

Technological Change in the U.S. Beef and Pork Sectors: Impacts on Farm-Wholesale Marketing Margins and Livestock Prices

*John M. Marsh, Professor
Gary W. Brester, Associate Professor
Montana State University*

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Abstract

Real livestock prices and farm-wholesale marketing margins have steadily declined over the past 20 years. Many studies have examined the effects of increasing packer concentration on these declines. However, most have generally failed to account directly for technological change in livestock production and red meat slaughtering. We estimate reduced form models for beef and pork farm-wholesale marketing margins and cattle and hog prices that specifically include measures of technological change. Empirical results indicate that meat packing technology has reduced real margins and technological change embodied in cattle and hog production accounts for substantial declines in real slaughter cattle and hog prices. When technological change is explicitly considered, we find that increasing packer concentration:

(1) does not affect real farm-wholesale marketing margins, (2) positively affects real slaughter cattle prices, and (3) does not affect real slaughter hog prices.

Key Words: livestock prices, marketing margins, packer concentration, technological change

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Introduction

Livestock producers are generally concerned about marketing margins, particularly the effects of margin size and incidence of margin changes on farm-level prices. In the beef and pork sectors, real farm-retail price spreads (marketing margins) have remained relatively constant since 1970. However, when disaggregated, the farm-wholesale and wholesale-retail margins have demonstrated opposite trends (Figures 1 and 2). Specifically, from 1970 to 1997 real farm-wholesale margins decreased by 59.8 percent for beef and 64.1 percent for pork, while real wholesale-retail margins increased by 26.9 percent for beef and 98.9 percent for pork (USDA 1997).

Although changes in marketing margins are not necessarily indicative of farm-level price changes (i.e., a decrease in the farm-wholesale margin can occur with wholesale and farm prices both moving up or down, but at different rates), livestock producers have perceived themselves to be adversely affected by widening wholesale-retail margins and narrowing farm-wholesale margins. In fact, real prices for slaughter cattle and hogs have declined about 45 percent since 1970 (Figure 3). Industry analysts often attribute this decline to decreased retail demand and increased red meat and poultry production (Purcell). Many livestock producers argue that increasing packer concentration (hence, presumed reductions in competitive behavior) also contribute to declining real cattle and hog prices (MacDonald).

Many studies have evaluated the effect of packer concentration on the livestock industry (Azzam and Anderson provide a comprehensive review). When packer concentration is specified as an explanatory variable in margin and farm price models, its interpretation can be nebulous since several (and perhaps opposing) facets are involved; i.e., market power, technological change, scale economies, risk, transaction costs, etc. (Azzam and Anderson; USDA 1996). Many studies have indicated that increasing packer concentration increases margins and/or decreases prices (Brester and Musick; Hall, Schmitz, and Cothorn; Heyneman; Marion and Geithman; Menkhaus, St. Clair, and Ahmaddand; Miller and Harris; Multop and Helmuth; Quail, et al.). Some studies have indicated that increasing packer concentration has decreased livestock margins and increased prices (Ward; Multop and Helmuth). However, most previous studies have generally failed to directly account for technological change in the livestock production and red meat slaughtering sectors. If the issue has

been addressed at all, it has simply been through the use of a time trend as a proxy for technological change.

The purpose of this research is to quantify the annual impacts of technological change on real farm-wholesale beef and pork marketing margins and real slaughter cattle and hog prices. Our work differs from other studies of red meat margins in that: (1) farm-level and processing-level technologies in the red meat industry are defined and specified separately from market concentration in the output supply and input demand functions, (2) the model is based upon an integrated structure of derived relations at the wholesale and farm levels, and (3) beef and pork marketing margins are jointly estimated to reflect substitution among the two commodities at the retail-level and their technological interdependencies at the slaughtering-level.

Our results indicate that technological change in red meat slaughtering has caused farm-wholesale beef and pork marketing margins to decline and real farm prices to increase. Enough competition appears to remain in the beef and pork processing sector to distribute these cost savings to the farm and retail levels. Furthermore, technological change embodied in farm-level beef and hog production practices and structure is responsible for declines in real slaughter cattle and hog prices. When technological change is explicitly considered, we find that increasing packer concentration: (1) does not affect real farm-wholesale marketing margins, (2) positively affects real slaughter cattle prices, and (3) does not affect real slaughter hog prices.

Increasing Packer Concentration and Changing Technologies

Two major approaches to modeling marketing margins have evolved -- traditional structure-conduct-performance (SCP) models and new empirical industrial organization (NEIO) models (Azzam and Anderson). Structural approaches are a subset of SCP modeling strategies and provide a comprehensive empirical means for understanding margin behavior. For example, consumer expenditures and substitutes in consumption at the retail-level, marketing costs and packer technology at the processing/wholesale-level, and production scale and feed costs at the farm-level can each contribute to changes in marketing margins. Significant changes in livestock-meat production and processing technologies have occurred during the past 30 years. Thus, including measures of technological change in output supply and input demand functions may be important for identifying margin and price behavior. Often, technological change is ignored or attributed to other factors. For example, Figure 4 shows that similar trends have occurred in meat packing technology (as measured by worker output per hour) and market concentration in the beef sector (the sample

correlation is 0.91). Previous SCP studies reported various price and margin effects from increasing packer concentration. However, ignoring technological change in such models could lead to erroneous conclusions due to model misspecification.

Increasing packer concentration in the red meat industry has evolved for several reasons including attempts by firms to obtain size economies, establishment of negotiating power to offset increasing retail concentration, development and adoption of new technology, and reductions in transactions costs (Nelson and Hahn). As packer concentration has increased, significant reductions in slaughter and processing costs per head have been realized (Duewer and Nelsen). Some researchers have postulated the existence of a positive relationship between industry concentration and productivity (Gisser; Lustgarten; Peltzman). Livestock producers have been particularly concerned with whether enough competition remains in the processing sector so that these cost savings are passed through the marketing system in the form of lower wholesale meat prices and/or higher livestock prices.

Concurrent with increased packer concentration, technology (for which labor productivity is used as a proxy) in the meat packing sector has increased significantly. For example, in 1970 the index of output per hour in meat packing was 57.7. By 1997, it had increased to 103.1 (U.S. Department of Labor). Thus, technology changes embedded in this sector may provide plausible explanations for marketing margin and price behavior which has often been attributed to packer concentration (Nelson and Hahn). Hence, we investigate the extent to which marketing margin and livestock price behavior is influenced by technological change.

Model Development: Structural Equations

Development of a beef and pork farm-wholesale margin model begins with a general specification of structural inverse demand and supply functions at the wholesale and farm levels. The structural model is used to develop reduced form marketing margin relations. Inverse demand and supply specifications are commonly used in statistical estimation of agricultural commodity models, particularly if production/processing quantities are considered predetermined (Dunn and Heien; Eales; Huang). If prices and quantities are jointly determined, then it matters little which variable is specified as dependent (Thurman). However, the particular specification chosen usually depends upon research objectives (Brester and Marsh).

Our model assumes completely elastic supplies of marketing services (Wohlgenant). The general structural specification of the inverse wholesale and farm-level supply and demand functions for beef and pork is represented as:¹

Wholesale Sector:

- (1) $P_w^d = f_1(Q_w^d, Q_w^{ds}, Y, MC)$ (inverse demand)
- (2) $P_w^s = f_2(Q_w^s, P_f, LC, BP, T_{mp})$ (inverse supply)
- (3) $P_w^d = P_w^s = P_w$ (market-clearing price identity)
- (4) $Q_w^d = Q_w^s = Q_w$ (market-clearing quantity identity)

Farm Sector:

- (5) $P_f^d = f_5(Q_f^d, P_w, LC, BP, T_{mp})$ (inverse demand)
- (6) $P_f^s = f_6(Q_f^s, P_{fd}, P_{cn}, T_f, T_a)$ (inverse supply)
- (7) $P_f^d = P_f^s = P_f$ (market-clearing price identity)
- (8) $Q_f^d = Q_f^s = Q_f$ (market-clearing quantity identity)

Equations (1) and (2) represent inverse demand and supply relations at the wholesale-level. Equation (1) indicates that wholesale demand price (P_w^d) depends upon per capita wholesale demand for the commodity (Q_w^d), per capita wholesale demand of substitutes (Q_w^{ds}), per capita total personal consumption expenditures (Y), and processing and distribution costs (MC). Quantity of meat substitutes and per capita expenditures represent the effect of primary demand (retail sector) on wholesale derived demand (Marsh 1988). Equation (2) indicates wholesale supply price (P_w^s) depends upon per capita production of the wholesale commodity (Q_w^s), cost (price) of slaughter livestock (P_f), labor costs (wages) in food processing (LC), the value of slaughtering by-products

¹The framework of the market inverse demand and supply functions encompasses the conceptual arguments of derived demands, supplies, and marketing margin behavior (Tomek and Robinson). Price dependent functional forms have been applied in various livestock-meat models (Brester and Marsh; Eales; Heien; Huang; Marsh 1992; Wohlgenant). Theoretical restrictions are not imposed since the structural model is not directly estimated, but is merely used to identify variables to be included in a reduced form model.

(BP), and meat slaughtering technology (represented by output per employee hour in the meat packing industry, T_{mp}). Equations (3) and (4) are wholesale-level market clearing identities.

Equations (5) and (6) describe inverse derived demand and primary supply functions at the farm (slaughter) level. Equation (5) indicates slaughter demand price (P_f^d) depends upon quantity demanded of slaughter livestock (Q_f^d), output price of the wholesale commodity (P_w), labor costs (wages) in food processing (LC), the value of slaughtering by-products (BP), and meat slaughtering technology (represented by output per employee hour in the meat packing industry, T_{mp}). Equation (6) indicates that slaughter supply price (P_f^s) depends upon quantity supplied of slaughter livestock (Q_f^s), the price of feeder animals (P_{fd}), the price of feed (P_{cn}), technology in the animal production and feeding industries (firm size), T_f , and technology manifest in average dressed weights of livestock (animal size), T_a (Marsh 1999). Equations (7) and (8) are farm-level market clearing identities.

The technology variables specified above represent productivity measures relevant for each demand and supply function. Increasing productivity in livestock and meat production is generally the result of increasing capital-to-labor ratios, new feeding and processing methods, improved nutrition and management, and advanced genetics. Except for meat processing technology, all other technology variables are assumed to be exogenous shifters of output supplies and input demands.² Output per employee hour in meat packing is specific to wholesale supply and packer demand, and firm and animal size are specific to slaughter supply (for beef, percent of cattle marketed by firms with capacities of more than 16,000 head and average dressed weights of slaughter cattle -- for pork, percent of firms with farrowing capacities of more than 500 head and average dressed weights of hogs). The sizes of cattle and hog production firms have increased because of technological changes embodied in capital substitution for labor and vertical coordination (Hayenga, et al.). Anderson and Trapp noted that declining real feed costs contribute to increased average dressed weights of slaughter animals. However, average dressed weights have also increased because of improved genetics and nutrition/animal health management practices (Brester, Schroeder, and Mintert).

Since the model consists of derived demands and supplies, marketing costs and labor costs (MC , LC) are necessarily specified as margin shifters (Tomek and Robinson). The MC variable is

² The meat processing technology variable is defined as output per employee hour in meat packing plants. Thus, the output (quantity) component of this technology measure could be jointly dependent with the left-hand side price variables in the margin model.

more comprehensive than the LC variable as the former consists of labor, processing, merchandising, and transportation costs, while the latter represents only labor costs (Harp). Consequently, MC was specified in the wholesale demand equation while LC was specified in slaughter demand and wholesale supply equations. Excluding costs of cattle procurement, labor accounts for 40 to 50 percent of packer slaughtering and processing costs, depending upon plant size and production procedures (Duewer and Nelsen). Each market level is assumed to be in equilibrium over annual time periods which allows for a reduction in the number of quantity and price variables required in the reduced form model.

Model Development: Reduced Form Marketing Margin and Farm Price Equations

Reduced form expressions for the farm-wholesale marketing margin equations are obtained by substituting equations (1) and (2) into equation (3), and substituting equations (5) and (6) into equation (7). The general specification of the farm-wholesale margin (M_{fw}) for beef and for pork is obtained by subtracting P_f from P_w :³

$$(9) \quad M_{fw} = \ell_1(Q_w^d, Q_w^s, Q_f^d, Q_f^s, Q_w^{ds}, Y, MC, LC, BP, T_{mp}, T_f, T_a, P_{fd}, P_{cn}).$$

The margin relationship incorporates farm-to-wholesale price linkages by including wholesale demand shifters, farm product supplies, and food marketing costs as specified in the structural model. Therefore, no restrictions are imposed on input substitutability in meat processing; consequently, the reduced form marketing margin model subsumes variable input proportions (Wohlgenant).

Equation (9) contains several variables which represent similar factors in both the wholesale and farm levels of the market. Because many of these variables contain near identical information, a more parsimonious specification of the reduced form model is needed to mitigate collinearity problems. The market-clearing quantity identities (equations (4) and (8)) allow for wholesale quantities to be represented by Q_w and farm quantities by Q_f . Assuming that carcass wholesale quantities contain production information regarding live weight quantities, farm quantity (Q_f) is subsequently omitted from the specification. Labor costs (LC) are a major component of food

³ Since equations (1)-(8) do not involve econometric estimation, equation (9) does not inherit economic restrictions on the slope parameters; such would not be the case if the structural price-dependent equations were estimated and the margin relations were then solved.

marketing costs (MC) (Harp). Hence, LC is omitted from the margin model. Many studies assume that packer concentration is also an important factor in determining market margins (Azzam and Anderson). Packer concentration is not included in our formal structural model *per se*. However, variables representing four-firm packer concentration ratios (C_r) for beef and pork are incorporated in the model on an *ad hoc* basis to test for their ability to explain margin and slaughter price behavior (Multop and Helmuth; Quail et al.).

The following reduced form equation (for each marketing margin) is used for empirical estimation:

$$(10) \quad M_{fw} = \ell_2(Q_w, Q_w^{ds}, Y, MC, BP, T_{mp}, T_f, T_a, P_{fd}, P_{cn}; C_r).$$

The specification of equation (10) is based upon the structural demand and supply model, with provision for the *ad hoc* specification of packer concentration (C_r). This specification follows the logic of Anderson, et al. in developing micro and aggregate arguments that determine packer/processor profits (margins). Likewise, it follows the market concentration and cost arguments used by Hall, Schmitz and Cothorn for estimating wholesale-retail beef marketing margins.

To empirically evaluate the influence of technology and packer concentration on marketing margins, equation (10) will be first estimated using the theoretically-consistent specification which excludes C_r . Then, the equation will be re-estimated with the *ad hoc* inclusion of C_r . Finally, the empirical results will be compared to a model in which C_r is included in the margin specification in the absence of measures of technological change.

The reduced form equations for cattle and hog farm-level prices are obtained by returning to the structural model of the farm sector, and substituting equations (5) and (6) into equation (7):

$$(11) \quad P_f = \ell_3(Q_f^d, Q_f^s, P_w, LC, BP, T_{mp}, T_f, T_a, P_{fd}, P_{cn}).$$

Using equation (8) and adding the packer concentration variable (C_r) to equation (11) results in a general empirical specification of real farm-level cattle and hog prices:

$$(12) \quad P_f = \ell_4(Q_f, P_w, LC, BP, T_{mp}, T_f, T_a, P_{fd}, P_{cn}; C_r).$$

Equation (12) will be estimated using three different specifications: (1) the theoretically-consistent specification which excludes C_r , (2) an *ad hoc* specification which includes C_r , and (3) a traditional specification which includes C_r and excludes measures of technological change.

Data

The sample period for the margin and slaughter price models consists of annual data from 1970 to 1997. All marketing margins, wholesale production, cattle and hog slaughter, feeder prices, corn price, and by-product values were obtained from *Red Meats Yearbook* (USDA) and *Livestock, Dairy and Poultry Situation and Outlook* (USDA). The marketing cost and labor cost indexes were obtained from *Agricultural Outlook* (USDA), while the Consumer Price Index (CPI), per capita consumption expenditures, and population series were obtained from the *Economic Report of the President*. All the price and value variables (including marketing and labor costs) were deflated by the CPI (1982-84=100) while wholesale production was divided by population.

Four-firm concentration ratios for the beef and pork packing industries were obtained from Lesser (p. 366) and Azzam and Anderson. The meat processing technology variable (index of output per employee hour in meat packing) was obtained from the U.S. Department of Labor. The firm size technology variables at the farm-level (percent of cattle marketed by firms with fed cattle marketings greater than 16 thousand head; percent of firms with sow inventories greater than 500 head) were obtained from *Cattle Final Estimates* (USDA-NASS) and *Hogs and Pigs Final Estimates* (USDA-NASS). The farm-level technology variables for animal size (average dressed weights of cattle; average dressed weights of hogs) were obtained from *Red Meats Yearbook* (USDA) and *Livestock, Dairy and Poultry Situation and Outlook* (USDA).

Empirical Results for the Farm-Wholesale Marketing Margins

Equation (10) represents the margin relationships to be estimated for beef and pork. Table 1 presents the variable definitions. Hausman specification tests were conducted on the own-quantity, feeder price, and meat packing technology regressors. The results indicated the null hypothesis of no simultaneity could not be rejected at the $\alpha = 0.05$ level for either of the two margin equations (Johnston and DiNardo, pp. 338-42).

Augmented Dickey-Fuller unit root tests (ADF) were used to test each of the variables for stationarity. The null hypothesis of unit roots could not be rejected for several of the variables which were integrated of order one (I(1)). Because nonstationary data can yield spurious regression results, one could difference the data to ameliorate problems associated with infinite variances (Pindyck and

Rubinfeld, pp 513-514). However, data in first-difference (or higher) form may not reflect the long-run relationships among variables. Johnston and DiNardo (pp 259-269) suggest that a multiple regression equation involving nonstationary variables can be estimated in data-level form if the function is cointegrated (i.e., if the ADF rejects the null hypothesis of unit roots in the equation residuals). The ADF test results rejected the null hypothesis of unit roots in the residuals for both margin equations. Thus, the empirical model is estimated with the data in levels (using double log transformations).

The residuals of the two margin equations were tested for first-order autoregressive behavior [AR(1)] and non-constant variance (heteroskedasticity) using OLS regressions. Durbin-Watson tests could not reject AR(1) disturbances for both equations. Using White's test for heteroskedastic disturbances (Johnston and DiNardo, pp. 166-67), the null hypothesis of constant variance of the residuals could not be rejected for each margin equation at the $\alpha=0.05$ level. In addition, the residuals were tested for normality. The Jarque-Bera (JB) statistic failed to reject the null hypothesis of normal residuals for both equations at the $\alpha=0.05$ level (Pindyck and Rubinfeld, pp. 47-48).

The error terms between the beef and pork margin equations were hypothesized to be contemporaneously correlated since the two products are consumption substitutes and the beef and pork packing industries share similar technologies. Thus, the beef and pork farm-wholesale marketing margin equations are jointly estimated using Iterative Seemingly Unrelated Regressions (ITSUR) and AR(1) corrections in the error terms.

Table 2 presents the ITSUR results of the beef and pork margin equations. Overall, the regression fits were high, with adjusted R^2 's (\bar{R}^2) of 0.966 and 0.972 and standard errors of regression (SE) of 0.067 and 0.069 (less than 2.4 percent of the mean log margins) for the beef and pork equations. Further, in-sample tests were used to empirically evaluate the model. Specifically, root mean squared errors of forecast (RMSE) and Theil's inequality coefficient (TC) were calculated. The results tend to verify a robust model specification as the RMSEs are relatively small (about 5 percent of mean real margins) and TCs are close to zero (Pindyck and Rubinfeld, pp 210-211). Contemporaneous correlation of the error terms between the margin equations was relatively high with a correlation coefficient of -0.44.

Our analysis of the farm-wholesale margins focuses primarily on the effects of technological change and whether market concentration adds explanatory power. Most of the other variables are

statistically significant in the beef marketing margin model, i.e., marketing costs, corn price, feeder cattle price, by-product values, poultry production, and consumer expenditures are significant at the $\alpha=0.05$ level. However, in the pork marketing margin equation, most are insignificant with marketing costs significantly different from zero at only the $\alpha=0.15$ level.

The effects of meat processing technology are negative and significant at the $\alpha=0.01$ level in beef margin equation, and negative and significant at the $\alpha=0.01$ level in the pork margin equation. Given wages, increases in output per employee hour effectively reduces unit labor costs, with the resulting productivity (cost savings) reducing farm-wholesale margins. A 1 percent increase in meat packer productivity reduces beef margins by 1.53 percent and reduces pork margins by 0.83 percent.

The production technologies represented by firm size and dressed weights are significantly different from zero ($\alpha=0.15$ and $\alpha=0.01$, respectively) in the beef margin equation. Increases in both production technologies positively influence beef margins. The effects of firm size, though not strong, were expected to decrease margins by reducing transactions costs and market price and quantity risk. Alternatively, it has been suggested that larger firm sizes may increase bargaining power and/or vertical coordination and market contracting (Hayenga, et al.; Nelson and Hahn; Schroeder, et al.). Increases in dressed weights may negatively affect farm prices and, thus, increase margins. The firm size and dressed weight variables were not statistically significant in the pork margin equation.

The relatively elastic coefficient for meat packer technology in the beef margin equation suggests non-trivial impacts. Essentially, enough competition remains in the packing industry to cause margins to decline in response to cost savings generated by technological changes (Anderson et al.). That is, over the long run, technological cost savings have not been rent-captured, but rather have been bid into the value of live animals and wholesale products. This conclusion is reinforced by the long-standing existence of excess capacity in meat packing which leads to more aggressive pricing of inputs and outputs among large packers (Azzam and Anderson).

To further test this conclusion, the margin model was re-estimated by including four-firm concentration ratios for beef (C_b) and pork (C_p) in the margin equations. After accounting for technological change, the inclusion of concentration in the model should reveal if other factors often presumed to be associated with concentration (e.g., market power, anti-competitive behavior) add to the explanatory power of the real margins model. Table 3 presents the regression results. The

coefficient estimates for C_b and C_p are not statistically different from zero, indicating that the four-firm concentration ratios add little information about the behavior of real beef and pork margins.

Given that increasing market concentration has occurred simultaneously with technological change, the effects of technology could be erroneously attributed to concentration if one fails to account for the former. Therefore, Table 4 presents regression results obtained by re-estimating the original model with the addition of four-firm concentration ratios and excluding all technology variables. The coefficient estimates for the concentration variables are not significantly different from zero in either margin equation. Ward estimated beef and pork farm-wholesale margin equations with commercial meat production, labor costs, and packer concentration included in the specification. His results indicated that packer concentration significantly reduced beef margins, but had no significant effect on pork margins.

Empirical Results for the Slaughter Price Equations

To livestock producers, information regarding the effects of market concentration and technological change on marketing margins may not be as important as associated impacts on farm-level prices. Simply because real farm-wholesale marketing margins narrow over time does not mean that farm-level prices are concurrently increasing. Equation (12) represents the slaughter price relationships to be estimated for farm-level cattle and hog prices.

The time-series tests that were conducted on the margin equations were also applied to the slaughter price equations. Hausman specification tests were conducted on the relevant right-hand side slaughter quantity, wholesale price, and feeder price variables. The null hypothesis of no simultaneity was rejected at the $\alpha=0.10$ level for both equations. Therefore, each slaughter price equation was estimated (in double log form) using Iterative Three Stage Least Squares (IT3SLS), in which all exogenous variables in equations (10) and (12) were used as instruments. The ADF test rejected the null hypothesis of unit roots in the residuals of both equations at the $\alpha=0.05$ level, permitting the use of the data in levels for estimation. Given results of Durbin-Watson tests, each equation was corrected for AR(1) disturbances. White's test could not reject the null hypothesis of constant variance of the residuals for each price equation at the $\alpha=0.05$ level, and the JB statistic failed to reject the null hypothesis of normal residuals at the $\alpha=0.05$ level.

Table 5 presents the regression results and indicates that the models fit the data well (\bar{R}^2 's of 0.99 for both equations and SE's of 0.015 and 0.018). As expected, boxed beef and pork prices were highly significant and indicate price transmission elasticities of 0.77 and 0.42 between the wholesale

and farm sectors for beef and pork. Own-slaughter quantities were significant and negative in both equations, which is consistent with downward sloping inverse demand functions. Positive and significant coefficient estimates on feeder cattle and feeder pig prices indicate that increases in these input prices shift the supplies of fed cattle and hogs to the left, which increases slaughter prices. A similar interpretation is made for the price of corn in the slaughter hog price equation.

The importance of meat packing productivity (technology) on slaughter prices is illustrated by the significance of T_{mp} ($\alpha = 0.05$) in both equations. Both coefficients are inelastic, but indicate positive effects on slaughter prices. For example, a one percent increase in meat packing productivity increases slaughter cattle and hog prices by 0.12 and 0.39 percent, respectively. Given that these productivity measures also reduce packer margins, it appears that at least some of the cost savings generated by increased meat packing technology are passed along in terms of higher cattle and hog prices. Output per hour in meat packing increased by 31.5 percent from 1980 to 1997. Using the estimated coefficients, *ceteris paribus*, this increase translates into real price increases of 3.8 percent for cattle and 12.3 percent for hogs, or about \$2.00/cwt for slaughter steers and \$4.90/cwt for slaughter hogs (based on real mean values over the period).

The firm size technology variable is not significantly different from zero in the beef price equation, but is significantly different from zero in the hog equation. Conversely, the animal size technology variable is significant in the beef equation, but not in the pork equation. Note that these effects are both negative. Thus, increasing farm-level technology manifest in increasing average dressed cattle weights is a significant contributor to the decline in real slaughter cattle price. A one percent increase in average dressed weights reduces real slaughter cattle price by 0.75 percent. From 1980 to 1997, average dressed weights of steers and heifers increased by 13.8 percent, indicating that slaughter cattle price decreased 10.4 percent, or \$5.90/cwt using mean price.

Although increasing average dressed weights did not influence real hog slaughter prices, the changing structure of hog production (essentially, much larger breeding operations) has had a significant influence on reducing real hog slaughter price. A one percent increase in the percentage of firms with sow inventories exceeding 500 head reduces hog slaughter price by 0.17 percent. From 1980 to 1997, the number of these firms increased by 39.7 percent, implying a 6.7 percent reduction in slaughter hog price (or \$3.32/cwt using mean real price). Previous researchers have noted that technological improvements in hog production are manifest in larger production operations (Brester, Schroeder, and Mintert; Hurley, Kliebenstein, and Orazem). Therefore, differences in the

technology factors which influence beef versus pork prices are not unexpected. While larger feedlots may reduce marketing costs and produce size economies, the primary technological change has involved genetics and nutrition improvements which are manifest in larger dressed beef weights. However, technological changes in genetics, animal health, and vertical coordination in hog production have allowed for substantial increases in the feasible size of hog farms.

Table 6 indicates that the addition of four-firm concentration ratios to the slaughter price equations adds marginal explanatory power to the slaughter cattle price model, but has no effect on the slaughter hog price model. In the cattle price equation, the C_b variable is significant and increases the \bar{R}^2 from 0.996 (table 5) to 0.997. However, contrary to the expectations of many cattle producers, over the long-term packer concentration positively affects real cattle price, albeit by a small amount. Note that the coefficient on technology in meat packing (T_{mp}) is no longer significant in the slaughter cattle price equation. Thus, it appears that the inclusion of C_b simply proxies technological changes in the beef packing sector (the two coefficients are nearly the same at 0.12 and 0.14, respectively, between the two models).

Table 7 presents the regression results obtained by re-estimating equation (12) and omitting all technology factors while including packer concentration variables. Relative to the theoretically consistent model presented in table 5, the explanatory power of this alternative specification is poorer. Packer concentration is significant ($\alpha=0.10$ level) and positive in the slaughter cattle price equation. Multop and Helmuth estimated a structural demand and supply model and found that an increase in packer concentration was associated with higher cattle prices. Marion and Geithman found the opposite result using a regional time series model.

The packer concentration variable is significant and negative in the slaughter hog price equation. Heyneman also found a significant negative relationship between concentration and slaughter hog price. Likewise, Miller and Harris found a negative effect of concentration on slaughter hog price using regional data. Thus, evidence indicates that a model which includes packer concentration while ignoring technological information could lead to false conclusions that increasing packer concentration has caused real slaughter hog prices to decline.

Conclusions

Livestock producers are frequently concerned about the impacts of increasing packer concentration on real livestock prices and marketing margins. Specifically, producers often assume that increasing packer concentration is responsible for decreasing real livestock prices. Although real farm-

wholesale beef and pork marketing margins have declined over the past 20 years (because of increased processing efficiencies), this does not necessarily mean that cost savings have been beneficial to livestock prices.

Numerous studies have considered the impacts of increasing packer concentration on marketing margins and livestock prices. However, these studies have not directly modeled the impact of technological change in the meat packing and livestock production sectors. We consider this a serious specification error and, therefore, specify a structural demand and supply model which includes farm- and processing-level technology measures. The empirical results of the reduced form models indicate that technology in the meat packing sector has been a significant contributor to declining real beef and pork farm-wholesale marketing margins. After accounting for technological change, the addition of packer concentration variables does not add to the explanatory power of the marketing margin models. In addition, the omission of technology factors does not change the insignificant influence of the concentration variables.

In the slaughter cattle and hog price models, technology in the meat packing sector has positively influenced real cattle and hog prices. Thus, it appears that enough competitive behavior exists in the meat processing sector to bid cost savings generated by technological change to the livestock production sector. However, technological change in cattle production (e.g., genetics, nutrition) has negatively influenced real slaughter cattle prices. In the hog sector, increasing technology manifest in the sizes of hog production firms has negatively influenced real hog prices.

Our results do not contradict studies which indicate that packer concentration may have small, negative regional or short-term effects on livestock prices. Our research focuses on national impacts of long-term technological change on livestock prices and marketing margins. We conclude that technological change is a primary cause of declining real marketing margins and livestock prices. We did not find any evidence to suggest that increasing packer concentration and associated presumed anti-competitive behavior has either positively affected farm-wholesale marketing margins or negatively affected slaughter prices.

Successful firms in a competitive commodity production sector rely heavily upon the adoption of low-cost strategies. Livestock and meat producers adopt technologies which lower unit production costs and, unless commensurate demand increases occur, cause real livestock prices to decline. Given the potential for the introduction of biotechnological and informational technologies into the livestock production sector, real livestock prices are likely to continue their downward trend.

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Table 1. Variable Descriptions of Beef and Pork Marketing Margin Model

Variables	Definition
M_b, M_p	farm-to-wholesale margins for beef and pork, respectively, (cents/lb).
Q_b, Q_p, Q_y	per capita commercial production of beef, pork, and poultry, respectively, pounds of carcass weight and ready-to-cook weight.
Q_c, Q_h	quantity of cattle and hogs commercially slaughtered, respectively, millions of head.
M_c, L_c	index of food marketing costs and index of labor costs in food processing, respectively, 1967=100.
B_b, B_p	farm by-product values (hide and offal) for beef and pork, respectively, cents per pound.
P_{wb}, P_{wp}	price of boxed beef cut-out value, Choice 2-3, and price of boxed pork cut-out value, no. 2, Central U.S., respectively, (\$/cwt).
P_c, P_b, P_d, P_p	price of choice steers, 2-4, 1100-1300 lbs, Nebraska direct (\$/cwt); price of barrows and gilts, no. 1-3, 230-250 lbs, Iowa/S. Minnesota (\$/cwt); price of feeder steers, medium no. 1, 600-650 lbs, Oklahoma City (\$/cwt); price of 40-50 lb feeder pigs, no. 1-2, So. Missouri (\$/head).
P_n	price of no. 2 yellow corn, Central Illinois, (\$/bu).
C_b, C_p	four-firm concentration ratios for beef and pork packing, respectively, percent.
T_{mp}	index of output per employee hour in meat packing, 1987=100.
T_{fb}, T_{fp}	percent of fed cattle marketed by feedlots with capacities exceeding 16 thousand head; percent of hog production firms with sow inventories exceeding 500 head.
T_{ab}, T_{ap}	federally inspected average dressed weight of steers and heifers (lbs); federally inspected average dressed weight of hogs (lbs).
Y	per capita total consumption expenditures, (\$).

Table 2. Iterative Seemingly Unrelated Regression Results for the Beef and Pork Double Log Marketing Margin Model.

Margin Equations (10)	Regressors/Statistics
Beef Farm-Wholesale (M_b) = 4.69 - 1.42 Q_b + 1.56 M_c - 0.42 P_n - 0.88 P_d + 0.93 B_b (0.67) (-3.28) (4.25) (-4.70) (-5.87) (8.60)	
- 0.12 Q_p - 0.68 Q_y - 1.59 Y - 1.53 T_{mp} + 0.22 T_{fb} + 2.64 T_{ab} (-0.53) (-3.10) (-4.63) (-5.05) (1.49) (3.15)	
$\bar{R}^2 = 0.966$ SE = 0.067 RMSE = 1.236 TC = 0.025	
Pork Farm-Wholesale (M_p) = -28.34 - 0.09 Q_p + 1.99 M_c + 0.13 P_n + 0.15 P_p - 0.09 B_p (-1.02) (-0.12) (1.49) (1.14) (0.90) (-0.56)	
+ 0.41 Q_b + 0.44 Q_y - 0.10 Y - 0.83 T_{mp} - 0.92 T_{fp} + 4.32 T_{ap} (0.98) (0.67) (-0.34) (-1.90) (-1.10) (1.06)	
$\bar{R}^2 = 0.972$ SE = 0.069 RMSE = 2.018 TC = 0.025	

Note: Numbers in parentheses below each estimated parameter represent asymptotic t ratios. \bar{R}^2 is the adjusted R-squared and SE is the standard error of regression. RMSE is the root-mean-square forecast error and TC is Theil's inequality coefficient. The means of the real margin variables are: $M_b = 23.93$ and $M_p = 38.21$, cents per pound. The log means of the margin variables are: $M_b = 3.131$ and $M_p = 3.572$. The critical t values for the $\alpha=0.05$ and $\alpha=0.10$ significance levels are 2.042 and 1.697, respectively (30 degrees of freedom).

Table 3. Iterative Seemingly Unrelated Regression Results for the Beef and Pork Double Log Marketing Margin Model (including packer concentration).

Margin Equation (10)	Regressors/Statistics
Beef Farm-Wholesale (M_b) = 4.55 - 1.05 Q_b + 1.88 M_c - 0.43 P_n - 0.78 P_d + 0.85 B_b (0.64) (-1.78) (3.30) (-4.75) (-4.45) (6.43)	
- 0.05 Q_p - 0.75 Q_y - 1.84 Y - 1.78 T_{mp} + 0.47 T_{fb} + 2.67 T_{ab} + 0.19 C_b (-0.23) (-3.14) (-3.68) (-3.92) (1.35) (3.26) (0.78)	
$\bar{R}^2 = 0.962$ SE = 0.072 RMSE = 1.282 TC = 0.026	
Pork Farm-Wholesale (M_p) = -20.78 + 0.28 Q_p + 1.45 M_c + 0.15 P_n + 0.26 P_p - 0.08 B_p (-0.78) (0.37) (1.16) (1.31) (1.50) (-0.45)	
+ 0.63 Q_b + 0.49 Q_y - 0.17 Y - 0.89 T_{mp} - 0.68 T_{fp} + 3.48 T_{ap} - 0.22 C_p (1.46) (0.73) (-0.58) (-2.08) (-0.86) (0.89) (-0.84)	
$\bar{R}^2 = 0.969$ SE = 0.073 RMSE = 1.909 TC = 0.024	

Note: Numbers in parentheses below each estimated parameter represent asymptotic t ratios. \bar{R}^2 is the adjusted R-squared and SE is the standard error of regression. RMSE is the root-mean-square forecast error and TC is Theil's inequality coefficient. The means of the real margin variables are: $M_b = 23.93$ and $M_p = 38.21$, cents per pound. The log means of the margin variables are: $M_b = 3.131$ and $M_p = 3.572$. The critical t values for the $\alpha=0.05$ and $\alpha=0.10$ significance levels are 2.048 and 1.701, respectively (28 degrees of freedom).

Margin Equation (10)	Regressors/Statistics
<p>Beef Farm-Wholesale (M_b) = 23.44 - 0.55Q_b - 0.38M_c - 0.07P_n - 0.40P_d</p> <p>(4.30) (-0.83) (-1.38) (-0.69) (-1.90)</p> <p>+ 0.68B_b + 0.06Q_p - 0.16Q_y - 1.72Y - 0.27C_b</p> <p>(4.02) (0.22) (-0.64) (-2.62) (-1.22)</p> <p>$\bar{R}^2 = 0.952$ SE = 0.081 RMSE = 1.424 TC = 0.028</p>	
<p>Pork Farm-Wholesale (M_p) = 0.23 + 1.61Q_p - 0.50M_c + 0.22P_n + 0.49P_p</p> <p>(0.04) (4.21) (-1.42) (1.79) (2.89)</p> <p>- 0.04B_p + 1.42Q_b - 0.36Q_y - 0.17Y + 0.06C_p</p> <p>(-0.23) (4.16) (-0.92) (-0.40) (0.19)</p> <p>$\bar{R}^2 = 0.960$ SE = 0.083 RMSE = 3.205 TC = 0.039</p>	

Note: Numbers in parentheses below each estimated parameter represent asymptotic t ratios. \bar{R}^2 is the adjusted R-squared and SE is the standard error of regression. RMSE is the root-mean-square forecast error and TC is Theil's inequality coefficient. The means of the real margin variables are: $M_b = 23.93$ and $M_p = 38.21$, cents per pound. The log means of the margin variables are: $M_b = 3.131$ and $M_p = 3.572$. The critical t values for the $\alpha=0.05$ and $\alpha=0.10$ significance levels are 2.030 and 1.690, respectively (34 degrees of freedom).

Table 5. Iterative Three Stage Least Squares Regression Results for the Double Log Cattle and Hog Slaughter Price Equations.

Slaughter Equation (12)	Regressors/Statistics
Cattle Slaughter Price (P_c) = 6.69 - 0.28 Q_c + 0.05 B_b - 0.22 L_c + 0.77 P_{wb} + 0.11 P_d (2.91) (-2.58) (1.44) (-1.85) (12.56) (1.83)	
+ 0.03 P_n + 0.12 T_{mp} + 0.02 T_{fb} - 0.75 T_{ab} (1.36) (2.10) (0.32) (-2.95)	
$\bar{R}^2 = 0.996$ SE = 0.015 RMSE = 0.851 TC = 0.006	
Hog Slaughter Price (P_h) = -0.38 - 0.29 Q_h + 0.04 B_p + 0.10 L_c + 0.42 P_{wp} + 0.30 P_p (-0.11) (-4.80) (0.82) (0.83) (5.97) (6.61)	
+ 0.18 P_n + 0.39 T_{mp} - 0.17 T_{fp} + 0.01 T_{ap} (6.26) (4.77) (-2.70) (0.03)	
$\bar{R}^2 = 0.997$ SE = 0.018 RMSE = 0.714 TC = 0.007	

Note: Numbers in parentheses below each estimated parameter represent asymptotic t ratios. \bar{R}^2 is the adjusted R-squared and SE is the standard error of regression. RMSE is the root-mean-square forecast error and TC is Theil's inequality coefficient. The means of the slaughter prices are: $P_c = 66.17$ and $P_h = 50.25$, dollars per cwt. The log means of the slaughter price variables are: $P_c = 4.158$ and $P_h = 3.853$. The critical t values for the $\alpha=0.05$ and $\alpha=0.10$ significance levels are 2.030 and 1.690, respectively (34 degrees of freedom).

Table 6. Iterative Three Stage Least Squares Regression Results for the Double Log Cattle and Hog Slaughter Price Equations (including packer concentration).

Slaughter Equation (12)	Regressors/Statistics
<p>Cattle Slaughter Price (P_c) = 7.91 - 0.24Q_c - 0.01B_b + 0.06L_c + 0.74P_{wb} + 0.15P_d (3.99) (-2.90) (-0.25) (0.48) (15.19) (3.28)</p> <p>+ 0.06P_n - 0.06T_{mp} + 0.05T_{fb} - 1.15T_{ab} + 0.14C_b (2.95) (-0.84) (0.99) (-4.65) (3.63)</p> <p>$\bar{R}^2 = 0.997$ SE = 0.014 RMSE = 0.751 TC = 0.006</p>	
<p>Hog Slaughter Price (P_h) = 0.22 - 0.32Q_h + 0.04B_p + 0.12L_c + 0.43P_{wp} + 0.28P_p (0.06) (-4.88) (0.90) (1.02) (6.29) (5.93)</p> <p>+ 0.17P_n + 0.43T_{mp} - 0.19T_{fp} - 0.17T_{ap} + 0.04C_p (6.30) (4.47) (-2.83) (-0.33) (0.86)</p> <p>$\bar{R}^2 = 0.997$ SE = 0.018 RMSE = 1.014 TC = 0.010</p>	

Note: Numbers in parentheses below each estimated parameter represent asymptotic t ratios. \bar{R}^2 is the adjusted R-squared and SE is the standard error of regression. RMSE is the root-mean-square forecast error and TC is Theil's inequality coefficient. The means of the slaughter prices are: $P_c = 66.17$ and $P_h = 50.25$, dollars per cwt. The log means of the slaughter price variables are: $P_c = 4.158$ and $P_h = 3.853$. The critical t values for the $\alpha=0.05$ and $\alpha=0.10$ significance levels are 2.042 and 1.697, respectively (32 degrees of freedom).

Table 7. Iterative Three Stage Least Squares Regression Results for the Double Log Cattle and Hog Slaughter Price Equations (excluding technology variables and including packer concentration).

Slaughter Equation (12)	Regressors/Statistics
Cattle Slaughter Price (P_c) = -1.39 - 0.01 Q_c - 0.02 B_b + 0.10 L_c + 0.93 P_{wb} + 0.12 P_d (-1.61) (-0.05) (-0.48) (0.95) (11.89) (1.56) + 0.01 P_n + 0.07 C_b (0.33) (1.76) $\bar{R}^2 = 0.994$ SE = 0.019 RMSE = 1.025 TC = 0.008	
Hog Slaughter Price (P_h) = 2.34 - 0.33 Q_h + 0.03 B_p + 0.07 L_c + 0.38 P_{wp} + 0.32 P_p (3.28) (-4.12) (0.56) (0.58) (3.55) (5.46) + 0.14 P_n - 0.10 C_p (4.88) (-3.69) $\bar{R}^2 = 0.995$ SE = 0.023 RMSE = 1.225 TC = 0.012	

Note: Numbers in parentheses below each estimated parameter represent asymptotic t ratios. \bar{R}^2 is the adjusted R-squared and SE is the standard error of regression. RMSE is the root-mean-square forecast error and TC is Theil's inequality coefficient. The means of the slaughter prices are: $P_c = 66.17$ and $P_h = 50.25$, dollars per cwt. The log means of the slaughter price variables are: $P_c = 4.158$ and $P_h = 3.853$. The critical t values for the $\alpha=0.05$ and $\alpha=0.10$ significance levels are 2.021 and 1.684, respectively (38 degrees of freedom).

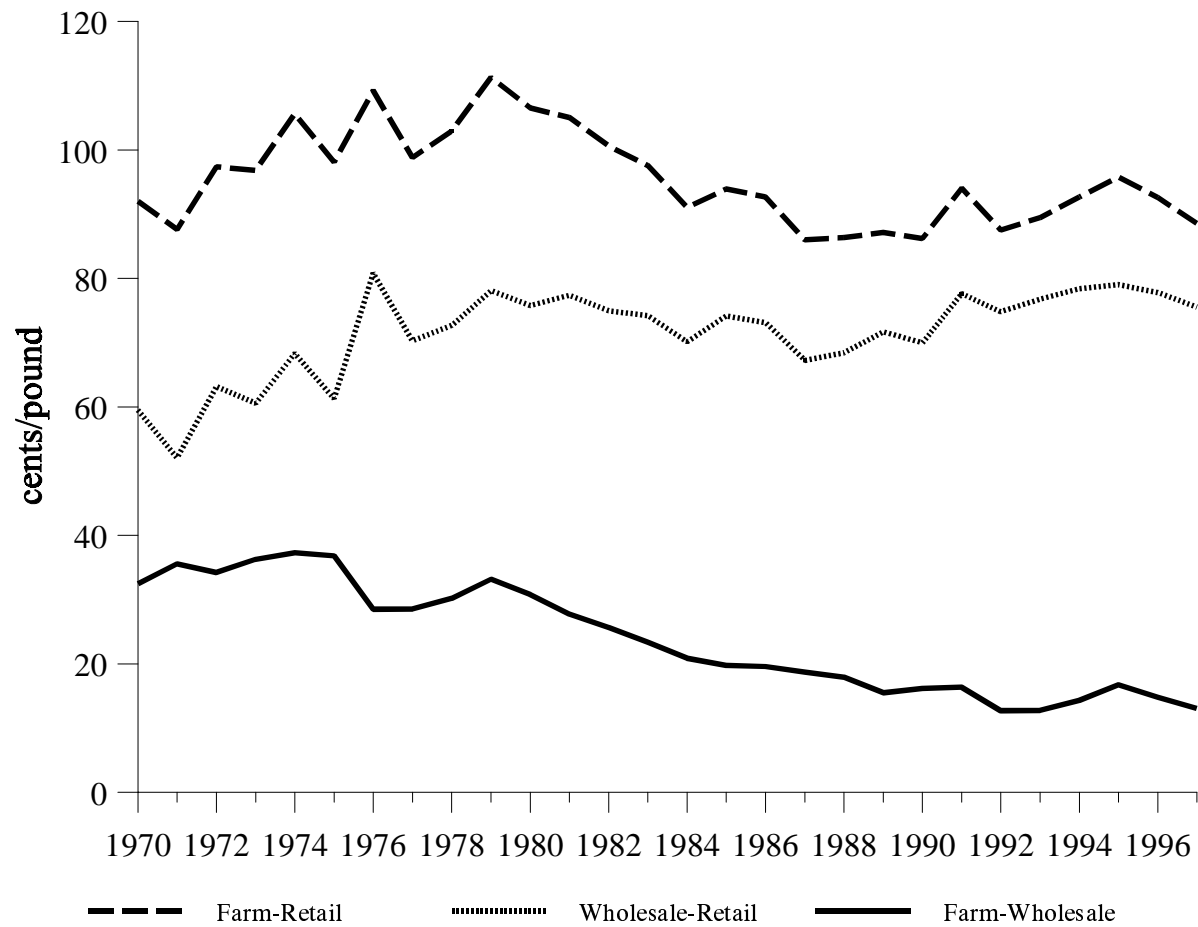
Figure 1. Real Beef Marketing Margins, 1970-1997.

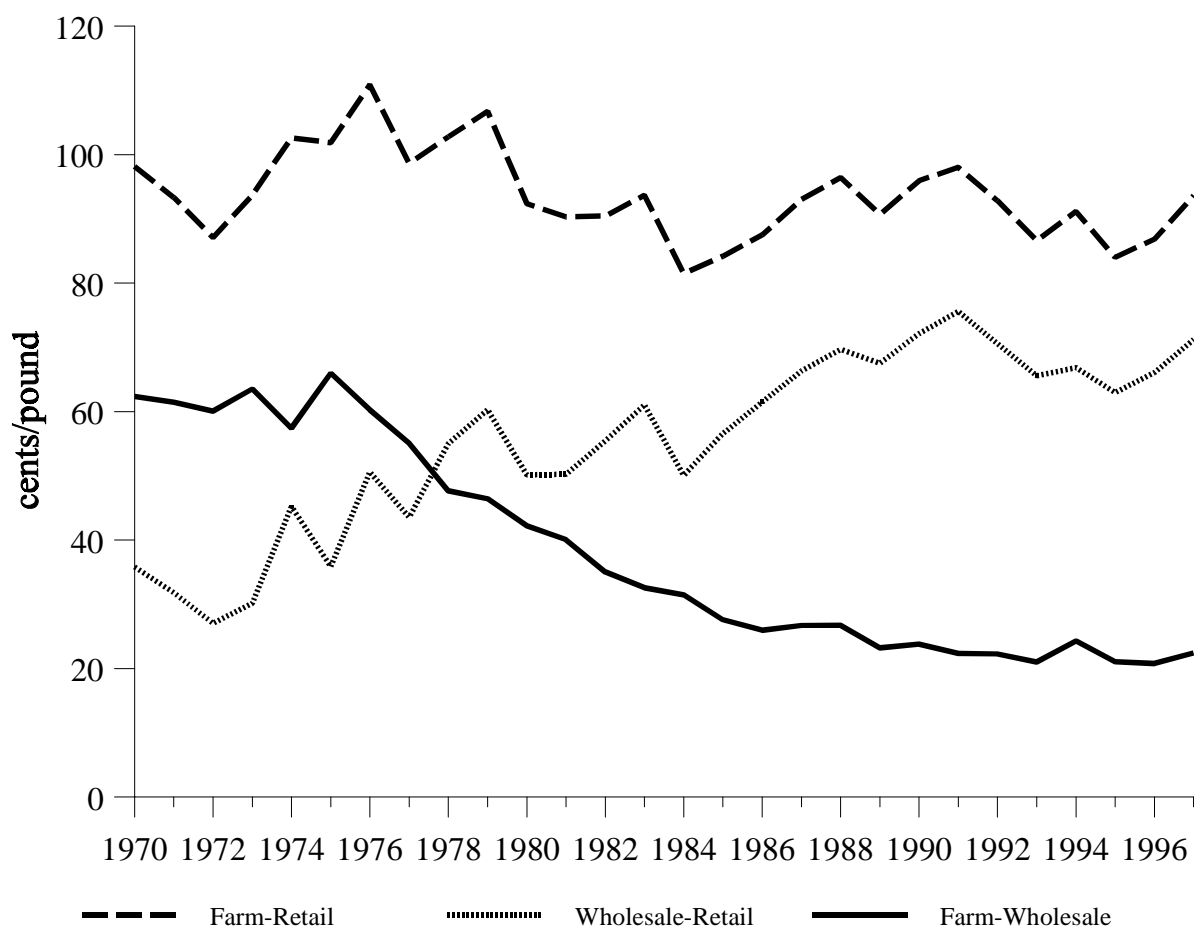
Figure 2. Real Pork Marketing Margins, 1970-1997.

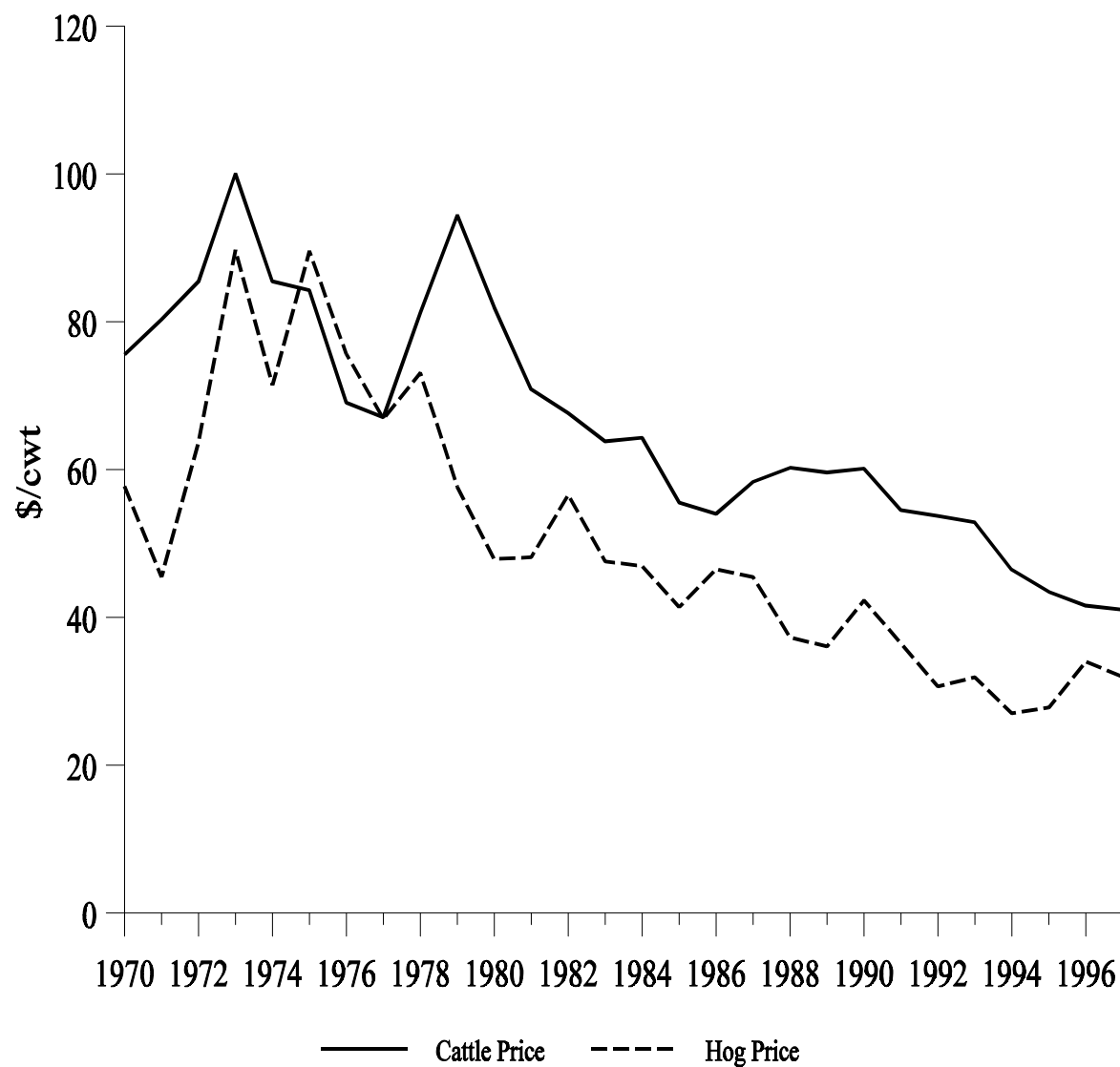
Figure 3. Real U.S. Slaughter Cattle and Hog Prices, 1970-1997.

Figure 4. Index of Output Per Employee Hour in Meat Packing and Four-Firm Beef Packer Concentration Ratio, 1970-1997.

