois (dollars per bushel). The two variables, P_{fd_i}, represent the price of feeder steers, medium no. 1, 500–550 pounds, Oklahoma City (specific to the $ADWS$ equation), and the price of feeder heifers, medium no. 1, 450–500 pounds, Oklahoma City (specific to the $ADWH$ equation). All livestock prices are in dollars per hundredweight ($/cwt). S is the set of quarterly dummy variables for seasonality: S_2 = quarter 2, S_3 = quarter 3, and S_4 = quarter 4 (quarter 1 is omitted). The four independent variables, Q_j, represent individual commercial slaughter of steers, heifers, cows, and barrows and gilts (all in thousand head), each relevant to their specific equations; T is the time trend, and U_j are the equation random errors, each assumed to be white noise.

The first right-hand-side variable is the relevant livestock-corn price ratio (i.e., steer-, heifer-, cow-, and hog-corn price ratio). Such output-input price ratios are commonly used in livestock demand/supply estimation as proxies for finishing profitability; but since they form a more parsimonious set of regressors, they also mitigate multicollinearity problems (Rucker, Burt, and LaFrance). The ratios are specified as contemporaneous and lagged (for steers and heifers) since producers add weight according to expected price ratios in the current period of slaughter, while beginning weights are relevant to price ratios of the previous period. Though cull cows are not grain fed to the extent of steers and heifers, dividing slaughter cow price by corn price may approximate general profitability for cow-calf producers using grain to add weight and grade to culled stock (Feuz). Feeder cattle prices are relevant input costs in the dressed weight equations of steers and heifers. Feeder cattle prices were lagged so that

current fed marketings reflect placement costs of the previous quarter; i.e., most feeders placed in the current quarter likely do not reach finishing maturity. Livestock slaughter was specified to allow for effects of the current quarter's marketings on dressed weights. The lagged dependent variable ($ADW_{j,\tau-1}$) indicates dressed weights may not fully adjust within quarter t given shocks in market prices. A geometric distributed lag is inferred and may occur due to biological, expectational, or technical factors in supply behavior (Marsh).

Data and Testing

Quarterly data for the years 1980–97 were used in the supply model. Price and quantity data for 1970–96 were obtained from the USDA's *Red Meats Yearbook* in the form of Lotus spreadsheets (on disk). Data for 1997 were taken from the USDA's 1997 and 1998 *Livestock, Dairy, and Poultry Situation and Outlook Reports.* The feeder cattle price data are in real terms, deflated by the Producer Price Index (1982 = 100), obtained from the *Economic Report of the President* (Congress of the U.S.).

All quarterly variables were subjected to tests of stationarity using the augmented Dickey-Fuller (ADF) unit root test. Regressions involving random walks of the dependent and independent variables can lead to spurious results by biasing the conventional significance tests (Johnston and DiNardo). Based on the MacKinnon critical values in testing stationarity series, the null hypothesis of a unit root could not be rejected for any variable (in level form) at the $\alpha = 0.05$ significance level. The variables were integrated of order one. Because of multiple variables in the equations, the residuals of the average dressed weight equations were ADF tested for nonstationary series, i.e., a test for equation cointegration. Johnston and DiNardo (pp. 259–69) indicate that when equations with unit root variables reject nonstationary residuals, the relations are cointegrated, allowing equation estimation in level form. Results were to reject unit roots of all equation residuals at the $\alpha = 0.05$ significance level.[4]

The potential statistical problems of estimating the dressed weight functions of equation (16) by OLS include endogeneity of the slaughter-corn price ratios, lagged dependent variables and autoregressive (AR) errors, and a nondiagonal covariance matrix of equation errors. The Hausman specification test for simultaneous equations bias was conducted, and results (at the $\alpha = 0.05$ significance level) rejected the null hypothesis of no joint dependency of all slaughter-corn price ratios. This result is not surprising since increased dressed weights would increase wholesale meat tonnage and thus reduce slaughter prices. AR errors often occur with seasonal time-series data, but based on the Durbin h-tests, the null hypothesis of no AR disturbances could not be rejected at the $\alpha = 0.05$ level of significance.

Occurring less often are problems with heteroskedastic errors in time-series data (Johnston and DiNardo). Nevertheless, to test for dressed weight variances against high and low profitability ratios, White's disturbance test for constant variance was

[4] DeJong et al. argue that for a sample size of less than 100, the cointegration test has low power against the trend stationary alternative. In the current model of integrated variables, the residuals of the structured equations were ADF tested for stationarity (hence, to determine equation cointegration) with the lagged dependent variables omitted. Johnston and DiNardo (pp. 317–18) also indicate that if joint dependency is present in a multiple-equation structure, the use of a simultaneous-equations estimator on data levels is appropriate when nonstationary variables and cointegrated relations exist.

conducted. Results failed to reject the null hypothesis of no heteroskedasticity at the $\alpha = 0.05$ significance level. The Jarque-Bera (JB) test statistic for residual normality was also conducted, with the results failing to reject the null hypothesis of a normal distribution at the $\alpha = 0.05$ level (Pindyck and Rubinfeld, p. 41).[5]

Cross-correlation of equation errors would be expected to be strong between the steer and heifer dressed weight equations, but less so among the others. Johnston and DiNardo (pp. 318–20) indicate that if two equations have identical right-hand-side regressors, little asymptotic efficiency is gained with seemingly unrelated regressions (SUR) estimation. Though the similarly defined variables (i.e., the steer- and heifer-corn price ratios and feeder prices) are highly correlated, and the economic behavior between the *ADWS* and *ADWH* equations would be expected to be quite similar, the right-hand-side variables nonetheless are not identical. In particular, the individual steer slaughter and heifer slaughter variables as well as the lagged dependent variables differ. Consequently, with joint dependency of the livestock-corn price ratios and expected non-diagonal covariance matrix of errors, the dressed weight functions were estimated by iterative three-stage least squares (I3SLS), the equations estimated in double-log form.

Empirical Results

Table 2 presents the I3SLS regression results for the dressed weights equations. Correlations between the *ADWS* and *ADWH* residuals were about 0.91, and between *ADWS* (*ADWH*) and *ADWG* the residual correlations were about 0.20. Overall, the statistical results were quite satisfactory. The adjusted R^2s ranged from 0.91 to 0.98, and the standard errors of estimate ranged from 0.6% to 1.2%. A relative root mean squared error (RMS) forecast of the model was also performed for the sample period. Based on estimates of Theil's inequality coefficient (U, or relative RMS forecast), the bias proportion (systematic deviation of predicted and actual values), and the variance proportion (replicating degree of variability), the forecast performances of the functions were robust. Specifically, each coefficient was close to zero (Pindyck and Rubinfeld, pp. 210–11).

The statistical results of the steer and heifer dressed weight equations indicate the asymptotic t-ratios of the slaughter-corn price ratios, lagged feeder price variables, trend, and lagged dependent variables are significant at the $\alpha = 0.01$ level. The coefficients of the steer- and heifer-corn price ratios, measured as short-run supply elasticity coefficients (double logs), demonstrated negative impacts on steer and heifer dressed weights. This result confirms theoretical expectations that increasing ratios decrease dressed weights since placement weights decline, resulting in reduced end weights of fed cattle.[6] For example, if corn price declines, it is cheaper to add weight to

[5] The F-statistics for the White heteroskedasticity test ranged from 0.651 to 1.300 for the equations. The critical F-value to reject the hypothesis of no heteroskedasticity at the $\alpha = 0.05$ level is 1.820. The Jarque-Bera statistics for residual normality ranged from 0.338 to 1.895. The critical χ^2 value to reject the hypothesis of normal residuals at the $\alpha = 0.05$ level is 5.99.

[6] The coefficients of the steer- and heifer-corn price ratios lagged one period were not statistically significant and were therefore dropped. However, significant lagged dependent variables in the dressed weight equations imply distributed lags on the price variables, thus inferring past price ratios affect placement weights. With lack of consistent quarterly time-series data on average feeder placement weights, direct empirical tests of relevant prices on W_f could not be performed. Thus, the empirical signs of the effects of prices on average dressed weights rely upon the theoretical reasonings given in equations (11)–(13).

Table 2. Three-Stage Least Squares Estimates of Average Dressed Weights for Live Cattle and Hogs (double-log model)

	Average Dressed Weights			
Regressors/Statistics	Steers ($ADWS_\tau$)	Heifers ($ADWH_\tau$)	Cows ($ADWC_\tau$)	Hogs ($ADWG_\tau$)
Livestock-corn price ratio	-0.025	-0.015	0.015	0.004
$(P_{SL_j}/P_{CN})_\tau$	(-3.268)	(-2.148)	(3.048)	(0.866)
Price of feeder cattle	0.048	0.045		
$(P_{fd_i})_{\tau-1}$	(4.559)	(5.084)		
Livestock slaughter	0.004	0.029	-0.054	0.015
$(Q_{j,\tau})$	(0.251)	(3.281)	(-3.552)	(0.825)
Trend	0.0008	0.001	0.0004	0.001
(T)	(6.588)	(7.397)	(4.443)	(5.412)
Lagged dependent variable	0.519	0.500	0.555	0.408
$(ADW_{j,\tau-1})$	(7.872)	(7.730)	(7.299)	(3.822)
Constant*	2.981	2.824	3.155	2.859
	(6.317)	(7.005)	(5.796)	(5.055)
S_2	-0.006	-0.009	-0.034	0.004
	(-1.486)	(-2.443)	(-9.170)	(2.128)
S_3	0.022	0.012	-0.035	-0.018
	(5.086)	(2.956)	(-10.939)	(-9.918)
S_4	0.023	0.020	-0.029	0.013
	(6.084)	(5.579)	(-7.532)	(3.797)
Adjusted R^2	0.906	0.967	0.923	0.978
Standard error of regression	0.012	0.011	0.009	0.006
U-coefficient:	0.006	0.006	0.006	0.003
Bias proportion	0.0004	0.002	0.003	0.0002
Variance proportion	0.025	0.019	0.041	0.003

Notes: The asymptotic t-ratios are given in parentheses below the estimated coefficients. The U-coefficient is the Theil-inequality coefficient. The independent variables shown in the "Regressors/Statistics" column are specific to each dressed weight class. S_2, S_3, and S_4 are the second, third, and fourth quarter dummy variables for seasonal intercept shifts. The critical t-values for significance levels of $\alpha = 0.10$ and $\alpha = 0.05$ are 1.671 and 2.000, respectively (with 60 degrees of freedom).

lighter feeders than to buy heavier feeders, and the lighter placement weights usually result in lower slaughter weights (offsetting extra weight added in the feedlot). If slaughter price declines and corn price is constant (hence decreasing the ratio), cattle may be held to heavier weights in anticipation of price improvement. This result is consistent with that of Anderson and Trapp. They report in a nonlinear breakeven analysis that an increase in the corn-steer price ratio (corn price divided by slaughter price) would increase the in-weights of feeder placements and out-weights of live cattle. The increased corn price would also reduce weight added in the feedlot, but as Anderson

and Trapp indicate, a certain amount of weight gain is necessary from grain finishing to reach Choice grade.

The coefficients of the profitability ratios are highly inelastic. For example, for one quarter, 10% increases in the steer- and heifer-corn price ratios decrease average dressed weight of steers by 0.25% and average dressed weight of heifers by 0.15% (table 2). The small values of the coefficients may be due, in part, to opposing effects of add-on weight discussed earlier; i.e., a decreasing corn price that lowers placement weights also is an incentive to add more weight in the feedlot. In addition, the small elasticities may reflect the price discounts due to deviation from desired quality and yield grades in feeding regimes. Not enough finish can result in a lower carcass quality grade, while excess finish increases the chance of reducing the yield grade (Boggs and Merkel).

The coefficient signs of the relevant feeder price variables in the *ADWS* and *ADWH* equations are positive (table 2). These empirical results are consistent with earlier reasoning that when feeder cattle prices increase, profit maximizers add more weight to compensate for higher input costs. Note that the feeder price effects are also highly inelastic; i.e., 10% increases in feeder steer and heifer prices increase average dressed weights of steers and heifers by 0.48% and 0.45%, respectively.

Both dressed weight functions also possess significant trend effects. The trend coefficients imply quarterly growth of 0.6 and 0.9 pounds for *ADWS* and *ADWH*, respectively (based on sample means of dressed weights) (table 2). These trends represent technology changes net of the effects of the other independent variables. Partial adjustments in market weights are also important, reflected in coefficients of the lagged dependent variables. Based on the values of these coefficients (i.e., 0.52 for $ADWS_{t-1}$ and 0.50 for $ADWH_{t-1}$), the equilibrium (long-run) periods are estimated to be from 3.3 to 3.5 quarters (Nerlove and Addison, p. 874). Consequently, supply elasticities are calculated for one quarter, and for the long run as given in table 3. Since the equilibrium period allows for complete adjustments, the long-run elasticities exceed those of one quarter. For example, the elasticities for the steer-corn price ratio in the *ADWS* equation are -0.025 (one quarter) and -0.052 (equilibrium).[7]

The coefficient of the slaughter cow-corn price ratio is positive and significant at the $\alpha = 0.01$ level. However, the marginal impact (one quarter elasticity) is very small at 0.015 (table 3). The positive effect indicates that producers will add weight to cull cows if output price increases relative to feed costs; Feuz has argued that adding weight and grade to healthy cull cows is a feasible marketing alternative under the right economic incentives.

The impact of the hog-corn price ratio on average dressed weights of hogs, though positive, is not significant at the $\alpha = 0.10$ level (table 2). The statistical insignificance is not surprising as hog finishing involves rapid marketing turnover once barrows and gilts reach the 230–260 pound weight range. Turnover is a product of biological factors, farrow-to-finishing technology (i.e., large confinement operations), and increased producer contracting with pork packers (Hayenga et al.).

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[7] The equilibrium (or long-run) periods are calculated based upon solving for T in the formula $\lambda^T \leq 0.10$, where λ is the coefficient of the lagged dependent variable and 0.10 is the significance level ($\alpha = 0.10$). The latter indicates the dressed weight market is within 10% of equilibrium given a permanent price shock. The equilibrium elasticities are calculated by dividing the one quarter elasticities by $1 - \lambda$.

Table 3. Short-Run and Long-Run Supply Elasticities for Average Dressed Weights of Live Cattle

	Average Dressed Weights		
Variable Changing	Steers ($ADWS_\tau$)	Heifers ($ADWH_\tau$)	Cows ($ADWC_\tau$)
Livestock-corn price ratio $(P_{SL_j}/P_{CN})_\tau$	-0.025 (-0.052)	-0.015 (-0.030)	0.015 (0.034)
Price of feeder cattle $(P_{fd_i})_{\tau-1}$	0.048 (0.100)	0.045 (0.090)	—

Notes: Table figures are the elasticities of the average dressed weights with respect to relevant slaughter-corn price ratios and feeder prices. Short-run elasticities are based on one quarter, while the long-run elasticities (in parentheses) are based on 3.5 quarters. The long-run elasticities are the short-run elasticities divided by one minus the difference equation coefficient of the relevant equation. Since the coefficient on the hog-corn price ratio was not statistically significant, its elasticity was not included in the table.

Livestock finishers are interested in total weight sold (average dressed weight × slaughter numbers). Including slaughter quantities in the equations therefore accounts for inventory levels when analyzing the effects of output and input prices on dressed weights. Slaughter quantities were significant only for heifers and cows at the $\alpha = 0.05$ level. Except for the second quarter in the *ADWS* equation, seasonality for all dressed weight functions was statistically significant at the $\alpha = 0.05$ level. The seasonal coefficients indicate steer and heifer dressed weights, relative to the first quarter, decline in the second quarter but are higher in the third and fourth quarters (table 2). Dressed weights tend to be seasonally smaller in the third quarter for hogs, while dressed weights for cull cows are seasonally smaller in the second through fourth quarters relative to the first quarter. The first quarter reflects a major marketing period for cows that were culled in the fall and fed to improve weight and grade.

Conclusions

U.S. beef and pork producers, in maximizing net returns, exercise control over numbers produced and production weights (given quality) since producers sell pounds of beef and pork. Much work has been done in estimating numbers produced (inventories and slaughter supplies), but relatively little in estimating average liveweights or their direct extension, average dressed weights. Average dressed weights for beef and pork have experienced significant trends and substantial fluctuations. Regarding beef, the 35% decline in cattle prices from 1994 to 1996 has been attributed to increasing dressed weights of fed cattle as well as to increasing feed costs and supplies of competitive meats.

In this study, supply responses of average dressed weights for steers, heifers, cows, and barrows and gilts were estimated employing an I3SLS double-log model. Average dressed weights of steers and heifers were negatively related to livestock-feed price ratios, and positively related to costs of feeder placements. The coefficients, however, are

highly inelastic, reflecting opposing economic decisions of placement weights and weight added in the feedlots. Trend was statistically significant, and was assumed to reflect technology factors such as breeding genetics and feed nutrition. Dressed weights of cows positively responded to the cow-corn price ratio; however, the impact of the hog-corn price ratio on hog dressed weights was not significant.

Results of the model infer that short-run changes in market prices impact dressed weights, and hence wholesale production. For example, dividing the standard deviations of the slaughter-corn price ratios for steers, heifers, and cows by their respective means, an indication of price dispersion (percentages) in the market is provided. Applying these percentages to the relevant supply elasticities then permits estimating potential responses in per quarter meat production. Specifically, using the sample means of steer, heifer, and cow average dressed weights and slaughter quantities, the result is a 29.2 million pound change in wholesale beef production per quarter, or about one-half percent of quarterly beef production.

The longer term has inferences about the effects of technology. For example, consider the weight trends of steers and hogs, of which their average dressed weights increased by 53 pounds (steers) and 21 pounds (hogs) from 1980–97. Using the percentage growth rates given by the trend coefficients (net of price influence), the result indicates about 44 of the 53-pound dressed weight increase for steers and 13 of the 21-pound dressed weight increase for hogs may be accounted for by technology, or 83% and 62%, respectively.

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