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by Catherine J. Morrison Paul

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**California Agricultural Experiment Station  
Giannini Foundation for Agricultural Economics**

COST ECONOMIES AND MARKET POWER:  
THE CASE OF THE US MEAT PACKING INDUSTRY

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## *ABSTRACT*

Increasing size of establishments and resulting concentration in US industries may stem from various types of cost economies. In particular, scale economies arising from technological factors embodied in plant and equipment may be a driving force for such market structure changes. In this case typical market power measures like Lerner indexes can be misleading; if scale (cost) economies prevail, cost efficiencies rather than market deficiencies may actually underlie the observed patterns. In this study I provide measures of scale economies and market power for the US meat packing industry, where increased consolidation and concentration have raised great concern in policy circles. The results suggest that this trend has been motivated by cost economies, but that little excess profitability exists, and on the margin the potential for taking further advantage of such economies has become minimal.

## I. *Introduction:*

Concentration and consolidation are on the rise in many US industries. One industry that has been the target of great concern and debate by policy makers is the US meat packing industry. It has been alleged that monopsony and monopoly power, that could harm farm animal producers or meat consumers while generating excess profits for firms, is a result of these market structure patterns. It has also been suggested that scale economies imbedded in the technological or cost structure, and thus cost efficiency, may be the driving force for such patterns.

The questions raised about this industry mirror those voiced in the late 1800s when the largest four meat packing firms (the “Big Four”) produced two-thirds of the country’s dressed beef supply,<sup>1</sup> stimulating the US Senate to adopt a resolution investigating the impacts of this market structure on pricing policies. Major developments in transportation and refrigeration technology in the 1930s, that reduced the importance of local networks, facilitated a drop in concentration levels to a low in 1977 when the four largest packers controlled about 20 percent of the market. However, new production processes (“boxed beef” production) and lower red meat demand then led to another wave of consolidation where the share of these firms rose to 82 percent in the early 1990s.<sup>2</sup> The resulting policy concerns are documented in the 1996 USDA/GIPSA (Packers and Stockyards) study *Concentration in the Red Meat Packing Industry*.

As summarized by Azzam and Schroeter [1997], studies focusing on these issues for beef packing ultimately raise the “obvious question”: “Have the benefits of increased concentration, realized through slaughter and processing cost savings, been large enough to offset the losses to cattle producers and beef consumers from concentration-induced market power?” (p. 26).

Addressing such a question, however, requires detailed consideration of the cost as well as market structure in the industry.<sup>3</sup>

A variety of cost economies may underlie the production structure, and thus be determinants of costs and prices, in the meat packing industry. Such economies primarily arise from changes in the scale of operations. Scale economies may result from fixities imbedded in the technology (short run rigidities or “lumpiness” of capital, implying utilization economies), or external factors such as thick market effects, as well as more standard long run internal scale relationships. If such economies prevail, firms that are larger, more integrated, or more highly utilized, will exhibit lower unit costs. This greater cost efficiency will provide an incentive for plant size to increase and high concentration levels to emerge in the industry.

Reductions in competitiveness due to such technological cost economies could have positive effects if the lower costs help to keep product prices down, and thus sales up. It could, however, have adverse effects if concentration allows firms remaining in the industry to take advantage of their market position – to use their market power to depress prices to input suppliers, or elevate prices to consumers of the final product.

Evaluating market power impacts involves modeling and measuring the difference between market price and marginal factor cost for inputs (markdowns), or price and marginal cost for outputs (markups). Assessing the causes of these gaps such as cost economies, and their consequences such as excess profitability, in turn requires careful measurement of marginal (output and factor) as compared to average costs, which will deviate unless restrictive assumptions about the cost structure hold.

The objective of this study is to generate measures of cost structure characteristics, to provide insights about the determinants and impacts of input and output market power patterns in the US meat packing industry from the 1970s to the early 1990s. A dynamic model based on a restricted cost function is used to represent input demand and output supply behavior, with distortions from standard Hotelling's lemma optimization conditions due to technological factors, adjustment costs, and imperfect competition, incorporated. The estimated model is then used to measure cost economies (short, intermediate and long run scale economies), their input-specific components, market power (markdowns and markups), and implied profitability.

The results indicate significant but not substantive overall market power, which seems primarily associated with the output market. And the significant scale economies that also are evident in a sense counteract the apparent market power. Markups of output price over average costs, and so measured profitability, are negligible. Cost structure and economies thus seem crucial factors underlying the observed market structure patterns; they are a critical "piece of the puzzle" for interpreting and using market power measures.

## II. *The Model:*

Modeling and measuring scale economies (the cost-output relationship), monopsony power (markdowns of price below the marginal benefit to the firm), and monopoly power (markups of output prices over marginal cost) requires a detailed representation of the cost structure. This can most directly be accomplished through specification and estimation of a cost function model.

A restricted cost function is suitable for the current application, since utilization of quasi-fixed capital stocks is likely very important, and adjustment of livestock input levels may best be

modeled as a sequential decision. Thus adjustment costs for capital, and a joint pricing and quantity decision for the materials or livestock input, should be incorporated into the cost relationship. A general form for a cost function allowing for these structural characteristics is  $G(K, K, M, Y, \mathbf{p}, \mathbf{r})$ , where  $K$  is capital plant and equipment,  $K$  represents internal adjustment costs for capital,  $M$  is materials input,  $Y$  is output,  $\mathbf{p}$  is a vector of variable input prices, and  $\mathbf{r}$  is a vector of shift variables.

For the meat packing industry  $M$  is comprised primarily of livestock.<sup>4</sup>  $Y$  is a combination of carcasses, packaged cuts of meat, byproducts, and hides.<sup>5</sup> The variable inputs include labor ( $L$ ) and energy ( $E$ ). To allow as much as possible for technological changes in the industry,  $\mathbf{r}$  includes not only a standard disembodied technical change (trend) variable,  $t$ , but also an indicator of automation,  $A$ .<sup>6</sup>

Including both  $M$  and  $Y$  levels as arguments of  $G(\cdot)$  allows direct representation of materials input demand and output supply behavior, through pricing equations capturing the associated optimal marginal benefit-cost balances. It thus also facilitates characterizing the gaps between the market prices for and the marginal benefits or costs of  $M$  or  $Y$ , that result from market power, as elaborated further below.

The functional form approximation of  $G(K, K, M, Y, \mathbf{p}, \mathbf{r})$  for empirical implementation should capture the cross-effects among all arguments of the function and therefore not put *a priori* restrictions on the shapes of curves representing the production technology. One such flexible functional form is a generalized Leontief (GL) function:



$$1) G(K, K, M, Y, \mathbf{p}, \mathbf{r}) = \sum_{i,j} \alpha_{ij} p_i^{.5} p_j^{.5} + \sum_{i,m} \alpha_{im} p_i s_m^{.5} + \sum_{i,k} \alpha_{ik} p_i x_k^{.5} \\ + \sum_i p_i (\alpha_{mn} s_m^{.5} s_n^{.5} + \alpha_{mk} s_m^{.5} x_k^{.5} + \alpha_{lk} x_k^{.5} x_l^{.5}),$$

where  $s_m, s_n$  denote  $K, Y$ , and the components of  $\mathbf{r}$ , and  $x_k, x_l$  are the  $K$  and  $M$  levels.<sup>7</sup>

This functional form is similar to, but more symmetric, than that implemented in Morrison [1988]. Although this precludes using it to nest a constant returns to scale (CRTS) specification,<sup>8</sup> standard errors may be computed to indicate the statistical significance of scale economy measures and thus implicitly test for the existence of CRTS. The GL function, as compared to alternative flexible forms such as the translog, also may be more likely to satisfy curvature restrictions (especially for a function with input levels rather than prices, and thus sequential optimization, incorporated).<sup>9</sup> In addition, the function's flexibility allows for a fully non-neutral representation of short- (utilization) and long- run scale economies – and thus the associated input-specific impacts or biases – through the  $K$  and  $Y$  interaction terms, respectively. (Further elaboration of the measures to be constructed is pursued in the next section.)

As alluded to above, this specification of the  $G(K, K, M, Y, \mathbf{p}, \mathbf{r})$  function facilitates the representation of sequential optimization decisions, and thus incorporation of the potential market power for  $M$  and quasi-fixity of  $K$  that cause the demand equations for these inputs to have a different structure than implied by a simple Shephard's or Hotelling's lemma condition. The sequential optimization steps that industry analysts suggest appropriately represent this industry involve making very short run (perhaps weekly) decisions about labor and energy use, then adjustments to materials/livestock demand based on conditions in this market and the existing

capital stock (the “intermediate run”), and then ultimately investment decisions to adjust capital to long run equilibrium levels. These cost minimizing decisions based on “given” output levels can then be augmented by incorporating joint determination of profit maximizing output supply choices.

This behavior may be formalized as a system of demand and supply equations based on Shephard’s lemma ( $v_i = G / p_i$ ) for the variable inputs, plus shadow-value relationships ( $p_k = -G / x_k + \lambda_k$ , where the  $\lambda_k$  gap stems from either monopsony power or adjustment costs and  $p_k$  is the market price for  $x_k$ ) for M and K, and a marginal cost equality ( $p_Y = G / Y + \lambda_Y$ , where  $\lambda_Y$  represents the impact of monopoly power and  $p_Y$  is the observed price of Y) for output. A partial characterization of behavioral choices – just short run responses, for example, with the remaining arguments of the function fixed – may also be distilled from this full optimization problem. This optimization framework therefore provides the basis for developing a rich set of measures representing different aspects of the technological and market structure, and the decision-making process.

Before moving on to discuss these measures, we need to be more explicit about allowing for market power in the M and Y optimizing equations. The treatment of market power in both the M and Y markets is similar to that used in Morrison [1992] to model imperfect competition or “monopoly” behavior for output. This is based on the standard profit maximizing equation  $MC=MR$ , where  $MC = G / Y$  is marginal cost, and  $MR = p_Y(Y) + Y \cdot p_Y' / Y$  is marginal revenue, computed from an inverse demand function  $p_Y(Y)$  representing the output demand structure. For

our purposes the  $p_Y(Y)$  function is assumed to take the simple square-root functional form:<sup>10</sup>

$$p_Y(Y) = \alpha_Y + \beta_Y Y + \gamma_Y Y^5.$$

A similar approach may be used to allow for monopsony in the M market, since the GL function is expressed in terms of the quantity instead of price of M. If an inverse supply function  $p_M(M)$  is appended to the model, the optimal pricing (and implicit demand) equation for M stems from the profit maximization condition  $Z_M = -G/M = MFC_M = p_M + M \cdot p'_M/M$  (where  $Z_M$  is the shadow value of M,  $MFC_M$  is the associated marginal factor cost, the first and last equalities are definitional and the middle equality reflects the optimizing decision).<sup>11</sup>

The differential between the marginal input price and the average price the firm would pay if it had no market power is thus the  $M \cdot p'_M/M$  component.<sup>12</sup> That is, market power causes  $Z_M = MFC_M > p_M$ ; as more M is purchased it pulls up the price of all units of the factor due to an upward sloped input supply curve. The markdown of price below the shadow value may therefore be expressed as  $p_M/Z_M$ , analogously to the measurement of the markup of output price over marginal cost,  $p_Y/MC$ , which is in turn similar to a Lerner index.<sup>13</sup> For purposes of implementation, the  $p_M(M)$  function is assumed to have a simple quadratic functional form such as that for output;<sup>14</sup>  $p_M = \alpha_M + \beta_M M + \gamma_{MM} M^5$ .

Finally, two issues that complicate the cost-based representation of the meat packing industry should be kept in mind for motivation and interpretation of the empirical model and results. First, although some substitution among labor, energy and materials inputs is possible in this industry, material inputs comprise an even larger cost share than is usual for most manufacturing industries, and little substitution may be possible between M and the other variable

inputs. The technology in this industry has, in fact, often been assumed to be well approximated by a fixed proportions model.

Secondly, the large capital base in this industry suggests that utilization- or short-run-scale- economies are important to recognize for appropriate marginal valuation of materials/livestock inputs. That is, it could well be that increased throughput for an existing plant increases efficiency (lowers unit costs) more significantly than would be the case if full adjustment of the capital stock to the long run were to take place. This would provide an incentive to keep utilization levels high by maintaining high  $Y$ , and thus  $M$ , levels. It will also affect the true shadow value of  $M$ , and thus the appropriate  $Z_M$  measure to use for imputation of monopsony power impacts.

The framework overviewed above provides a rich structure for analysis of the meat packing industry. In particular, it allows a multitude of cost and pricing characteristics including utilization and scale cost economies, and market power from monopsonistic or monopolistic structure, to be evaluated via elasticity measures. We now turn to the specification of such measures and their input-specific components.

### *III. Measurement of Cost Economies and Market Power:*

Measures of overall and input-specific cost economies and market power may be constructed from the model framework developed above through elasticities of costs and input demands with respect to output. These indicators are therefore fundamentally based on marginal cost measures, which should incorporate as many different aspects of the production structure as possible to facilitate their interpretation, will vary depending on the “run” being considered, and are evaluated in terms of total costs (TC).

The first of these issues is accommodated by the detailed specification of the cost function above, as a flexible functional form allowing for a full set of interactions terms across arguments of the function, non-neutral scale economies and technical change, and adjustment costs. The different “runs” that might be distinguished depend on the sequential optimization steps already outlined, which result in short- (S), intermediate- (I) and long-run (L) measures depending on what potential behavioral responses to an output demand increase are taken into consideration. And the measurement of marginal costs is based on a total cost definition that includes both restricted costs  $G(\cdot)$ , and M, K costs.

The S, I, and L marginal cost measures may thus be expressed as:

$$2a) \quad MC^S = TC / Y = G / Y \quad (TC = G(\cdot) + p_M(M) M + p_K K)$$

$$b) \quad MC^I_M = TC^I_M / Y \quad (TC^I_M = G(\cdot, M^*) + p_M(M^*) \cdot M^* + p_K K), \text{ and}$$

$$c) \quad MC^L_K = TC^L_K / Y \quad (TC^L_K = G(\cdot, M^*, K^*) + p_M(M^*) \cdot M^* + p_K K^*),$$

where  $M^*$  is the desired M level corresponding to the optimization equality  $MFC = p_M + M \cdot p_M / M = Z_M = - G / M$ . Similarly,  $K^*$  is the long run optimal K value solved for when the market price and shadow value of capital are equated:  $p_K = Z_K = - G / K$ .<sup>15</sup>

These measures allow the representation of cost economies (the cost-based scale economy measure  $\ln TC / \ln Y = \tau_{CY}$  is founded on 2a, b and c respectively), and optimal output supply (where the  $p_Y = MC$  optimization condition is similarly based on 2a, b or c) for the sequence of behavioral responses. For example, short run scale economies based on existing M, K levels are defined as  $\tau^S_{TCY} = G / Y \cdot (Y/TC)$ . This differs from the standard textbook measure  $\tau_{CY}$

$= \ln TC / \ln Y$  from an instantaneous adjustment specification of  $TC(\cdot)$  with  $p_M$  and  $p_K$  as arguments, thus implying that the M and K markets are in equilibrium at all observed sample points. Further, the  ${}^I_{TCY} = \ln TC^I_M / \ln Y = TC^I_M / Y(Y/TC^I_M)$  measure can be interpreted as representing utilization economies given fixed K, but with adjustment of M accommodated. This measure is thus similar to a typical short run measure allowing all inputs except capital to adjust to their equilibrium values. Finally, a long run scale economy measure, reflecting the slope of a long- instead of short- run average cost curve, can be computed as  ${}^L_{TCY} = \ln TC^L_K / \ln Y = TC^L_K / Y(Y/TC^L_K)$ .

An important question for this type of model that requires imputing optimal values is exactly how one might compute the (2a,b,c) MC measures and their logarithmic scale economy counterparts. The most immediately obvious possibility is to analytically compute  $M^*$  and  $K^*$  expressions to substitution into the  $TC(\cdot)$  definitions. This may be, however, computationally cumbersome, as well as limiting the interpretability of the differences between the measures. An alternative possibility that avoids these inconveniences is to create combined elasticities such as those often used in models recognizing subequilibrium from input fixities. This latter approach turns out empirically to generate nearly equivalent measures, and is therefore used in this study.<sup>16</sup>

Such a measure implicitly invokes the chain rule, while the resulting expression is evaluated at observed values to facilitate the representation of adjustment processes. For example, long run scale economies may be computed as  ${}^L_{TCY} = \ln TC / \ln Y = TC / Y \cdot (Y/TC) =$

$MC \cdot (Y/TC) = (TC/Y + TC/M \cdot M^*/Y + TC/K \cdot K^*/Y) \cdot (Y/TC)$ , based on the definition  $TC = G(\cdot) + p_M(M) \cdot M + p_K K$  (so  $MFC_M = p_M + M \cdot p'_M/M$  is appropriately characterized in  $TC/M$ ). The  $Z_{TCY}^I$  measure would be similarly constructed, but without the  $K$  adjustment term in the first set of parentheses.

Imputing the long run in this manner facilitates interpretation of the notion of utilization economies. The underlying optimization framework (elaborated further in the next section) is based on the presumption that capital adjustment would take place if  $Z_K$  and  $p_K$  diverge. However, if capital investment is in large discrete chunks, little adjustment may be observed even in the long run, since a great divergence between the shadow and market prices may be necessary to make a substantive investment. The existence of a chunk of capital that is not being used fully efficiently may make it economical to expand output production and thus input ( $M$ ) use to increase effective utilization, even if it imposes pecuniary costs from associated decreases in  $p_Y$  and increases in  $p_M$  due to market power. As alluded to above, this suggests a somewhat different balancing act or optimization decision than is true in a more partial analysis. These cost economies must be taken into account for the appropriate valuation of  $M$ .

A secondary version of the “intermediate run”, which allows inclusion of the profit-maximizing adjustment of output explicitly in the construction of the  $Z_M$  value, is useful for representing this aspect of the sequential process. Such a measure can be denoted  $Z_M^I = G^I_Y/M$ , where  $G^I_Y = G(\cdot, Y^*)$ . Although accommodating this aspect of the optimization process in the  $M$  valuation further emphasizes the complexity of the implicit dynamics of the model, it also highlights the rich potential for measurement and interpretation of the various production structure characteristics underlying the cost economy and market power measures. More generally, for this

type of model one must take care for both construction and interpretation of the measures to explicitly recognize what should be held fixed and what is adjusting to address the question under consideration.

The final extension for our cost structure representation involves the division of overall cost economy measures into their input-specific components. Since in this framework demand functions are derived for L and E via Shephard's lemma, and for M and K by solving the pricing expressions  $Z_k = p_k + \lambda_k$  for the implied  $M^*$ ,  $K^*$  levels, the impacts of an exogenous change on input composition can be expressed in terms of elasticities of these functions. So, adaptations in input use due to changes in output production can be expressed as  $\epsilon_{iY} = \ln v_i / \ln Y$  ( $i=L,E$ ) and  $\epsilon_{kY} = \ln x_k^* / \ln Y$  ( $k=M,K$ ). Adaptations to represent the I and L measures can also be made analogously to those for the cost elasticities above by appending M and K adjustments to the Y change, respectively.

Once these cost structure measures are computed, pricing behavior indicators may be constructed to evaluate market power and profitability. These measures also depend on the notion of a shadow value, derived as a derivative of the cost function, as overviewed in the last section. In particular, instead of the Shephard/Hotelling's lemma result that  $M = -G / p_M$ , or the inverse shadow value condition that  $p_M = -G / M$ , our optimizing equation for M was specified as:  $p_M = -M \cdot p_M / M - G / M$ . Similarly for Y we showed that  $p_Y = -Y \cdot p_Y / Y + G / Y$ . Thus, we can measure and evaluate the gap between the market and shadow prices of M and Y by computing the markdown and markup ratios  $P_M \text{RAT} = p_M / Z_M = p_M / \text{MFC}$ , and  $P_Y \text{RAT} = p_Y / Z_Y = p_Y / \text{MC}$ .<sup>17</sup> These ratios can be computed for the short-, intermediate- and long-run by



using MC and  $Z_M$  measures defined according to  $TC_M^I(\cdot)$  and  $TC_Y^I(\cdot) = G_Y^I(\cdot, Y^*) + p_M(M) \cdot M + p_K K$ , respectively.

Combining our information about cost economies with measures of monopsonistic and monopolistic pricing (market power) results in profitability indicators. These measures can be used to determine if cost economies are sufficient to imply that marginal costs are substantively low relative to average costs. In this case  $p_Y$ , for example, must exceed MC simply to cover costs, so excessive profitability is not necessarily implied by markups of output price over marginal cost (or markdowns of materials price below marginal factor cost). Instead cost economies or efficiencies underlie the evidence of market power, which provides a technological- rather than market-structure motivation for deviations from what is typically thought of as a competitive outcome. Market structure changes that take advantage of cost economies could be the *efficient* way of operating in such a scenario, rather than implying inefficiency. And if near zero economic profitability prevails, this could also be consistent with some form of *effective* competition given demand conditions.

Formalizing this notion requires a further look at the cost economy and market power measures developed above. First note that  $P_YRAT$  is defined as a marginal measure, which may be made more explicit by adding an “m” superscript denoting marginal;  $P_YRAT^m = p_Y/MC$ . Although this measure is the basis for marginal decision making, its deviation from one does not necessarily provide information about profitability. To more directly consider profits, a corresponding average measure may be constructed as  $P_YRAT^a = p_Y/AC$ . Note, however, that the general scale economy measure  $TC_Y = \ln TC / \ln Y = TC / Y \cdot (Y/TC) = MC \cdot (Y/TC)$  may be written as  $MC/AC$ . Our

profitability indicator is therefore simply a product of the market power and scale economy measures (with monopoly only):  $P_Y \text{RAT}^m \cdot \text{TCY} = P_Y \text{RAT}^a$ .

Accommodating monopsony in a profitability measure is somewhat different since it directly affects the measurement of marginal cost. The marginal valuation of M (MFC), which is reflected in  $\text{MC}_M^L$  (or  $\text{MC}_K^L$ ) through recognition of the dependence of  $p_M$  on M, varies from the average valuation of M ( $p_M$ ) that appears in the AC measure. Since this is accommodated in the definition of  $\text{TCY}^L$ , this is therefore the appropriate basis for incorporating the potential impact of monopsony power in the  $\text{PRAT}^a$  measure.

#### IV. Empirical Implementation and Results:

The model developed in the previous sections is implemented by using the cost function to generate variable input demand equations for L and E, pricing equations for M and Y, and an Euler equation for K. These expressions, which represent a broad range of input and output decisions and interactions and by construction satisfy theoretically required conditions, comprise the system of estimating equations.

More specifically, as briefly motivated in Section II, Shephard's lemma is used to derive input demand equations from  $G(\cdot)$  as

$$3) v_i = G / p_i = .5 \sum_j \beta_{ij} (p_j/p_i)^5 + \sum_m \beta_{im} S_m^{.5} + \sum_k \beta_{ik} X_k^{.5} \\ + (\sum_m \beta_{mn} S_m^{.5} S_n^{.5} + \sum_m \beta_{mk} S_m^{.5} X_k^{.5} + \sum_k \beta_{lk} X_k^{.5} X_l^{.5}),$$

( $i=E,L$ ), where  $v_i$  is the cost minimizing demand for variable input  $i$ . The M pricing (demand) estimating equation, that incorporates the  $p_M(M)$  relationship, becomes:

$$4) p_M = -M \frac{p_M}{M} - G/M = -M \cdot (M + .5 M M^{-.5}) - .5 \sum_i p_i M^{-.5} - .5 \sum_i p_i (m_{mM} s_m^{.5} M^{-.5} - \sum_i p_i k_{KM} K^{.5} M^{-.5}).$$

Similarly, the profit-maximizing output pricing (supply) equation is specified as:

$$5) p_Y = -Y \frac{p_Y}{Y} + G/Y = -Y \cdot (Y + .5 Y Y^{-.5}) + .5 \sum_i p_i Y^{-.5} + .5 \sum_i p_i (m_{mY} s_m^{.5} Y^{-.5} + \sum_k p_k x_k^{.5} Y^{-.5}).$$

In addition, we incorporate dynamic behavior through an Euler equation representing optimal capital adjustment ( $\Delta K$ ) toward long run equilibrium in response to a deviation between the marginal costs and benefits of investment in  $K$ :<sup>18</sup>

$$6) p_K = -G/K - i \cdot G/K + K \Delta G/K + (\Delta K)^2 G/(\Delta K)^2, \\ = -.5 \sum_i p_i k_{iK} K^{-.5} - .5 \sum_i p_i (m_{mK} s_m^{.5} K^{-.5} - \sum_k p_k x_k^{.5} K^{-.5}) - i \cdot [.5 \sum_i p_i k_{iK} K^{-.5} + .5 \sum_i p_i (m_{mK} s_m^{.5} K^{-.5} + \sum_k p_k x_k^{.5} K^{-.5})] + K \cdot (.25 \sum_i p_i k_{iK} K^{-.5} K^{-.5}) + (\Delta K) \cdot (.25 \sum_i p_i k_{iK} K^{-.5} K^{-1}),$$

where  $\Delta K$  is the second difference of  $K$ ,  $i$  is the discount rate,  $-G/K = Z_K$  is the instantaneous shadow value of  $K$ , and  $i \cdot G/K$  represents amortized adjustment costs. This last equation is the solution to the long run present value optimization problem:

$$7) \text{Min}_{K, \dot{K}} G(0) = \int_0^{\infty} e^{-it} [G(K, \dot{K}, Y, \mathbf{p}, \mathbf{r}) + p_M(M)M + p_K K] dt + q_K K(0),$$

representing the minimum present value of the stream of costs from producing output  $Y$  using input  $M$  at each future period, where  $p_K = q_K(i + \delta_K)$  is the rental price of  $K$ ,  $q_K$  the asset price of new capital goods,  $\delta_K$  the depreciation rate, and  $K(0)$  the initial  $K$  stock.<sup>19</sup>

The estimating system is thus comprised of equations (1) and (3)-(6), which are estimated simultaneously. The joint choice of Y and M prices and quantities with the potential for market power recognized, however, raises endogeneity issues not appropriately accommodated by system estimation methods such as seemingly unrelated regression. So the system was estimated by generalized method of moments (GMM) techniques.<sup>20</sup> This procedure, as discussed by Pindyck and Rotemberg [1983], permits expectations about future price paths and joint price-quantity decisions to be dealt with by instrumenting the variables that may be measured with error or are endogenous. The instruments used for our final specification include all exogenous variables, the lagged values of input prices and capital and output levels, (as in Pindyck and Rotemberg [1983]), and output composition (the proportion of white to red meat purchased).<sup>21</sup>

Since there are too many parameters in this model to allow useful interpretation of the individual coefficient estimates, we will focus on the indicators constructed as combinations of the parameters and data, and their associated combined significance levels.<sup>22</sup> It is worth noting, however, that many of the coefficients seemed insignificant from t-tests, but that attempts to restrict the model by setting groups of parameters to zero (such as cross-terms with the  $r$  or  $K$  variables) were invariably rejected by joint tests. Thus the full flexible specification of the restricted cost function was retained.

More specifically, the coefficient estimates were used to calculate the derivatives required for construction of the overall and input-specific cost (or scale) economy and market power elasticity measures discussed in the previous section. The statistical significance of the measures was computed by evaluating them for each individual data point using the ANALYZ procedure

in TSP. These measures are presented for the 4-digit US meat packing (SIC 2011) industry in the Tables below.<sup>23</sup>

First consider the marginal price ratio measures reported in Table 1. The  $P_YRAT^m$  measures suggest monopoly power; they exceed and differ significantly from one. The markup estimates vary little across the S, I and L runs. They do, however, appear to be dropping over time, although this impression is somewhat misleading since the *difference* between  $P_YRAT^m$  and  $P_MRAT^m$  is falling (and significant in the I and L runs), implying reduced rather than increased overall market power over time.<sup>24</sup>

**Table 1: Market Power Measures**

Year	$P_YRAT^m$	$P_MRAT^m$	$P^I_YRAT^m$	$P^I_MRAT^m$	$P^L_YRAT^m$	$P^L_MRAT^m$
1971	1.113*	1.081	1.127*	0.889	1.125*	0.891
1981	1.067*	1.047	1.070*	0.942	1.074*	0.937
1991	1.045*	1.040	1.046*	0.951	1.047*	0.948

*\*in all Tables denotes significantly different at the 5% level from the comparison level of the elasticity (0.0 or 1.0 depending on the measure)*

The  $P_MRAT^m$  estimates differ more across runs, but are invariably statistically insignificant. It appears that although net market power is substantive, it is primarily evident on the output side.<sup>25</sup> In fact, the short run  $P_MRAT^m$  measures exceed rather than fall short of one, as would be expected for a markdown. Once the potential increase in Y and thus utilization is recognized, the ratio falls short of but remains insignificantly different from one. Monopsony power in the C market thus does not seem identifiable.

Turning to Table 2, we can see that this market power evidence coexists with substantive measured cost economies, especially in the earlier part of the sample. Scale economies appear larger and more significant when M adjustment is embodied – so potential utilization changes are appropriately accommodated – in the  $I_{CY}$  measure. They also seem to be declining over time, but not to differ much between the I and L runs. In fact slightly smaller long run economies are evident;<sup>26</sup> cost economies measured on a K-fixed “I” cost curve are greater than when K can adjust to its long run level, documenting the importance of utilization economies. The reduced scope for cost economies evident late in the sample also shows that potential economies may largely have been internalized by 1991.

**Table 2:** *Scale Economy and Profitability Measures*

Year	$S_{CY}$	$I_{CY}$	$L_{CY}$	$P^S_{YRAT}^a$	$P^I_{YRAT}^a$	$P^L_{YRAT}^a$
1971	0.952	0.853*	0.916*	1.059*	0.961	1.031
1981	0.972	0.922 <sup>m</sup>	0.924*	1.037	0.994	0.992
1991	0.982	0.967	0.970	1.026	1.012	1.016

*m denotes “marginally” significant, or very close to the 5% significance level*

The profitability measures reported in Table 2 combine the information about markups/downs and scale economies. These measures are nearly always insignificantly different from one (except the S measure in 1971), and the most representative measures of observed market choices, with M but not K adjustment included (I), indicate a *shortfall* of profits from costs in the earlier years of the sample. This is consistent with the fact that the industry was in serious trouble in these years, with many plants going under.<sup>27</sup>

This evidence of low profitability is driven by the substantive measured scale economies (implying high average as compared to marginal costs), particularly in the 1970s. By 1991 the  $P_{YRAT}^a$  measures exceed one, but not significantly, suggesting that plant size expansion, consolidation, and resulting concentration have allowed scale economies to be taken advantage of and profitability to increase somewhat, but has not necessarily generated excessive economic profits. Since on balance profitability appears negligible once scale economies are taken into account, this suggests some form of effective competition is at work, given both technological (cost) and output demand conditions. This could be consistent with some type of monopolistically competitive market structure.

The input-specific impacts underlying the measured scale economies, evident from the measures in Tables 3a and b for the S and I runs, are also of interest to facilitate interpretation of these patterns. The large (and significant) short run  $LY$  and  $EY$  measures found in Table 3a stem from small L and E cost shares and low substitutability; increasing production with existing M levels requires large variable input increases. Once M or K are able to increase, L and E (and thus variable costs) drop.

**Table 3: *Input-Specific Scale Measures***

***3a: S measures (L,E only variable)***

YEAR	LY	EY	LM	EM	LK	EK
1971	11.414*	11.917*	-9.814*	-11.882*	-0.773*	-3.352*
1981	14.878*	18.479*	-12.917*	-18.506*	-1.051*	-4.981*
1991	16.648*	30.069*	-14.776*	-26.370*	-1.278*	-6.978*

*3b: I measures (M adjusted)*

YEAR	LY	EY	MY	LK	EK	MK
1971	-4.439	-6.711	1.491	0.666	-1.661	-0.135
1981	-3.654	-8.115	1.383	0.689	-2.475	-0.130
1991	-4.187	-8.055	1.373	0.743	-3.281	-0.133

The I measures presented in Table 3b indicate that output expansion implies large increases in livestock demand but decreases in labor and energy use. Thus it seems more economical at higher scale levels for existing plants to increase the M-intensity of production; scale biases are M-using and L- and E-saving. Such patterns are maintained in the L elasticities, with capital also rising but just slightly more than proportionally to output.

By contrast, increasing capital (for given output levels) motivates increases in labor but decreases in material inputs; it seems to increase overall efficiency of materials/energy use relative to labor. This could be a result of greater diversity of output in larger (or more highly capitalized) operations. In particular, it could suggest changes in output composition toward more processed or fabricated products, which require more L input.

Additional insights about the input-use patterns suggested by the scale-based measures may be gained from perusing the cost shares in Table 4. A clear trend toward labor-saving in this industry is indicated by these numbers. Although labor intensity is initially very low, it drops further from 8% in 1971 to less than 5% of costs in 1991. This suggests that output demand rather than capitalization was a driving force underlying production patterns (although output grew only by about 10% between 1971 and 1981 and then largely stabilized with a short-term decline in



1989-91). At the same time, the E share rose and then fell, which largely is due to price patterns; the quantity of energy used dropped throughout the time period, indicating that capital investment was accompanied by increased energy efficiency.

**Table 4:** Input Shares

Year	L	E	M	K
1971	0.080	0.0043	0.834	0.082
1981	0.058	0.0063	0.875	0.061
1991	0.048	0.0052	0.874	0.073

By contrast, capital intensity dropped from the early 1970s when many plants were going out of business, and then rose again in the 1980s when larger plants were being built and heavy consolidation was occurring. This cost pattern, however, reflects a slightly stronger growth rate of the capital stock than output in both periods (K increased more than Y and then did not drop as far) as well as a slower increase in its price over the whole time period than for Y. M intensity also increased somewhat; materials use closely followed the rise and then fall in output levels, but with a slightly larger average growth rate. The M share grew slightly but then stabilized, perhaps suggesting that plants going out of business early in this period were smaller more specialized plants that could not maintain the cost efficiency of the larger, more capital-intensified and diversified operations.

## *V. Concluding Remarks*

The measures reported in this study indicate significant but declining market power and cost economies in the US meat packing industry. Markups of output price from monopoly power are apparent, although evidence of markdowns from monopsony behavior in livestock input markets is weak. Analysis of the underlying cost structure, however, suggests that utilization issues and long run scale economies have been a driving force toward expansion in the scale of production. This implies low marginal as compared to average costs, which calls into question the interpretation of the market power measures. That is, in a sense the markups are supported by the measured scale economies, since they are barely high enough to allow average costs to be covered, and thus support zero economic profits (especially early in the sample). Some form of effective competition seems to prevail, given technological and output demand conditions.

This evidence underscores the importance of appropriately representing the technological base or cost structure when generating and assessing indicators of market power and its abuse. It also highlights the usefulness of “new empirical industrial organization” (NEIO) models<sup>28</sup> as compared to the structure-conduct-performance approaches often used to study the linkage between concentration and markup behavior, since an important aspect of NEIO models is the emphasis on modeling optimization processes, and thus on the cost structure.

The evidence for this industry contradicts the messages of economists like Bain [1956] that high concentration implies fundamental market inefficiencies. However, it is consistent with the idea that technical efficiency rather than market power may be implied by evidence of markups, if they are motivated by cost economies, raised in classic studies such as Adelman [1951] and emphasized by Demsetz [1973]. Some empirical studies in the macro-oriented literature based on

Hall [1988] have come to similar conclusions, and interpreted the implied lack of profitability as evidence of monopolistic competition.<sup>29</sup> The findings here also complement those for beef packing from Azzam and Schroeter [1995].<sup>30</sup>

Important policy implications stem from these findings. They suggest that focusing on the output demand (input supply) side to assess market structure provides too limited a framework to motivate policy formation and implementation promoting “competitiveness”. Policies forcing downsizing in industries characterized by high concentration levels may, for example, be misdirected if consolidation and resulting concentration are motivated by cost economies. Such action could limit the potential to lower costs in the industry, and thus ultimately reduce the product price for consumers, as well as strengthen input markets through associated increases in output levels.

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## Notes:

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<sup>1</sup> See Azzam and Schroeter [1997] for more discussion of these industry patterns, and Azzam and Anderson [1996] for an overview of the literature addressing these issues.

<sup>2</sup> Note, however, that a large proportion of the market is made up of smaller single-plant firms. For example, in the Packers and Stockyards [1996] survey of the 43 largest beef packing plants in this industry (that make up more than 90% of the industry) the five multi-plant firms only accounted for thirteen of the plants, and the rest were single-plant firms. Also, although most of the industry, and certainly the largest plants/firms, are in the Plains region, large plants exist across the country.

<sup>3</sup> Although Ball and Chambers [1982] addressed some questions about the technological basis of this industry using aggregate US meat packing data, most studies (such as those surveyed in Azzam and Anderson [1996]) have focused on the market structure with quite simplistic assumptions made about costs.

<sup>4</sup> As documented by survey information from Packers and Stockyards [1996], on average cattle inputs are about 93% of the M aggregate for the beef packing industry. Intermediate beef and “other” materials (primarily packaging materials) comprise 5% and 2% of M, respectively.

<sup>5</sup> The approximate output proportions on average across the 43 largest US beef packing plants comprising more than 90% of the industry were 24%, 66%, 4%, and 6%, respectively for carcasses (slaughter output), partly fabricated meat products (primarily “boxed beef”, or packaged cuts of beef), byproducts, and hides in 1992-93. (See Packers and Stockyards [1996].) Although the 4-digit meat packing aggregate here includes also pork production, this is representative of the balance of outputs produced in this industry, as is the description of the M component presented above.

<sup>6</sup> This external shift variable is measured as the percentage of high-tech capital in the capital stock for the food processing industries as a whole, as in Morrison and Siegel [1997]. Note that imports and exports are not taken into account as components of this vector, although the increasingly international nature of markets may also have shift effects on production (cost and market) structure. In the meat packing industry, however, imports and exports are small components of total output (imports stayed quite constant at about 5% from 1970 to 1991 with slight yearly fluctuations and exports have increased from about 2% to slightly more than 6% during this period). They also seem to have had little empirical impact on production patterns for meat products markets overall, as documented in Paul [1999c].

<sup>7</sup> These distinctions – here not really necessary due to the general nature of the functional form – are typically invoked to identify factors subject to homogeneity conditions (inputs  $K, M$ ) separately from those without homogeneity restrictions ( $K, r$ )

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<sup>8</sup> As explained in more detail in Morrison [1988], this problem stems from homogeneity restrictions with respect to quasi-fixed inputs that must be accommodated in the model to allow CRTS to be a nested specification, and thus for CRTS to be tested for directly by coefficient restrictions.

<sup>9</sup> This is important, since flexible functional forms do not impose global curvature, and as a practical matter (particularly for models with fixed inputs) translog functions more often tend to violate these conditions.

<sup>10</sup> Alternative functional forms and arguments for the inverse output demand ( $p_Y(Y)$ ) and materials input supply  $p_M(M)$  functions were tried to evaluate sensitivity to the assumed form. Although in subsequent work focusing more on these demand and supply structures may be a useful extension of this work, this exercise suggested that the form of the function is not critical for the analysis. In fact very similar results were generated for alternative assumptions. Thus, the simple form was maintained for this study to preserve the focus on the cost structure.

<sup>11</sup> Although this simple assumption (as for the output market) limits the scope of analysis for the market structure aspects of production processes, other work using cross-section data to focus more on market structure questions supports the use of this type of framework as compared to more complex oligopsonistic models (see Paul [1999b]).

<sup>12</sup> This is an adaptation of the usual  $MRP_k = MFC_k$  (where  $MRP_k$  is the marginal revenue product) equality for profit maximization in an input market when market power exists. In the cost-based model the marginal benefit of a change in  $M$  is captured by the dual shadow value,  $Z_k$ , instead of the primal measure,  $MRP_k$ .

<sup>13</sup> The Lerner index, from Lerner [1934], is discussed in any modern industrial organization text. It is typically written in the form  $(p_Y - MC)/MC$ , so a deviation from zero, rather than from one as for the markup measure, indicates imperfect competition.

<sup>14</sup> An alternative twist on this approach could be to implicitly include the marginal factor cost optimization equation by imbedding the expression for the “effective” price  $MFC = (p_M + M \cdot p'_M / M) = p'_M$  in the GL function. This is similar to the usual approach of including  $p_M$  in the  $G(\cdot)$  function and using Shephard’s lemma to represent optimization, although in this case the lemma would be defined in terms of  $p'_M$ . This may perhaps be a more elegant representation than the framework used in this study, since it explicitly characterizes optimization over  $M$  simultaneously with other input demand decisions, but it does not allow direct consideration of the very short run dependence on existing materials/livestock levels. Also, initial empirical results of such a model generated somewhat more volatile results than those found for the final specification.

<sup>15</sup> See Morrison [1988, 1992] for further consideration of capital fixity issues that are glossed over in this analysis due to the focus on the  $M$  and  $Y$  markets.

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<sup>16</sup> These alternatives for constructing elasticities representing dynamic adjustment, as well as the additional possibility of evaluating the prices at their shadow values, thus imposing equilibrium in price rather than quantity terms, are further discussed in Paul [1999a]. The empirical equivalence of the two primary approximations mentioned here, and the advantage of the chosen method that the elasticities are interpretable as movements from the observed point, are elaborated. The conceptual difficulties of the shadow valuation approach also sometimes invoked for these types of models, based on imposition of the envelope condition, is also discussed.

<sup>17</sup> Note also that theoretically it is analogous to compute a ratio for  $K$  --  $p_K/Z_K$  -- which is the inverse of a “Tobin’s  $q$ ” or  $K$  utilization measure since the wedge between  $p_K$  and  $Z_K$  arises because of quasi-fixity rather than market structure..

<sup>18</sup> See Morrison [1988] and the related literature referred to in that paper for further motivation of the specification of this Euler equation.

<sup>19</sup> See Berndt, Fuss and Waverman [1980] or Morrison and Berndt [1981] for clarification of the underlying steps in this derivation.

<sup>20</sup> Since the estimation was robust to the autocorrelation specification for our data, this essentially collapses to three stage least squares.

<sup>21</sup> Exogenous variables such as population, import prices, and income did not seem in preliminary estimation to be important determinants of the demand and supply functions facing firms in this industry. They were also alternatively used for instruments for some models – again with little impact on the results.

<sup>22</sup> The parameter estimates are available from the author upon request.

<sup>23</sup> The data for this study is U.S. 4-digit manufacturing industry data for 1958-91 from the National Bureau of Economic Research (NBER) Productivity database for industry 2011/*Meat Packing Plants*. This database, includes current and constant-dollar measures of output and capital, labor, energy and materials inputs for 450 manufacturing industries, as documented at the NBER website [www.nber.org/nberprod](http://www.nber.org/nberprod). It is worth noting that results for an industry aggregate – even at the 4-digit level – may not reflect plant-level patterns, due to heterogeneity across the industry. However, cost and market structure modeling of a cross-section of plants in the beef packing industry, as discussed in Paul [1999b], suggests that similar patterns to those exhibited in the industry-level data emerge from analysis of these data. Although many production characteristics accommodated in the time series analysis in the current study (such as adjustment costs, technical change, and investment behavior) may not be incorporated in a cross-section analysis, this provides some evidence that the aggregation bias is not driving the results found in this study. This support for a “representative plant” aggregation argument could potentially be due to the degree of homogeneity in the product and input markets in this industry (beef and



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pork carcasses and cuts are produced from cattle and hogs). The national nature of the market (although most plants are concentrated in the plains region, ease and cheapness of transportation make location a relatively low priority issue for this market) may also contribute to this robustness of the overall patterns.

<sup>24</sup> Estimation of this model was also carried out for monopoly- and monopsony- only models. The substantive results were similar for these models.

<sup>25</sup> If monopsony only is allowed for a greater degree of statistical significance is reflected in the monopsony estimates; in particular the  $\beta_M$  coefficient is the right sign to indicate monopsony power and is significant. Thus overall (net) market power is evident even if it cannot directly be attributable to input markets in a monopoly/monopsony specification. Also, utilization economies tend to counteract the apparent monopsony impact, in the sense that the technological economies exceed the pecuniary diseconomies from increasing cattle input, and thus throughput and ultimately output.

<sup>26</sup> This suggests some over- rather than under-capitalization in this industry. Since overall adjustment costs from the Euler equation are significant, but the magnitude seems small, this may imply indivisibilities or “lumpiness” of the capital stock that makes it optimal to maintain somewhat high K levels.

<sup>27</sup> Olley and Pakes [1996] looked at the linkage between entry and exit and productivity in the context of production function estimation across plants for the telecommunications industry. They found that exit of less productive plants was dependent on their productivity, so that efficiency changes largely stemmed from exit of these less productive plants or of reallocation of capital toward more productive establishments, rather than increased productivity of existing plants. Although the aggregate level of the data used here for analysis precludes direct consideration of such plant-level dynamics, the results are generally consistent with this hypothesis if one interprets the evidence in the context of a representative plant. The greater cost efficiency and reduction in potential further gains from expansion evident over time could well be a result of both movements down existing long run cost curves (shifts downward of SAC from increasing K) and shifts down in unit costs of the average plant from exit of less efficient plants.

<sup>28</sup> These models are well summarized by, and often largely attributed to, Bresnahan [1989].

<sup>29</sup> See also Gilbert [1989] for a useful discussion of how effective competition may work even in an industry in which the potential exists for abuse of market power.

<sup>30</sup> This study incorporates market power in terms of oligopoly/oligopsony through conceptual variation parameters, but is therefore unable to include as detailed a specification of the cost structure in the analysis.