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May 10, 1999

Gerald E. Grinnell, Director
Economics/Statistical Support Packers and Stockyards Programs
1400 Independence Ave., S.W.
Washington, D.C. 20250-3647

Dear Gerald:

I have reviewed the material relative to the Texas fed beef cattle investigation and have attached an eleven page report that indicates my concerns about the investigation and areas where improvements in analyses could be made. Overall, I was impressed that you have taken the charge seriously, to attempt to come to some indication whether prices had been manipulated by beef packers during the time period in question. My main concerns relate to the specific modeling approaches taken by Azzam and Schroeter, whether it was possible with the models they used to actually determine if there was price manipulations; and second to the scope of the analysis, whether it was broad enough to address producers' concern.

With regard to the first concern, *my conclusion is that the analysis should focus on the relationship between cash price and volume marketed under different supply regimes of cattle sold on the cash market and not on the relationship between captive supplies and the cash price. Relative to the scope, I am particularly concerned that the time period for analysis needed to be longer to examine larger structural issues affecting fed beef industry, and that the analysis should have been extended to include the feedlot-producer price determination process.* Because this is the price actually received by many producers, an expanded analysis could show the factors affecting discounts and premiums. Also, I think it would be useful to disaggregate the analysis to examine the spatial configuration of prices, both within the Panhandle region, and between the Pandhandle region and other U.S. regions. I also express concern about some of the statistical methods used and whether they were able to uncover the relationships among the variables sought.

Please let me know if you need any additional information, clarification, etc., on my critique of the investigation. I can be reached at (919)-515-4673 or by e-mail at Michael_Wohlgenant@NCSU.EDU.

Sincerely,
Michael K. Wohlgenant

Michael K. Wohlgenant
William Neal Reynolds Professor

Rec'd 5/13/99

Comments on GIPSA's Texas Fed Cattle Investigation

by

Michael K. Wohlgenant

My comments will focus mainly on the statistical report by Azzam and Schroeter, "Captive Supplies and Spot Market Prices for Fed Cattle in the Texas Panhandle." I think the general approach taken to the problem was overall quite reasonable and that great care had been taken in defining the scope of the investigation and in collecting the data for the analysis. My main concerns relate to the specific modeling approach taken, whether it was possible with the reduced-form models to determine if there had been any price manipulation; and to the scope of the analysis, whether it was broad enough to address producers' concerns.

My first concern is that the modeling approach used to identify and determine the extent of market power is not robust enough to answer that question definitively. One of Schroeter and Azzam's main conclusions is that the negative relationship between captive supplies and spot market prices should not be taken as evidence of packers' intent to use captive supplies to depress cattle prices. I agree with this conclusion. While their explanation of why an essentially competitive market could produce such a correlation is fine, this phenomenon might be explained more intuitively using the concept of residual demand. That is, demand for cattle on the spot market can be viewed as total demand for cattle less the (fixed) supply of cattle obtained under non-cash price agreements (i.e., captive supplies). Thus, if the proportion of cattle obtained from non-cash sources increases, then derived demand for cattle on the spot market will be less at each price level and the whole demand schedule for cattle on the spot market will shift toward the origin. With an upward sloping supply curve for cattle on the spot market, the spot price will fall as the proportion of cattle obtained from non-cash markets increases. If the supply curve for cattle marketed on the spot market depends on prices of non-cash prices, supply could shift to the left as well so the relationship between captive supplies and cash price will be negative (positive) according as demand decreases more (less) than supply. Notice that in this discussion, there is no indication that any of the demanders tried to exploit producers by paying prices below their marginal value product. However, if they did, we could not distinguish that behavior from competitive behavior based simply on an observed negative relationship between captive supplies and cash price. In order to distinguish between competitive and monopsonistic behavior one would have to be able to identify and estimate the gap between the cash price and marginal value product of cattle on the spot market. Unfortunately, as shown for example by Muth and Wohlgenant (1999), "markdown" pricing of this type can be attributable to monopsony market power only if the supply curve of cattle shifts in a non-parallel manner. Statistically, this means one would have to estimate at a minimum two structural equations: one depicting the relationship between "perceived" marginal factor cost of the firm and marginal value product, and the other equation being the supply schedule of cattle.

To see why it is important to test for market power in the manner indicated above, consider the following two-equation model:

$$(1)\ \ P = \alpha + \beta Q + \gamma QZ + \delta V$$

$$(2)\ \ P = \lambda + \mu Q + \nu QZ$$

where the first equation represents the relationship between perceived marginal factor cost and marginal value product and the second equation represents the (inverse) supply function of cattle. The variables P and Q represent cash price and quantity marketed, respectively; V represents factors shifting demand for cattle on the cash market (including, among other things, proportion of supplies sold in non-cash outlets, prices of marketing inputs like wage rates, the prices of products sold by the packers, and variables representing specific characteristics of the lots purchased like expected grade yield); and Z represents factors shifting the supply function of cattle for cattle sold on the cash market. If these two equations were estimated by appropriate econometric methods, values for the various parameters could be estimated. An estimate of the degree of market power in this case could be obtained by dividing the negative value of the coefficient of QZ in the first equation by the coefficient of QZ in the second equation, i.e., $-\gamma/\mu$. If this ratio is zero, then pricing behavior is competitive; if the ratio is positive, then that would indicate that there was market power. The amount by which price is marked down due to market power could be estimated by dividing $-\gamma/\mu$ by the price elasticity of supply derived from the second equation.

The most significant thing to notice about equations (1) and (2) is that an interaction variable between the quantity of cattle marketed and a variable (variables) that shifts (shift) the supply curve *must* be included in the model in order to separate the effects of competitive behavior from anti-competitive behavior. Likely candidates for such variables would include prices received for non-cash sales and cost of feeding cattle. Such variables were not included in the analysis of Schroeter and Azzam (e.g., equation 1 p. 18) and not only lead to inconclusive evidence of anti-competitive behavior, but also to a potentially serious misspecification of the parameters of the price relationship estimated. In fact, because what is important in distinguishing the two price regimes is the relationship between the cash price and volume marketed under different supply regimes of the cattle sold on the cash market (and not on the relationship between captive supplies and the cash price), *we could say that the attention has focused on the wrong relationship*.

Azzam and Schroeter recognize that there are problems with examining the relationship between cash price and captive supplies and, therefore, proceed to look at the relationship between the delivered hot cost of each lot (really the portion of each lot unexplained by systematic factors affecting costs) and the weekly volumes of cattle deliveries under marketing agreements (equation 4 page 38). A negative relationship between the price residual and volume of cattle marketed using a specific marketing agreement would indicate price manipulation on the part of packers. Their results indicated no statistical significance of this result, suggesting little support for the claim that packers try to manipulate base prices through their pricing strategies in spot market purchases.

While their conclusions may be right, it is important to recognize that such regressions again cannot "prove" the absence of market power. This is because as, for example, Faminow and Benson (1990) point out, so-called "efficiently integrated markets" can be caused by collusive basing-point pricing. Because the USDA price is a function of spot prices offered by the same packers offering contracts, and if these firms have significant market share, there could be scope for collusion in price setting. Faminow and Benson (1990) offer a test for basing-point pricing, using an expanded version of the cointegration test developed by Ravillion (1986). Such a test involves regressing prices at different locations on prices at other locations at different time lags and then testing to see how correlated contemporaneous prices are.

Recently, Walburger and Foster (1998) have developed a general approach to studying price relationships across spatially segmented markets. Two things interesting about their efforts are first that they take into account interrelationships among different regions in an attempt to identify focal pricing regions, and second that they apply their modeling approach and find separate focal pricing regions for the U.S. fed cattle market. Their results indicate some evidence of a separate focal pricing area for Texas panhandle district, suggesting that prices in that region do move somewhat independently of prices in other regions. If true, this would indicate that a basing-point pricing scheme is in place. However, this conclusion seems quite tentative because when the sample period analyzed was changed, the Texas panhandle district no longer exhibited any dominant market characteristics. *Nevertheless, studies of this type suggest that the analysis of the Texas fed beef market might benefit from an examination of the relationship of spot prices paid by packers in the area of the study with prices paid by packers in other regions of the country, especially other areas of the plains.*

With regard to the scope of the analysis, I have some additional concerns. First, analyzing prices paid by packers assumes that any price manipulation occurs only at that level and not between the feedlot operator and cow-calf operator. I don't know what the structure of the feedlot operations are in the Texas panhandle, but larger feeders could be a source of market power. Even if it is reasonable to exclude the feeder/cow-calf nexus from the formal investigation, it still would seem useful to examine the transactions to be in a position to explain to individual producers why their prices were determined as they were. Perhaps this could be done with the information that has already been collected, but it seems to me it would be helpful to expand the analysis to include prices paid by feedlot operators.

I suspect it matters a lot where the complaints are coming from. If the complaints are coming primarily from producers on the "fringe," i.e., producers in regions outside Texas and the panhandle region, then perhaps it would be helpful to look more closely at that set of observations to see if there is evidence of price manipulation. At the very least, it would be helpful to have some explanation, whether discount because of quality considerations, or whatever so that concerns of these producers might be alleviated. One thing is clear when conducting such an analysis is that you must have an explanation for why prices differ in the way they do. Producers are simply not going to be satisfied if you say that you have done an investigation and conclude that you have found no evidence of price manipulation. I suspect that the reason producers are complaining has more to do with why their prices are low rather than whether prices are being manipulated. This suggests that, in conjunction with a specific investigation of whether packers are manipulating prices, you might want to have a more general study done on factors determining the evolution of prices of the markets analyzed. Among other things, that would suggest adding both time and spatial dimensions to the analysis to have a large enough data base to explore larger structural adjustment problems.

Along these lines, I am concerned that the omission of economies of scale considerations from both the empirical work and collection of data could have skewed the results. Many researchers (especially Azzam and Schroeter) have pointed out the importance of economies of scale in discerning the role played by market power in price determination. How that consideration is accounted for, or why it is ignored , in this study needs to be documented.

The description of the data used indicated somewhere on the order of 157,000 head were sold at prices below the daily low price reported by Market News. A question of interest here is what is the nature of those transactions? Did they mainly represent cattle coming from producers outside the panhandle region? If so, that might suggest these cattle are quite different than those coming from the panhandle region and, therefore, an opportunity for packers to exert some market power in purchasing those animals. This suggests that perhaps separate regressions of the type indicated by equation (4) on page 38 be redone for just the sub-sample of observations where prices were below the average market price.

It is commendable that Azzam and Schroeter recognized the potential problem of simultaneity between price and quantity in some of their models. However, because it is well known that the results can be quite sensitive to the set of instruments used in the analysis, it would seem prudent to consider how sensitive these results are to alternative sets of instruments.

I also have a few specific questions concerning some details of the study.

1. It would be helpful to have means, standard deviations, maximum, and minimum values reported on the different variables used in the empirical analysis. For example, in the regression results reported in table VI.1.1, what was the average price of live cattle?

2. In the regression results reported in tables VI.2.2, why was correction made for first-order autocorrelation in the residuals and was first-order correction sufficient? Correcting for serial correlation is important to get the right standard errors, but existence of serial correlation suggests that there may be some left out variables. In other words, serial correlation may be a reflection of misspecification of the model. Were any specification tests on the residuals performed like the RAMSEY test? How about calculation of recursive residuals and evaluation of CUSUM and CUSUMQ tests? Did you check for influential observations in the data sets used?
3. I am also concerned about heteroskedasticity, particularly for pooled data like table VI.1.1. Correcting for heteroskedasticity, if present, is important because it can bias the standard errors of the parameter values and thereby bias the statistical tests.
4. I had difficulty following the economic rationale for equation (2) on page 28. Specifically, why is there not a variable representing the inventory of cattle in this specification? Standard inventory theory, based on Brennan's supply of storage model for example, would suggest holding stocks to the point where marginal returns (the difference between expected marginal revenue and current marginal revenue) equals the marginal cost of storage (which is a function of beginning inventories plus additions to inventories less withdrawals from inventories during that period). This relationship between marginal returns and marginal cost suggests that expected marketings are a function of the supply in period t (beginning inventory plus additions to stock) and expected marginal revenue from sales in the future period less the current period. While marginal revenue in each period depends upon price in that period, this specification suggests that market power can cause there to be a deviation

from competitive or price taking behavior. So not only is it not clear why there is not some inventory variable in this model, but why the current period price and expected future price are included instead of expressions for marginal revenue and expected marginal revenue.

5. I also have some problems with the lack of theoretical justification for the price forecasting equation (3) , p.28. An alternative approach to using this model to forecast expected price would be to use the methods of moments estimation procedure, which permits consistent estimation of expected price—see, e.g., Goodwin, Grennes, and Wohlgenant (1990) for a discussion of this method.
6. A question, based in part on the regression results in table VIII.1. which indicate a nonlinear relationship between price and weight, is whether Azzam and Schroeter have investigated other functional relationships other than the simple linear relationship indicated by equation (4)? For example, if the true relationship is better approximated by including the square of M on the right-hand side of equation (4), then the test results in table VIII.2 may be biased and show no significance when in fact there is a significant relationship.
7. Was equation (4) also estimated by 2SLS like some of the other relationships, and if so, how did those results differ? Simultaneity between prices and marketings is clearly a concern and not accounting for it could bias the t-tests as well as the parameter estimates.
8. In the regressions using equation (4), I am concerned about the properties of the error structure given that this is really the second-stage of a two-step estimation method. Azzam and Schroeter indicate in footnote 35, p. 37, that the residuals from which the

dependent variable are constructed are really based upon weighted residuals rather than average residuals. How does that weighting procedure influence the standard errors of the parameter estimate on the marketing variable in equation (4) and has that been taken into account when calculating the consistent standard error used to construct the t-value for the beta coefficient?

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MEMORANDUM

TO: Gerald Grinnell

This is a copy of Muth and Wohlgenant paper cited in review on p. 2. See especially pp. 4-6 in regard to discussion on p. 2 of review.

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Date 5/11/99 Signed Mike Wohlgenant

MEASURING THE DEGREE OF OLIGOPSONY POWER IN THE BEEF PACKING INDUSTRY IN THE ABSENCE OF MARKETING INPUT QUANTITY DATA

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April 1999

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The authors wish to acknowledge the insightful comments of Brian Murray on an earlier draft and the editing expertise of Sharon Barrell.

MEASURING THE DEGREE OF OLIGOPSONY POWER IN THE BEEF PACKING INDUSTRY IN THE ABSENCE OF MARKETING INPUT QUANTITY DATA

ABSTRACT

We develop a model to measure the degree of oligopsony power in the beef packing industry, while accommodating variable proportions technology, that can be estimated with fewer data requirements. In particular, nonspecialized input quantities, which are often not available, are not needed. Through application of the envelope theorem, we show that the relationship between value marginal product and marginal factor cost can be defined over the prices of the nonspecialized inputs rather than their corresponding quantities. When applied to the beef packing industry, we find no evidence of oligopsony power over the sample period.

Key Phrases: beef industry
envelope theorem
oligopsony power
variable proportions

MEASURING THE DEGREE OF OLIGOPSONY POWER IN THE BEEF PACKING INDUSTRY IN THE ABSENCE OF MARKETING INPUT QUANTITY DATA

I. INTRODUCTION

Since Appelbaum first developed an econometric method to measure the degree of oligopoly power in imperfectly competitive markets, models under alternative assumptions have been developed and estimated. Schroeter demonstrated how this model could be extended to measure the degree of oligopoly and oligopsony power. However, Schroeter's model assumed fixed proportions technology, an assumption that one may wish to relax in some applications. In particular, there is evidence that the food processing industries are characterized by substantial input substitutability (Wohlgenant; Goodwin and Brester); thus the assumption of variable proportions is more appropriate. In this case, if the price of a specialized input increases, firms may maintain output while reducing their purchases of the input by substituting the nonspecialized inputs in its place.

More recently, Murray developed a model to measure the degree of oligopsony power in the pulpwood and sawlogs markets while allowing for variable proportions technology. Application of this method requires data on the quantities of nonspecialized inputs (e.g., labor and materials); however, in many cases, these data are not available at an individual product level. In this paper, we develop a model to measure the degree of oligopsony power, while accommodating variable proportions technology, that can be applied to markets in which data on nonspecialized input quantities are not available. Through application of the envelope theorem, we show that the relationship between value marginal product and marginal factor cost can be defined over the prices of the nonspecialized inputs rather than their corresponding quantities.

The model is applied to the beef packing industry, an industry that has generated much interest of late as measures of market concentration reach high levels.[1] Recently, concern has focused on market power on the input side due to the spatial characteristics of the market. Because live cattle can be transported a limited distance to slaughter, cattle producers in a particular location may face few buyers for their cattle. The results of most previous structural models of the beef packing industry have concluded that beef packing firms, at least part of the time, are exercising market power in the purchase of finished cattle for slaughter (Schroeter; Schroeter and Azzam; Azzam; Azzam and Park; Koontz, Garcia, and Hudson). These results are in contrast to the Packers and Stockyards Administration report issued in 1996 that found little evidence of market power in beef packing. In fact, they found that larger beef packing firms paid higher prices for cattle after adjusting for differences in cattle quality (Texas Agricultural Marketing Research Center).

This contradiction in results may be due, in part, to inappropriate restrictions on the structural models. Specifically, all of the studies listed above assume a fixed proportional relationship between live cattle inputs and processed beef output. However, Wohlgenant found evidence of substantial substitution possibilities between farm inputs and marketing inputs for beef and veal. In addition, Goodwin and Brester concluded that technological changes in the food industry as a whole have allowed for greater input substitutability. Other restrictions found in these models include the use of prior point estimates or estimated series of the input supply elasticities (Schroeter and Azzam; Azzam and Park), yet it is likely that these input supply elasticities have changed over time. Also, the standard errors of the estimated coefficients in these studies have not been adjusted for the use of prior estimates, thus overstating the level of significance of the market power components.

The model we develop in this paper allows variable proportions technology, yet does not require marketing input quantity data. Quantity data are available for some of the nonspecialized production inputs for the meat packing industry as a whole. However, they are not available for individual animal species such as beef. When we apply this model to the beef packing industry, we find no evidence of oligopsony power over the sample period. These results confirm those of the model in Muth and Wohlgenat (1999) which tests for market power in either the input or output market but does not measure the degree of market power. This model may be applied in similar situations where imperfect competition in the input market is of concern, but where data limitations on input quantities might preclude one from using a more general specification of oligopsony behavior.

II. A THEORETICAL MODEL OF AN IMPERFECTLY COMPETITIVE INPUT MARKET

Assume that the inverse input supply equation for a specialized input can be represented by

(1) $$w_I = g(x_I, \mathbf{z})$$

where w_I is the deflated input price, x_I is the input quantity, and $\mathbf{z}$ is a vector of supply shifters. Given this representation of input supply, the profit equation for a representative firm can be written as

(2) $$\Pi = p \cdot f(x_I, \mathbf{x}) - w_I x_I - \mathbf{w} \cdot \mathbf{x}$$

where p is the deflated output price (at the wholesale level), $f(\cdot)$ is the production function, $\mathbf{x}$ is a vector of quantities of other inputs in the production process (e.g., labor and energy), and $\mathbf{w}$ is a vector of deflated prices of other inputs.

If the market for the specialized input is perfectly competitive, then the first-order condition with respect to the level of the input is such that the input price equals its value marginal product. That is,

(3) $$w_I = p \cdot \frac{\partial f(x_I, \mathbf{x})}{\partial x_I}.$$

A more general form of the first-order condition that allows for imperfect competition is

(4) $$w_I + \theta \cdot \frac{\partial g(x_I, \mathbf{z})}{\partial x_I} \cdot x_I = p \cdot \frac{\partial f(x_I, \mathbf{x})}{\partial x_I}$$

where θ is a parameter that indexes the degree of market power. If the market is perfectly competitive, then $\theta = 0$, and the first-order condition reduces to equation (3) above. If the market is monopsonistic, then $\theta = 1$, and equation (4) represents marginal factor cost (the input price plus a monopsony markdown) equaling value marginal product. Intermediate values of θ are taken to mean some degree of less than complete market power, in which case, the interpretation of this first-order condition is that the "perceived" marginal factor cost equals the value marginal product of finished cattle.

The interpretation of θ in equation (4) from the viewpoint of an individual firm depends on the assumptions made about aggregation. If it is assumed that the aggregate marginal product term is obtained by averaging over all firms' marginal products, then θ is interpreted as the average input conjectural elasticity of firms in the industry. Alternatively, if it is assumed that the aggregate marginal product term is a share-weighted average, θ takes on the interpretation of an input market Herfindahl index. Each of these interpretations is derived in the appendix.

III. AN EMPIRICAL MODEL WITH FEWER DATA REQUIREMENTS

The joint estimation of empirical specifications of equations (1) and (4) allows us to measure the degree of oligopsony power in a particular market. As specified, however, data on the quantities of nonspecialized inputs (i.e., inputs other than x_1) are necessary to estimate the degree of oligopsony power because they are components of the marginal product. Such data were available for Murray's analysis of the pulpwood and sawlogs markets; however, they are not available for other markets that are of interest. In this section, we derive a model that does not require data for these input quantities. In addition, since identifying the degree of oligopsony power requires specifying an input supply equation, we discuss the empirical specification of the input supply equation for our particular application to the beef packing industry.

First, note that the marginal product term, $\partial f(x_1, \mathbf{x}) / \partial x_1$, requires the quantities of nonspecialized inputs used in the production process. The need for these nonspecialized input quantities can be circumvented by applying the envelope theorem to a redefined profit equation.

Thus, we rewrite the profit equation for beef packing firms, substituting in the optimal quantities of the noncattle inputs conditional on the level of cattle input, x_1, in place of the previously specified unconditional quantities. Assuming that there are two nonspecialized inputs in the production process, labor and energy, equation (2) can be rewritten as

$$\Pi(p, x_1, \mathbf{z}, w_2, w_3) = p \bullet f(x_1, x_2^*, x_3^*) - g(x_1, \mathbf{z})x_1 - w_2 x_2^* - w_3 x_3^* \qquad (5)$$

where x_2^* and x_3^* are the optimal quantities of x_2 and x_3 conditional on the level of the specialized input, x_1.[2] Specifically, $x_2^* = x_2(x_1, p, w_2, w_3)$ and $x_3^* = x_3(x_1, p, w_2, w_3)$.

Now, the first-order condition with respect to the choice of x_1 is

$$\frac{\partial \Pi}{\partial x_1} = p \bullet \frac{\partial f(x_1, x_2^*, x_3^*)}{\partial x_1} + p \bullet \frac{\partial f(\bullet)}{\partial x_2^*} \bullet \frac{\partial x_2^*}{\partial x_1} + p \bullet \frac{\partial f(\bullet)}{\partial x_3^*} \bullet \frac{\partial x_3^*}{\partial x_1} - \theta \bullet \frac{\partial g(x_1, \mathbf{z})}{\partial x_1} \bullet x_1 - w_1 - w_2 \bullet \frac{\partial x_2^*}{\partial x_1} - w_3 \frac{\partial x_3^*}{\partial x_1} = 0 \qquad (6)$$

which can be arranged as

$$w_1 + \theta \bullet \frac{\partial g(x_1, \mathbf{z})}{\partial x_1} \bullet x_1 = p \bullet \frac{\partial f(\bullet)}{\partial x_1} + \left(p \bullet \frac{\partial f(\bullet)}{\partial x_2^*} - w_2\right) \frac{\partial x_2^*}{\partial x_1} + \left(p \bullet \frac{\partial f(\bullet)}{\partial x_3^*} - w_3\right) \frac{\partial x_3^*}{\partial x_1} \qquad (7)$$

Assuming that the nonspecialized inputs are purchased in perfectly competitive markets, equation (7) reduces to

$$w_1 = -\theta \bullet \frac{\partial g(x_1, \mathbf{z})}{\partial x_1} \bullet x_1 + p \bullet \frac{\partial f[x_1, x_2(x_1, w_2, w_3, p), x_3(x_1, w_2, w_3, p)]}{\partial x_1}. \qquad (8)$$

That is, the first-order condition for profit maximization can be derived by simply differentiating equation (5) with respect to x_1, holding x_2 and x_3 at their optimally determined levels (an application of the envelope theorem). Note that now the marginal product is defined over the prices of the nonspecialized inputs rather than the corresponding quantities.

In an output market counterpart to our model, Lau establishes that only the reduced form parameters of the marginal cost function are necessary for identifying oligopoly power.

Applying the same logic to the input market model, the degree of oligopsony power can be identified with a reduced form value marginal product specification. Inserting a linear reduced form value marginal product and solving for w_1 results in the following expression:

$$w_1 = -\theta \cdot \frac{\partial g(\cdot)}{\partial x_1} \cdot x_1 + \alpha_1 x_1 + \alpha_2 w_2 + \alpha_3 w_3 + \alpha_4 p. \qquad (9)$$

To complete the model, the input supply equation must be specified. The supply specification we employ is intended to characterize the short-run supply response of cattle producers whereby the supply of finished cattle is expressed as a function of the price of cattle (w_1), beginning of the year inventories of finished cattle (I), and the price of feed corn (C) (Rosen; Brester and Wohlgenant; and Marsh). Based on a preliminary plotting of the data, this short-run supply relationship is specified in terms of the slaughter-inventory ratio as a linear function of the beef-corn price ratio as follows:

$$\frac{x_1}{I} = \delta_0 + \delta_1 \cdot \frac{w_1}{C} + \delta_2 \cdot \frac{w_1}{C} \cdot T + \delta_3 \cdot T \qquad (10)$$

where T is a linear time trend to account for technical change and other unaccounted for factors affecting short-run supply response of beef. As indicated below, one advantage of this specification is that it allows for identification of the degree of market power.[3]

To complete the specification, $\partial g(\cdot) / \partial x_1$ is derived from the empirical specification of the input supply equation above. Solving equation (10) for w_1 and differentiating with respect to x_1 yields the following expression for the marginal effect of the input level on cattle prices:

$$\frac{\partial g(\cdot)}{\partial x_1} = \frac{C}{I}\left(\frac{1}{\delta_1 + \delta_2 T}\right). \qquad (11)$$

Note that equation (10) allows for identification of θ because the slope of the supply function, given by equation (11), is a function of C / I and T.[4] Substituting this expression into equation (9) yields the final empirical specification of the first-order condition, or the demand relation:

$$w_1 = -\left(\frac{\theta}{\delta_1 + \delta_2 T}\right) \cdot \frac{C}{I} \cdot x_1 + \alpha_1 x_1 + \alpha_2 w_2 + \alpha_3 w_3 + \alpha_4 p. \qquad (12)$$

Equations (10) and (12) make up the system of equations that will allow for determination of whether beef packing firms have been exercising market power in their purchases of finished cattle. Estimates of the model are obtained assuming both that θ remained constant over the sample period and, because the structure of the industry has changed over time, θ varied as a function of trend (i.e., $\theta = \theta_0 + \theta_1 T$).[5]

We also investigate whether the results regarding oligopsony power are sensitive to the choice of functional form for the reduced form expression of the marginal product function in equation (8). Two alternative functional forms are considered: a log-linear form and a functional form in which the variables are replaced by their square roots. In a general sense, these functional forms may be viewed as first-order approximations of the unknown functional form. In the first case, the derivative may be viewed as the first-order partial derivative of a translog function and in the second case, the first-order partial derivative of the generalized Leontief.[6]

Assuming the log derivative of f(•) with respect to x_1 in equation (8) is linear in the logarithms, the marginal product of x_1 can be written as

$$(13) \qquad \frac{\partial f(\cdot)}{\partial x_1} = \frac{q}{x_1}\left(\alpha_1 + \gamma_{11}\ln x_1 + \gamma_{12}\ln w_2 + \gamma_{13}\ln w_3 + \gamma_{1p}\ln p\right).$$

Substituting this expression into the first-order condition, equation (8), and multiplying through by $x_1 / p \cdot q$ results in the following demand relation:

$$(14) \qquad s_1 = \frac{w_1 x_1}{p \cdot q} = -\theta \cdot \frac{\partial g(x_1, \mathbf{z})}{\partial x_1}\frac{x_1^2}{p \cdot q} + \alpha_1 + \gamma_{11}\ln x_1 + \gamma_{12}\ln w_2 + \gamma_{13}\ln w_3 + \gamma_{1p}\ln p$$

where s_1 is the cost share of input x_1 in the production of beef and $q = f(\cdot)$. This second form of the demand relation is then estimated jointly with the input supply equation.

In the third functional form considered, the reduced form marginal product in equation (8) is approximated by:

$$(15) \qquad \frac{\partial f(\cdot)}{\partial x_1} = \beta_{10} + \beta_{11}x_1^{1/2} + \beta_{12}w_2^{1/2} + \beta_{13}w_3^{1/2} + \beta_{1p}p^{1/2}.$$

By substituting this expression for marginal product into the first-order condition, equation (8), and dividing through by p, the following third specification of the demand relation is obtained:

$$(16) \qquad r_1 = \frac{w_1}{p} = -\theta \cdot \frac{\partial g(x_1, \mathbf{z})}{\partial x_1} \cdot \frac{x_1}{p} + \beta_{10} + \beta_{11} x_1^{1/2} + \beta_{12} w_2^{1/2} + \beta_{13} w_3^{1/2} + \beta_{1p} p^{1/2}.$$

where r_1 is the ratio of the price of cattle to the wholesale price of beef. Again, this equation was estimated jointly with the input supply equation. In both of these alternative specifications, the market power parameter, θ, was estimated both as a constant and a linear time trend.

IV. DATA DESCRIPTION

The data used to estimate the preceding model are aggregate annual time-series data for the years 1967 through 1993. Farm beef quantities and inventories of beef cattle were obtained from the USDA's *Red Meats Yearbook* and *Livestock and Meat Statistics*. The farm price for cattle is the series "slaughter steer prices, choice grade 2-4, Omaha, 1000-1100 pounds" in both of the publications. These prices were adjusted for by-product allowances, which were obtained, along with wholesale beef prices, from USDA's Animal Products Branch of the Economic Research Service. Corn prices were obtained from USDA's *Feed Situation and Outlook*, the energy price index was obtained from USDA's *Food Cost Review*, and the average hourly meat packing wage was obtained from the Bureau of Labor Statistics' *Employment, Hours, and Earnings, United States, 1909-1994*. Per capita consumption expenditures and population data, which were used as instrumental variables for the endogenously determined wholesale beef price, and the consumer price index were obtained from the *Economic Report of the President*. The additional instrumental variables, the retail poultry CPI and the retail pork CPI were obtained from the USDA's *Food Consumption, Prices, and Expenditures*. All price and income data were deflated using the consumer price index.

IV. ESTIMATION RESULTS AND SPECIFICATION TESTING

The input supply equation and the perceived demand equation were estimated jointly with additive error terms using nonlinear three-stage least squares. Three alternative specifications of the market power component were considered: one in which θ was estimated as a constant parameter, one in which θ was specified as a linear function of time, and one in which θ was restricted to zero. In this last case, the perceived demand equation represents the competitive condition that the input price is equal to its value marginal product. The price of finished cattle, w_1, the quantity of finished cattle, x_1, the price of processed beef, p, and the ratio x_1 / I are endogenous. The instrument set included the exogenous variables in the model in addition to variables that influence the final demand for beef and thus the price of processed beef, namely, population, consumer expenditures, the retail price of pork, and the retail price of poultry.

Initially, equations (10) and (12) were overfitted with first-order autoregressive terms. In both equations in each specification, the estimated autoregressive parameter was close to one, thus indicating the presence of a unit root error process. Therefore, both equations were reestimated in first differences and the resulting error process was stationary. Visual inspection of the autocorrelation and partial autocorrelation plots of the residuals revealed no remaining evidence of autocorrelation. All of the estimated autocorrelations and partial autocorrelations were within two standard errors of zero for 12 lags. Ljung and Box statistics calculated at six and 12 lags failed to reject the null hypothesis that the residual series are white noise at the 5% level. Therefore, no further corrections for autocorrelation were made.

Regardless of the model specification, estimates of the market power component, θ, were close to zero and insignificant. The results are summarized in Table 1. For the specifications in which θ varied over time, its values were calculated at the first and last observations of the sample. Overall, estimates of θ range from -0.00067 to 0.00135.[7] For each estimate, 95% confidence intervals, which appear in Table 1 as well, contained the value zero. Furthermore, for the linear value marginal product specification, each of the models containing the market power component was tested against the perfect competition model using Gallant and Jorgenson's method of testing nonlinear restrictions. In each case, the restriction that θ is zero could not be rejected at the 5% level. Hence, it appears from these data that beef packers were not exercising market power in the purchase of finished cattle over the 1967 to 1993 time period. These results are opposite those noted earlier in which fixed proportions was assumed and have implications for the market conduct investigation activities of the U.S. Grain Inspection, Packers and Stockyards Administration.

The complete results for the reduced form value marginal product specification are presented in Table 2. For the most part, the results of estimation appear reasonable. The relationship between the ratio of prices, w_1 / C, and the marketing ratio, x_1 / I, is positive. The slopes, given by the inverse of equation (18), and standard errors of the input supply equation were calculated conditional on the sample means for each model specification. The corresponding elasticities, which ranged from 0.017 to 0.042 depending on the model specification indicate nearly fixed cattle supply, as does the estimate of 0.14 obtained by Ospina and Shumway over an earlier time period (1956 to 1979).

The remaining results of the perceived demand equation are dominated by the effect of output prices, p, on input prices, w_1. As expected, an increase in output prices for processed beef has a strongly positive effect on the price of finished cattle. For the most part, the deflated noncattle input prices, labor (w_2) and energy (w_3), each have negative effects on the input price for cattle. This result occurs because noncattle input prices cause two opposing effects on input demand for cattle. An increase in the price of an input causes a substitution away from the input and towards an increase in demand for cattle. However, the increase in the price of the input may also cause a decrease in production and thus a decrease in demand for cattle. The negative coefficient estimates for the price of labor and the price of energy indicate that the latter effect dominates. Finally, the relationship between the finished cattle quantity, x_1, and finished cattle prices, w_1, is not significantly different from zero. This result most likely occurs because the technology approximates constant returns to scale; hence the effect of output prices on input prices dominates.

The results of the two alternative specifications of the value marginal product terms are similar to the reduced form specification. The results of the specification derived from the translog conditional production function are presented in Table 3. As mentioned previously, the estimates of θ are near zero and insignificant. The input supply elasticities are again small, ranging from 0.004 to 0.039, again indicating nearly fixed cattle supply. Most of the coefficients on the value marginal product term have expected signs. However, with this specification, the effect of output prices on the input share is positive but less dominant than the effect of output prices on input prices in the previous specification. Noncattle input prices again have negative effects. Finally, the effect of the input quantity on the input share is positive indicating that the input demand relation (holding output price constant) is elastic.

The results of the final specification using the generalized Leontief conditional production function are presented in Table 4. Again, the estimates of θ are near zero and insignificant. Input supply elasticities ranged from 0.02 to 0.05, and all other results are similar to the reduced form value marginal product specification.

V. CONCLUSIONS

Most models that allow for the estimation of the degree of oligopsony power assume fixed proportions technology. For some applications, the assumption of variable proportions technology is more appropriate. However, relaxing the assumption of fixed proportions increases the data requirements of the model. In particular, data on the quantities of nonspecialized input quantities that are needed are frequently not available.

We develop a general model that allows one to estimate the degree of oligopsony power without these data yet still allows for variable proportions technology. When applied to the beef packing industry, we find no evidence of oligopsony power over the sample period. This general framework has applications beyond those presented here. For example, it may be appropriate if one is interested in regional measures of oligopsony power and data are available for regional prices, but the only regional quantities that are available are those of the output and the specialized input.

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FOOTNOTES

1. For 1994, the Packers and Stockyards Administration reported a four-firm concentration ratio (CR4) of 80.9 and a Herfindahl index of 2096 (USDA).

2. Capital costs are not included because they are generally a small share of food processing costs (Morrison).

3. One potential problem with a short-run supply model for cattle is that it can produce a negative supply response. As discussed by Rosen, the reason is that, in the short run, higher cattle prices can induce farmers to delay the slaughter age of cattle to increase the weight at which they are sold. In addition, if cattle prices are rising and farmers expect higher prices to prevail in the future, then they will retain heifers to add to the breeding stock rather than marketing them immediately. The reason a negative supply response is problematic when estimating the degree of market power is that it switches the sign of the markdown term to that of a markup term instead. For our particular data set, this situation does not seem to be of concern because graphical analysis strongly suggests a positive supply response in the short run.

4. Bresnahan demonstrated graphically the requirement for identifying oligopoly power: the slope of the demand curve for the product must be changing over time. The input market analog to Bresnahan's analysis is demonstrated in Muth and Wohlgenant and is similar conceptually to Just and Chern except that Just and Chern assumed monopoly in the output market for the product in question (processing tomatoes) and analyzed the effect of a one time change in input supply. In either case, changes in the slope of the input supply equation allow for the identification of market power. The implication for the model presented here is that the input supply equation must be modeled in such a way that its slope, $\partial g(x_1, \mathbf{z}) / \partial x_1$, varies over time.

5. Another possibility is to specify θ as a function of the Herfindahl index, but the series is only available beginning in 1980. The CR4, which could be used as a proxy, is highly correlated with time and hence yields results similar to a time trend.

6. As a referee pointed out, it is important to recognize that $\partial f(\bullet)/\partial x_1$ in equation (8), when expressed in terms of x_1, w_2, w_3, and p, is a reduced form expression for the marginal product of x_1. Therefore, it cannot be derived directly by partially differentiating a function in which x_1, w_2, w_3, and p appear as arguments. However, it is valid to consider this reduced form marginal product function as a function in its own right, and therefore to utilize a flexible functional form as an approximating function to the true, unknown functional form. The functional forms chosen for this application cover a wide range of flexible forms and satisfy the requirement for identification set forth by Lau.

7. Although the negative values of θ are not theoretically possible, they arise in this situation from sample variation.

Table 1.—Summary of Values and 95% Confidence Intervals for the Market Power Coefficient

	Value	95% Confidence Interval
1. Reduced Form Value Marginal Product Specification		
a. Constant θ	0.00001	[-0.00005, 0.00007]
b. $\theta = \theta_0 + \theta_1 T$		
T=1	0.00115	[-0.00460, 0.00690]
T=27	-0.00067	[-0.01145, 0.01011]
2. Translog Conditional Production Function Specification		
a. Constant θ	0.00008	[-0.00139, 0.00155]
b. $\theta = \theta_0 + \theta_1 T$		
T=1	0.00135	[-0.00375, 0.00645]
T=27	-0.00016	[-0.00108, 0.00076]
3. Generalized Leontief Conditional Production Function Specification		
a. Constant θ	-0.00015	[-0.00090, 0.00059]
b. $\theta = \theta_0 + \theta_1 T$		
T=1	-0.00037	[-0.00036, 0.00001]
T=27	0.00006	[-0.00008, 0.00020]

Table 2.—Results of Nonlinear 3SLS Estimation of Cattle Input Supply and Perceived Demand Equations, 1967-1993 (Reduced Form VMP Specification)

Variable (Coefficient)	Market Power Models: Constant θ	Market Power Models: $\theta = \theta_0 + \theta_1 T$	Competition Model
Input Supply Equation (Dependent Variable: x_1 / I)			
$\frac{w_1}{C}$ (δ_1)	0.00307	0.000484	0.00303
	(0.00227)	(0.00122)	(0.00234)
$\frac{w_1}{C} \cdot T$ (δ_2)	-0.00016	-0.00001	-0.00016
	(0.00012)	(0.00003)	(0.00012)
T (δ_3)	0.00602	0.00279	0.00608
	(0.00396)	(0.00303)	(0.00408)
Perceived Demand Equation (Dependent Variable: w_1)			
Constant (θ_0)	0.00001	0.00122	—
	(0.00003)	(0.00312)	
T (θ_1)	—	-0.00007	—
		(0.00017)	
x_1 (α_1)	-0.00010	-0.00013	-0.00010
	(0.00016)	(0.00016)	(0.57394)
w_2 (α_2)	-0.23722	0.13139	-0.25077
	(0.61500)	(0.62566)	(0.00015)
w_3 (α_3)	-0.00601	-0.00573	-0.00616
	(0.00402)	(0.00410)	(0.00375)
p (α_4)	0.54608	0.54842	0.54642
	(0.02460)	(0.02434)	(0.02323)
Objective Value	1.5836	1.5283	1.6150

Notes: (1) Numbers in parentheses are standard errors.
(2) Both equations are estimated in first differences.
(3) Endogenous variables are w_1, x_1, p, and x_1 / I.

Table 3. Results of Nonlinear 3SLS Estimation of Cattle Input Supply and Perceived Demand Equations, 1967-1993 (Log-Linear Marginal Product Specification)

Variable (Coefficient)	Market Power Models: Constant θ	Market Power Models: $\theta = \theta_0 + \theta_1 T$	Competition Model
Input Supply Equation (Dependent Variable: x_1 / I)			
$\frac{w_1}{C}$ (δ_1)	0.00007	0.00084	0.00298
	(0.00061)	(0.00149)	(0.00233)
$\frac{w_1}{C} \cdot T$ (δ_2)	0.00000	-0.00002	-0.00016
	(0.00001)	(0.00004)	(0.00012)
T (δ_3)	0.00261	0.00352	0.00612
	(0.00306)	(0.00305)	(0.00406)
Perceived Demand Equation (Dependent Variable: *SHARE*)			
Constant (θ_0)	0.00008	0.00140	—
	(0.00075)	(0.00271)	
T (θ_1)	—	-0.00006	—
		(0.00011)	
$\ln x_1$ (γ_{11})	0.15319	0.15010	0.13862
	(0.08632)	(0.07915)	(0.07990)
$\ln w_2$ (γ_{12})	-0.13211	-0.07766	-0.12167
	(0.07684)	(0.08211)	(0.07396)
$\ln w_3$ (γ_{13})	-0.01368	-0.00350	-0.02659
	(0.02768)	(0.02679)	(0.02605)
$\ln p$ (γ_{1p})	0.10038	0.10790	0.10257
	(0.04141)	(0.03925)	(0.04064)
Objective Value	1.6739	1.6252	1.6752

Notes: (1) Numbers in parentheses are standard errors.
(2) Both equations are estimated in first differences.
(3) Endogenous variables are $w_1, x_1, p, x_1 / I$, and $SHARE = w_1 x_1 / pq$.

Table 4. Results of Nonlinear 3SLS Estimation of Cattle Input Supply and Perceived Demand Equations, 1967-1993 (Square-Root Marginal Product Specification)

Variable (Coefficient)	Market Power Models: Constant θ	Market Power Models: $\theta = \theta_0 + \theta_1 T$	Competition Model
Input Supply Equation (Dependent Variable: x_1 / I)			
$\frac{w_1}{\tau}$ (δ_1)	0.00075 (0.00156)	0.00238 (0.00219)	0.00310 (0.00234)
$\frac{w_1}{\tau} \cdot T$ (δ_2)	-0.00002 (0.00005)	-0.00010 (0.00010)	-0.00016 (0.00012)
T (δ_3)	0.00260 (0.00308)	0.00480 (0.00358)	0.00613 (0.00408)
Perceived Demand Equation (Dependent Variable: w_1 / P))			
Constant (θ_0)	-0.00015 (0.00038)	-0.00037 (0.00038)	—
T (θ_1)	—	0.00002 (0.00002)	—
$x_1^{1/2}$ (β_{11})	-0.00022 (0.00046)	-0.00044 (0.00040)	-0.00010 (0.00044)
$w_2^{1/2}$ (β_{12})	-0.01234 (0.02885)	-0.00032 (0.02759)	-0.02319 (0.02607)
$w_3^{1/2}$ (β_{13})	-0.00211 (0.00131)	-0.00462 (0.00145)	-0.00233 (0.00126)
$p^{1/2}$ (β_{1p})	0.00513 (0.00399)	0.00152 (0.00367)	0.00421 (0.00389)
Objective Value	1.6526	1.5618	1.6789

Notes: (1) Numbers in parentheses are standard errors.
(2) Both equations are estimated in first differences.
(3) Endogenous variables are $w_1, x_1, p, x_1 / I$, and w_1 / p.

APPENDIX

In this appendix, we demonstrate the derivation of each of the two alternative interpretations of the market power parameter, θ. Consider the following profit function of a representative firm i:

(1A) $$\Pi_i = p \cdot f_i(x_{1i}, \mathbf{x}_i) - w_1 \cdot x_{1i} - \mathbf{w} \cdot \mathbf{x}_i$$

where $w_1 = g(x_1, \mathbf{z})$ as before and each firm has a unique production function. The general form of the first-order condition with respect to the choice of the input level, x_1, for firm i is

(2A) $$\frac{\partial \Pi_i}{\partial x_{1i}} = p \cdot \frac{\partial f_i(x_{1i}, \mathbf{x}_i)}{\partial x_{1i}} - w_1 - \frac{\partial g(x_1, \mathbf{z})}{\partial x_1} \cdot \frac{\partial x_1}{\partial x_{1i}} \cdot x_{1i} = 0.$$

Rearranging this expression so that the marginal factor cost terms are on the left-hand side and the value marginal product is on the right-hand side results in the following:

(3A) $$w_1 + \frac{\partial x_1}{\partial x_{1i}} \cdot \frac{x_{1i}}{x_1} \cdot \frac{\partial g(x_1, \mathbf{z})}{\partial x_1} \cdot x_1 = p \cdot \frac{\partial f_i(x_{1i}, \mathbf{x}_i)}{\partial x_{1i}}.$$

Averaging this expression over all firms in the industry results in

(4A) $$w_1 + \frac{1}{n} \sum_{i=1}^{n} \frac{\partial x_1}{\partial x_{1i}} \cdot \frac{x_{1i}}{x_1} \cdot \frac{\partial g(x_1, \mathbf{z})}{\partial x_1} \cdot x_1 = p \cdot \frac{1}{n} \sum_{i=1}^{n} \frac{\partial f_i(x_{1i}, \mathbf{x}_i)}{\partial x_{1i}}$$

where n is the number of firms in the industry.

If the aggregate marginal product term in equation (4) of the text is interpreted as the average of the marginal product terms over firms in the industry, that is, $\frac{\partial f(x_1, \mathbf{x})}{\partial x_1} = \frac{1}{n} \sum_{i=1}^{n} \frac{\partial f_i(x_{1i}, \mathbf{x}_i)}{\partial x_{1i}}$, then equation (4A) takes on the same form as equation (4), except now θ is interpreted as the average of the input conjectural elasticities: $\theta = \frac{1}{n} \sum_{i=1}^{n} \frac{\partial x_1}{\partial x_{1i}} \cdot \frac{x_{1i}}{x_1}$. The input conjectural elasticity measures the percentage increase in total industry input purchases in response to a 1% increase in a particular firm's input purchases. If the industry is perfectly competitive in its input purchases, then the conjectural elasticity is zero. If it is monopsonistic, the conjectural elasticity is one. In an oligopsonistic industry, the conjectural elasticity will fall between zero and one.

The second interpretation of θ is obtained by assuming a Cournot input market, in which each firm in the industry expects no reaction by other firms in the industry to changes in the level of its input purchases. That is, they expect $\partial x_1 / \partial x_{1i} = 1$. Then equation (3A) can be written instead as the following:

(5A)
$$w_1 + s_i \bullet \frac{\partial g(x_1, \mathbf{z})}{\partial x_1} \bullet x_1 = p \bullet \frac{\partial f_i(x_{1i}, \mathbf{x}_i)}{\partial x_{1i}}$$

where s_i is the input market share of firm i (i.e., $s_i = x_{1i} / x_1$). Multiplying through by s_i and summing over the firms in the industry result in the share-weighted industry expression

(6A)
$$w_1 + \sum_{i=1}^{n} s_i^2 \bullet \frac{\partial g(x_1, \mathbf{z})}{\partial x_1} \bullet x_1 = p \bullet \sum_{i=1}^{n} s_i \frac{\partial f_i(x_{1i}, \mathbf{x}_i)}{\partial x_{1i}}.$$

Now, if the aggregate marginal product term in equation (4) of the text is interpreted as the share-weighted marginal products of firms in the industry, that is, $\frac{\partial f(x_1, \mathbf{x})}{\partial x_1} = \sum_{i=1}^{n} s_i \frac{\partial f_i(x_{1i}, \mathbf{x}_i)}{\partial x_{1i}}$, then θ takes on the interpretation of the input market counterpart to the Herfindahl index: $\theta = \sum_{i=1}^{n} s_i^2$. Thus, θ can be related back to a measure of concentration in the industry.