Cost Economies and Market Power in U.S. Beef Packing

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Giannini Foundation Monograph Number 44

May 2000

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CALIFORNIA AGRICULTURE EXPERIMENT STATION
OAKLAND, CALIFORNIA

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1. INTRODUCTION

Concerns about market power in the beef packing industry, and its impact on both producers of farm inputs (cattle) and consumers of beef products, have been raised in the United States for more than a century. As highlighted by Azzam and Schroeter [1997], in 1888, the US Senate adopted a resolution to "examine fully all the questions touching the meat products of the United States," and especially to investigate whether "there exists or has existed any combination of any kind…by reason of which the prices of beef and beef cattle have been so controlled or affected as to diminish the price paid the producer without lessening the cost of meat to the consumer." In the 1990s, these concerns have again come to the forefront due to dramatic increases in concentration in this industry since the late 1970s.

Concentration levels dropped from their peak in 1888 when the "Big Four slaughtered 89 percent of the cattle in Chicago and produced two-thirds of the country's dressed beef supply," to a low in 1977 "with 22 percent of cattle slaughter and 20 percent of fed steer and heifer slaughter controlled by the four largest packers" (Azzam and Schroeter, p. 26). Then, with the advent of new production processes, concentration levels again began to escalate. In particular, more fabrication was evident with a move toward "boxed beef" production (individually packaged cuts rather than carcasses as the primary output). Low capacity utilization levels also prevailed, due to falling demand for red meat products. These and other factors resulted in a wave of consolidation, where the share of the top four packers rose to 82 percent in 1994.

The resulting perception, as in the late 1800s, is that this has reduced the welfare of the agricultural community through lower cattle prices to farmers than would have existed in a competitive environment. Some have also blamed the apparent lack of competition in this industry for higher consumer prices for beef products than can be attributed just to the strength of meat demand.

These concerns raised by observed market structure trends are based on the specter of an "abuse of market power" in both output and input markets, including the potential for excess markups of output prices and markdowns of input prices from those that would prevail under more competitive conditions. Allegations of lack of competition and abuse of market power have, however, been tempered somewhat by the recognition that consolidation could have potentially been caused by efficiency gains, supporting lower cost production and greater productivity than otherwise would be possible.

That is, the technological base could be such that cost efficiencies are captured by large producers (plants and firms) if cost economies exist in the industry. Such economies could include utilization (short run), scale (long run), or size (differential input composition) economies, scope economies, and multiplant economies. If these types of cost economies are evident, lower costs allowed by large-scale, diversified, and joint operations could potentially be passed on in the form of better market conditions for both consumers of final products and producers of primary inputs (cattle).

If such efficiencies or economies exist, however, the usual "test" for market power based on the deviation between price and marginal cost (for an output, or similarly the price and shadow value for an input) may be misleading. Specifically, the impacts of cost economies on the gap between marginal and average costs are important to recognize and measure for appropriate evaluation and interpretation of production (technological and market) structure, and its implications for consumer and farmer welfare.

Characterization of the cost structure is therefore a crucial part of the puzzle when evaluating "the questions touching the meat products of the United States" (as stated in the 1888 US Senate resolution) – especially, the causes and welfare consequences of concentration or market power. To pursue this characterization, in this study we have used cost and revenue data from a USDA/GIPSA (Grain Inspection, Packers and Stockyards Administration) survey of US beef packing plants to carry out a detailed analysis of the production structure of these plants, with a particular focus on measures of cost economies and market power.

The methodological approach is based on a cost function model of plants in this industry, with profit maximization over cattle purchases, and fabricated (boxed beef), slaughter (carcasses), hide, and byproduct output production incorporated. Various technological and market structure characteristics have been recognized in the model to allow their impacts to be estimated. Cost economies from short-run, long-run, and input-biased scale economies, as well as jointness deriving from output diversification (scope economies) and spillovers across plants (multiplant economies) are accommodated and measured. Market power parameters for (fabricated) outputs and cattle inputs are estimated to facilitate evaluation of output price markups and input (cattle) price markdowns due to monopoly and monopsony power. A cattle-price relationship is included to allow for conditions specifically related to the cattle market. Regional, firm, and monthly differences are taken into account as "fixed effects" through dummy variables, as are differences in output and input structure (for example if plants sell only fabricated or only slaughter output).

Empirical findings about the crucial market power and cost economy characteristics in the industry are very robust. Across various model specifications, virtually no evidence is found for monopsony behavior. The only indication of market power appears in the output market for fabricated products, for which the average markup is about 9 percent. Measured technological cost economies (of approximately 4 percent when increased throughput and thus capacity utilization are taken into account) also underlie or support any observed "market power" measured by a price-marginal cost ratio, in the sense that they cause marginal costs to be significantly lower than average costs.

These and other cost measures indicate that output increases may, on average, be accomplished with a 4 to 8 percent smaller proportionate increase in costs in an existing plant (depending on whether the margin is evaluated before or after full adjustment of cattle throughput levels). So, raising capacity utilization reduces marginal input costs appreciably. Further economies seem possible, on average, from increasing the size of plant. Scope economies from joint production also contribute significantly to efficiency, especially when byproduct and hide output production is recognized, and, particularly, for larger plants. Overall, larger and more diversified plants appear to be more efficient, as long as high utilization levels are maintained.[1]

The conclusion that little substantive monopsony power exists is based in part on small perceived markdowns at existing utilization levels. However, when the potential to take advantage of cost savings from increasing capacity utilization is accommodated, the resulting full price ratio measure indicates that a somewhat higher price is paid (on average for an incremental unit of cattle) than would be suggested by the shadow value without such adjustment.

Finally, firm, monthly, regional, and categorical dummies are almost invariably statistically significant. However, they are also small in terms of magnitude and impact on the overall patterns (especially monthly effects). Small multi-plant economies or firm effects prevail for the three largest firms. Regional variation exists, especially when compared to eastern plants, but cost patterns are, on average, similar across other regions (plants in the West and the Western Corn Belt produce at about 1.6 to 1.7 percent lower costs, and in the Plains about 2.6 percent lower costs, than in the East). Clear structural differences also appear for plants that use a lot of purchased or transferred "intermediate" beef compared to those that do not, and for plants that sell only slaughter or only fabricated output.[2] And plants that purchase larger quantities of intermediate meat products tend to produce more fabricated output, which contributes to cost efficiency.

[1] "Long-run" scale economy measures suggest that the optimal size of the average plant would be slightly smaller than is evident (average long-run marginal diseconomies of 2 percent are estimated). However, the long-run estimates are less definitive than other measures, due to difficulties in measuring the true value of the physical capital input.

[2] However, much of this seems to be size-related; large plants are more likely to have joint production and to either purchase or transfer intermediate beef products.

2. OVERVIEW OF METHODOLOGICAL ISSUES

Modeling and measuring cost economies (the cost-output relationship) and monopsony/monopoly power ("markdowns"/"markups" of price paid/received below/above the marginal benefit/cost to the firm) in beef packing plants requires a detailed model of the technological structure in the industry. The first step toward constructing a model that allows estimation of these aspects of the production structure is to develop a representation of input costs that incorporates cattle input supply conditions and differing types of input and output jointness.

Various forms for this representation were utilized in preliminary investigation to determine which specifications appeared most consistent with the data, and whether the results generated were sensitive to the functional and behavioral assumptions. Although any empirical analysis requires a series of judgement calls about issues such as the construction of output and input data, the theoretical methodology, and the econometric treatment, the substantive results presented in this study were very robust across a wide variety of alternative specifications.

An important initial issue was one of functional form. It is important to account for cattle as a primary input potentially subject to monopsony conditions, for joint (multiple) outputs, and for differential composition of both outputs and inputs across plants. This last matter raises the problem of zero values for arguments of the function, since many plants did not produce (use) at least one of the outputs (inputs).

In particular, many (particularly smaller) plants sell only slaughter or only fabricated output. This heterogeneity causes problems using many standard functional forms such as log-linear approximations. Such functions do not deal well with zero values and the common "fix" of including a very small number instead is not only arbitrary but can cause results to be sensitive to specification.

To accommodate this without generating further problems (such as the need to normalize by an arbitrarily chosen input price to impose regularity conditions, as for a quadratic (Q) form), a variation on the generalized Leontief (GL) form was derived for the underlying cost function. The resulting function embodies the advantages of both the GL from the square-root form in input prices (incorporating linear homogeneity), and the Q from the quadratic form for inputs and outputs specified in levels. So it naturally satisfies the required regularity conditions for a cost function, and deals with zero output values.

The relevance of a profit maximization assumption was also a question. However, preliminary estimation of cost patterns alone, using only the assumption of cost minimization, resulted in estimates that were sensitive to specification, whereas incorporating profit maximizing conditions for the outputs (Y_m) and the cattle input (C) stabilized the results and generated more reasonable implications.

These "netputs" (Y_m and C) are represented as quantity levels in the cost function used in the final analysis, so that the corresponding optimizing equations are pricing relationships. Such equations are based on conventional $p_{Ym} = MC_m$ and $p_j = Z_j$ profit maximizing conditions, where p_{Ym}, p_j are output m and input j prices, MC_m is the marginal cost of output m and Z_j is the shadow value of input j (the dual of the value marginal product VMP_j). In this form, however, these optimizing conditions are based on assuming perfect competition in the output and cattle input markets. To adapt these equations to allow for the potential for market power, "wedges" between the prices and their marginal costs or values are incorporated.

In the output market, for example, this requires allowing for a deviation between p_{Ym} and marginal revenue (MR_m) if p_{Ym} depends on the production level of Y_m ($p_{Ym} = p_{Ym}(Y_m)$) rather than being exogenous to the plant. The associated deviation between price and marginal revenue, and thus price and marginal cost (since $MR_m = MC_m$ with profit maximization), is embodied in the expression $MR_m = p_{Ym} + \partial p_{Ym}/\partial Y_m{\cdot}Y_m = MC_m$. The wedge $\partial p_{Ym}/\partial Y_m{\bullet}Y_m$ arises from the reduction in p_{Ym} necessary to sell additional Y_m output when the plant faces a downward sloping demand curve. Estimation of this wedge, and the resulting measurement of monopoly (output market) power, may be accomplished simply by including a parameter representing this difference.

Similarly, monopsony power may be incorporated by recognizing that p_C (the market price of cattle) is dependent on C (the quantity of cattle purchased) if increased demand for cattle by the plant drives up the associated price ($p_C = p_C(C)$). This dependence, in turn, drives a wedge between the price and marginal factor cost (MFC_C) or shadow value of C; $MFC_C = p_C + \partial p_C/\partial C \cdot C = Z_C$. The resulting estimable indicator of input market power ($\partial p_C/\partial C \neq 0$) must therefore be included in the optimization equation, either just as a parameter or through explicit recognition of the input supply function.

Although the representation of output market demand conditions was left in quite a simple form for this study, various determinants of the cattle price or supply relationship $p_C(C)$ were explicitly included in an expression that becomes part of the estimating model. The overall results were very robust to different specifications of this function. The base relationship was assumed to be linear. In the final specification monthly dummies[3], cattle procurement expenses, the number of cattle buyers, the amount of overtime worked, a quality measure, and captive supplies (percentage by weight of packer-fed cattle) were included as indicators of plant-specific market conditions. Other arguments and quadratic (cross and squared) terms provided little explanatory power and thus were deleted from the final specification.

The market power treatment also raised some estimation issues. Systems estimation procedures must be used to take into account joint optimization over multiple outputs and inputs, recognizing cross-equation restrictions. However, incorporating potential market power requires recognizing that the price/quantity decision is a joint one; the manager faces a demand function for an output or a supply function for an input, and the decision of how much to produce/use jointly determines price and quantity. This endogeneity must be accommodated in the estimating method.

This may be accomplished in various ways. In general, however, when external or environmental conditions may affect these relationships – so there are questions about what is endogenous versus exogenous in these models, and what might thus be measured with some error – instrumental variable techniques (IV) seem the most justifiable. In a systems context this suggests the use of three stage least squares (THSLS).[4] This is a useful method to accommodate both omitted market characteristics and possible endogeneity or misspecification of effective output and input prices (especially in dynamic models), as well as endogeneity of both price and quantity in a particular market.

IV techniques allow the incorporation of market power for a variety of netputs without necessitating explicit modeling of demand (output) or supply (input) conditions in each market. This is useful since modeling output demand and input supply conditions in multiple markets can increase the complexity of the model beyond the potential of the data to identify market structure. However, utilizing IV techniques requires making decisions about what instruments to use and how to treat them.

The instruments used are measures of cattle buyers, sales costs, shifts, overtime pay and fringes, and other plant characteristics that do not have a clear role in the estimating equations but provide complementary information about the demand and supply structure. Many of these may be thought of as proxies for unmeasured market conditions, such as the effort made to purchase cattle. Others simply represent plant-specific conditions. Little sensitivity was found from specification tests carried out to assess the effects of adding or deleting particular instruments.

The treatment of capital in the model also required careful consideration. The appropriate measure of the effective capital input was not obvious. The basis for (and thus the comparability of) existing responses in the survey was not clear; some plants did not even report estimates of "replacement cost". Regression estimates were, therefore, derived to link indicators of the effective capital level – maximum slaughter and fabricating rates, the number of slaughter and fabricating shifts, electricity use, and the amount of fabricated output – to an associated measure of available productive capital.

[3] Monthly dummies were not, however, included in the cost equation, since cost conditions other than those for cattle are relatively independent of the time of the year.

[4] Generalized method of moments (GMM) techniques could alternatively be used. This is essentially an extension of THSLS that allows serial correlation to be taken into account. However, such time dependence is not relevant here where the data are in a cross section or panel format. This lack of additional power of the GMM method was evident in preliminary investigation; the THSLS and GMM estimates were virtually identical.

Various functional forms were tried in an attempt to "fit" the relationship as closely as possible. Most of the resulting fitted values matched replacement estimates quite closely. For consistency, fitted values were used for all plants.

Two points should be made about this approximation. First, because capital for a plant does not vary with the time period, it becomes a control rather than an explanatory variable. Thus, capital is not as critical a part of the analysis as it would be for a time series dynamic model where the focus is long-term adjustment and attribution of capital costs. However, plant-level scale economies – the potential to increase cost efficiency by expanding the size of plant (to the long run) rather than utilizing the existing plant – do depend on these values. Results do differ slightly depending on the capital approximation used, despite other findings being relatively insensitive to specification. It should, therefore, be emphasized that the long-run results are not as definitive as other indicators.

Second, fixed effects from other factors may be important; an example is the potential for multi-plant economies or lower costs for plants associated with an "umbrella" firm. Fixed effects were initially handled with simple dummy variables, but, in the final specification, a cattle cross-term was incorporated, so that the cattle-pricing equation also includes firm-specific dummies. The results were not very sensitive to this choice; as for other changes in specification, the fundamental emerging story remained the same. Analogous to the firm effects, regional dummies were incorporated in the cost relationship. And time (month) fixed effects were included in the cattle-pricing specification, as this is where time effects would seem likely to have an impact. All of these additional terms representing fixed effects were statistically significant, but did not affect the basic conclusions about cost economies and market power.

This summary of the issues addressed for construction of the model indicates the types of model variations used in preliminary analysis of the data to assess sensitivity of the results. Overall, the most general models seem more justifiable, and the primary results – the patterns of cost economy and markup/down estimates – are very consistent across specifications. The final model used, its empirical implementation, the measures constructed, and the primary estimates underlying the conclusions about market power and its linkage to cost efficiency, are elaborated in turn in the following four sections.

3. THE PRODUCTION STRUCTURE MODEL IN MORE DETAIL

Representation of the cost structure of US beef packing plants is fundamental for the questions addressed in this study. Various types of cost relationships can be modeled and measured using a detailed cost function. In particular, scale economies are reflected by the slope of the average cost function, or equivalently, the deviation between marginal and average costs. Other types of cost economies are based on cost efficiencies from technological or market "connectedness" or jointness – such as interactions among outputs (scope or specialization economies) or plants (multiplant economies). Evidence of market power – although dependent on the demand (output) or supply (input) structure facing the plant – ultimately is derived from comparing the average price of the output received or input paid and its marginal cost or benefit, which, in turn, depend on the cost structure. For an output, the relevant measure is the marginal cost of producing an incremental unit of the output, and for an input it is the shadow value of an extra unit of the input.

These aspects of the cost structure may be directly represented through a cost function specification. For our purposes, a restricted cost function is appropriate. Because capital costs are essentially fixed in the one-year period under evaluation, the function includes the capital stock (K) as a control or environmental variable. In a sense, this is a plant-specific effect, as it is constant for a given plant. However, because capital intensity and output composition vary across plants, a full set of cross-effects with the capital variable is allowed to accommodate differing capital patterns across plants.

The cost function is also dependent on the input prices faced by the firm, and on the outputs produced. The general form for such a function, therefore, becomes $G(\mathbf{Y},\mathbf{p},\mathbf{r})$, where $\mathbf{Y}$ is a vector of outputs produced, $\mathbf{p}$ is a vector of variable input prices, and $\mathbf{r}$ is a vector of control variables including K.[5] Cattle input (C) is also included in the $\mathbf{r}$ vector for the final reported model, as discussed below.

For this study the $\mathbf{Y}$ vector includes four outputs – slaughter and fabricated meat products (Y_S and Y_F), byproducts (Y_B) and hides (Y_H). The $\mathbf{p}$ vector includes the prices of three inputs – labor (L); energy (E), an index of utility use and expenditures; and purchased intermediate beef products (M_B), where M indicates that this a "materials" input and B denotes "beef". Labor is not divided into slaughter and fabrication categories, as the output division effectively captures this difference. Thus potential problems of allocating labor across categories are alleviated. And discrepancies between hours paid and worked, as well as the linkage of labor input to its associated output, are smoothed with the monthly (as compared to weekly) data used.

The remaining three inputs are treated as $\mathbf{r}$ vector components:

- First, capital (K) is a control variable, as discussed above, and thus is in the $\mathbf{r}$ vector.

- Second, "other" materials inputs (M_O), largely packaging supplies, are reported in dollar values rather than real quantities. Because the data are essentially a one-year cross-section, increases or inflation in prices of M_O are not an issue.[6] Also, the proportion of M_O in total M input is only about 2 percent, so their treatment is not critical. Thus, these inputs are included in the $\mathbf{r}$ vector as values, but are recognized as part of variable or restricted costs, G.[7]

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[5]It is worth emphasizing that representing "total" costs (including fixed capital costs) is not as critical in this cross-sectional analysis as in more typical time series models as measurement of capital trends over time or modeling the "long run" is not as much a focus. The main purpose of representing the long run is to distinguish size from scale economies – to determine whether potential economies are due to (possibly excessive) existing capacity, or may be increased by further capital expansion. Similarly, the typical inclusion in this equation of a "t" variable designed to represent technical change over time is not relevant. An analogous role is played by the **r** variables that identify differences across plants.

[6] These other materials are likely to have a national market so regional differences would not be expected.

[7] Purchased hides are also included in this measure, since it was not possible to appropriately aggregate them into the M_B measure. Note that as an alternative specification, M_O was included as part of the M_B vector to

- Third, the cattle input (C), total chilled carcass weight, is included in the **r** vector as a level or quantity rather than as a price, reflecting its differential (and critical) nature in a plant's optimization process. C is by far the most important input (in terms of cost-share), fundamental to production. Increasing C directly increases capacity utilization, a fact important to model explicitly. The sequential nature of the implied optimization process (as discussed further below) facilitates representing cattle pricing behavior in terms of an "inverse Shephard's lemma" optimization condition, $p_C = Z_C = -\partial G/\partial C$, adapted for market power.[8]

Once the arguments of G(**Y**,**p**,**r**) are specified, a functional form must be chosen. Ideally a function that captures cross-effects among the various inputs and outputs without putting *a priori* restrictions on the shapes of isoquant curves, production functions, and production possibility frontiers is desirable for empirical implementation. There are various flexible functional forms that could be candidates.

For this study a combined generalized Leontief-Quadratic (GL-Q) function was constructed, based on the GL function developed in Morrison [1988]:

$$G(\mathbf{Y},\mathbf{p},\mathbf{r}) = \Sigma_i\Sigma_j\, \alpha_{ij}\, p_i^{.5}\, p_j^{.5} + \Sigma_i\Sigma_m\, \delta_{im}\, p_i\, Y_m + \Sigma_i\Sigma_k\, \delta_{ik}\, p_i\, r_k + \Sigma_i p_i\, (\Sigma_m\Sigma_n\, \gamma_{mn}\, Y_m\, Y_n + \Sigma_m\Sigma_k\, \gamma_{mk}\, Y_m\, r_k + \Sigma_k\Sigma_l\, \gamma_{lk}\, r_k\, r_l). \quad (1)$$

This function accommodates a number of issues. As alluded to in the previous section, the GL has the advantage that the square-root form in the input prices naturally imposes linear homogeneity in prices (the Σp_i terms also are required to satisfy this regularity condition). Thus, the normalization required for the quadratic function (and resulting asymmetry of the input demand functions) is bypassed. The GL-Q function retains this advantage.

However, if zero values for any output or input levels appear in the function and they are also in square root form (as is common for the GL), optimization equations based on a derivative with respect to these arguments cannot be used (zeroes appear in the denominator). Nor can a form based on logarithms, such as the translog, deal with zero values (besides commonly falling subject to problems with correct curvature of the function when input levels are included as arguments). The fact that a number of plants in the study produce no fabricated or no slaughter output creates a potential problem for specifying the output pricing equations. However, the quadratic form of the Y_m variables in the GL-Q avoids this difficulty. Also, unlike functional forms that treat output asymmetrically, like a standard GL form with a single output, this function facilitates including multiple outputs.

Once the cost function is specified, the next issue is how to allow for market power – in particular, monopsony behavior. (The construction of appropriate cost economy and market power measures from these functional relationships is discussed in section V.) Possible output market power may be allowed for as in the monopoly model developed in Morrison [1992]. This involves including a profit maximizing equation (MR = MC, where MR is marginal revenue and MC is marginal cost, $\partial G/\partial Y$), and an inverse demand function p(Y) (to incorporate the output demand structure on which to base computation of $MR = p(Y) + Y \bullet \partial p/\partial Y$)[9] for one output. Extension to multiple outputs is analogous.

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generate a measure of "all materials inputs except cattle." This adaptation hardly affects the main estimated results, so distinguishing them is primarily due to its conceptual justification.

[8] This treatment seems empirically justified by the data because the resulting estimates are very robust and reasonable. Other specifications tried as alternatives, however, such as representing C input demand by including (a market power adapted) p_C in the G(•) function, generated broadly analogous results about monopsony and cost economies.

[9] Note that for oligopoly specifications the $MR = p(Y) + Y\ \partial p/\partial Y$ equality is often adapted to be $MR = p(Y) + \lambda Y\ \partial p/\partial Y$, where λ represents the degree of oligopoly (λ= 1 implies monopoly and λ= 0 competitiveness). In this case, the market power for a representative plant is a combination of λ and $\partial p/\partial Y$. Identifying these two parts of the market structure typically proves problematic, particularly when the output demand side of the

A similar approach can be used in the case of monopsony, as the cost function is expressed in terms of the level or quantity of C. If monopsony exists, and thus p_C is dependent on C ($p_C = p_C(C)$), profit maximization in the C market implies that marginal factor cost, $MFC_C = p_C + C \cdot \partial p_C/\partial C$, is equal to $Z_C = -\partial G/\partial C$, or, to represent pricing behavior more directly, $p_C = -C \cdot \partial p_C/\partial C - \partial G/\partial C$. Such an equation may be included as part of the optimization model to represent both cattle demand behavior and any kind of pricing power. Then, as for monopoly in an output market, price and quantity are determined jointly, given the input supply (average sales price) function facing the plant.

This is a cost-side or dual version of the usual MFC = VMP (value of the marginal product) equality for profit maximization in an input market when market power exists. The marginal benefit of an additional unit of the input, VMP (or marginal revenue product with output market power), is represented by the dual cost-side value (the marginal shadow value of the C input, Z_C). The marginal cost of an incremental change in C (MFC_C) adapts the observed price per unit (average factor cost, p_C) to a marginal value, derived from the sloped input supply function.

This approach to representing input-side market power – or monopsony behavior – allows direct representation of the differential between the observed input price and the price under "competitive" conditions as the $C \cdot \partial p_C/\partial C$ component of the pricing expression $p_C = Z_C - C \cdot \partial p_C/\partial C$, or $p_C - Z_C = C \cdot \partial p_C/\partial C$. This deviation can be thought of as representing the "markdown" of market price below the shadow value when expressed in ratio form $p_C/Z_C = (Z_C - C \cdot \partial p_C/\partial C)/Z_C$. This is analogous to the usual representation of the "markup" of output price over marginal cost $p_Y/MC = (MC - Y \cdot \partial p_Y/\partial Y)/MC$.

Including market power in this manner requires generating an input supply $C(p_C)$ (and thus an inverse supply $p_C(C)$) expression. This could be as simple as a linear form relating p_C and C, so that $\partial p_C/\partial C$ is just a parameter that can be estimated directly within the pricing equation. Ideally, however, the input supply function can be represented as a more complex supply relationship with curvature of the function and the role of "shift" variables (other arguments) of the function being determined by the data.[10]

Such an (inverse) input supply or sales price relationship can be written as:

$$p_C = \alpha_C + \beta_C \cdot C + \beta_{CNB} \cdot NB + \beta_{CP} \cdot PRC + \beta_{COT} \cdot OT + \beta_{CCS} \cdot CS + \beta_{CQU} \cdot QU + \beta_{CCS2} \cdot C \cdot CS + \Sigma_i \delta_M \cdot DUM_M \quad (2)$$

where NB is the number of cattle buyers, PRC is expenditures on cattle procurement, OT is pay for overtime workers, CS is captive supplies (percentage by weight of packer-fed and marketing agreement cattle), QU is quality (percentage of steers and heifers),[11] and DUM_M are monthly dummies. Note that the arguments of this function are not standard input supply determinants, but rather represent characteristics of the sales market. Thus, the interpretation of this equation should be in the context of an (average) sales price relationship, capturing the potential for plants to affect the price, given other characteristics of their market.

Including profit maximization and the potential for output market power follows analogously; as suggested above, the pricing equations become $p_{Ym} = -\partial p_{Ym}/\partial Y_m \cdot Y_m + MC_m$, where $MC_m = \partial G/\partial Y_m$. Specification of the (inverse) output demand functions $p_{Ym}(Y_m)$ is also necessary to identify $\partial p_{Ym}/\partial Y_m$, but this is not as important a part of the analysis for the current application as for the input supply relationship. Because the

market is not definitively modeled. In addition, answering questions about market power involves both of these aspects of market structure, since if competitiveness exists $p_Y = MC$ for each firm and for the industry overall. Thus, the simpler specification seems justified for this application.

[10] This extension appears to be important to facilitate understanding of the sales price relationships and increase the robustness and explanatory power of the model, although the fundamental implications about monopsony remained similar across various specifications tried. The final form includes only one cross-term, because additional quadratic terms tended to be insignificant.

[11] For example, plants with more dairy cattle have lower percentages of steers and heifers, and therefore lower quality. Only one plant in the sample had a negligible percentage of steers and heifers; others varied but the percentages were typically high. An alternate quality variable based on percentage of final product graded choice was also constructed, that more effectively represents "quality" rather than "type" of cattle. This variable was problematic, however, as some plants reported no quality-grade information.

estimating system becomes increasingly complex (and arbitrary) as additional equations representing market conditions external to the production process are added, a simple demand equation for the output markets – where $\partial p_{Ym}/\partial Y_m$ is a single parameter – was assumed for final estimation.

Variants of the model based on differing profit maximization assumptions, including profit maximization with no market power ($\partial p_{Ym}/\partial Y_m$ constrained to zero) and joint or "overall output" profit maximization ($\Sigma_m p_{Ym} = \Sigma_m MC_{Ym}$), were also estimated. Although the less restrictive joint optimization model generated somewhat different implications for long-run behavior, the models otherwise resulted in very similar conclusions, particularly for the crucial monopsony and cost economy implications. The final specification included market power parameters in all output markets except byproducts, Y_B, for which estimates were very volatile across plants. Market power parameters for the hides, Y_H, and slaughter, Y_S, markets were retained in the corresponding pricing equations for completeness, although they tended to be statistically and numerically insignificant.

We now turn to an overview of some of the issues involved for econometrically implementing this framework, and then of measures of cost economies and market power, along with their determinants and consequences, that can be generated from the model.

4. EMPIRICAL IMPLEMENTATION OF THE MODEL

The model specified in the preceding section was initially implemented by deriving input demand equations from the cost function, and estimating these along with the function itself to represent the input cost structure. As the model was subsequently elaborated, dummy variables were added to represent firm- and region-specific effects, and to recognize differences for plants that demanded no M_B input, or produced no Y_F or no Y_S output. Ultimately, profit maximization pricing equations for the Y_F and Y_S outputs and for C were appended to this system, with parameters capturing potential market power in these markets. Finally, the input supply relationship for cattle was explicitly derived and incorporated in this system of equations. All estimations were carried out using data at the monthly level of aggregation, to better represent the linkage between inputs and outputs, and hours paid and worked, than would be possible with weekly data.

To summarize the final estimating system, we will begin with the cost function and then characterize the other equations in turn. The general cost equation (1) was adapted to include dummy variables (fixed effects) for the firms (DUM_f) and regions (DUM_r) as:

$$\begin{aligned} G(\mathbf{Y},\mathbf{p},\mathbf{r},\mathbf{DUM}) = \; & \Sigma_i p_i \cdot C \cdot (\Sigma_r \, \delta_r \, DUM_r + \Sigma_f \, \delta_f \, DUM_f) \\ & + \Sigma_i\Sigma_j \, \alpha_{ij} \, p_i^{.5} \, p_j^{.5} + \Sigma_i\Sigma_m \, \delta_{im} \, p_i \, Y_m + \Sigma_i\Sigma_k \, \delta_{ik} \, p_i \, r_k \\ & + \Sigma_i p_i \, (\Sigma_m\Sigma_n \, \gamma_{mn} \, Y_m \, Y_n + \Sigma_m\Sigma_k \, \gamma_{mk} \, Y_m \, r_k + \Sigma_k\Sigma_l \, \gamma_{lk} \, r_k \, r_l). \qquad (3) \end{aligned}$$

Note that the dummy variables are multiplied by a Σp_i term to retain the property of linear homogeneity in prices (and thus they appear in the labor (L), energy (E), and intermediate beef materials (M_B) input demand equations), and by C (so they also appear in the cattle pricing equation).[12]

Although it is not necessary to estimate the cost function itself, including it in the estimating system typically increases the robustness of the results. Further, because firm- and region-specific characteristics would be expected to affect cost levels, the cost function seems an appropriate vehicle to measure these effects. Therefore, this function becomes the first in the system of estimating equations.

The next set of equations in the system are those for the "variable" inputs, L, E and M_B. Each of these input levels is small relative to average levels of output and the cattle input, but the cost proportion of the M_B input varies dramatically depending on the structure of production – from zero to quite a large component of costs. Thus, it is useful to include two dummies in the M_B demand function representing plants with differing structures, one for plants with zero M_B input and one for those with large M_B levels, assuming the different production structures reflected by these variables act like fixed effects.

The demand equations for these inputs were otherwise constructed according to Shephard's lemma, which shows that for an appropriately defined cost function $v_i = \partial G/\partial p_i$, where v_i is the cost minimizing demand for variable input i (i = E, L, M_B). The resulting demand equations thus depend on all the arguments of G(•), have a specific form which satisfies all theoretically required regularity conditions, and contain appropriate cross-equation parameter restrictions to represent the interactions among input demands.

These three demand equations therefore have the form:

$$\begin{aligned} v_i(\mathbf{Y},\mathbf{p},\mathbf{r},\mathbf{DUM}) = \; & C \cdot (\Sigma_r \delta_r DUM_r + \Sigma_f \delta_f DUM_f) + \Sigma_j \, \alpha_{ij} \, (p_j/p_i)^{.5} + \Sigma_m \, \delta_{im} \, Y_m \\ & + \Sigma_k \, \delta_{ik} \, r_k + \Sigma_m\Sigma_n \, \gamma_{mn} \, Y_m \, Y_n + \Sigma_m\Sigma_k \, \gamma_{mk} \, Y_m \, r_k + \Sigma_k\Sigma_l \, \gamma_{lk} \, r_k \, r_l \qquad (4a) \end{aligned}$$

for i = E,L, and

[12] The primary results were not very sensitive to whether C was included as a multiplicative factor or not, so this adaptation, although somewhat arbitrary, is also quite innocuous. It was retained as any additional information contained in the C pricing equation seems desirable. Including the Y_F and Y_S output levels as cross effects was also tried, but did not substantively affect the results, and was left out of the final specification as these markets are really not the focus of the analysis.

$$M_B(\mathbf{Y},\mathbf{p},\mathbf{r},\mathbf{DUM}) = DUM_{MB0}\bullet\delta_{MB0} + DUM_{MBL}\bullet\delta_{MBL} + C\bullet(\Sigma_r\delta_r DUM_r + \Sigma_f\delta_f DUM_f) + \Sigma_i\, \alpha_{iMB}\,(p_i/p_{MB})^{.5} + \Sigma_m\, \delta_{MBm}\, Y_m + \Sigma_k\, \delta_{MBk}\, r_k + \Sigma_m\Sigma_n\, \gamma_{mn}\, Y_m\, Y_n + \Sigma_m\Sigma_k\, \gamma_{mk}\, Y_m\, r_k + \Sigma_k\Sigma_l\, \gamma_{lk}\, r_k\, r_l \tag{4b}$$

for M_B, where DUM_{MB0} and DUM_{MBL} are dummy variables for $M_B = 0$ and M_B large.

Profit maximizing equations are also included in the system to represent output supply and pricing decisions. If perfect competition existed, such equations would take the form $p_{Ym} = MC_m = \partial G/\partial Y_m$, as alluded to in the previous sections. However, since the potential for plants to take advantage of market power in the output market is of interest, the equations are adapted to take the wedge between marginal revenue and price into account. Because the Y_F and Y_S output levels, like MB, are sometimes equal to zero (some plants do no fabrication, others sell no slaughter output), dummy variables are included in the pricing equations. The resulting equations, based on the implicit assumption of linear output demand functions $p_{Ym}(Y_m)$ facing the plant, take the form:

$$p_{Ym} = -\lambda_{Ym}\bullet Y_m + \delta_{Ym0}\bullet DUM_{Ym0} + \Sigma_i\, \delta_{im}\, p_i + \Sigma_i\, p_i\, (\Sigma_n\, \gamma_{mn}\, Y_n + \Sigma_k\, \gamma_{mk}\, r_k) \tag{5}$$

where m,n = F,S,H,B; DUM_{Ym0} represents the $Y_m= 0$ plants; $\lambda_{Ym} = \partial p_{Ym}/\partial Y_m$, and $\lambda_{YB}= 0$.

The final estimating equation in the system is founded on the input supply function for C, specified as (2) above, included for completeness of the cattle market representation. In addition, the derivative $\partial p_C/\partial C$ is computed from (2) to include in the C pricing equation $p_C = -\partial p_C/\partial C\bullet C - \partial G/\partial C = -\partial p_C/\partial C\bullet C + Z_C$, discussed in previous sections. Thus the equation has the form:

$$p_C = -C\bullet(\beta_C + \beta_{CCS2}\bullet CS) - \Sigma_i p_i\bullet(\Sigma_r\, \delta_r\, DUM_r + \Sigma_f\, \delta_f\, DUM_f) - \Sigma_i\, \delta_{iC}\, p_i - \Sigma_i p_i\, (\Sigma_m\, \gamma_{mC}\, Y_m + \Sigma_l\, \gamma_{lC}\, r_l + 2\bullet\gamma_{CC}\, C). \tag{6}$$

Note that the terms included in (6) depend on the form of (2). Other variables initially included in the input supply relationship (2), including a quadratic C-term, do not appear in (6) because when cross- or interaction-terms for the factors underlying the $p_C(C)$ relationship were included the associated coefficients were insignificant. Nevertheless, because equation (2) is included in the system of estimating equations, measures of the impacts of these shift variables on the position – if not the slope – of the average $p_C(C)$ function are still generated.

The resulting ten equations (2) through (6) – two for cattle input supply, three for input demand (L,E,M_B), four for output profit maximization (Y_F,Y_S,Y_B,Y_H), and the cost function – comprise the final estimating system. When only the cost structure is estimated, the system reduces to equations (3) and (4). Because no simultaneity or endogeneity of left-hand variables is embodied in this smaller system, seemingly unrelated regression (SUR) techniques may be used for estimation.

When equations (5), (6) and (2) are included, and potential market power is recognized, endogeneity issues arise. The plant chooses both price and quantity of the output and input levels, as it faces output demand and input supply functions, rather than just price levels. Then, alternative estimation methods must be used.

One possibility would be to use full-information maximum likelihood (FIML) methods, but then the full demand and supply model for all inputs and outputs would have to be included to complete the model. Thus the output demand functions would have to be more explicitly specified, increasing the possibility of model misspecification.

Also, supplementary information about the differential structure of plants may be captured in measures reported in the base survey, but would have no obvious role as arguments in the supply and demand equations. Such variables could potentially be included as instruments for instrumental variable (IV) estimation, increasing the estimates' robustness and justifiability. Thus IV estimation is an attractive alternative.

Various types of IV estimation may be carried out. Since the model results in a system of equations, however, three stage least squares (THSLS) or some variant of this technique, such as Generalized Method of Moments (GMM) is required. The primary advantage of GMM over THSLS is that it is somewhat more general in terms of the stochastic specification, thus allowing for serial correlation. But for a cross section analysis serial correlation is not an issue, suggesting THSLS is appropriate, even though the monthly estimates for each plant could have a time trend. As it turned out, the two methods generated virtually identical estimates; the final reported estimates are based on THSLS.

The main issue arising when using IV techniques is what to use for instruments. For this study, however, the results are so robust that the instruments do not appear fundamental to the final story. The instruments used in the final analysis were ratios of C, Y_S, Y_F, and M_B to total revenues, *DMSEXP* (distributing, merchandising and sales expenses), *TOTBUYCP* (total compensation of cattle buyers), *FRGCOSTS* (cost of fringe benefits), *CUSTMREV* (revenue from custom cattle slaughter), and *MILLS* (explained below). These variables provide additional information about the structure of production and market characteristics facing a particular plant. *DMSEXP* is an indicator of output demand conditions, *TOTBUYCP* adds information on the intensity of effort devoted to cattle procurement, *FRGCOSTS* represents labor market conditions, and *CUSTMREV* reflects the specialty nature of production.

MILLS is an inverse Mills ratio commonly used as an indicator of sample selection differences across a panel of observations. The notion is that this ratio helps represent factors underlying the decisions of some plants to do just fabrication or just slaughter, or to demand (or not) M_B inputs. The *MILLS* measure was initially constructed and used as an argument in various combinations of equations, with some impact on the results, but a negligible effect on the overall conclusions. In the final estimation, the *MILLS* measure was used as an instrument, to include any information represented by this ratio in as general a form as possible. Again, this was not at all fundamental to the results, but seemed conceptually appropriate.[13]

A final econometric issue has to do with the construction of replacement capital values for the plants that did not report them, and, for consistency, an evaluation of the numbers that were reported in the survey. The effective capital stock available is related to a number of factors, a relationship conceptually similar to that underlying a hedonic model that relates characteristics to measures of the actual or effective quantity of a factor. Such measures can be used to refine existing estimates, as well as to predict the effective level of a factor if there are data only on the characteristics.

There are a number of independent indicators of the effective capital stock level that are "harder" data than are the estimates of replacement values, whose reporting basis is not clear. For example, maximum slaughter or fabrication rates are important indicators of the capital base of a plant. The extent of fabrication will also be related to capital services, because plants that do more fabrication tend to require more capital per unit of output. Electricity use, providing information on both the electricity required to "fire" equipment and to heat or cool structures, also seems to be an important indicator of capital stock. Another good indicator could be information on the number of shifts for a plant.

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[13] The sample selection issue is that this is essentially a two-step procedure; implicitly the plant or firm manager decides whether or not to produce/demand these outputs/inputs, and *then* decides on the optimal level. Because the output decisions are, however, modeled as a price determination procedure rather than input supply decision, the most critical decision to worry about here is that over M_B. The inverse Mills ratio or *MILLS*, was initially used in an attempt to capture this. Typically in a single equation model with a zero-one left hand variable, this sample selection issue is accommodated by doing a PROBIT estimation, obtaining an inverse Mills ratio, which is then used as an argument of the second-stage procedure – or the decision of how *much* output/input to supply/demand. In our more complex estimation process the model is not a zero-one but zero-positive value model for M_B, so TOBIT estimation was initially used on the cost function to obtain a *MILLS* estimate, and then estimation using this as an argument or instrument proceeded over those observations where $M_B \neq 0$. The theory for accomplishing this is not well developed for a model as complicated as that used for this study. Thus various treatments of the estimated *MILLS* measure were used to determine sensitivity to different specifications, and to attempt to "tie down" the results affected by the zero values as effectively as possible.

These variables were used as arguments in regressions for the "replacement" value of capital, carried out in linear form, log form, and with various combinations of squared (quadratic) and cross-terms, for plants that did report a value for K. The final ("best" or most close-fitting) specification was a linear regression of "replacement capital" on *SLTR93* (maximum slaughter rate as of April 3, 1993), *FAB93* (maximum fabricating rate as of April 3, 1993), *NOSLSHFT* (number of slaughter shifts worked), *NOFBSHFT* (number of fabrication shifts worked), *QELEC* (quantity of electricity purchased), *FABTOTVA* (total fabrication value), and squared values of *SLTR93* and *FAB93*.

This relationship was estimated separately from the rest of the model, and the fitted capital values substituted for K in the estimating equations. Although this hedonic-type equation could be estimated as part of the system, this would increase the potential for misspecification. Independent estimation separates errors arising from the approximation of K from those associated with the stochastic nature of the estimating equations. In addition, the K variable is essentially only a plant-specific control variable. The possibility for convoluting the model with extraneous error, combined with the relative unimportance of this variable in the estimation process (in terms of representing patterns within an existing plant), supports the separate estimation of this relationship.

Two final comments should be made about the construction and interpretation of estimates from what is essentially cross-section data. Cost structure estimation is typically based on time series data. Although using cross-section data simplifies the model somewhat because changes in technology and long-run adjustment of capital are virtually irrelevant, other problems arise as comparisons across plants provide only indirect measures of the effect of a *particular* plant's changing its scale of operation. That is, rather than being based on observed changes, estimates must be imputed from information across plants, a procedure complicated by unobserved differences across plants.

These differences have been taken into account to the extent possible by incorporating fixed effects with capital stocks as control variables and plant-specific instruments proxying demand and supply differentials that might cause technological and behavioral variations. Interpretation of results for specific categories, however, should be carried out with some care because unmeasured causes of variation remain.

Also, it should be emphasized that the estimated measures are conceptualized in terms of sequential optimization processes so only the "long-run" estimates provide implications about expanding plant capacity. Imputation of the long run is essentially based on comparison across plants, given the cross-section nature of the data, whereas the estimates of "short-run" behavior may be better interpreted as internal optimization, based on observed within-plant behavior, given the existing capacity constraints. Without time series data, we cannot provide a more specific representation and interpretation of the long run. We will defer further discussion of these issues until the measures used for analysis are formalized in the next subsection.

5. INDICATORS CONSTRUCTED FROM THE ESTIMATED MODEL

5.1. Cost Economy Measures

Measures of cost economies are fundamental for this study and may be represented through elasticities derived from the estimating equations developed in the previous section. The central cost elasticity measure stemming from the model is the elasticity of cost with respect to output, $\varepsilon_{TCY} = \partial \ln TC/\partial \ln Y$, where TC is *total* (rather than variable) costs, as elaborated below. This measure summarizes the full cost-output relationship, and thus reflects all internal cost economies such as utilization, size, scale, and scope economies. Other exogenous factors that could affect costs become shift variables. Multi-plant economies may appear either way, depending on their role in the production process. If they vary across output levels they may be internal and thus appear directly in the ε_{TCY} expression; if fixed effects, they instead act as shift factors.

Two questions arise in the context of the cost economy and market power issues addressed in this study: (1) What type of adjustment or sequential optimization might be implied by such an elasticity, given that the function is specified only in terms of "variable" input prices, with both C and K inputs included as quantity levels?; and (2) How is "output" Y defined with multiple products? The first issue, in particular, requires elaboration. Because this model is conceptualized in terms of the endogeneity of a sequence of decisions, what is assumed constant or restricted at each stage must be addressed.

Note that cost economy measures based on the elasticity $\varepsilon_{TCY} = \partial \ln TC/\partial \ln Y$ are typically interpreted as cost-side scale economies. However, scale economies are a somewhat restricted notion, suggesting proportional adjustment of inputs and long-run behavior. They also bury the issue of how scope economies might be embodied in this measure with multiple outputs.

That is, in simpler models, the cost economy measure ε_{TCY} reflects scale economies by measuring the proportionate change in costs – and thus the use of each input – necessary to support a given proportionate output increase. If a 1 percent increase in output requires (in the long run) 1 percent increases in all inputs and thus in costs, constant returns to scale would be implied and $\varepsilon_{TCY} = 1$. If scale economies exist, then costs do not increase proportionately to output, and $\varepsilon_{TCY} < 1$.

However, in this more comprehensive model, additional issues arise when defining and interpreting ε_{TCY}. First, if some input(s) such as capital are restricted or fixed in the short run, the ε_{TCY} measure may reflect short-run behavior and thus utilization changes. Similarly, with sequential optimization (output increases stimulate second-order increases in cattle demand, for example), this multiple-stage process must explicitly be built into the ε_{TCY} measure. Second, if there are scale biases (output increases are supported by proportionately differential input changes), there may be a difference between size and scale economies.[14] Economies may also arise due to output mix. Jointness in production and resulting scope economies (or, in reverse, economies of specialization) could mean the extent of cost economies differs depending on the composition of output changes. These types of *technological* economies are conceptually different from the standard notion of long-run scale economies, and should be distinguished both theoretically and empirically, but all will appear as part of the overall cost economy measure ε_{TCY}.

[14] This distinction will not be emphasized in this document, although it is often made in the agricultural economics literature. Differences in adjustment across inputs could arise due to changes in technological efficiencies as scale (output) levels increase (isoquants are sloped differently as one moves out the isoquant map, and thus optimal input composition changes). It might alternatively be the case that restrictions on some inputs impose constraints on adjustment, so that as output changes, the plant or firm is unable to move immediately along the scale expansion path but instead optimizes, given the restrictions. In the latter case, the differences may be conceptually equivalent to utilization changes due to short-run fixities. The important issue, however, is to untangle these differing technological and adjustment factors underlying the evidence of cost economies contained in the ε_{TCY} measure.

In addition, *pecuniary* economies (or diseconomies) may exist if input prices are dependent on the amount purchased (such as $p_C(C)$ here). In this case ε_{TCY} will depend on the marginal factor cost (MFC_C) instead of p_C. If, for example, monopsony power exists, production of greater Y (and thus C) levels will only be possible at higher factor costs, and the associated increase in cattle prices will appear in the ε_{TCY} measure.

More formally, we can trace through and identify the technical and market forces underlying the overall cost economy measure by carefully considering how they might individually be represented within our cost structure model. When basing analysis on a restricted cost function model, total costs (TC) are defined as $TC = G(\bullet) + \Sigma_k p_k r_k$, where the r_k represent any inputs included in the function as a quantity that is subject to adjustment, thus forming part of the definition of restricted costs. For our model, therefore, $TC = G(\bullet) + p_C(C)C + p_K K$, for which a difference emerges between cost economies measured at given levels of K and C, and those measured with adjustment of these factors recognized. However, if these inputs are close to their optimal levels, and, particularly, if input adjustment is explicitly included in the model structure, and thereby endogenous, the difference will be small, unless large discrete changes are approximated.

Specifically, in the "short run," from the restricted cost function evaluated at observed **r** levels, the cost economy elasticity (for the moment based on a single output, Y) becomes $\varepsilon^S_{TCY} = \partial G/\partial Y \bullet (Y/TC)$, as only $G(\bullet)$ explicitly depends on Y. This measure is based on the existing levels of C and K, and thus is often motivated as reflecting movement along a short-run cost curve, with "fixed inputs" constant. However, if an input quantity level is included in the function due to a difference in the optimization assumption rather than short-run fixity, the implication is not quite the same.

For the C input, in particular, the conceptual basis for including C as a quantity in the cost function is that pricing behavior and a deviation from perfect competition, rather than input demand based on a given market price, is the appropriate assumption. This violation of Shephard's lemma does not, however, imply a time-oriented restriction or fixity; C input use is assumed in the empirical model to adjust at any point to given market conditions. The estimates, therefore, reflect equilibrium in the C market, including recognition of the dependence of p_C on C. The model represents this equilibrium in terms of profit maximizing pricing behavior as a second stage of the contemporaneous optimization process.

If, however, we wish to represent adjustment to a *change* in economic conditions, such as a change in Y for the cost elasticity ε_{TCY}, the direct measure based on $G(\bullet)$ is evaluated at the existing level of C rather than embodying the resulting optimization in the C market. On the margin, the envelope condition suggests that there will be little difference from that incorporating the full equilibrium response for this input (actually, no difference if the model is truly continuous or evaluation of the function is at the fitted value of C). However, for a discrete change evaluated from observed C levels, the C demand (and thus pricing) response to the output change should be embodied in the cost economy elasticity ε^S_{TCY} to reflect the full cost-output relationship.

The resulting expression may be called an "intermediate run" elasticity, ε^I_{TCY} (see Paul [1999a,d]), as it explicitly incorporates the underlying sequential optimization, although it does not imply a time lag in the adjustment process. This measure is thus the most appropriate representation of potential cost economies for an existing plant, but the distinction between the short (S) and intermediate (I) measures facilitates interpretation about adjustment processes and the impacts of utilization changes.

The intermediate (I) measure can be constructed in various ways, including substituting the optimal fitted level for C derived from the pricing expression into $G(\bullet)$, or using a "combined" elasticity that directly appends the adjustment of C due to a change in output.[15] These approaches to the problem generally are very similar empirically (see Paul [1999a]), but the latter seems conceptually more appealing.

This method is based on the chain rule of differentiation. Since the desired level of C depends on the output produced, the $G(\bullet)$ function may be written as $G(\bullet,Y,C(Y))$,

[15] If the expression for the desired C value from the optimal pricing equation is substituted in the second part of the ε^I_{TCY} measure the $\partial TC/\partial C$ derivative becomes zero and the I elasticity collapses to the S elasticity evaluated at the fitted C levels.

where (•) represents all other arguments of the function. Thus, the cost elasticity becomes: $\varepsilon^{I}_{TCY} = [\partial TC/\partial Y + \partial TC/\partial C \ \partial C/\partial Y](Y/TC)$, where the term $\partial C/\partial Y$ comes from solving the C pricing equation (6) for the implied desired level of C, and taking the derivative.

For this study the differences between the short and intermediate run measures are typically small, so the implied endogeneity of C is effectively embodied in the model. Because the intermediate elasticity measures are conceptually more justifiable, they are presented below in the summary results tables as the primary cost economy measures. The restricted short-run measures are presented in the appendix tables to aid in interpretation.

A similar argument may be made for imputing a long-run elasticity taking capital adjustment into account. In this case K is *not* considered an (immediately) endogenous variable, so substantive subequilibrium could exist (K may be at a non-optimal level in the short run, given output demands). Thus the short- (or intermediate-) and long-run elasticities would be likely to differ.

Accommodating capital adjustment to the implied long run is based on the notion that at the desired long-run level of capital, the shadow value and price of capital are equilibrated. This implies that the cost economy measure incorporating long run K adjustment may be constructed by solving the shadow value equation $p_K = Z_K = -\partial G/\partial K$ for the desired level of K, and taking the derivative $\partial K/\partial Y$ to substitute into the expression $\varepsilon^{L}_{TCY} = [\partial TC/\partial Y + \partial TC/\partial C \ \partial C/\partial Y + \partial TC/\partial K \ \partial K/\partial Y](Y/TC)$ (see, for example, Morrison [1985]).

As alluded to above, our imputation of the long run is not as justifiable as would be the case if we had more appropriate data on capital and the price of capital, and time series data for the plants. The user cost of capital, p_K (discussed in the data supplement) for this computation was simply assumed to be 0.185, based on the notion that the user price should be the investment price p_I multiplied by $r+\delta$, (where r is the rate of return to investment, δ is the percentage depreciation rate, and $p_I = 1$ as there is no deflator for a cross-section). This qualification about the p_K computation, combined with questions about the K data raised above, suggest that the resulting long-run measures should be viewed with some skepticism. However, these are not crucial estimates for the questions addressed in this study; the restricted cost notion suffices for most issues of interest. Further, the resulting long-run cost economy estimates ε^{L}_{TCY} presented in the Appendix C tables are generally quite reasonable, supporting their use at least to indicate the direction of long-run change.

The second primary issue raised above about the cost economy measures has to do with the multi-output nature of the model, that implies multiple "scale" measures. However, these may simply be combined as in Baumol, Panzar and Willig [1982] (BPW) to generate an overall scale- (or in our case cost-) economy measure. Such a measure is typically expressed as the (inverse of the) BPW measure $SG = 1/S(Y) = \Sigma_m Y_m TC_m(\mathbf{Y})/TC(\mathbf{Y})$, where $TC_m = \partial TC/\partial Y_m$.[16] This can be rewritten more analogously to ε_{TCY} above as: $\varepsilon_{TCY} = \Sigma_m \ \partial TC/\partial Y_m \bullet (Y_m/TC)$. Note, however, that refinements overviewed above about the overall ε_{TCY} measure now pertain to each of the $\varepsilon_{TCYm} = \partial TC/\partial Y_m \bullet (Y_m/TC)$ measures. And that information on scope economies is also embodied in this ε_{TCY} measure since each $\partial TC/\partial Y_m$ derivative includes cross-terms with other outputs.

That is, scope economies (SC) involve jointness of output production implied by the cross-output terms in the cost function. Following Fernandez-Cornejo *et al* [1992] (our static measure is analogous to their dynamic one), this measure may be written as $SC = ([\Sigma_m TC(Y_m) - TC(\mathbf{Y})]/TC(\mathbf{Y}))$, where $TC(Y_m)$ is the minimum cost of producing output Y_m. Because the difference between TC for each output separately and combined

[16] This is written in terms of 1/S(Y) instead of S(Y) since BPW defined scale economies as the inverse of the cost-side scale measure, $1/\varepsilon_{TCY}$, in order to more closely relate it to the usual expression for scale economies. Clearly, either is appropriate as long as the interpretation is adapted. Because we have expressed scale economies in terms of costs, this orientation is retained here. Thus, if ε_{TCY}, our scale economy measure, falls short of one, scale economies are implied – costs (and therefore inputs) do not increase proportionately to output increases.

simply depends on the cross-cost parameters γ_{mn}, this measure is ultimately dependent on the second derivatives $\partial^2TC/\partial Y_m\partial Y_n = \partial^2G/\partial Y_m\partial Y_n$.

Since $\partial G/\partial Y_F$ is, for example, the marginal cost of producing Y_F, the second derivative $\partial^2G/\partial Y_F\partial Y_S$ essentially asks whether this marginal cost is less (or greater) if production of slaughter output Y_S is being carried out in the same plant. In the first case, scope economies prevail (joint production is cheaper, due to some kind of "connectedness" of input use), and in the second case specialization economies are evident.

Finally, in addition to the various cost economy aspects contained in the ε_{TCY} measures, exhibited cost efficiency may depend on multi-plant economies, represented by fixed effects. Although most of the firms in the GIPSA sample are single-plant firms, five are multi-plant, with three having more than two plants. This suggests that cost economies may be derived from expanding the number of plants under the control of one firm, implying jointness among plants or spillovers. This could involve increasing (input and output) market power or borrowing power (more control in *financial* markets) from consolidation, as well as the ability to spread overhead marketing and management costs across plants.

The measurement of firm effects or multi-plant economies is not well motivated in the literature. Including these as fixed cost effects through the DUM_f and DUM_r variables in equation (3) facilitates the characterization of such economies as a cost shift from being associated with a particular firm, or $\partial G/\partial DUM_f$. Given input price and cattle supply conditions, if this measure is negative (positive), it suggests that costs for plants connected with that firm have lower (higher) costs.

5.2. Market Power Measures

The second group of other primary measures generated for this study are the market power and, especially, monopsony measures. Formally, these measures are again based on elasticities with respect to output and input levels, but, in this case, they are with respect to functions representing market conditions in addition to costs.

For example, in the most familiar case of market power in an output market – monopoly – output price deviates from marginal cost and marginal revenue; monopoly optimization is represented by MR = MC instead of p_Y = MC. As discussed above, the difference between p_Y and MR is due to the "wedge" $Y\bullet\partial p_Y/\partial Y$, from the definition of MR as: $\partial TR/\partial Y = \partial p_Y(Y)Y/\partial Y = p_Y + Y\bullet\partial p_Y/\partial Y$. Thus, the market power wedge can be thought of as deriving only from the $p_Y(Y)$ relationship, although it implicitly also is based on MC and the cost function through the p_Y - MC distinction.

Since the MR = MC equality can be written as $p_Y = -Y\bullet\partial p_Y/\partial Y + MC = -Y\bullet\partial p_Y/\partial Y + \partial TC/\partial Y$, the impact of output market power can be modeled and measured as the markup of price over marginal cost through the ratio $Prat_Y = p_Y/MC = (-Y\bullet\partial p_Y/\partial Y + \partial TC/\partial Y)/\partial TC/\partial Y$ (where "rat" denotes "ratio"). This measure embodies the same information as a Lerner index. If it is statistically significant and exceeds one, market power may be inferred, with the deviation of the measure from one interpreted as a percentage markup.

Similar treatments can be developed for the cases of monopsony and multiple outputs. First, for monopsony in the cattle market the relevant "markdown" measure, to represent the amount a plant facing an upward sloping input supply function would hold the price down below its true marginal benefit from the input, would be $Prat_C = p_C/Z_C = p_C/(-\partial G/\partial C)$. Because, analogous to the monopoly case, we have found that for the C input $MFC_C = p_C + C\bullet\partial p_C/\partial C = Z_C = -\partial G/\partial C$, or $p_C = -C\bullet\partial p_C/\partial C - \partial G/\partial C$, this price ratio can be computed as $(-C\bullet\partial p_C/\partial C - \partial G/\partial C)/(-\partial G/\partial C)$. If this measure significantly falls short of one, markdowns are evident and monopsony power appears to exist. The magnitude of the deviation indicates the percentage markdown from the price that could feasibly be paid on the margin, given the incremental benefit to the plant of additional C input.

Markup measures may also be constructed for multiple outputs. The marginal cost of any particular output can be defined as $MC_m = \partial TC/\partial Y_m = \partial G/\partial Y_m$, analogous to the single output case. And the wedge from market power, $Y_m \bullet \partial p_{Ym}/\partial Y_m$, may be derived from the associated price relationships $p_{Ym}(Y_m)$. Combining this results in the output-specific markup or price ratio equations $Prat_{Ym} = p_{Ym}/MC_m = (-Y_m \bullet \partial p_{Ym}/\partial Y_m + \partial TC/\partial Y_m)/\partial TC/\partial Y_m$.

Constructing an overall markup measure from these individual price ratios is analogous the development of the BPW cost economy measure. Recall that the BPW measure is written $\varepsilon^I_{TCY} = \Sigma_m \partial TC^I/\partial Y_m (Y_m/TC)$, or $\Sigma_m MC^I_m Y_m/TC$ (including the "I" superscript to explicitly recognize the C adjustment). Thus, a comparable price margin measure is $P^M rat_Y = \Sigma_m p_{Ym} Y_m/\Sigma_m MC^I_m Y_m$ when multiple outputs are taken into account.

The output- and input-oriented market power measures, therefore, depend on the cost elasticities with respect to Y_m ($MC_m = \partial G/\partial Y_m$) and C ($Z_C = -\partial G/\partial C$),[17] as well as the own elasticities of the (inverse) output demand and input supply functions ($\varepsilon_{pYmYm} = \partial \ln p_{Ym}/\partial \ln Y_m = \partial p_{Ym}/\partial Y_m \bullet (Y_m/p_{Ym})$, so $\varepsilon_{pYmYm} \bullet p_{Ym} = \partial p_{Ym}/\partial Y_m \bullet Y_m$, and $\varepsilon_{pCC} = \partial \ln p_C/\partial \ln C = \partial p_C/\partial C \bullet (C/p_C)$, so $\varepsilon_{pCC} \bullet p_C = \partial p_C/\partial C \bullet C$). Once these relationships are estimated, market power measures may easily be computed based on the derivatives of the functions.

[17] Similarly to other measures here, the cost elasticities embodied in the market power measures may also be computed in terms of intermediate- and long-run marginal costs. However, since the markup or markdown measures more fundamentally depend on the output demand or input supply elasticities, this is unlikely to make much difference.

6. FURTHER MEASUREMENT AND INTERPRETATION ISSUES

6.1. Linkages among cost economy and market power measures

An important point to emphasize about the cost economy and market power measures developed above is that they are all connected. For example, a standard Lerner index is not fully appropriate when monopsony power exists, as the MC measure used for construction of the index embodies these pecuniary economies; MC depends on the marginal factor cost of the input subject to monopsony power (MFC_C) rather than the observed average price (p_C). Similarly, any scale or scope economies will be incorporated in the MC computation, causing marginal and average costs to differ, thereby convoluting the implications of market power abuse or lack of competition. Standard market power measures may therefore potentially be misleading if these types of technological and market structure characteristics are not effectively modeled and measured.

The usual connotation of the term "market power" is that something is "wrong" – that firms or plants are taking advantage of a strong presence in the market to make excessive profits by charging high prices for their outputs or paying low prices for their inputs. This is appropriate if the technological and market structure is such that the true net benefit to the plant of a decision – such as whether to purchase an additional unit of cattle – is represented by the marginal valuation, and this value is not passed on to (in this case) the seller of the commodity. However, there may not be a problem – in terms of market power generating excessive profits – if the marginal cost-benefit deviation arises from the cost structure of plants. In this case, the marginal deviation may arise from marginal cost efficiencies allowed by technological processes, rather than an ability to generate more revenue than is justified by the cost base due to a high market share.

To expand on this, first let us refine the notion of the net benefit from the purchase of a unit of cattle or sale of a unit of product. Since the latter is usually more familiar, in the context of a one-output model, we will initially use this scenario for motivation.

The inference of an abuse of market power in an output market typically is based on the notion that price exceeds marginal cost (p_Y>MC). Since MC is the cost of producing the incremental unit of a particular output, this suggests "excess" profits are being made on that unit of production. This is true if the technology is such that constant returns to scale (with appropriate qualifications to generalize this notion for a more complex cost model) prevail, so marginal and average costs are equal. If instead scale economies exist so the average cost (AC) curve slopes down, MC must by definition fall short of AC. Therefore, for long-term survival in the market, price must cover average cost for even zero economic profits to be made, so traditional market power measures may be misleading in the context of an abuse of market power or excessive profitability. In fact, a price-cost margin may be due to cost efficiencies allowed by the technological base, and thus could be beneficial overall.

This fairly standard argument, often attributed initially to Demsetz [1973], gains layers of potential interpretability, but also associated increased complexity, when more aspects of the cost structure are represented. Then, the interactions among, and distinctions between, the various factors affecting cost economies must be carefully disentangled for appropriate interpretation and use of the resulting market power measures.

As we have seen, for example, a deviation between MC and AC is particularly likely to exist in the short run with some restricted inputs, as in the beef packing industry (incorporated in our model). In this case, increasing output may allow more efficient use of the fixed factor (say, capital plant and equipment), or better utilization of the existing capacity. The most optimal or "economical" production decisions must then be made, recognizing this short-run fixity that affects the computation and interpretation of MC and thus of market power measures.

Some types of fixities extend to the long run, typically defined as the point where all factors under control of the firm are at their optimal or "best" levels. In this case, cost economies (deviations between MC and AC) may still exist due to more efficient use of, say, managerial inputs, even though the existing levels of these inputs are at their steady state levels, given perceived output demand. This generates long-run scale economies that must be recognized when measuring and using standard market power measures.

A related issue is that cost economies and MC-AC discrepancies may also be due to technological factors such as jointness or "lumpiness" of inputs. For example, if two pieces of machinery are complementary, so that they are more effectively used in combination, the firm may find it economical to purchase both pieces of machinery over a wide range of output levels, even though they are in a sense "better used" at higher ones. Similarly, it may be the case that is it necessary to purchase a large piece of capital machinery to be cost effective, even though the machinery would be most efficient with high throughput. This discreteness or "lumpiness" of capital (and the technology embodied in the capital) may also result in short- or even long-run cost economies, and thus requires careful adaptation and interpretation of market power measures based on measured MC.

These types of scale-based cost economies are further complicated by the other aspects of cost economies we have discussed. For example, with multiple outputs any measure of marginal cost for one output is conditional on the level of other outputs, and, therefore, depends on their jointness – or scope economies. If measures of total cost economies include economies of scope as well as scale, a full cost analysis is crucial, as are interpretation and application of the measures to market power issues, to independently identify these components of cost economies.

Similarly, in the case of technological versus pecuniary (dis)economies, it must be explicitly recognized that if when output and corresponding C input use expands, p_C is affected, then this distinction must be built directly into the model in order to independently assess these special characteristics of the production structure. That is, the total cost measure ε^I_{TCY}, characterized with $p_C(C)$ incorporated, will depend on MFC_C, so the difference between the measure evaluated at MFC_C and at $AFC_C = p_C$ should be identified separately from other factors affecting MC as a pecuniary diseconomy effect.[18]

These kinds of interpretational matters suggest the importance of untangling technological and market structure characteristics for careful representation and analysis of the production structure issues addressed in this study. In particular, identifying the various types of technological and pecuniary economies embodied in the cost structure is the purpose of a detailed cost analysis culminating in a decomposition of overall cost economies. The bottom line, however, is that if such economies exist, output price exceeding marginal cost or input price falling short of marginal factor cost does not necessarily imply abuse of market power or excessive profitability. It may, in fact, reflect cost savings allowed by expanding the scale of production. Although marginal values are the basis for profit maximization, average values determine the extent of profitability.

[18] This also highlights the importance of representing the cost elasticities in terms of total costs. Although including capital costs, $p_K K$, is not as important here as for more aggregated time series studies, appending the $p_C(C)C$ component of costs to the G(•) specification is crucial for appropriate interpretation of the resulting estimates.

6.2. Sub- and combination-production structure measures

Formally, constructing sub-measures to allow detailed evaluation of cost structure relationships can be pursued by initially unraveling the components of the overall cost economy measure $\varepsilon_{TCY} = \partial \ln TC/\partial \ln Y = \partial TC/\partial Y \bullet (Y/TC)$, and then evaluating their impact on output and input price and cost margins. First, consider the cost function underling the ε_{TCY} measure. Recall that total costs were defined as $TC = G(\mathbf{Y},\mathbf{p},\mathbf{r}) + p_C(C)C + p_K K$. Cost economies reflected in the $\varepsilon_{TCY} = \partial \ln TC/\partial \ln Y$ measure, therefore, depend on the individual short-run changes, $\partial G/\partial Y_m$; interactions among the Y_m variables (scope economies); the "intermediate" adjustment of the C input necessary to support output increases, $\partial C/\partial Y_m$; adaptations in p_C resulting from changes in C, $\partial p_C/\partial C$; and finally the long-run adjustment of the capital stock to its "desired" level corresponding to the new output level, $\partial K/\partial Y_m$. Each of these impacts can be identified independently by constructing these derivatives or the associated elasticities.

In particular, as developed in the previous section, the short-run measure $\varepsilon^S_{TCY} = [\partial G/\partial Y](Y/TC)$ as defined does not capture C or K adjustment. Rather, these adjustments are embodied in the combination long-run elasticity $\varepsilon^L_{TCY} = [\partial TC/\partial Y + \partial TC/\partial C\ \partial C/\partial Y + \partial TC/\partial K\ \partial K/\partial Y](Y/TC)$. The most appropriate representation of current potential cost economies is the intermediate elasticity, $\varepsilon^I_{TCY} = [\partial TC/\partial Y + \partial TC/\partial C\ \partial C/\partial Y](Y/TC)$. The short and intermediate elasticities may, therefore, be considered partial in the sense that they identify particular aspects of the adjustment process.

To distinguish separately the impacts of scale and scope economies contained in these measures, the multiple-output cost economy elasticity may be written as $\varepsilon_{TCY} = (\Sigma_m \partial TC/\partial Y_m \bullet Y_m)/TC$. The scope economy measure is $SC_{FSHB} = -H(Y_F,Y_S,Y_H,Y_B)/TC$, where H includes only the joint cost impacts of producing the four outputs, and thus only the cross-Y terms of the G(•) function, and the FSHB subscript indicates that it includes cross-effects for all four outputs. Thus, for example, given the functional relationship for G(•) in (3), H(•) is $\Sigma_i p_i\ (\Sigma_m \Sigma_n\ \gamma_{mn}\ Y_m\ Y_n)$, so $SC_{FSHB} = -\Sigma_i p_i\ \Sigma_m \Sigma_n\ \gamma_{mn}\ Y_m\ Y_n/TC$. However, if the equation for ε_{TCY} is fully expanded, it will include the component $2 \bullet \Sigma_i p_i\ \Sigma_m \Sigma_n\ \gamma_{mn}\ Y_m\ Y_n/TC$. Thus, the impact of jointness across – as well as overall levels of – produced outputs is included in the cost economy measure as output composition adjustments are embodied in $\Sigma_m \partial TC/\partial Y_m \bullet Y_m$.

Because negative γ_{mn} terms imply scope economies are present (complementarity between outputs implies that increasing one output shifts the marginal cost of the other down), ε_{TCY} is lower than only direct scale economies would suggest by $\Sigma_i p_i\ \Sigma_m \Sigma_n\ \gamma_{mn}\ Y_m \bullet Y_n/TC$. Thus, ε_{TCY} may be decomposed into a measure purged of jointness effects or "net" scale economies (ε^n_{TCY}), and one directly capturing economies of jointness or scope (SC_{FHSB}), as $\varepsilon_{TCY} = \varepsilon^n_{TCY} - SC_{FHSB}$. In reverse, the scale economy measure purged of jointness can be represented as $\varepsilon^n_{TCY} = \varepsilon_{TCY} + SC_{FHSB}$. Since $SC_{FHSB} > 0$ if scope economies exist, $\varepsilon^n_{TCY} > \varepsilon_{TCY}$, indicating fewer remaining economies when scope economies are removed from the cost economy measure.[19]

The last impact contained in the full cost economy measure is the change in p_C when C demand changes – this begins to move us toward the connection of cost economies with market power. The base cost economy measure $\varepsilon^I_{TCY} = [\partial TC/\partial Y + \partial TC/\partial C\ \partial C/\partial Y](Y/TC)$ includes in the $\partial TC/\partial C$ portion the component $\partial p_C/\partial C \bullet C$ from the definition $TC = G(\mathbf{Y},\mathbf{p},\mathbf{r}) + p_K K + p_C(C)C$. The cost economy measure is larger (fewer economies) if monopsony power exists, for the MC measure recognizes the additional pressure on the input market. That is, if MC is measured without this component ($\partial p_C/\partial C$ is set to zero), the pure *cost* measure, not including pecuniary (dis)economies, ε^C_{TCY}, is defined, and will typically indicate greater overall economies than the base measure.

Although the relationship between ε^C_{TCY} and ε_{TCY} does not have a simple analytical representation, their ratio is closely related to the $Prat_C$ measure, since $Prat_C = AFC/MFC$

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[19] As clarified further in the results section, the appropriate ε_{TCY} for construction of these measures would be ε^S_{TCY}, since the scope economy measure is based on G(•).

= $(Z_C - \partial p_C/\partial C \cdot C)/Z_C$, and $\varepsilon^C_{TCY}/\varepsilon_{TCY} = MC^C/MC$ = MCrat = $(MC - \partial p_C/\partial C \cdot C \cdot \partial C/\partial Y)/MC$ (where MC^C is the "pure" cost- or technological-based MC and MC is the full marginal cost including the p_C change). The relationship between MCrat and $Prat_C$ depends on the marginal valuation of C as compared to Y, adjusted for the pressure on the input market when C changes either independently (the $Prat_C$ measure) or as a result of a change in output (the MC measure).

For most purposes the base ε_{TCY} measure, ε^I_{TCY}, remains the appropriate one for cost analysis, as it represents all cost impacts arising from output increases. However, for interpretational purposes it may be useful to distinguish input market effects from other cost effects; this is facilitated by decomposing ε^I_{TCY} into $\varepsilon^I_{TCY} = MCrat \cdot \varepsilon^C_{TCY} \approx (1/Prat_C) \cdot \varepsilon^C_{TCY}$.

This development of the role of $Prat_C$ in the construction of cost economy measures raises another concept – that of net market power. This notion is based on determining the overall potential for excessive profits, as compared to the possibility of lower cost production from the various cost economies embodied in ε_{TCY}. Exploring this idea moves us again into the more familiar realm of output markets and a specific representation of marginal market power measures, as compared to profitability measures based on average or total costs and benefits.

To pursue this final refinement, consider the typical market power or markup measure for the output market (for a single output initially), $Prat_Y = p_Y/MC$. Again, the notion underlying this ratio is that if p_Y exceeds MC due to market power, inefficiencies exist because too little output is produced at too high a price, allowing the plant to generate monopolist profits. However, this conclusion requires an implicit assumption that marginal costs are representative of average costs, since profitability depends on the comparison of average revenue and costs.

We have seen a number of reasons why marginal and average cost could differ so that $\varepsilon_{TCY} = MC/AC$ would deviate from one. The combined impact of pricing behavior that causes $p_Y/MC>1$ and cost economies that allow additional output to be produced more cheaply ($MC/AC<1$), may be obtained by multiplying these two numbers together: $\varepsilon_{TCY} \cdot P^M rat_Y = (p_Y/MC) \cdot (MC/AC) = p_Y/AC = P^A rat_Y$ (where superscript A denotes "average" and M, "marginal"). With multiple outputs, an analogous procedure multiplying $P^M rat_Y$ by ε^I_{TCY}, results in $P^A rat_Y = \Sigma_m p_{Ym} Y_m/TC$ (where $\Sigma_m p_{Ym} Y_m = TR$ is total revenue), or dividing TR and TC by Y, AR/AC.

Price margins may, in this sense, be "supported" by cost economies. The economies embodied in the technology may allow lower prices on *average* than would be possible at smaller output levels. In such a case $p_Y/MC>1$ does not necessarily imply inefficiencies or an abuse of market power, but could instead suggest cost efficiency.

Finally, the impact of market power in the input markets must be included. Input markets are not as independent from cost economies as the output market is – input costs and economies incorporate the impacts of input price changes from supply conditions. As noted above, this impact may be decomposed from the technological economies using the relationship $\varepsilon^I_{TCY} = MCrat \cdot \varepsilon^C_{TCY} \approx (1/Prat_C) \cdot \varepsilon^C_{TCY}$.

The profitability measure representing separately the impacts of market power in the output and input markets and technological cost economies may be written as PROF = $P^M rat_Y \cdot \varepsilon^I_{TCY} = Prat_Y \cdot MCrat \cdot \varepsilon^C_{TCY} \approx Prat_Y \cdot (1/Prat_C) \cdot \varepsilon^C_{TCY}$. This expression, in turn, suggests that the combination component $Prat_Y \cdot Mcrat = Prat_T$, or its approximation $Prat_Y \cdot (1/Prat_C)$, may be considered a measure of "total" market power in all output and input markets.

Each of the components of the PROF measure, along with their individual decompositions (into individual output markets or scale versus size versus scope economies, for example), has a specific interpretation and information to portray. In sum, however, only if PROF>1 is the combination of market power in the output and input markets sufficient for excess profitability in the presence of cost economies.

Finally, note that cost effects not reflected by the MC measure, such as fixed effects from multi-plant economies, will still show up in the denominator of the cost economy measure (AC). Such economies increase ε_{TCY}, implying lower true cost economies, so smaller markup measures would be consistent with excess profitability.

6.3. Additional cost and market structure measures

The cost economy and markup measures and their refinements, decompositions, and combinations developed in the previous sections already suggest numerous indicators that might be computed to facilitate a detailed assessment of an industry's production structure. Associated complementary measures may provide additional useful insights about underlying output and input patterns.

In particular, measures of input-specific substitution patterns, scale effects, and other factors underlying the cost structure may be computed as elasticities. These indicators can be developed using the expressions for variable input demand behavior and the cattle shadow value. Also, elasticities of the pricing, cost economy, and markup/down measures may be constructed to directly address the impacts of exogenous changes on them.

The variable input demand elasticities are the most straightforward and familiar. Recall that the demand equations for L,E,and M_B, are constructed as $v_i = \partial G/\partial p_i$. Because the G(•) function in (3) is a second-order or flexible approximation to the underlying restricted cost function, the resulting $v_i(\mathbf{Y},\mathbf{p},\mathbf{r},\mathbf{DUM})$ equations depend on all the arguments of G(•), allowing the elasticities with respect to any of these arguments to be computed.

For example, the own-demand elasticity (price responsiveness of labor demand, say, to wage increases) is $\varepsilon_{ipi} = \partial \ln v_i/\partial \ln p_i$. Similarly, substitutability or complementarity among the variable inputs may be represented by the cross-demand elasticities $\varepsilon_{ipj} = \partial \ln v_i/\partial \ln p_j$. Input-specific scale effects may be constructed as elasticities with respect to components of the **Y** vector; $\varepsilon_{iYm} = \partial \ln v_i/\partial \ln Y_m$.[20] For example, $\varepsilon_{iYm} < \varepsilon_{TCY}$ suggests that an increase in input i smaller than the average increase over all inputs is needed to support an output increase – i.e., output Y_m expansion is input v_i-saving.

The impacts of changes in components of the **r** vector can also be computed as elasticities reflecting substitutability among the **v** and **r** inputs (with reversed signs from the price elasticities since they are based on quantity levels). For C and K, such elasticities thus become: $\varepsilon_{iC} = \partial \ln v_i/\partial \ln C$ and $\varepsilon_{iK} = \partial \ln v_i/\partial \ln K$.

Recall that we defined the shadow value of cattle, which provides information on the price a plant would be willing to pay for additional cattle units, as $Z_C(\mathbf{Y},\mathbf{p},\mathbf{r},\mathbf{DUM}) = -\partial G/\partial C$. This cost elasticity again depends on all arguments of the G(•) function, so that elasticities with respect to these arguments may be computed. Such elasticities indicate, for example, what the impact of an increase in demand for Y_m would imply for cattle valuation (Z_C). In turn, an increase in Z_C would stimulate greater cattle demand. These elasticities may be written as $\varepsilon_{ZCYm} = \partial \ln Z_C/\partial \ln Y_m$, $\varepsilon_{ZCi} = \partial \ln Z_C/\partial \ln p_i$, $\varepsilon_{ZCK} = \partial \ln Z_C/\partial \ln K$, and $\varepsilon_{ZCDf} = \partial \ln Z_C/\partial \ln DUM_f$.

Cost-side elasticities do not, however, allow consideration of what might affect the input supply side of the cattle-pricing problem. Rather, input supply impacts may be computed using elasticities based on equation (2) – the input supply or sales price p_C equation, of the general form $p_C = p_C(C,NB,PRC,OT,QU,CS,DUM_M)$. Elasticities with respect to arguments of this function may be constructed, as, for example, $\varepsilon_{pCCS} = \partial \ln p_C/\partial \ln CS$, indicating how p_C changes with a 1 percent change in the extent of captive supplies.

Finally, because the functional representations of the ε_{TCY}, $Prat_C$ and $Prat_{Ym}$ measures are based on first order derivatives of the cost and output demand or input supply (price) functions, second-order elasticities may be computed to indicate the impact of exogenous changes,[21] for example, $\varepsilon_{TCY,Ym} = \partial \ln \varepsilon_{TCY}/\partial \ln Y_m$, $\varepsilon_{TCY,i} = \partial \ln \varepsilon_{TCY}/\partial \ln p_i$, and $\varepsilon_{TCY,K} =$

[20] Note that there will be no input-specific scope elasticities because this would require a third-order approximation.

[21] The primary exogenous changes that may be evaluated stem from the cost function, as ε_{TCY} is purely a cost elasticity, and the linear functions for the output demand and input supply equations preclude cross-effects from these equations appearing in the Prat measures. This is not an important issue, however, since when cross-effects were included they were invariably empirically insignificant. Also, the estimated price ratios are very

$\partial \ln \varepsilon_{TCY}/\partial \ln K$ for the cost economy elasticities, $\varepsilon_{PRYm,Yn} = \partial \ln \varepsilon_{PRYm}/\partial \ln Y_n$, $\varepsilon_{PRYm,i} = \partial \ln \varepsilon_{PRYm}/\partial \ln p_i$, and $\varepsilon_{PRYm,K} = \partial \ln \varepsilon_{PRYm}/\partial \ln K$, for the markup elasticities $Prat_{Ym} = \varepsilon_{PRYm}$, and $\varepsilon_{PRC,Ym} = \partial \ln \varepsilon_{PRC}/\partial \ln Y_m$, $\varepsilon_{PRC,i} = \partial \ln \varepsilon_{PRC}/\partial \ln p_i$, and $\varepsilon_{PRC,K} = \partial \ln \varepsilon_{PRC}/\partial \ln K$, for the markdown elasticities $Prat_C = \varepsilon_{PRC}$.

The measures discussed in this and the previous section provide a detailed picture of production processes and pricing behavior for a plant. Although they comprise a complicated and extensive set of indicators, each tells part of the story – from the most basic and crucial technological and behavioral characteristics to the more detailed linkages underlying these patterns. Since the goal in this study is to look for overall cost economies and market power, indicators of these patterns are the primary focus in the discussion of empirical results below. However, additional insights may be drawn from the more detailed set of measures developed in this section and reported in the appendix, allowing further evaluation and interpretation of the results.

constant, which suggests an impact on costs tends to be met with a corresponding change in price, leaving the price *ratio* virtually unaffected.

7. THE EMPIRICAL RESULTS

The data patterns, summarized in the Appendix B tables and the Appendix D data supplement, highlight both the differences and the similarities across plants in this industry. The widely varying production structures across plants are apparent from the "categories" dividing the total sample into plants selling only fabricated or only slaughter output, and those using no M_B or a significant amount of that input. Also, the data are divided into regions (West, Western Corn Belt and Plains)[22], as well as a separate category, the "Adapted" Plains, for the 13 largest slaughter/fabrication plants.[23]

Although important structural differences emerge (capital and labor costs for plants that do more fabrication tend to be higher, for example), the output-to-input ratios are quite similar across sub-groups, as are patterns of prices of both outputs and inputs. Distinct differences that emerge when comparing across plants, in some cases, seem to stem from data anomalies. The greatest inconsistencies have been purged by deleting one plant in the sample that exhibited clear reporting differences, and using dummy variables to accommodate two plants with other identifiable (but not fatal) discrepancies. Some variation in the reporting procedures is still evident, but the stochastic structure of the model seems sufficient to accommodate this noise and still generate representative estimates of the industry's production structure.

Using the discussion of cost economy and market power measures in previous sections as a foundation, the main results of the analysis can be summarized quite succinctly. Exploring the patterns further, both with respect to the breakdowns of the data and to the broad set of measures complementary to the base estimates, can be very involved. Although some of this is discussed here, we will mainly highlight the general patterns, leaving the perusal of additional reported estimates to those interested in particular questions or comparisons.

The parameter estimates from the final model are presented in Appendix Table C1. The t-statistics for these estimates show that virtually all have extremely high significance levels. In fact, the coefficients are so statistically significant that estimates of almost all elasticities, even those with small magnitudes, are also statistically significant. The issue, therefore, becomes whether their magnitude is sufficient to suggest an important impact.

Although numerous variations on the model and specification or sensitivity tests were carried out for this model, as overviewed in Section II, results stayed substantively the same, and the overall "story" resulting from the numbers is quite clear. The primary results are presented in summary Table S1, where the base cost economy and market power estimates are provided for categories and regions.

The most fundamental cost economy measure for our purposes is ε^{I}_{TCY}. The average ε^{I}_{TCY} value across all plants is 0.960, indicating that a 1 percent increase in overall production may be obtained with a 0.96 percent increase in costs, or a 4 percent cost savings on the marginal unit of output. Recall that this measure explicitly includes adjustment of the C input necessary for output changes, as well as all technological and pecuniary economies and diseconomies that might be faced by the plant.

Comparing this intermediate measure to the short run average ε^{S}_{TCY}, presented in the Appendix C supporting tables, shows that the ε^{S}_{TCY} of 0.919 for the average plant falls short of ε^{I}_{TCY} by 0.041, or by about the amount marginal costs increase from C input adjustment. This difference can be thought of as the direct effect of increasing utilization or throughput.

From the initial production point, the perceived cost economies are about 8 percent (from the cost economy measure of 0.919). Thus, if output demand is sufficiently strong to support a 1 percent increase in production, a plant will find it optimal to increase throughput to the point where the extra valuation of cattle from increasing utilization drops to 4 percent. That is, *ex post*, evaluated at input and output levels after all

[22] The regions are defined as East (PA), West (AZ, CA, UT, WA), Western Corn Belt or WCB (IL, WI, IA MN, MI), and Plains (CO, NE, TX, KS). To preserve confidentiality, data for the East, that has fewer than three plants, are not presented.

[23] "Adapted" Plains includes five plants from *EXCEL*, five from *IBP*, and three from *MONFORT*.

adjustment takes place, apparent cost economies are lower. Potential scale (utilization) economies have been taken advantage of by increasing utilization through higher cattle purchases.

We can disentangle the pecuniary diseconomies embodied in ε^{I}_{TCY} (due to market power for cattle) from the technological economies reflected by the "pure" cost economy measure ε^{C}_{TCY} = 0.947, reported in Appendix Table C2.[24] Comparing this with ε^{I}_{TCY} (0.960) indicates that cost economies net of cattle price changes exceed those with these price changes included by 0.013; pecuniary diseconomies reduce cost economies by about 1.3%.

By contrast, $\varepsilon^{L}_{TCY} = 1.022 > \varepsilon^{I}_{TCY}$; long-run cost economies are less than economies based on utilization of the *existing* plant. In fact, on average there appear to be (small) diseconomies, suggesting optimal long-run decreases in plant size. Although differences appear across categories, these diseconomies mostly seem to affect the largest plants and firms. However, these long-run estimates are the least robust of the model, due to the statistical insignificance of many K parameters (see Appendix Table C1), the difficulties in measuring K and its user cost appropriately, and problems with imputing long-run behavior from cross-section data. In particular, while variations in the K data do not really affect the base cost economy and market power measures, they do cause the ε^{L}_{TCY} measures, that are fundamentally based on the K and p_K data, to vary. And, in fact, some alternative model specifications even suggest that scale economies persist in the long run.

It is also useful to separately distinguish scope economies from those accruing more directly to (short- or long-run) scale effects. The scope economy measure, including all cross-effects, is presented in Table S1 as SC_{FSHB} = 0.030 on average. This indicates that 3 percent of the total (short-run) 8 percent technological economies are due to scope economies; the remaining scale economies account for 5 percent. This is also evident from the ε^{n}_{TCY} = 0.949 measure in Table C2.[25] Also, in Table C2, one can see from the SC_{FS} measure that only 0.008 of the measured scope economies are due to complementarities between fabricated and slaughter output; the remainder has to do with the cross effects between Y_H and Y_B.

The Y_F- and Y_S-specific components of the cost economy expression, reported in Table S1, depend in part on the shares of Y_F and Y_S in total production, but also provide information on the relative cost savings from each output. The respective estimates of ε^{I}_{TCYF} = 0.626 and ε^{I}_{TCYS} = 0.231 can be compared to output shares (from Appendix Table B1) of 0.662 for Y_F and 0.239 for Y_S. These numbers suggest that Y_F contributes more to cost economies than Y_S, as the ε^{I}_{TCYF} value is significantly less than the fabrication share; whereas there is much less difference between the elasticity and share for slaughter. That is, changes in Y_F contribute less to cost increases than to output production, while changes in Y_S increase both closer to proportionately.

Completing the overall story of cost economies and market power requires consideration of the associated base markdown (monopsony) and markup (monopoly) measures $Prat_C$ and $Prat_{Ym}$ in Table S1. An average value of 1.023 for $P^{I}rat_C$ indicates a 2.3 percent premium (over the direct marginal benefit of the input) paid for an incremental unit of cattle, rather than a markdown or discount implied by monopsony behavior. This finding is consistent with the evidence above about the extra value of the marginal cattle input associated with resulting increased utilization of the plant.

That is, the $P^{I}rat_C$ measure embodies the adjustment of output to take advantage of short-term cost (utilization) economies. When the "markdown" measure is evaluated at existing output and input levels rather than imputing the marginal value of increased throughput in terms of utilization economies, $P^{S}rat_C$ = 0.987 (from table C2).[26] This short-run measure directly represents the difference between the MFC and AFC of an additional unit of cattle, or the slope of the underlying input supply or pricing curve. If the plant wishes to purchase another unit of cattle, the price will increase. Without the

[24] This measure is directly comparable to ε^{I}_{TCY} in the sense that the computations used accommodate full adjustment of cattle inputs to output changes.

[25] Note that the appropriate comparison here is with the ε^{S}_{TCY} measure, since both these indicators are evaluated at observed output and input levels.

[26] This measure may also be computed for the "long run" with full capital adjustment, but the values are so close to those for $P^{I}rat_C$ they are not separately presented.

increased utilization value, the price a plant is willing to pay on average for cattle input is 1.3 percent below its directly measured marginal valuation or MFC.

However, the true marginal factor cost or shadow value of the cattle for the firm also involves the impact on the marginal cost of increasing output levels by raising cattle input levels, or the utilization impact of increasing throughput. Once full adjustment and thus augmented utilization occurs, the plant is willing to pay more, rather than less, for additional cattle. This is reflected in the "intermediate" $P^I rat_C$ value that incorporates the impact on output production, and, thus, marginal costs of production, of increasing C. Price increases from the supply side are more than compensated for by the reduced marginal production costs due to the cost structure.

On the output side, the output-specific markup ratios $Prat_{YF}$ and $Prat_{YS}$ are measured as 1.099 and 1.005 on average, respectively.[27] This indicates a nearly 10 percent premium, on average, from sales of fabricated output. By contrast, markups for sales of carcasses or slaughter output are negligible; $Prat_{YS}$ not only very closely approximates one, but the "monopoly" coefficient is statistically insignificant (See Appendix Table C1). The estimated markup for Y_H (hides) is likewise insignificant, with the implied $Prat_{YH}$ slightly below one. The λ_{YB} parameter in the Y_B (byproducts) market was set to zero, as it was quite volatile across plants, suggesting too much variation in the sample to generate reasonable estimates. Thus, the combined markup measure for all outputs hardly differs from that for Y_F; $Prat_Y = 1.087$ (from Table C2).[28]

Evaluated after full adjustment of output associated with throughput increases, the *total* market power impact including pricing for all outputs and cattle inputs is 6.2 percent: $P^I rat_T = (1/ P^I rat_C)\bullet Prat_Y \approx MC^I rat\bullet Prat_Y = 1.062$ from Table C2, where the I superscripts indicate that this sequence of measures is based on the $P^I rat_C$ "monopsony" measure. This result could suggest that plants are obtaining a "bonus" over the cost of producing additional product and, thus, could possibly be generating excess profits. However, as shown in the previous section, to assess the potential for excessive profitability this greater-than-one measure must be compared with the evidence of cost economies.

To pursue this comparison, recall that imputing profitability involves comparing measures of market power (representing discrepancies between output and input prices and their associated marginal costs or marginal factor costs) and those of underlying cost economies (causing a deviation between marginal and average production costs). Our overall market power measure is $Prat^I_T$, that embodies all market power indicators and is based on evaluation after full adjustment of C and the Y_m. Thus, to assess potential profitability, it is appropriate to compare $Prat^I_T$ to the ε^C_{TCY} measure that reflects only technological cost economies and incorporates full adjustment.

The resulting $PROF = Prat^I_T\bullet\varepsilon^C_{TCY}$ measure reported in Table C2 does slightly exceed one on average (1.004), but by a negligible amount. PROF, therefore, does not indicate excessive profitability from any type of output or input market power for the average plant and month, although the measures do vary across a broad range (from 0.794 to 1.376).[29]

A final cost consideration, before moving on to explore supporting measures for data sub-aggregates and for additional underlying indicators, pertains to firm- and plant-specific cost effects. As suggested by the values and ratios provided in Table B1, cost relationships do not appear to depend in any obvious manner on location or firm association.

Regional and firm-specific dummy variables are virtually always negative but tend to be small. The percentage values (from elasticity computations) are actually quite consistent with the parameter values due to data scaling; regions other than the East tend to produce at 1.5 to 2.5 percent below overall average costs.

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[27] These measures differ negligibly with accommodation of C adjustment, so are not distinguished by S and I superscripts.

[28] It is worth noting that these results are not at all dependent on the characterization of market structure in this study in terms of a "monopoly" framework. Alternative and more detailed oligopoly characterizations generate very similar market power and profitability results, as documented in Paul [1999c].

[29] As for all the measures in this document, however, as emphasized earlier, variation in them across plants should be interpreted with caution as the parameter estimates are primarily indicative of average behavior across plants.

In particular, plants in the Western Corn Belt and West have 1.6 to 1.7 percent lower costs than those in the East, while in the Plains these savings jump to 2.7 percent. Although these lower costs may seem inconsistent with the long-run elasticity values that suggest optimal plant sizes may be too high in these regions, the elasticities are marginal estimates, whereas the dummy variables are shifters indicating differences in cost *levels*. Plants associated with multi-plant firms also tend to have somewhat lower costs than those with only one plant.

To pursue the notion of structural differences, we can compare the results for the cost economy and pricing measures for the various categories and regions. Results presented in Table S1 (and Appendix Tables C2-C6 for the additional associated measures), show little variation in cost economies when plants are separated out into specific categories versus values for the average plant.

Plants with no M_B input have slightly lower cost economies, with an average ε^I_{TCY} measure of 0.963, although the corresponding scope economies are also smaller as these plants tend to have less variation in products – in particular less fabrication. Similarly, plants that do no fabricating exhibit fewer cost economies and much smaller scope economies than the average, and have low marginal profitability due to limited potential markup power.

By contrast, plants that specialize in fabrication seem to have reasonably high markup power and marginal profitability compared to the average plant overall. And plants using a large amount of M_B input exhibit slightly greater cost economies, primarily arising from fabricated output. The price paid for cattle in the "M_B large" plants also appears slightly higher on the margin as compared to its shadow valuation (when the potential for utilization increases is accommodated), and scope economies are more substantive.

These patterns may be due to the larger size of the "M_B large" plants, particularly since their slight estimated long-run diseconomies suggest that they may have expanded more than is ultimately optimal (although, as noted above, the long-run measures are not as reliable). On balance, their PROF = 1.033 measure is higher than the overall average, suggesting that these plants, which tend to be more diversified, are also more profitable.

Among the regions, large scope economies and a relatively high $P^I rat_C$ value are characteristic of the Plains plants, and particularly those in the "Adapted Plains" (AP) region, that has the 13 largest slaughter/fabrication plants. This combination of characteristics also means that these large plants are the most profitable.

In fact, the greatest overall cost economies, driven by both utilization and scope economies, appear in the Plains plants, so that it is very important that these large plants maintain high utilization levels stay profitable. This is particularly evident from the ε^S_{TCY} measure that averages 0.862 for the AP plants, a result suggesting their ability and willingness to pay more on the margin than otherwise would be optimal for cattle input. Although the short-run price paid for cattle is very close to the marginal benefit ($P^S rat_C$ = 0.977 for the AP plants), when the potential for augmenting utilization by increasing cattle input is recognized, plants in these regions appear to pay a 4 percent premium to support high throughput, by contrast to the approximately 1 percent premium in other regions.

Some of the price differential observed in the larger Plains plants could be connected to other factors. Parameter estimates underlying the specification of the cattle input price (from equation (2)) provide indicators of p_C determinants. They suggest that measured prices are greater when cattle are of higher quality, when procurement costs are higher, and when there are more captive supplies (although at a declining rate given the cross-term with CS, $\beta_{CCS2}<0$, that is small and only marginally significant).

This discussion highlights output compositional variations across differing types of plants that make it difficult to determine the "optimal" size plant, in the sense of the minimum of the average cost curve (with or without capital adjustment).[30] The reasons for the extensive variability are not possible to ascertain from the data, but the results

[30] See Paul [1999b] for further discussion of the representation of the "optimal" plant from this framework and data. The definition of optimality (in terms of costs or profits, and with multiple outputs) becomes an issue. Also, an optimizing system of equations must be solved with multiple outputs, so existing output composition patterns are built into the computations.

suggest that there could be efficiency-based motivations to expand plants' scale of operations toward that characterized by the larger plants in the sample.

Overall, it appears that although significant structural differences exist, plants that are more diversified (in terms of both outputs and inputs) and larger exhibit lower marginal costs of expanding output relative to their average costs, and thus they enjoy both greater cost efficiency and profitability. These cost structure characteristics result from cost (utilization, scope, and scale) economies rather than from cattle input market power. Thus it appears that these plants are more likely both to be willing to pay a premium for marginal cattle units and to hold captive supplies, in order to support high utilization levels, despite some market power in the sense that higher cattle demand tends to drive prices up slightly.

The prevailing story for the industry overall seems generally consistent with the patterns for the large Plains plants. On average plants appear willing to pay a higher marginal price than would be suggested by the direct marginal benefits of cattle inputs, in order to take advantage of short-run cost economies by increasing utilization. That is, if output expansion is supported by demand patterns, plants are willing to pay higher prices for cattle than is supported by the shadow value alone, that is computed without taking lower marginal production costs into account. It is in this sense that the cost structure motivates more cattle use and higher input prices paid than would be the case if cost economies did not prevail. This behavior is exhibited to varying degrees for the different types of plants, but there is virtually no evidence of plants or firms taking advantage of market power by forcing cattle input prices down. Forces of supply (cost or technology) and demand (for meat products) seem to be driving the market.

Additional elasticity estimates complementary to the primary cost economy and market power measures are presented in Tables C2-C6. These estimates allow further analysis of production structure patterns and their determinants for the interested reader to peruse. Still some features of the Appendix C tables deserve specific comment.

First, input demand elasticities for L and E, in Tables C3 and C4, exhibit reasonable patterns. For example $\varepsilon_{LYF} > \varepsilon_{LYS}$ suggests that fabricated output requires a greater increase in labor input than does slaughter output. Also, the own-elasticities for labor and energy are negative, so demand for these inputs is apparently price responsive. And inputs, generally, appear substitutable in the short run for producing a given amount of output (all these elasticities represent short-run responses). However, values for the M_B elasticities are notably absent; they are too volatile to be meaningfully interpreted due to the very large variations in M_B use.[31]

Other interpretational issues arise for the Z_C (shadow value) elasticities in Table C4. The ε_{ZCC} elasticity is positive, whereas a variant of the notion of diminishing returns would suggest that it should be negative (additional increments of the input reduce its value at the margin). However, recall that these are "short-run" elasticities, indicating the variable input savings of increasing the cattle input. Higher cattle levels appear to augment labor, energy and M_B (variable input) savings on the margin, possibly because plants with higher C levels are less likely to be fabricated-output intensive. Another interpretation might be that larger plants with greater relative cattle demand also value the inputs at the margin more highly due to utilization issues.

Another factor could be the substitutability of C and M_B. The positive ε_{ZCpMB} value indicates that increasing the price of intermediate beef products, M_B, tends to increase the cattle shadow value, suggesting substitutability between these inputs. This could reflect a pure substitution effect, i.e., that output may be produced with cattle or purchased (or transferred) beef products, or it could indicate a compositional difference between plants that rely more on M_B and those that use mostly C. Since larger plants seem not only more diversified in terms of outputs (tend to do more fabrication), but also in terms of inputs (more M_B use), it may be that these plants also are more cost effective.

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[31] As noted above, there are three clearly differentiable "categories" of M_B use – no M_B use, little M_B use, and significant M_B use. The elasticities of M_B demand contain a measure of M_B in the denominator, and as this approaches zero, the values blow up, causing great volatility in the estimates among those plants that report little M_B use. Although these estimates have not been presented, it is worth noting that the signs of their elasticities are appropriate. Own elasticities are negative, so increasing Y_F production stimulates large increases in M_B (with the same sign but lower magnitude for Y_S). Greater capital values also imply more M_B use.

This discussion of the Z_C input elasticities also facilitates interpretation of the negative ε_{ZCYF} and ε_{ZCYS} elasticities that imply that increasing either kind of output *reduces* the valuation of C on the margin, if only by a small amount. However, the (unreported) ε_{MBYF} and ε_{MBYS} elasticities tend to be large and positive – plants that expand operations or, perhaps, plants that are larger and more diversified, apparently demand significantly greater amounts of M_B than of C.

Table C5 contains estimates of the cattle input supply or pricing elasticities. Note first that the ε_{pCC} elasticities are positive, confirming that the input supply function has an upward slope – but the measures are not large, especially for smaller, more specialized plants. As highlighted above in the context of coefficient estimates, these elasticities show that cattle prices are greater when procurement expenditures, captive supplies, and quality are higher.

Table C5 also reports estimates of the effects of exogenous factors on cost economies, reflecting a number of interesting patterns. First, increased C input use is consistent with higher ε_{TCY} measures, implying reduced cost economies. Expanding the cattle input is valuable in that it promotes increased throughput and reduces excess capacity. Similarly, increases in the use of intermediate beef products, M_B, stimulates greater capacity utilization. Higher fabricated output levels, Y_F, also imply greater cost economies, suggesting more excess capacity but also more scope and scale economies for plants expanding fabricated output production.

"Comparative static" measures for the Y_F and C price *ratio* elasticities are presented in Table C6. The determinants of the $Prat_C$ measure include only cost-side exogenous variables, because of the insignificance of cross-terms with other arguments of the p_C pricing equation that removes them from consideration. The magnitude of these elasticities is invariably small; that is, nothing appears to substantively affect the pricing relationship. Neither does the Y_F price ratio seem to be very susceptible to outside forces, although there is a clear connection between greater Y_F production and higher markups. Also, if the prices of variable inputs – especially intermediate beef products – increase, $Prat_{YF}$ declines with the increase in production costs.

8. CONCLUDING REMARKS

The overall market power story in the US beef packing industry seems clearly portrayed by the robust cost economy and market power indicators found in this study. The details of the underlying interactions are complex, but the estimates plainly indicate significant cost economies, and little if any depression of cattle prices or excess profitability, in the industry. Although these conclusions clearly depend on the model specification, they remain robust to many variations in the model, data, and assumptions.

The overriding evidence of significant utilization, scope, and scale economies, and the associated value of high throughput levels and cattle input demand, even with market pressure on cattle prices, is quite consistent across plants whose production structures vary widely. Although plants appear to affect cattle prices by incurring market pressure when cattle input demand increases, there is little evidence of market power in the sense that plants seem to pay more on the margin for cattle units than would be directly justified by the associated marginal benefits. Utilization increases and corresponding cost savings, and thus market forces, motivate such economic behavior.

Larger and more diversified plants have the potential to take even greater advantage of technological economies (especially scope economies) than smaller plants. Some regional variation exists, with Plains plants exhibiting the lowest costs, and thus slightly higher profitability. These cost efficiencies are associated, however, with particularly significant utilization economies that require these large plants to achieve high utilization or throughput levels to maintain cost efficiency and profitable operations. Firms with more than one plant seem able to generate additional multiplant economies.

In sum, some plants in the US beef packing industry – especially those that are larger, more diversified, are in the Plains states, and are associated with multi-plant firms – appear to receive slightly higher than "normal" (zero economic) profits. These profits apparently stem from significant cost economies, implying that cost efficiencies are a driving force for consolidation and concentration in this industry. They do not, therefore, serve as evidence of market power abuse; but rather appear attributable to market forces of supply and demand, given the technological base in the industry.

TABLE S1: SUMMARY STATISTICS – CATEGORIES AND REGIONS

	Mean	St. Dev.	Min.	Max.
total				
ε^{I}_{TCY}	**0.960**	0.057	0.774	1.268
ε^{I}_{TCYF}	**0.626**	0.334	0.000	1.094
ε^{I}_{TCYS}	**0.231**	0.335	0.000	0.996
$Prat^{I}_{C}$	**1.023**	0.020	0.949	1.163
$Prat_{YF}$	**1.099**	0.090	1.000	1.395
$Prat_{YS}$	**1.005**	0.006	1.000	1.027
SC_{FSBH}	**0.030**	0.027	0.001	0.116
M_B=0				
ε^{I}_{TCY}	**0.963**	0.049	0.857	1.157
ε^{I}_{TCYF}	**0.527**	0.419	0.000	0.943
ε^{I}_{TCYS}	**0.331**	0.410	0.000	0.996
$Prat^{I}_{C}$	**1.018**	0.011	1.004	1.052
$Prat_{YF}$	**1.068**	0.070	1.000	1.246
$Prat_{YS}$	**1.006**	0.008	1.000	1.027
SC_{FSBH}	**0.017**	0.020	0.001	0.084
M_B large				
ε^{I}_{TCY}	**0.944**	0.034	0.859	1.004
ε^{I}_{TCYF}	**0.806**	0.061	0.671	0.888
ε^{I}_{TCYS}	**0.037**	0.019	0.004	0.083
$Prat^{I}_{C}$	**1.030**	0.013	1.014	1.069
$Prat_{YF}$	**1.186**	0.080	1.075	1.395
$Prat_{YS}$	**1.003**	0.002	1.000	1.007
SC_{FSBH}	**0.047**	0.025	0.013	0.113
Y_F=0				
ε^{I}_{TCY}	**0.973**	0.054	0.885	1.086
ε^{I}_{TCYF}	**0.000**	0.000	0.000	0.000
ε^{I}_{TCYS}	**0.861**	0.063	0.739	0.996
$Prat^{I}_{C}$	**1.014**	0.008	1.004	1.034
$Prat_{YF}$	**1.000**	0.000	1.000	1.000
$Prat_{YS}$	**1.015**	0.006	1.006	1.027
SC_{FSBH}	**0.003**	0.002	0.001	0.006
Y_S=0				
ε^{I}_{TCY}	**0.973**	0.015	0.940	0.991
ε^{I}_{TCYF}	**0.891**	0.018	0.857	0.927
ε^{I}_{TCYS}	**0.000**	0.000	0.000	0.000
$Prat^{I}_{C}$	**1.016**	0.011	1.004	1.042
$Prat_{YF}$	**1.085**	0.061	1.015	1.215
$Prat_{YS}$	**1.000**	0.000	1.000	1.000
SC_{FSBH}	**0.013**	0.011	0.002	0.038

	Mean	St. Dev.	Min.	Max.
West				
ε^{I}_{TCY}	**0.950**	0.046	0.800	1.014
ε^{I}_{TCYF}	**0.562**	0.289	0.000	0.888
ε^{I}_{TCYS}	**0.286**	0.262	0.019	0.806
$Prat^{I}_{C}$	**1.010**	0.011	0.984	1.064
$Prat_{YF}$	**1.043**	0.048	1.000	1.176
$Prat_{YS}$	**1.004**	0.003	1.001	1.012
SC_{FSBH}	**0.017**	0.009	0.003	0.034
WCB				
ε^{I}_{TCY}	**0.968**	0.040	0.885	1.078
ε^{I}_{TCYF}	**0.474**	0.405	0.000	0.927
ε^{I}_{TCYS}	**0.390**	0.400	0.000	0.980
$Prat^{I}_{C}$	**1.014**	0.009	1.003	1.042
$Prat_{YF}$	**1.047**	0.057	1.000	1.194
$Prat_{YS}$	**1.006**	0.008	1.000	1.027
SC_{FSBH}	**0.013**	0.014	0.001	0.060
Plains				
ε^{I}_{TCY}	**0.955**	0.067	0.774	1.268
ε^{I}_{TCYF}	**0.730**	0.253	0.000	1.094
ε^{I}_{TCYS}	**0.125**	0.264	0.000	0.996
$Prat^{I}_{C}$	**1.033**	0.023	0.949	1.163
$Prat_{YF}$	**1.151**	0.088	1.000	1.395
$Prat_{YS}$	**1.004**	0.006	1.000	1.026
SC_{FSBH}	**0.045**	0.028	0.002	0.116
"Adapted" Plains				
ε^{I}_{TCY}	**0.936**	0.072	0.774	1.268
ε^{I}_{TCYF}	**0.803**	0.055	0.671	1.094
ε^{I}_{TCYS}	**0.035**	0.017	0.009	0.095
$Prat^{I}_{C}$	**1.041**	0.024	0.949	1.163
$Prat_{YF}$	**1.199**	0.061	1.091	1.395
$Prat_{YS}$	**1.004**	0.002	1.001	1.012
SC_{FSBH}	**0.062**	0.020	0.026	0.116

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A. SUMMARY OF VARIABLES, MEASURES, TERMS AND EQUATIONS

Variable Definitions

Outputs:
Four outputs, denoted $\mathbf{Y_m}$:
slaughter and fabricated meat products ($\mathbf{Y_S}$ and $\mathbf{Y_F}$),
byproducts ($\mathbf{Y_B}$), and
hides ($\mathbf{Y_H}$).

Inputs:
Three variable inputs – included as prices (p_i) for arguments of cost function:
labor (**L**) (hours),
energy (**E**) (indexed), and
purchased beef products ("beef and by-products purchased or transferred in", $\mathbf{M_B}$, (lbs.), where M indicates that this a "materials" input, and B denotes "beef").
Inputs in **r** vector – included as quantities:
packaging, "other" materials inputs and purchased hides, $\mathbf{M_O}$ (dollar value),
"total chilled carcass weight" in lbs., **C**, as the cattle input, and
capital, **K**, (estimated dollar value based on reported "replacement" values).

Cattle Supply Determinants (in pricing equation):
NB, *NOBUYERS*, the number of cattle buyers
PRC, *PROCEXP*, expenditures on cattle procurement
OT, *HROTPAY*, pay for overtime workers
CS, captive supplies, percentage by weight of packer-fed cattle
QU, quality, percentage of steers and heifers

Regions:
West – AZ, CA, UT, WA
Western Corn Belt (WCB) – IL, WI, IA MN, MI
Plains – CO, NE, TX, KS
"Adapted" Plains – 13 largest slaughter/fabrication plants in the Plains

Overview of Constructed Measures (in order of appearance in the document)

The shadow value of the C input, $\mathbf{Z_C = -\partial G/\partial C}$, would equal p_C in equilibrium with perfect competition in these markets.

The marginal cost of output Y_m is defined as $\mathbf{MC_m = \partial G/\partial Y_m}$.
The marginal revenue of this output is defined as $\mathbf{MR_m = p_{Ym}(Y_m) + Y_m\ \partial p_{Ym}/\partial Y_m}$, so $\mathbf{p_{Ym} = -\partial p_{Ym}/\partial Y_m \cdot Y_m + MC_m}$ is the optimal Y_m pricing equation.

The marginal factor cost for an input (C in this case) is $\mathbf{MFC = p_C + C\ \ \partial p_C/\partial C}$, which will equal the shadow value $-\partial G/\partial C$ in equilibrium, so the optimal pricing equation becomes $\mathbf{p_C = C\ \partial p_C/\partial C\ -\partial G/\partial C}$.

The "markdown" of input C price below the shadow value in ratio form is $\mathbf{Prat_C = p_C/Z_C = p_C/(-\partial G/\partial C)}$, analogous to the usual measurement of a "markup" of output price over marginal cost as $\mathbf{Prat_{Ym} = p_{Ym}/MC_m = p_{Ym}/(\partial G/\partial Y_m)}$.
The general cost-side measure of cost economies (for one output) is $\varepsilon_{TCY} = \mathbf{\partial lnTC/\partial ln\ Y}$, where $\mathbf{TC = G(\bullet) + p_C(C)C + p_K K}$. This includes all cost changes with output expansion, such as scale and scope economies, and input price changes with C adjustment.

Thus, in the "short run," defined as the immediate perception of cost changes without adjusting C (requiring other substitutions), this becomes $\varepsilon^{S}_{TCY} = \partial G/\partial Y(Y/TC)$;

when the possibility of increasing throughput and thus raising capacity utilization is recognized, this becomes $\varepsilon^{I}_{TCY} = [\partial TC/\partial Y + \partial TC/\partial C\ \partial C/\partial Y](Y/TC)$ (*this is the relevant current measure of cost economies used in this document*);

and when investment or disinvestment in K is included to recognize the possibility of "long run" behavior, this is $\varepsilon^{L}_{TCY} = [\partial TC/\partial Y + \partial TC/\partial C\ \partial C/\partial Y + \partial TC/\partial K\ \partial K/\partial Y](Y/TC)$.

These measures are defined for each output, Y_m, where m = S,F,B, and H.

Total cost economies for changes in all outputs are defined as $\varepsilon_{TCY} = \Sigma_m Y_m TC_m(Y)/TC(Y) = \Sigma_m \partial TC/\partial Y_m (Y_m/TC)$, where $TC_m = \partial TC/\partial Y_m$.

Scope economies are defined as: $SC = ([\Sigma_m\ TC(Y_m)] - TC(Y)/TC(Y)) = -\Sigma_i p_i\ \Sigma_m \Sigma_n \gamma_{mn} Y_m Y_n/TC$.

Because the cost economy measure includes both scale and scope economies, economies "net" of scope economies can therefore be computed as: $\varepsilon^{n}_{TCY} = \varepsilon_{TCY} + SCP_{FHS}$.

The pure *cost* measure not including pecuniary diseconomies, ε^{C}_{TCY}, is defined if the marginal cost measure in the numerator of ε_{TCY} is constructed without recognizing the impact on input prices ($\partial p_C/\partial C$ is set to zero).

The relationship between ε^{C}_{TCY} and ε_{TCY} does not have a simple analytical representation, but their ratio is closely related to $Prat_C$, since $Prat_C = (Z_C - \partial p_C/\partial C \bullet C)/Z_C$, and $\varepsilon^{C}_{TCY}/\varepsilon_{TCY} = MC^{C}/MC = MCrat = (MC - \partial p_C/\partial C \bullet C \bullet \partial C/\partial Y)/MC)$.

Thus, ε^{I}_{TCY} can be *decomposed* into $\varepsilon^{I}_{TCY} = MCrat \bullet \varepsilon^{C}_{TCY} \approx (1/Prat_C) \bullet \varepsilon^{C}_{TCY}$, and $Prat_T = Prat_Y \bullet MCrat$, or its approximation $Prat_Y \bullet (1/Prat_C)$, is considered a measure of "total" market power in all output and input markets.

In reverse, $\varepsilon_{TCY} = \partial \ln TC/\partial \ln Y = \partial TC/\partial Y \bullet (Y/TC) = MC/AC$, and $Prat_Y = p_Y/MC$ (for one output) can be *combined* into $\varepsilon_{TCY} \bullet P^{M}rat_Y = p_Y/MC \bullet MC/AC = p_Y/AC = P^{A}rat_Y$, where "M" denotes marginal and "A" average, implying profitability.

With multiple outputs, we have $\varepsilon^{I}_{TCY} = \Sigma_m\ \partial TC^{I}/\partial Y_m\ (Y_m/TC) = \Sigma_m\ MC^{I}_m\ Y_m/TC$, and $P^{M}rat_Y = \Sigma_m\ p_{Ym}\ Y_m/\Sigma_m\ MC^{I}_m\ Y_m$, so $P^{A}rat_Y = \Sigma_m\ p_{Ym}\ Y_m/TC = AR/AC$. (Note that this includes all costs including those for K, not just operating costs.)

Thus, finally, profitability (recognizing all scale economies and "markup" or "markdown" behavior) can be imputed by: $PROF = P^{M}rat_Y \bullet \varepsilon^{I}_{TCY} = Prat_Y \bullet MCrat \bullet \varepsilon^{C}_{TCY} \approx Prat_Y \bullet (1/Prat_C) \bullet \varepsilon^{C}_{TCY}$.

Elasticity measures are also computed to identify the substitution patterns underlying the indicators of pricing behavior, cost economies, and profitability:

The own-input-demand elasticity (price responsiveness of labor demand, say, to wage increases) is $\varepsilon_{ipi} = \partial \ln v_i/\partial \ln p_i$.

The cross-demand elasticities with other "variable inputs" are $\varepsilon_{ipj} = \partial \ln v_i/\partial \ln p_j$.

Input-specific "scale" (cost economy) effects are be computed as elasticities with respect to components of the **Y** vector; $\varepsilon_{iYm} = \partial \ln v_i/\partial \ln Y_m$.

Elasticities representing substitutability between the variable and **r** inputs (with reversed signs to the price elasticities since these are in terms of quantities), are $\varepsilon_{iC} = \partial \ln v_i/\partial \ln C$ and $\varepsilon_{iK} = \partial \ln v_i/\partial \ln K$.

Elasticities computed for the C shadow value expression identify changes in cattle demand, since if $Z_C = -\partial G/\partial C = Z_C(\mathbf{Y},\mathbf{p},\mathbf{r},\mathbf{DUM})$ is larger, optimal C is greater: $\varepsilon_{ZCYm} = \partial \ln Z_C/\partial \ln Y_m$, $\varepsilon_{ZCi} = \partial \ln Z_C/\partial \ln p_i$, $\varepsilon_{ZCK} = \partial \ln Z_C/\partial \ln K$.

Elasticities of the cattle pricing "input supply" equation, $p_C = p_C(C, NB, PROC, OT, CS, QU)$, are computed, for example, as $\varepsilon_{pCNB} = \partial \ln p_C/\partial \ln NB$.

"Comparative Statics" elasticities, directly indicating the determinants of the cost economy (ε^{I}_{TCY}), "markdown" ($Prat_C = \varepsilon_{PRC}$) and "markup" ($Prat_{Ym} = \varepsilon_{PRYm}$) measures are second-order elasticities:

$\varepsilon_{TCY,Ym} = \partial \ln \varepsilon_{TCY}/\partial \ln Y_m$, $\varepsilon_{TCY,i} = \partial \ln \varepsilon_{TCY}/\partial \ln p_i$, $\varepsilon_{TCY,K} = \partial \ln \varepsilon_{TCY}/\partial \ln K$, $\varepsilon_{TCY,Df} = \partial \ln \varepsilon_{TCY}/\partial \ln DUM_f$,

$\varepsilon_{PRC,Ym} = \partial \ln \varepsilon_{PRC}/\partial \ln Y_m$, $\varepsilon_{PRC,i} = \partial \ln \varepsilon_{PRC}/\partial \ln p_i$, $\varepsilon_{PRC,K} = \partial \ln \varepsilon_{PRC}/\partial \ln K$, $\varepsilon_{PRC,Df} = \partial \ln \varepsilon_{PRC}/\partial \ln DUM_f$, and

$\varepsilon_{PRYm,Yn} = \partial \ln \varepsilon_{PRYm}/\partial \ln Y_n$, $\varepsilon_{PRYm,i} = \partial \ln \varepsilon_{PRYm}/\partial \ln p_i$, $\varepsilon_{PRYm,K} = \partial \ln \varepsilon_{PRYm}/\partial \ln K$, $\varepsilon_{PRYm,Df} = \partial \ln \varepsilon_{PRYm} /\partial \ln DUM_f$.

B. VALUE, QUANTITY, PRICE AND RATIO MEASURES

TABLE B1: CATEGORIES AND REGIONS

VALUES, categories and regions

	Mean	St. Dev.		Mean	St. Dev.
Total			*West*		
VY	**57.746**	40.496	VY	**30.257**	20.534
VL	**1.996**	1.542	VL	**1.066**	0.739
VE	**0.193**	0.136	VE	**0.118**	0.060
VM	**51.551**	35.263	VM	**26.834**	18.811
M_O	**1.244**	2.074	M_O	**0.614**	0.630
K	**48.4273**	31.7304	K	**25.545**	13.2217
M_B=0			*Western Corn Belt*		
VY	**42.643**	25.314	VY	**34.023**	25.363
VL	**1.360**	1.069	VL	**1.088**	1.005
VE	**0.137**	0.090	VE	**0.121**	0.098
VM	**37.846**	20.889	VM	**30.924**	22.485
M_O	**0.530**	0.483	M_O	**0.472**	0.475
K	**34.7115**	22.1746	K	**30.8202**	21.4062
M_B large			*Plains*		
VY	**99.601**	41.292	VY	**81.357**	39.460
VL	**3.687**	1.506	VL	**2.835**	1.555
VE	**0.297**	0.111	VE	**0.263**	0.140
VM	**88.728**	35.569	VM	**72.346**	33.758
M_O	**4.028**	4.713	M_O	**1.837**	2.673
K	**71.7865**	33.31	K	**65.2321**	32.4135
Y_F=0			*Adapted "plains"*		
VY	**25.798**	12.269	VY	**103.250**	28.587
VL	**0.383**	0.151	VL	**3.652**	1.105
VE	**0.066**	0.030	VE	**0.342**	0.105
VM	**25.136**	12.245	VM	**91.061**	24.378
M_O	**0.092**	0.044	M_O	**2.574**	3.124
K	**23.4008**	13.6861	K	**85.6479**	20.3835
Y_S=0					
VY	**42.779**	29.589			
VL	**1.740**	1.389			
VE	**0.139**	0.083			
VM	**39.749**	27.188			
M_O	**0.800**	0.521			
K	**26.5594**	14.1974			

VY = total output value, including F, S, H, B; VL = value of labor; VE=value of energy; VM = value of material inputs, including C and MB; MO, value of other materials and supplies; and K = value of capital stock services based on "replacement cost", all in millions of dollars.

OUTPUT and INPUT LEVELS, categories **Prices**

	Mean	St. Dev		Mean	St. Dev.
total					
Y_F	**27.977**	23.906	p_{YF}	**1.470**	0.285

Y_S	**6.351**	8.706	p_{YS}	**1.004**	0.134
Y_B	**7.440**	7.646	p_{YB}	**0.452**	0.257
Y_H	**3.486**	2.562	p_{YH}	**0.936**	0.127
L	**1.842**	1.412	p_L	**1.096**	0.140
E	**0.176**	0.126	p_E	**1.045**	0.159
C	**38.948**	24.970	p_C	**1.179**	0.078
M_B	**3.433**	8.353	p_{MB}	**1.085**	0.219
M_B=0					
Y_F	**18.684**	18.611	p_{YF}	**1.400**	0.353
Y_S	**7.635**	10.584	p_{YS}	**1.013**	0.113
Y_B	**5.902**	7.042	p_{YB}	**0.461**	0.323
Y_H	**2.647**	1.533	p_{YH}	**0.899**	0.071
L	**1.320**	1.006	p_L	**1.024**	0.114
E	**0.127**	0.087	p_E	**1.029**	0.136
C	**32.185**	17.879	p_C	**1.164**	0.081
M_B	**0.000**	0.000	p_{MB}	**1.000**	0.000
M_B large					
Y_F	**51.026**	18.477	p_{YF}	**1.680**	0.097
Y_S	**3.652**	2.188	p_{YS}	**0.965**	0.046
Y_B	**9.613**	4.366	p_{YB}	**0.384**	0.083
Y_H	**5.242**	3.931	p_{YH}	**1.077**	0.199
L	**3.326**	1.365	p_L	**1.108**	0.052
E	**0.262**	0.079	p_E	**1.065**	0.149
C	**48.167**	18.706	p_C	**1.187**	0.062
M_B	**23.656**	9.588	p_{MB}	**1.162**	0.057
Y_F=0					
Y_F	**0.000**	0.000	p_{YF}	**1.000**	0.000
Y_S	**20.690**	9.944	p_{YS}	**1.114**	0.055
Y_B	**2.566**	1.560	p_{YB}	**0.489**	0.240
Y_H	**1.715**	0.819	p_{YH}	**0.930**	0.072
L	**0.353**	0.125	p_L	**1.067**	0.084
E	**0.060**	0.030	p_E	**1.059**	0.109
C	**20.902**	10.092	p_C	**1.193**	0.059
M_B	**0.000**	0.000	p_{MB}	**1.000**	0.000
Y_S=0					
Y_F	**24.715**	16.946	p_{YF}	**1.601**	0.068
Y_S	**0.000**	0.000	p_{YS}	**1.000**	0.000
Y_B	**2.654**	3.189	p_{YB}	**0.703**	0.296
Y_H	**2.635**	1.762	p_{YH}	**0.878**	0.060
L	**1.678**	1.189	p_L	**0.993**	0.106
E	**0.140**	0.096	p_E	**1.004**	0.100
C	**32.298**	21.277	p_C	**1.176**	0.093
M_B	**0.336**	1.089	p_{MB}	**1.035**	0.071

OUTPUT and INPUT LEVELS, regions			**Prices**		
West					
Y_F	**13.308**	13.158	p_{YF}	**1.509**	0.259
Y_S	**5.034**	4.296	p_{YS}	**1.071**	0.145
Y_B	**3.226**	2.559	p_{YB}	**0.480**	0.143
Y_H	**1.532**	0.750	p_{YH}	**0.908**	0.110
L	**1.039**	0.765	p_L	**1.121**	0.247
E	**0.102**	0.056	p_E	**1.081**	0.150

C	**17.846**	8.665	p_C	**1.166**	0.066
M_B	**4.501**	8.129	p_{MB}	**1.230**	0.305
Western Corn Belt					
Y_F	**13.605**	16.100	p_{YF}	**1.304**	0.277
Y_S	**8.670**	10.923	p_{YS}	**1.006**	0.190
Y_B	**3.216**	2.637	p_{YB}	**0.485**	0.274
Y_H	**1.848**	1.110	p_{YH}	**0.974**	0.163
L	**1.011**	0.926	p_L	**1.079**	0.114
E	**0.110**	0.087	p_E	**1.007**	0.144
C	**22.886**	14.380	p_C	**1.170**	0.072
M_B	**3.044**	5.613	p_{MB}	**1.058**	0.094
Plains					
Y_F	**41.801**	22.743	p_{YF}	**1.544**	0.241
Y_S	**5.303**	7.701	p_{YS}	**0.970**	0.078
Y_B	**11.506**	8.542	p_{YB}	**0.419**	0.277
Y_H	**5.001**	2.641	p_{YH}	**0.932**	0.115
L	**2.607**	1.417	p_L	**1.091**	0.111
E	**0.241**	0.130	p_E	**1.057**	0.174
C	**55.217**	22.778	p_C	**1.196**	0.078
M_B	**3.827**	9.911	p_{MB}	**1.069**	0.232
"Adapted" Plains					
Y_F	**55.001**	13.060	p_{YF}	**1.609**	0.124
Y_S	**3.776**	2.195	p_{YS}	**0.969**	0.050
Y_B	**15.869**	7.522	p_{YB}	**0.323**	0.137
Y_H	**6.326**	2.284	p_{YH}	**0.964**	0.120
L	**3.317**	1.058	p_L	**1.111**	0.097
E	**0.306**	0.103	p_E	**1.090**	0.195
C	**68.006**	14.439	p_C	**1.204**	0.059
M_B	**5.968**	11.978	p_{MB}	**1.101**	0.283

Y, M ratios, categories

	Mean	St. Dev.
total		
VY_F/VY	**0.662**	0.354
VY_S/VY	**0.239**	0.348
VY_B/VY	**0.041**	0.020
VY_H/VY	**0.058**	0.014
VC/VM	**0.926**	0.112
VM_B/VM	**0.053**	0.104
VM_O/VM	**0.021**	0.021

Y,K ratios

	Mean	St. Dev.
VL/VY	**0.033**	0.011
VE/VY	**0.004**	0.001
K/VY	**0.921**	0.402
VM/VY	**0.906**	0.078
VL/K	**0.042**	0.022
VE/K	**0.004**	0.001
VY/K	**1.300**	0.624
VM/K	**1.174**	0.567

M_B=0

VY_F/VY	**0.557**	0.441	VL/VY	**0.029**	0.013
VY_S/VY	**0.348**	0.431	VE/VY	**0.003**	0.001
VY_B/VY	**0.038**	0.022	K/VY	**0.868**	0.434
VY_H/VY	**0.057**	0.007	VM/VY	**0.913**	0.091
VC/VM	**0.988**	0.008	VL/K	**0.044**	0.034
VM_B/VM	**0.000**	0.000	VE/K	**0.004**	0.002
VM_O/VM	**0.012**	0.008	VY/K	**1.528**	0.939
			VM/K	**1.396**	0.875

M_B large

VY_F/VY	**0.878**	0.030	VL/VY	**0.037**	0.003
VY_S/VY	**0.034**	0.017	VE/VY	**0.003**	0.001
VY_B/VY	**0.035**	0.004	K/VY	**0.723**	0.148
VY_H/VY	**0.053**	0.022	VM/VY	**0.896**	0.030
VC/VM	**0.650**	0.068	VL/K	**0.054**	0.011
VM_B/VM	**0.313**	0.065	VE/K	**0.004**	0.001
VM_O/VM	**0.037**	0.029	VY/K	**1.443**	0.308
			VM/K	**1.293**	0.279

Y_F=0

VY_F/VY	**0.000**	0.000	VL/VY	**0.016**	0.004
VY_S/VY	**0.894**	0.020	VE/VY	**0.003**	0.001
VY_B/VY	**0.044**	0.023	K/VY	**0.859**	0.306
VY_H/VY	**0.062**	0.007	VM/VY	**0.971**	0.066
VC/VM	**0.996**	0.004	VL/K	**0.020**	0.008
VM_B/VM	**0.000**	0.000	VE/K	**0.003**	0.001
VM_O/VM	**0.004**	0.004	VY/K	**1.300**	0.430
			VM/K	**1.250**	0.384

Y_S=0

VY_F/VY	**0.929**	0.013	VL/VY	**0.039**	0.007
VY_S/VY	**0.000**	0.000	VE/VY	**0.004**	0.002
VY_B/VY	**0.015**	0.015	K/VY	**0.922**	0.679
VY_H/VY	**0.056**	0.006	VM/VY	**0.947**	0.067
VC/VM	**0.968**	0.027	VL/K	**0.070**	0.044
VM_B/VM	**0.010**	0.024	VE/K	**0.005**	0.002
VM_O/VM	**0.023**	0.013	VY/K	**1.914**	1.366
			VM/K	**1.791**	1.245

Y, M ratios, regions | **Y,K ratios**

West

VY_F/VY	**0.598**	0.317	VL/VY	**0.036**	0.014
VY_S/VY	**0.306**	0.297	VE/VY	**0.004**	0.002
VY_B/VY	**0.046**	0.021	K/VY	**0.955**	0.472
VY_H/VY	**0.051**	0.012	VM/VY	**0.870**	0.049
VC/VM	**0.872**	0.151	VL/K	**0.041**	0.014
VM_B/VM	**0.109**	0.145	VE/K	**0.005**	0.001
VM_O/VM	**0.020**	0.009	VY/K	**1.292**	0.534
			VM/K	**1.126**	0.466

Western Corn Belt

VY_F/VY	**0.494**	0.423	VL/VY	**0.030**	0.012
VY_S/VY	**0.410**	0.415	VE/VY	**0.003**	0.002
VY_B/VY	**0.039**	0.024	K/VY	**0.927**	0.443
VY_H/VY	**0.057**	0.008	VM/VY	**0.917**	0.066

VC/VM	**0.918**	0.106	VL/K	**0.037**	0.019
VM_B/VM	**0.069**	0.102	VE/K	**0.004**	0.001
VM_O/VM	**0.015**	0.012	VY/K	**1.300**	0.534
			VM/K	**1.187**	0.469
Plains					
VY_F/VY	**0.775**	0.271	VL/VY	**0.034**	0.008
VY_S/VY	**0.125**	0.265	VE/VY	**0.003**	0.001
VY_B/VY	**0.041**	0.017	K/VY	**0.847**	0.274
VY_H/VY	**0.059**	0.012	VM/VY	**0.910**	0.086
VC/VM	**0.941**	0.102	VL/K	**0.046**	0.026
VM_B/VM	**0.038**	0.090	VE/K	**0.004**	0.001
VM_O/VM	**0.021**	0.017	VY/K	**1.363**	0.694
			VM/K	**1.234**	0.639
"Adapted" Plains					
VY_F/VY	**0.862**	0.022	VL/VY	**0.035**	0.005
VY_S/VY	**0.034**	0.014	VE/VY	**0.003**	0.001
VY_B/VY	**0.045**	0.015	K/VY	**0.854**	0.166
VY_H/VY	**0.059**	0.014	VM/VY	**0.887**	0.076
VC/VM	**0.919**	0.122	VL/K	**0.043**	0.010
VM_B/VM	**0.056**	0.108	VE/K	**0.004**	0.001
VM_O/VM	**0.025**	0.020	VY/K	**1.220**	0.265
			VM/K	**1.078**	0.227

C. ADDITIONAL MEASURES FOR CATEGORIES AND REGIONS

TABLE C1: COEFFICIENT ESTIMATES

	estimate	*t-statistic*
δ_{r1}	-0.0192	*-8.267*
δ_{r2}	-0.0185	*-7.188*
δ_{r3}	-0.0238	*-10.419*
δ_{f1}	-0.0207	*-11.411*
δ_{f2}	-0.0183	*-9.790*
δ_{f3}	-0.0133	*-6.548*
δ_{f4}	0.0002	*0.053*
δ_{f5}	-0.0084	*-3.915*
α_{LE}	-0.1442	*-1.545*
α_{LMB}	1.1374	*6.945*
α_{EMB}	-0.2848	*-1.748*
α_{LL}	-0.8823	*-6.852*
α_{EE}	0.5018	*3.857*
α_{MBMB}	-0.3460	*-0.762*
δ_{LK}	-0.0827	*-1.619*
δ_{EK}	-0.1053	*-2.065*
δ_{MBK}	0.0522	*0.463*
δ_{LYF}	0.1091	*12.032*
δ_{EYF}	0.0757	*8.048*
δ_{MBYF}	1.1632	*75.389*
δ_{LYS}	0.0194	*2.414*
δ_{EYS}	0.0227	*2.708*
δ_{MBYS}	0.8708	*60.713*
δ_{LYB}	0.1018	*12.807*
δ_{EYB}	0.1310	*16.166*
δ_{MBYB}	0.2545	*20.252*
δ_{LYH}	0.0807	*4.561*
δ_{EYH}	0.1291	*7.205*
δ_{MBYH}	0.5584	*22.544*
δ_{LC}	-0.0011	*-0.151*
δ_{EC}	-0.0218	*-2.875*
δ_{MBC}	-0.9657	*-77.758*
δ_{LMO}	-0.8209	*-6.105*
δ_{EMO}	-0.9580	*-7.120*
δ_{MBMO}	-0.3841	*-2.377*
γ_{YFYF}	-0.0023	*-6.925*
γ_{YSYS}	0.0006	*1.608*
γ_{YBYB}	-0.0042	*-10.787*
γ_{YHYH}	-0.0160	*-5.614*
γ_{KK}	-0.0139	*-1.326*
γ_{CC}	-0.0014	*-5.411*
γ_{MOMO}	-0.0217	*-1.106*
γ_{YFYS}	-0.0010	*-4.011*
γ_{YFYH}	-0.0009	*-3.958*
γ_{YFYB}	-0.0003	*-1.210*

	estimate	*t-statistic*
γ_{YSYB}	-0.0001	*-0.317*
γ_{YSYH}	-0.0001	*-0.499*
γ_{YBYH}	-0.0013	*-5.207*
γ_{YFK}	0.0006	*0.222*
γ_{YSK}	-0.00001	*-0.004*
γ_{YHK}	0.0085	*4.211*
γ_{YBK}	0.0055	*2.375*
γ_{CYF}	0.0030	*5.778*
γ_{MOYF}	0.0073	*2.876*
γ_{CYS}	0.0011	*2.198*
γ_{MOYS}	0.0034	*1.695*
γ_{CYB}	0.0006	*1.489*
γ_{MOYB}	0.0053	*2.570*
γ_{CYH}	0.0039	*6.521*
γ_{MOYH}	0.0217	*6.865*
γ_{CK}	0.0026	*1.296*
γ_{MOK}	0.0811	*2.104*
γ_{CMO}	-0.0074	*-3.690*
δ_{MB0}	0.1414	*2.427*
δ_{MBL}	0.2587	*2.670*
$\delta_{MBI+I24}$	1.0593	*4.774*
α_{C}	0.0004	*3.870*
β_{CCS2}	-0.0007	*-1.970*
β_{CCS}	0.0973	*6.042*
β_{CQU}	0.1205	*10.441*
β_{C}	1.1981	*44.644*
β_{CNB}	-0.0089	*-6.417*
β_{CP}	0.6934	*3.056*
δ_{N}	-12.4480	*-15.114*
δ_{E}	0.9132	*2.299*
δ_{t1}	-0.1304	*-5.483*
δ_{t2}	-0.1542	*-6.483*
δ_{t3}	-0.1780	*-7.486*
δ_{t4}	-0.1740	*-7.320*
δ_{t5}	-0.1794	*-7.550*
δ_{t6}	-0.1654	*-6.970*
δ_{t7}	-0.1691	*-7.126*
δ_{t8}	-0.1357	*-5.720*
δ_{t9}	-0.1055	*-4.444*
δ_{t10}	-0.0850	*-3.582*
δ_{t11}	-0.0657	*-2.760*
λ_{YF}	-0.0046	*-10.681*
δ_{YF0}	-0.4771	*-23.199*
λ_{YS}	-0.0008	*-0.591*
δ_{YS0}	0.0574	*3.078*

λ_{YH}	0.0032	*0.254*

regions: r1= WCB, r2= West, r3=Plains (East left out)
months: t1=May, t2=June

δ_{MB0} is associated with a dummy for MB=0 plants, δ_{MBL} is for MB large plants

δ_{YS0} is associated with a dummy for Y_S=0 plants, and similarly for δ_{YF0} for Y_F=0 plants

δ_N and δ_E are dummy coefficients for two plants in the cost equation that were outliers

δ_{MBI} is associated with a dummy for a plant that was an M_B outlier

δ_{fi} are associated with dummy variables for the firms

TABLE C2: SCALE ECONOMIES AND PRICE RATIOS – CATEGORIES AND REGIONS

CATEGORY

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.
total					*total*				
ε^{S}_{TCY}	**0.919**	0.149	0.414	1.974	$P^{S}rat_{C}$	**0.987**	0.009	0.958	1.002
ε^{L}_{TCY}	**1.022**	0.076	0.806	1.418	$MC^{I}rat$	**0.978**	0.019	0.860	1.053
ε^{C}_{TCY}	**0.947**	0.060	0.732	1.245	$Prat_{Y}$	**1.087**	0.075	1.005	1.343
ε^{n}_{TCY}	**0.949**	0.147	0.460	2.081	$P^{I}rat_{T}$	**1.062**	0.062	0.947	1.279
SC_{FS}	**0.008**	0.009	0.000	0.051	PROF	**1.004**	0.068	0.794	1.376
M_B=0					*M_B=0*				
ε^{S}_{TCY}	**0.899**	0.108	0.711	1.604	$P^{S}rat_{C}$	**0.988**	0.007	0.971	0.997
ε^{L}_{TCY}	**1.002**	0.055	0.891	1.253	$MC^{I}rat$	**0.982**	0.010	0.951	0.996
ε^{C}_{TCY}	**0.952**	0.055	0.827	1.179	$Prat_{Y}$	**1.065**	0.059	1.006	1.233
ε^{n}_{TCY}	**0.917**	0.103	0.783	1.648	$P^{I}rat_{T}$	**1.046**	0.049	0.989	1.195
SC_{FS}	**0.001**	0.002	0.000	0.010	PROF	**0.994**	0.052	0.883	1.204
M_B large					*M_B large*				
ε^{S}_{TCY}	**0.868**	0.074	0.690	0.990	$P^{S}rat_{C}$	**0.982**	0.007	0.967	0.993
ε^{L}_{TCY}	**1.088**	0.113	0.971	1.418	$MC^{I}rat$	**0.971**	0.012	0.936	0.986
ε^{C}_{TCY}	**0.922**	0.040	0.821	0.987	$Prat_{Y}$	**1.155**	0.065	1.066	1.343
ε^{n}_{TCY}	**0.915**	0.059	0.773	1.006	$P^{I}rat_{T}$	**1.121**	0.052	1.051	1.279
SC_{FS}	**0.014**	0.008	0.001	0.030	PROF	**1.033**	0.041	0.961	1.119
Y_F=0					*Y_F=0*				
ε^{S}_{TCY}	**0.946**	0.080	0.799	1.126	$P^{S}rat_{C}$	**0.993**	0.003	0.986	0.997
ε^{L}_{TCY}	**0.982**	0.056	0.891	1.098	$MC^{I}rat$	**0.987**	0.008	0.967	0.996
ε^{C}_{TCY}	**0.972**	0.056	0.881	1.089	$Prat_{Y}$	**1.013**	0.006	1.006	1.024
ε^{n}_{TCY}	**0.950**	0.081	0.802	1.130	$P^{I}rat_{T}$	**1.000**	0.003	0.989	1.005
SC_{FS}	**0.000**	0.000	0.000	0.000	PROF	**0.972**	0.053	0.883	1.079
Y_S=0					*Y_S=0*				
ε^{S}_{TCY}	**0.899**	0.064	0.772	1.017	$P^{S}rat_{C}$	**0.988**	0.008	0.971	0.997
ε^{L}_{TCY}	**1.022**	0.046	0.952	1.095	$MC^{I}rat$	**0.984**	0.010	0.960	0.996
ε^{C}_{TCY}	**0.959**	0.014	0.931	0.982	$Prat_{Y}$	**1.076**	0.054	1.014	1.191
ε^{n}_{TCY}	**0.912**	0.059	0.774	1.023	$P^{I}rat_{T}$	**1.059**	0.042	1.009	1.152
SC_{FS}	**0.000**	0.000	0.000	0.000	PROF	**1.015**	0.039	0.944	1.081

REGION

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.
West					*West*				
ε^{S}_{TCY}	**1.000**	0.151	0.799	1.613	$P^{S}rat_{C}$	**0.996**	0.004	0.985	1.002

ε^{L}_{TCY}	**0.976**	0.059	0.806	1.067	$MC^{I}rat$	**0.990**	0.010	0.939	1.016
ε^{C}_{TCY}	**0.946**	0.042	0.812	1.026	$Prat_{Y}$	**1.037**	0.042	1.005	1.155
ε^{n}_{TCY}	**1.017**	0.151	0.802	1.628	$P^{I}rat_{T}$	**1.026**	0.039	0.947	1.129
SC_{FS}	**0.008**	0.007	0.000	0.026	PROF	**0.972**	0.061	0.794	1.082
WCB					*WCB*				
ε^{S}_{TCY}	**0.929**	0.068	0.803	1.106	$P^{S}rat_{C}$	**0.992**	0.005	0.978	0.998
ε^{L}_{TCY}	**0.991**	0.047	0.891	1.095	$MC^{I}rat$	**0.986**	0.009	0.960	0.997
ε^{C}_{TCY}	**0.961**	0.041	0.881	1.081	$Prat_{Y}$	**1.045**	0.045	1.006	1.161
ε^{n}_{TCY}	**0.941**	0.065	0.815	1.112	$P^{I}rat_{T}$	**1.030**	0.038	0.990	1.122
SC_{FS}	**0.004**	0.006	0.000	0.030	PROF	**0.990**	0.051	0.883	1.072
Plains					*Plains*				
ε^{S}_{TCY}	**0.888**	0.176	0.414	1.974	$P^{S}rat_{C}$	**0.981**	0.009	0.958	0.997
ε^{L}_{TCY}	**1.050**	0.081	0.926	1.418	$MC^{I}rat$	**0.969**	0.020	0.860	1.053
ε^{C}_{TCY}	**0.934**	0.072	0.732	1.245	$Prat_{Y}$	**1.131**	0.073	1.006	1.343
ε^{n}_{TCY}	**0.933**	0.175	0.460	2.081	$P^{I}rat_{T}$	**1.094**	0.063	0.959	1.279
SC_{FS}	**0.010**	0.010	0.000	0.051	PROF	**1.020**	0.076	0.855	1.376
"Adapted" Plains					*"Adapted" Plains*				
ε^{S}_{TCY}	**0.862**	0.194	0.414	1.974	$P^{S}rat_{C}$	**0.977**	0.008	0.958	0.997
ε^{L}_{TCY}	**1.062**	0.093	0.961	1.418	$MC^{I}rat$	**0.961**	0.021	0.860	1.053
ε^{C}_{TCY}	**0.909**	0.073	0.732	1.245	$Prat_{Y}$	**1.170**	0.052	1.077	1.343
ε^{n}_{TCY}	**0.924**	0.197	0.460	2.081	$P^{I}rat_{T}$	**1.124**	0.053	0.959	1.279
SC_{FS}	**0.015**	0.009	0.004	0.051	PROF	**1.022**	0.090	0.855	1.376

TABLE C3: SCOPE AND LABOR ELASTICITIES – CATEGORIES AND REGIONS

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.
total					*total*				
SCP_{FH}	**0.010**	0.010	0.000	0.054	ε_{LC}	**-1.002**	1.310	-6.524	0.725
SCP_{FB}	**0.007**	0.009	0.000	0.046	ε_{LYF}	**0.927**	0.611	-0.799	2.067
SCP_{SB}	**0.000**	0.000	0.000	0.002	ε_{LYS}	**0.807**	1.752	-0.100	8.541
SCP_{SH}	**0.000**	0.000	0.000	0.002	ε_{LpL}	**-0.665**	0.718	-3.773	-0.076
SCP_{BH}	**0.004**	0.004	0.000	0.022	ε_{LpE}	**-0.095**	0.103	-0.548	-0.012
SCP_{FSB}	**0.015**	0.015	0.000	0.065	ε_{LpMB}	**0.760**	0.820	0.088	4.312
					ε_{LK}	**0.153**	0.441	-0.815	2.246
M_B=0					*M_B=0*				
SCP_{FH}	**0.007**	0.007	0.000	0.025	ε_{LC}	**-1.437**	1.472	-6.051	0.076
SCP_{FB}	**0.005**	0.008	0.000	0.032	ε_{LYF}	**0.827**	0.688	0.000	2.001
SCP_{SB}	**0.000**	0.001	0.000	0.002	ε_{LYS}	**1.338**	2.023	-0.018	8.289
SCP_{SH}	**0.000**	0.000	0.000	0.002	ε_{LpL}	**-0.894**	0.932	-3.773	-0.112
SCP_{BH}	**0.003**	0.004	0.000	0.017	ε_{LpE}	**-0.132**	0.137	-0.548	-0.016
SCP_{FSB}	**0.007**	0.010	0.000	0.042	ε_{LpMB}	**1.025**	1.069	0.129	4.312
					ε_{LK}	**-0.020**	0.273	-0.815	0.612
M_B large					*M_B large*				
SCP_{FH}	**0.018**	0.012	0.007	0.054	ε_{LC}	**0.083**	0.249	-0.461	0.618
SCP_{FB}	**0.010**	0.005	0.003	0.024	ε_{LYF}	**0.499**	0.454	-0.799	1.096
SCP_{SB}	**0.000**	0.000	0.000	0.000	ε_{LYS}	**-0.021**	0.017	-0.077	-0.001
SCP_{SH}	**0.000**	0.000	0.000	0.001	ε_{LpL}	**-0.181**	0.073	-0.336	-0.076
SCP_{BH}	**0.005**	0.003	0.001	0.013	ε_{LpE}	**-0.024**	0.008	-0.042	-0.012
SCP_{FSB}	**0.025**	0.012	0.004	0.052	ε_{LpMB}	**0.205**	0.081	0.088	0.378
					ε_{LK}	**0.605**	0.785	-0.009	2.246
Y_F=0					*Y_F=0*				
SCP_{FH}	**0.000**	0.000	0.000	0.000	ε_{LC}	**-2.978**	1.636	-6.524	-0.986
SCP_{FB}	**0.000**	0.000	0.000	0.000	ε_{LYF}	**0.000**	0.000	0.000	0.000
SCP_{SB}	**0.001**	0.001	0.000	0.002	ε_{LYS}	**3.834**	1.973	1.245	8.541
SCP_{SH}	**0.001**	0.000	0.000	0.002	ε_{LpL}	**-1.606**	0.758	-3.773	-0.797
SCP_{BH}	**0.001**	0.001	0.000	0.003	ε_{LpE}	**-0.239**	0.109	-0.548	-0.105
SCP_{FSB}	**0.001**	0.001	0.000	0.002	ε_{LpMB}	**1.845**	0.866	0.918	4.312
					ε_{LK}	**-0.227**	0.137	-0.815	-0.024
Y_S=0					*Y_S=0*				
SCP_{FH}	**0.009**	0.006	0.002	0.023	ε_{LC}	**-0.589**	0.223	-1.065	-0.195
SCP_{FB}	**0.003**	0.003	0.000	0.010	ε_{LYF}	**1.444**	0.318	0.903	2.067
SCP_{SB}	**0.000**	0.000	0.000	0.000	ε_{LYS}	**0.000**	0.000	0.000	0.000
SCP_{SH}	**0.000**	0.000	0.000	0.000	ε_{LpL}	**-0.565**	0.465	-1.723	-0.112
SCP_{BH}	**0.001**	0.002	0.000	0.005	ε_{LpE}	**-0.081**	0.066	-0.224	-0.014
SCP_{FSB}	**0.003**	0.003	0.000	0.010	ε_{LpMB}	**0.646**	0.530	0.129	1.947
					ε_{LK}	**-0.013**	0.172	-0.378	0.250

REGION

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.
West					*West*				
SCP_{FH}	**0.004**	0.003	0.000	0.011	ε_{LC}	**-0.540**	0.629	-2.010	0.227
SCP_{FB}	**0.003**	0.003	0.000	0.011	ε_{LYF}	**0.860**	0.491	0.000	1.686

SCP_{SB}	**0.000**	0.000	0.000	0.002
SCP_{SH}	**0.000**	0.000	0.000	0.001
SCP_{BH}	**0.001**	0.001	0.000	0.003
SCP_{FSB}	**0.011**	0.007	0.001	0.027
WCB				
SCP_{FH}	**0.004**	0.005	0.000	0.017
SCP_{FB}	**0.002**	0.003	0.000	0.012
SCP_{SB}	**0.000**	0.000	0.000	0.002
SCP_{SH}	**0.000**	0.001	0.000	0.002
SCP_{BH}	**0.001**	0.001	0.000	0.005
SCP_{FSB}	**0.007**	0.009	0.000	0.041
Plains				
SCP_{FH}	**0.016**	0.010	0.000	0.054
SCP_{FB}	**0.012**	0.010	0.000	0.046
SCP_{SB}	**0.000**	0.000	0.000	0.002
SCP_{SH}	**0.000**	0.000	0.000	0.002
SCP_{BH}	**0.006**	0.005	0.000	0.022
SCP_{FSB}	**0.022**	0.016	0.000	0.065
"Adapted" Plains				
SCP_{FH}	**0.021**	0.007	0.012	0.054
SCP_{FB}	**0.017**	0.008	0.006	0.046
SCP_{SB}	**0.000**	0.000	0.000	0.001
SCP_{SH}	**0.000**	0.000	0.000	0.001
SCP_{BH}	**0.009**	0.004	0.002	0.022
SCP_{FSB}	**0.032**	0.012	0.010	0.065

ε_{LYS}	**0.540**	0.916	-0.020	2.822
ε_{LpL}	**-0.934**	0.676	-2.449	-0.191
ε_{LpE}	**-0.130**	0.102	-0.370	-0.025
ε_{LpMB}	**1.064**	0.777	0.216	2.818
ε_{LK}	**-0.060**	0.150	-0.308	0.260
WCB				
ε_{LC}	**-1.338**	1.768	-6.524	0.200
ε_{LYF}	**0.724**	0.660	0.000	1.864
ε_{LYS}	**1.471**	2.261	-0.033	8.541
ε_{LpL}	**-1.137**	0.961	-3.773	-0.141
ε_{LpE}	**-0.160**	0.135	-0.548	-0.021
ε_{LpMB}	**1.297**	1.094	0.162	4.312
ε_{LK}	**-0.088**	0.167	-0.426	0.320
Plains				
ε_{LC}	**-0.970**	1.143	-5.867	0.725
ε_{LYF}	**1.048**	0.582	-0.799	2.067
ε_{LYS}	**0.445**	1.415	-0.100	7.092
ε_{LpL}	**-0.352**	0.393	-1.723	-0.076
ε_{LpE}	**-0.052**	0.059	-0.260	-0.012
ε_{LpMB}	**0.403**	0.451	0.088	1.972
ε_{LK}	**0.350**	0.511	-0.815	2.246
"Adapted" Plains				
ε_{LC}	**-0.558**	0.443	-1.493	0.725
ε_{LYF}	**1.008**	0.529	-0.799	1.811
ε_{LYS}	**-0.016**	0.020	-0.100	0.022
ε_{LpL}	**-0.159**	0.040	-0.242	-0.076
ε_{LpE}	**-0.023**	0.007	-0.055	-0.012
ε_{LpMB}	**0.183**	0.046	0.088	0.287
ε_{LK}	**0.586**	0.483	-0.111	2.246

TABLE C4: ENERGY AND C SHADOW VALUE ELASTICITIES – CATEGORIES AND REGIONS

	Mean	St. Dev.	Min.	Max.
total				
ε_{EC}	**-13.052**	10.017	-64.605	5.287
ε_{EYF}	**5.323**	6.193	-26.563	21.917
ε_{EYS}	**5.310**	11.201	-1.385	55.813
ε_{EpL}	**2.565**	2.795	0.374	15.150
ε_{EpE}	**-0.873**	0.947	-5.316	-0.130
ε_{EpMB}	**-1.692**	1.853	-10.207	-0.244
ε_{EK}	**1.576**	5.463	-4.832	37.651
M_B=0				
ε_{EC}	**-18.023**	10.876	-50.512	-3.643
ε_{EYF}	**6.416**	6.531	-1.603	21.917
ε_{EYS}	**9.159**	13.346	-0.193	49.742
ε_{EpL}	**3.331**	3.619	0.591	15.150
ε_{EpE}	**-1.114**	1.175	-4.944	-0.188
ε_{EpMB}	**-2.217**	2.445	-10.207	-0.403
ε_{EK}	**-0.294**	2.566	-4.832	6.886
M_B large				
ε_{EC}	**-2.465**	3.445	-9.799	5.287
ε_{EYF}	**-1.332**	7.583	-26.563	7.430
ε_{EYS}	**-0.254**	0.295	-1.385	0.037
ε_{EpL}	**0.941**	0.309	0.470	1.514
ε_{EpE}	**-0.311**	0.101	-0.499	-0.157
ε_{EpMB}	**-0.630**	0.208	-1.015	-0.312
ε_{EK}	**7.984**	11.282	-0.524	37.651
Y_F=0				
ε_{EC}	**-26.358**	11.531	-64.605	-8.227
ε_{EYF}	**0.000**	0.000	0.000	0.000
ε_{EYS}	**25.100**	11.713	7.586	55.813
ε_{EpL}	**4.970**	3.654	1.765	15.150
ε_{EpE}	**-1.680**	1.175	-4.944	-0.623
ε_{EpMB}	**-3.290**	2.480	-10.207	-1.142
ε_{EK}	**-2.126**	0.910	-4.832	-0.691
Y_S=0				
ε_{EC}	**-13.916**	7.313	-29.005	-4.115
ε_{EYF}	**12.328**	5.597	5.093	21.917
ε_{EYS}	**0.000**	0.000	0.000	0.000
ε_{EpL}	**3.021**	2.712	0.697	9.137
ε_{EpE}	**-0.995**	0.890	-2.982	-0.233
ε_{EpMB}	**-2.026**	1.822	-6.155	-0.463
ε_{EK}	**-0.293**	2.173	-3.160	3.565

	Mean	St. Dev.	Min.	Max.
total				
ε_{ZCC}	**0.308**	0.203	0.034	0.831
ε_{ZCYF}	**-0.246**	0.217	-0.919	0.000
ε_{ZCYS}	**-0.019**	0.025	-0.110	0.000
ε_{ZCpL}	**0.026**	0.022	-0.049	0.093
ε_{ZCpE}	**0.044**	0.022	-0.021	0.121
ε_{ZCpMB}	**0.930**	0.043	0.787	1.069
ε_{ZCK}	**-0.030**	0.020	-0.087	-0.002
M_B=0				
ε_{ZCC}	**0.252**	0.148	0.056	0.634
ε_{ZCYF}	**-0.164**	0.168	-0.603	0.000
ε_{ZCYS}	**-0.022**	0.030	-0.108	0.000
ε_{ZCpL}	**0.032**	0.017	-0.005	0.074
ε_{ZCpE}	**0.052**	0.016	0.017	0.100
ε_{ZCpMB}	**0.917**	0.032	0.827	0.988
ε_{ZCK}	**-0.022**	0.015	-0.068	-0.003
M_B large				
ε_{ZCC}	**0.405**	0.173	0.152	0.769
ε_{ZCYF}	**-0.472**	0.195	-0.919	-0.195
ε_{ZCYS}	**-0.012**	0.007	-0.025	0.000
ε_{ZCpL}	**-0.007**	0.018	-0.049	0.029
ε_{ZCpE}	**0.014**	0.018	-0.021	0.050
ε_{ZCpMB}	**0.993**	0.036	0.924	1.069
ε_{ZCK}	**-0.047**	0.022	-0.087	-0.021
Y_F=0				
ε_{ZCC}	**0.16**	0.073	0.1	0.29
ε_{ZCYF}	**0.000**	0.000	0.000	0.000
ε_{ZCYS}	**-0.059**	0.027	-0.110	-0.02
ε_{ZCpL}	**0.046**	0.017	0.023	0.078
ε_{ZCpE}	**0.064**	0.017	0.042	0.102
ε_{ZCpMB}	**0.890**	0.033	0.827	0.931
ε_{ZCK}	**-0.014**	0.008	-0.024	-0.003
Y_S=0				
ε_{ZCC}	**0.244**	0.166	0.058	0.632
ε_{ZCYF}	**-0.205**	0.145	-0.523	-0.040
ε_{ZCYS}	**0.000**	0.000	0.000	0.000
ε_{ZCpL}	**0.025**	0.007	0.012	0.037
ε_{ZCpE}	**0.045**	0.008	0.023	0.055
ε_{ZCpMB}	**0.930**	0.014	0.908	0.965
ε_{ZCK}	**-0.016**	0.009	-0.026	-0.007

REGION

	Mean	St. Dev.	Min.	Max.
West				
ε_{EC}	**-7.934**	5.357	-24.221	-0.237
ε_{EYF}	**4.837**	4.349	-4.100	17.138

	Mean	St. Dev.	Min.	Max.
West				
ε_{ZCC}	**0.14**	0.07	0.0	0.309
ε_{ZCYF}	**-0.113**	0.12	-0.423	0.00

ε_{EYS}	**3.652**	5.568	-0.238	23.337
ε_{EpL}	**3.314**	2.448	1.091	14.099
ε_{EpE}	**-1.133**	0.945	-5.316	-0.356
ε_{EpMB}	**-2.181**	1.511	-8.783	-0.735
ε_{EK}	**-0.742**	1.498	-2.929	3.125
WCB				
ε_{EC}	**-14.812**	13.322	-64.605	-1.249
ε_{EYF}	**3.973**	4.163	0.000	13.280
ε_{EYS}	**10.249**	14.176	-0.330	55.813
ε_{EpL}	**4.345**	4.022	0.681	15.150
ε_{EpE}	**-1.466**	1.327	-4.944	-0.225
ε_{EpMB}	**-2.880**	2.698	-10.207	-0.456
ε_{EK}	**-1.154**	1.626	-4.832	3.429
Plains				
ε_{EC}	**-13.740**	8.462	-49.765	5.287
ε_{EYF}	**5.900**	7.391	-26.563	21.917
ε_{EYS}	**2.560**	8.640	-1.385	49.742
ε_{EpL}	**1.477**	1.562	0.374	9.137
ε_{EpE}	**-0.504**	0.521	-2.982	-0.130
ε_{EpMB}	**-0.973**	1.042	-6.155	-0.244
ε_{EK}	**3.838**	6.622	-4.466	37.651
"Adapted" Plains				
ε_{EC}	**-10.609**	5.927	-30.078	5.287
ε_{EYF}	**4.082**	7.120	-26.563	18.302
ε_{EYS}	**-0.164**	0.287	-1.385	0.261
ε_{EpL}	**0.772**	0.204	0.374	1.298
ε_{EpE}	**-0.265**	0.082	-0.482	-0.130
ε_{EpMB}	**-0.506**	0.128	-0.851	-0.244
ε_{EK}	**6.347**	7.092	-2.557	37.651

ε_{ZCYS}	**-0.015**	0.013	-0.045	-0.002
ε_{ZCpL}	**0.015**	0.015	-0.02	0.036
ε_{ZCpE}	**0.033**	0.015	0.002	0.059
ε_{ZCpMB}	**0.952**	0.030	0.907	1.017
ε_{ZCK}	**-0.015**	0.008	-0.027	-0.005
WCB				
ε_{ZCC}	**0.18**	0.117	0.0	0.507
ε_{ZCYF}	**-0.120**	0.144	-0.498	0.000
ε_{ZCYS}	**-0.025**	0.031	-0.110	0.00
ε_{ZCpL}	**0.025**	0.022	-0.014	0.078
ε_{ZCpE}	**0.043**	0.023	0.006	0.102
ε_{ZCpMB}	**0.931**	0.044	0.834	1.008
ε_{ZCK}	**-0.019**	0.014	-0.054	-0.002
Plains				
ε_{ZCC}	**0.438**	0.189	0.058	0.831
ε_{ZCYF}	**-0.368**	0.212	-0.919	0.000
ε_{ZCYS}	**-0.016**	0.022	-0.105	0.000
ε_{ZCpL}	**0.030**	0.023	-0.049	0.093
ε_{ZCpE}	**0.048**	0.022	-0.021	0.121
ε_{ZCpMB}	**0.922**	0.045	0.787	1.069
ε_{ZCK}	**-0.041**	0.021	-0.087	-0.007
"Adapted" Plains				
ε_{ZCC}	**0.548**	0.118	0.333	0.831
ε_{ZCYF}	**-0.490**	0.136	-0.919	-0.277
ε_{ZCYS}	**-0.012**	0.007	-0.041	-0.003
ε_{ZCpL}	**0.024**	0.025	-0.049	0.093
ε_{ZCpE}	**0.043**	0.023	-0.021	0.121
ε_{ZCpMB}	**0.933**	0.047	0.787	1.069
ε_{ZCK}	**-0.055**	0.012	-0.087	-0.035

TABLE C5: INPUT SUPPLY AND COST ECONOMY ELASTICITIES – CATEGORIES AND REGIONS

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.
total					*total*				
ε_{pCC}	**0.013**	0.009	-0.002	0.039	$\varepsilon_{TCY,C}$	**0.252**	0.242	-0.127	1.538
ε_{pCNOB}	**-0.023**	0.034	-0.130	0.000	$\varepsilon_{TCY,YF}$	**-0.240**	0.243	-1.251	0.143
ε_{pCPRC}	**0.010**	0.015	-0.022	0.062	$\varepsilon_{TCY,YS}$	**0.014**	0.053	-0.126	0.201
ε_{pCQU}	**0.095**	0.019	0.000	0.144	$\varepsilon_{TCY,pL}$	**0.032**	0.034	-0.085	0.125
ε_{pCCS}	**0.003**	0.011	0.000	0.073	$\varepsilon_{TCY,pE}$	**0.051**	0.033	-0.067	0.143
					$\varepsilon_{TCY,pMB}$	**0.824**	0.109	0.514	1.518
					$\varepsilon_{TCY,K}$	**-0.021**	0.037	-0.248	0.019

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.
$M_B=0$					$M_B=0$				
ε_{pCC}	**0.011**	0.007	0.003	0.028	$\varepsilon_{TCY,C}$	**0.154**	0.192	-0.127	1.014
ε_{pCNOB}	**-0.027**	0.034	-0.103	0.000	$\varepsilon_{TCY,YF}$	**-0.131**	0.170	-0.697	0.106
ε_{pCPRC}	**0.013**	0.017	0.000	0.057	$\varepsilon_{TCY,YS}$	**0.038**	0.061	-0.021	0.201
ε_{pCQU}	**0.102**	0.008	0.079	0.144	$\varepsilon_{TCY,pL}$	**0.040**	0.026	-0.039	0.098
ε_{pCCS}	**0.000**	0.001	0.000	0.005	$\varepsilon_{TCY,pE}$	**0.060**	0.027	-0.029	0.134
					$\varepsilon_{TCY,pMB}$	**0.882**	0.083	0.640	1.518
					$\varepsilon_{TCY,K}$	**-0.008**	0.010	-0.064	0.016

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.
M_B *large*					M_B *large*				
ε_{pCC}	**0.017**	0.007	0.007	0.034	$\varepsilon_{TCY,C}$	**0.340**	0.163	0.121	0.769
ε_{pCNOB}	**-0.022**	0.046	-0.123	0.000	$\varepsilon_{TCY,YF}$	**-0.463**	0.207	-1.018	-0.199
ε_{pCPRC}	**0.008**	0.017	0.000	0.051	$\varepsilon_{TCY,YS}$	**-0.011**	0.007	-0.028	-0.001
ε_{pCQU}	**0.093**	0.015	0.029	0.112	$\varepsilon_{TCY,pL}$	**-0.006**	0.025	-0.085	0.036
ε_{pCCS}	**0.000**	0.000	0.000	0.001	$\varepsilon_{TCY,pE}$	**0.013**	0.028	-0.067	0.062
					$\varepsilon_{TCY,pMB}$	**0.682**	0.077	0.514	0.872
					$\varepsilon_{TCY,K}$	**-0.062**	0.082	-0.248	-0.007

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.
$Y_F=0$					$Y_F=0$				
ε_{pCC}	**0.007**	0.004	0.003	0.015	$\varepsilon_{TCY,C}$	**0.028**	0.081	-0.127	0.201
ε_{pCNOB}	**-0.008**	0.012	-0.032	0.000	$\varepsilon_{TCY,YF}$	**0.000**	0.000	0.000	0.000
ε_{pCPRC}	**0.005**	0.007	0.000	0.030	$\varepsilon_{TCY,YS}$	**0.104**	0.051	-0.020	0.201
ε_{pCQU}	**0.098**	0.006	0.079	0.109	$\varepsilon_{TCY,pL}$	**0.060**	0.025	0.015	0.098
ε_{pCCS}	**0.000**	0.001	0.000	0.005	$\varepsilon_{TCY,pE}$	**0.080**	0.022	0.048	0.126
					$\varepsilon_{TCY,pMB}$	**0.839**	0.052	0.640	1.033
					$\varepsilon_{TCY,K}$	**-0.003**	0.004	-0.009	0.016

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.
$Y_S=0$					$Y_S=0$				
ε_{pCC}	**0.011**	0.007	0.003	0.028	$\varepsilon_{TCY,C}$	**0.162**	0.141	-0.124	0.523
ε_{pCNOB}	**-0.037**	0.026	-0.076	0.000	$\varepsilon_{TCY,YF}$	**-0.154**	0.157	-0.515	0.143
ε_{pCPRC}	**0.014**	0.011	0.000	0.037	$\varepsilon_{TCY,YS}$	**0.000**	0.000	0.000	0.000
ε_{pCQU}	**0.103**	0.008	0.086	0.121	$\varepsilon_{TCY,pL}$	**0.039**	0.009	0.016	0.069
ε_{pCCS}	**0.000**	0.000	0.000	0.000	$\varepsilon_{TCY,pE}$	**0.065**	0.019	0.026	0.107
					$\varepsilon_{TCY,pMB}$	**0.909**	0.041	0.834	1.047
					$\varepsilon_{TCY,K}$	**-0.013**	0.010	-0.049	0.008

REGION

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.
West					*West*				
ε_{pCC}	**0.004**	0.004	-0.002	0.013	$\varepsilon_{TCY,C}$	**0.169**	0.178	-0.127	0.873

ε_{pCNOB}	**-0.017**	0.018	-0.055	0.000
ε_{pCPRC}	**0.008**	0.009	-0.022	0.023
ε_{pCQU}	**0.101**	0.008	0.083	0.116
ε_{pCCS}	**0.017**	0.025	0.000	0.073

WCB

ε_{pCC}	**0.008**	0.005	0.002	0.022
ε_{pCNOB}	**-0.031**	0.039	-0.123	0.000
ε_{pCPRC}	**0.012**	0.014	0.000	0.051
ε_{pCQU}	**0.095**	0.016	0.019	0.121
ε_{pCCS}	**0.000**	0.001	0.000	0.005

Plains

ε_{pCC}	**0.018**	0.008	0.003	0.039
ε_{pCNOB}	**-0.014**	0.027	-0.086	0.000
ε_{pCPRC}	**0.007**	0.015	0.000	0.062
ε_{pCQU}	**0.092**	0.022	0.000	0.144
ε_{pCCS}	**0.001**	0.003	0.000	0.021

"Adapted" Plains

ε_{pCC}	**0.022**	0.007	0.004	0.039
ε_{pCNOB}	**-0.012**	0.028	-0.086	0.000
ε_{pCPRC}	**0.007**	0.017	0.000	0.062
ε_{pCQU}	**0.095**	0.009	0.061	0.111
ε_{pCCS}	**0.002**	0.004	0.000	0.021

$\varepsilon_{TCY,YF}$	**-0.139**	0.129	-0.484	0.010
$\varepsilon_{TCY,YS}$	**0.009**	0.061	-0.117	0.201
$\varepsilon_{TCY,pL}$	**0.023**	0.022	-0.019	0.070
$\varepsilon_{TCY,pE}$	**0.047**	0.019	0.003	0.077
$\varepsilon_{TCY,pMB}$	**0.740**	0.101	0.514	0.954
$\varepsilon_{TCY,K}$	**-0.010**	0.009	-0.029	0.005

WCB

$\varepsilon_{TCY,C}$	**0.098**	0.116	-0.100	0.447
$\varepsilon_{TCY,YF}$	**-0.100**	0.139	-0.522	0.073
$\varepsilon_{TCY,YS}$	**0.042**	0.061	-0.022	0.186
$\varepsilon_{TCY,pL}$	**0.036**	0.029	-0.009	0.098
$\varepsilon_{TCY,pE}$	**0.056**	0.030	0.008	0.126
$\varepsilon_{TCY,pMB}$	**0.785**	0.106	0.548	1.010
$\varepsilon_{TCY,K}$	**-0.008**	0.008	-0.049	0.008

Plains

$\varepsilon_{TCY,C}$	**0.377**	0.250	-0.124	1.538
$\varepsilon_{TCY,YF}$	**-0.363**	0.258	-1.251	0.143
$\varepsilon_{TCY,YS}$	**-0.003**	0.035	-0.126	0.172
$\varepsilon_{TCY,pL}$	**0.029**	0.038	-0.085	0.125
$\varepsilon_{TCY,pE}$	**0.046**	0.036	-0.067	0.134
$\varepsilon_{TCY,pMB}$	**0.868**	0.095	0.613	1.518
$\varepsilon_{TCY,K}$	**-0.028**	0.047	-0.248	0.019

"Adapted" Plains

$\varepsilon_{TCY,C}$	**0.500**	0.206	0.092	1.538
$\varepsilon_{TCY,YF}$	**-0.502**	0.200	-1.251	-0.069
$\varepsilon_{TCY,YS}$	**-0.012**	0.011	-0.066	0.005
$\varepsilon_{TCY,pL}$	**0.014**	0.037	-0.085	0.125
$\varepsilon_{TCY,pE}$	**0.030**	0.033	-0.067	0.116
$\varepsilon_{TCY,pMB}$	**0.861**	0.094	0.613	1.125
$\varepsilon_{TCY,K}$	**-0.038**	0.056	-0.248	0.019

TABLE C6: C "MARKDOWN" AND Y_F "MARKUP" ELASTICITIES – CATEGORIES AND REGIONS

	Mean	St. Dev.	Min.	Max.
total				
ε_{prCC}	**-0.008**	0.004	-0.014	0.002
ε_{prCYF}	**-0.005**	0.007	-0.031	0.000
ε_{prCYS}	**0.000**	0.000	-0.002	0.000
ε_{prCpMB}	**0.000**	0.001	-0.002	0.004
ε_{prCpL}	**0.001**	0.001	-0.001	0.005
ε_{prCpE}	**0.013**	0.009	-0.002	0.037
ε_{prCK}	**-0.001**	0.001	-0.003	0.000
M_B=0				
ε_{prCC}	**-0.008**	0.003	-0.013	-0.003
ε_{prCYF}	**-0.003**	0.004	-0.016	0.000
ε_{prCYS}	**0.000**	0.000	-0.001	0.000
ε_{prCpMB}	**0.000**	0.000	0.000	0.001
ε_{prCpL}	**0.001**	0.000	0.000	0.002
ε_{prCpE}	**0.011**	0.007	0.003	0.028
ε_{prCK}	**0.000**	0.000	-0.002	0.000
M_B large				
ε_{prCC}	**-0.010**	0.002	-0.012	-0.006
ε_{prCYF}	**-0.010**	0.008	-0.031	-0.002
ε_{prCYS}	**0.000**	0.000	-0.001	0.000
ε_{prCpMB}	**0.000**	0.000	-0.002	0.001
ε_{prCpL}	**0.000**	0.000	-0.001	0.002
ε_{prCpE}	**0.018**	0.007	0.007	0.037
ε_{prCK}	**-0.001**	0.001	-0.003	0.000
Y_F=0				
ε_{prCC}	**-0.006**	0.002	-0.010	-0.003
ε_{prCYF}	**0.000**	0.000	0.000	0.000
ε_{prCYS}	**-0.001**	0.000	-0.002	0.000
ε_{prCpMB}	**0.000**	0.000	0.000	0.001
ε_{prCpL}	**0.001**	0.000	0.000	0.001
ε_{prCpE}	**0.007**	0.003	0.003	0.012
ε_{prCK}	**0.000**	0.000	0.000	0.000
Y_S=0				
ε_{prCC}	**-0.008**	0.004	-0.013	-0.002
ε_{prCYF}	**-0.004**	0.004	-0.016	0.000
ε_{prCYS}	**0.000**	0.000	0.000	0.000
ε_{prCpMB}	**0.000**	0.000	0.000	0.001
ε_{prCpL}	**0.001**	0.000	0.000	0.002
ε_{prCpE}	**0.011**	0.008	0.002	0.028
ε_{prCK}	**0.000**	0.000	-0.001	0.000

	Mean	St. Dev.	Min.	Max.
total				
$\varepsilon_{prYF,C}$	**-0.038**	0.048	-0.242	0.000
$\varepsilon_{prYF,YF}$	**0.132**	0.133	0.000	0.667
$\varepsilon_{prYF,YS}$	**0.001**	0.003	0.000	0.020
$\varepsilon_{prYF,pL}$	**-0.005**	0.005	-0.036	0.016
$\varepsilon_{prYF,pE}$	**-0.002**	0.004	-0.021	0.026
$\varepsilon_{prYF,pMB}$	**-0.078**	0.069	-0.325	0.000
$\varepsilon_{prYF,K}$	**-0.001**	0.001	-0.004	0.000
M_B=0				
$\varepsilon_{prYF,C}$	**-0.022**	0.029	-0.120	0.000
$\varepsilon_{prYF,YF}$	**0.085**	0.093	0.000	0.358
$\varepsilon_{prYF,YS}$	**0.000**	0.000	0.000	0.002
$\varepsilon_{prYF,pL}$	**-0.004**	0.004	-0.012	0.000
$\varepsilon_{prYF,pE}$	**-0.002**	0.002	-0.007	0.001
$\varepsilon_{prYF,pMB}$	**-0.054**	0.055	-0.194	0.000
$\varepsilon_{prYF,K}$	**0.000**	0.001	-0.002	0.000
M_B large				
$\varepsilon_{prYF,C}$	**-0.070**	0.056	-0.236	-0.010
$\varepsilon_{prYF,YF}$	**0.264**	0.143	0.086	0.667
$\varepsilon_{prYF,YS}$	**0.004**	0.003	0.000	0.013
$\varepsilon_{prYF,pL}$	**-0.003**	0.005	-0.010	0.016
$\varepsilon_{prYF,pE}$	**0.001**	0.006	-0.006	0.026
$\varepsilon_{prYF,pMB}$	**-0.152**	0.062	-0.325	-0.065
$\varepsilon_{prYF,K}$	**-0.002**	0.001	-0.004	0.000
Y_F=0				
$\varepsilon_{prYF,C}$	**0.000**	0.000	0.000	0.000
$\varepsilon_{prYF,YF}$	**0.000**	0.000	0.000	0.000
$\varepsilon_{prYF,YS}$	**0.000**	0.000	0.000	0.000
$\varepsilon_{prYF,pL}$	**0.000**	0.000	0.000	0.000
$\varepsilon_{prYF,pE}$	**0.000**	0.000	0.000	0.000
$\varepsilon_{prYF,pMB}$	**0.000**	0.000	0.000	0.000
$\varepsilon_{prYF,K}$	**0.000**	0.000	0.000	0.000
Y_S=0				
$\varepsilon_{prYF,C}$	**-0.025**	0.029	-0.107	-0.001
$\varepsilon_{prYF,YF}$	**0.104**	0.083	0.016	0.297
$\varepsilon_{prYF,YS}$	**0.000**	0.000	0.000	0.000
$\varepsilon_{prYF,pL}$	**-0.005**	0.003	-0.012	-0.001
$\varepsilon_{prYF,pE}$	**-0.003**	0.002	-0.006	-0.001
$\varepsilon_{prYF,pMB}$	**-0.067**	0.046	-0.162	-0.013
$\varepsilon_{prYF,K}$	**0.000**	0.000	-0.001	0.000

REGION

	Mean	St. Dev.	Min.	Max.		Mean	St. Dev.	Min.	Max.

West

ε_{prCC}	**-0.004**	0.003	-0.010	0.002
ε_{prCYF}	**-0.001**	0.001	-0.006	0.000
ε_{prCYS}	**0.000**	0.000	0.000	0.000
ε_{prCpMB}	**0.000**	0.000	0.000	0.000
ε_{prCpL}	**0.000**	0.000	0.000	0.000
ε_{prCpE}	**0.004**	0.004	-0.002	0.015
ε_{prCK}	**0.000**	0.000	0.000	0.000

WCB

ε_{prCC}	**-0.006**	0.003	-0.012	-0.002
ε_{prCYF}	**-0.002**	0.003	-0.011	0.000
ε_{prCYS}	**0.000**	0.000	-0.002	0.000
ε_{prCpMB}	**0.000**	0.000	0.000	0.001
ε_{prCpL}	**0.000**	0.000	0.000	0.001
ε_{prCpE}	**0.008**	0.005	0.002	0.022
ε_{prCK}	**0.000**	0.000	-0.001	0.000

Plains

ε_{prCC}	**-0.010**	0.003	-0.014	-0.002
ε_{prCYF}	**-0.009**	0.007	-0.031	0.000
ε_{prCYS}	**0.000**	0.000	-0.001	0.000
ε_{prCpMB}	**0.001**	0.001	-0.002	0.004
ε_{prCpL}	**0.001**	0.001	-0.001	0.005
ε_{prCpE}	**0.018**	0.009	0.002	0.037
ε_{prCK}	**-0.001**	0.001	-0.003	0.000

"Adapted" Plains

ε_{prCC}	**-0.010**	0.003	-0.014	-0.002
ε_{prCYF}	**-0.012**	0.007	-0.031	-0.001
ε_{prCYS}	**0.000**	0.000	-0.001	0.000
ε_{prCpMB}	**0.001**	0.001	-0.002	0.004
ε_{prCpL}	**0.001**	0.001	-0.001	0.005
ε_{prCpE}	**0.022**	0.007	0.003	0.037
ε_{prCK}	**-0.001**	0.001	-0.003	0.000

West

$\varepsilon_{prYF,C}$	**-0.007**	0.011	-0.044	0.000
$\varepsilon_{prYF,YF}$	**0.051**	0.061	0.000	0.233
$\varepsilon_{prYF,YS}$	**0.000**	0.000	0.000	0.002
$\varepsilon_{prYF,pL}$	**-0.002**	0.001	-0.004	0.000
$\varepsilon_{prYF,pE}$	**-0.001**	0.001	-0.003	0.002
$\varepsilon_{prYF,pMB}$	**-0.037**	0.041	-0.150	0.000
$\varepsilon_{prYF,K}$	**0.000**	0.000	-0.001	0.000

WCB

$\varepsilon_{prYF,C}$	**-0.011**	0.018	-0.080	0.000
$\varepsilon_{prYF,YF}$	**0.058**	0.074	0.000	0.269
$\varepsilon_{prYF,YS}$	**0.001**	0.001	0.000	0.007
$\varepsilon_{prYF,pL}$	**-0.002**	0.002	-0.008	0.000
$\varepsilon_{prYF,pE}$	**-0.001**	0.001	-0.004	0.000
$\varepsilon_{prYF,pMB}$	**-0.039**	0.047	-0.157	0.000
$\varepsilon_{prYF,K}$	**0.000**	0.000	-0.002	0.000

Plains

$\varepsilon_{prYF,C}$	**-0.065**	0.052	-0.242	0.000
$\varepsilon_{prYF,YF}$	**0.206**	0.136	0.000	0.667
$\varepsilon_{prYF,YS}$	**0.002**	0.003	0.000	0.020
$\varepsilon_{prYF,pL}$	**-0.007**	0.006	-0.036	0.016
$\varepsilon_{prYF,pE}$	**-0.003**	0.005	-0.021	0.026
$\varepsilon_{prYF,pMB}$	**-0.117**	0.067	-0.325	0.000
$\varepsilon_{prYF,K}$	**-0.001**	0.001	-0.004	0.000

"Adapted" Plains

$\varepsilon_{prYF,C}$	**-0.092**	0.045	-0.242	-0.031
$\varepsilon_{prYF,YF}$	**0.279**	0.107	0.121	0.667
$\varepsilon_{prYF,YS}$	**0.004**	0.003	0.001	0.020
$\varepsilon_{prYF,pL}$	**-0.008**	0.006	-0.036	0.016
$\varepsilon_{prYF,pE}$	**-0.003**	0.006	-0.021	0.026
$\varepsilon_{prYF,pMB}$	**-0.153**	0.046	-0.325	-0.081
$\varepsilon_{prYF,K}$	**-0.002**	0.001	-0.004	-0.001

D. DATA SUPPLEMENT

The data used for this study are specified at the monthly level of time aggregation, allowing a more appropriate connection between output and input data than would weekly data. Monthly observations permit a more appropriate link between shipments and production (particularly for fabrication, which is often stored longer than carcasses). Monthly data also reduce concerns about outliers due to reporting "errors," facilitate ignoring the differences between hours paid and hours worked as discrepancies are minimized over a month, and allow the use of figures that were (explicitly or implicitly) allocated from monthly numbers in the "weekly" measures reported.

A few anomalies in the data should be raised. Only one firm submitted reports that differed sufficiently from others, and appeared incomplete enough, to be omitted from the sample. Some other plants were outliers, although their differences seemed effectively represented through dummy fixed effects in the cost function. Among these outliers was a plant that appeared to underreport M_B use (as was also true for some other plants from the same firm, although not as dramatically), thus exhibiting very low costs. In constrast, one other plant had excessively high costs, possibly due to mis-reporting meat packing and other operations, as this is a highly diversified plant. Sensitivity tests for differing treatments of these and other outlier plants indicated that they increased the volatility of the estimates, particularly if not recognized by fixed effects, but they did not alter the substantive conclusions about market power and cost economies.

Another issue was the "matchup" of the numbers, due to the incompatibility of the reporting for many of the initial and final months. The anomalies were quite easily seen from descriptive statistics (ratios of materials and labor payments to output for a beginning or ending month, for example); observations that were obviously mis-matched were deleted from the sample. Final results were reported primarily on observations "2-12," leaving out the first month of reporting and, often, the final month.

Observation of the data identified clear divisions in the structure of the plants, in addition to their obvious characterization by size. Plants that sold no fabricated output, or no slaughter output, would be expected to differ from plants that did not specialize in this manner. Similarly, some plants purchased no (or very little) M_B input, while another well-defined sub-sample used a large proportion of M_B. This difference suggested the usefulness of generating results by production structure "category." The difference also highlighted the importance of recognizing zero (or nearly zero) input and output values in the econometric model.

Initially, some separate estimation over sub-samples was attempted to deal with these differences in output and input use among plants. However, estimation using sub-samples that included few plants encountered degrees of freedom problems and caused comparability difficulties across different types of plants. Results from these trial estimations were close to those obtained when pooling the full sample with fixed effects included. Thus, pooled estimation, with fixed effects (dummy variables) representing differing production structures and outliers, was used for the final reported results. The K values also act as plant-specific controls.

Given these comments and qualifications, it is useful to look at Appendix Table B1, that presents summary statistics for the categories (total, plants with M_B=0, M_B large, Y_F=0, and Y_S=0 plants) and regions. The reported numbers present mean (average) values of the measures, their standard deviation (st. dev.), minimum over the sample (min.) and maximum (max.).

The first numbers presented are for total **values** of output (VY, including fabricated [Y_F], slaughter [Y_S], hides [Y_H] and byproduct [Y_B] sales), labor use (VL), energy (VE), "materials" input (VM, including cattle [C], purchased beef [M_B], and "other" materials and supplies [M_O]), and the estimated value of capital stock services based on the "replacement cost" reported (K), all reported in millions of dollars.

The overall or "total" (average across all plants) measures mask the great size differences across plants. An average plant produces over 55 million dollars worth of output monthly, but many plants vary far from this average. Even though only "large" plants are included in this sample, substantial size variation remains, in addition to the structural differences.

By far the greatest variable expenditure or opportunity cost is materials, including cattle and intermediate beef purchases. In fact, 91 percent of the value of output is spent on these inputs. Most of that is cattle, for M_B averages only 5 percent of materials costs. This is evident in the Y, M, and C ratios.

The K measures indicate that the replacement value of plants is typically slightly less than the value of output produced each month (although plants that produce more fabricated output also have greater capital costs per unit of output). Approximate capital costs per month may be computed from this. Assuming an interest rate of 8.5 percent (the Moody Baa bond yield in 1991), depreciation and maintenance of 10 percent, and allocating across months, we can compute an average monthly capital "user" cost of about 1.5 percent of the value of the capital stock K. This procedure for valuing capital was used for imputing the optimal level of capital for the estimated long-run elasticities reported. However, these somewhat rough estimates of the return to capital were not embodied in the econometric ("short-run") model.

Plants that purchase or transfer significant amounts of beef (M_B large) are the largest at nearly 100 million dollars worth of output per month on average. These large plants are also associated with the largest firms – both in terms of capital and output value. Plants within any one firm, however, vary considerably in size.

The more specialized plants tend to be smaller than the average; plants with either Y_F=0 or Y_S=0 are significantly smaller than average (about half and one-third the value of total output, respectively). Also, the Y_F=0 plants use primarily materials inputs – reported labor and energy costs are minimal – and virtually all the "materials" inputs are cattle (C). Plants that do all fabricating (Y_S=0 plants), by contrast, have a clearly higher labor to output ratio.

Regional differences are also evident. By far the largest plants are located in the Plains. Plants in the remaining three regions – the East, West and Western Corn Belt – produce less than half the output per plant than the average for the Plains, and typically less than one third of that from the "Adapted Plains" plants on average (as defined in Appendix A).

The **output and input levels** presented in the next section of Table B1 provide some indications of their composition. The numbers in these tables indicate that the plants that do no fabricating also use virtually no M_B, and those that only produce fabricated products use high levels of M_B. That is, in general, the plants that use no M_B have a relatively high proportion of slaughter (Y_S) output, and those with high M_B demand levels produce a much greater proportion of Y_F output.

Information about **price levels** is also presented in this section of Table B1. Although these values provide some indication of deviations above and below a price level of 1.0, it should be noted that "prices" for firms that produce or use no output or input were assumed to face corresponding prices of 1.0. This assumption was made for estimation purposes; it makes no sense to assume that plants that purchase no M_B face a zero price for this input. Implicitly, the decision to produce/demand an output/input is assumed to be separate from that price – they face approximately the average price.

Although this is conceptually reasonable, it makes the interpretation of prices in this table somewhat misleading as price measures for specialized plants will be biased toward one. Nevertheless, information may still be drawn from these numbers. First, prices are surprisingly consistent across categories, firms, and regions in terms of the means, although considerable variation within these categories is indicated by the standard deviations. But since these values are expressed in terms of pounds of product, variation likely indicates differences in type of output.

Across regions, it seems plants in the Plains, especially the M_B large plants, receive the highest prices for Y_F. Even without referring to the econometric results, fabrication appears profitable for the large Plains plants and firms.

Also, prices of M_B are highest, on average, for firms that use a significant amount of this input. Plants in the "Adapted Plains" category and, especially, those in the West, face relatively high prices for M_B inputs. Also, plants that produce only fabricated products exhibit slightly higher prices for cattle (C) input, as do the Plains and, particularly, the "Adapted Plains" plants.

The **Y and M ratios** presented in the third section of Table B1 highlight the output and input composition patterns indicated by the value, quantity and price levels. Plants with large M_B purchases produce by far the most fabricated as opposed to slaughter output, with Y_F comprising 87 percent of the value of output. In reverse, plants with M_B=0 average 35 percent slaughter output in terms of value, compared to a 24 percent overall average.

Plains plants, particularly the large ones, tend to produce both Y_S and Y_F with emphasis on fabrication; they purchase a significant amount of beef products, M_B. Meanwhile, the small specialized plants mostly do their own slaughtering and either market their product directly as slaughter output or use it for fabrication.

As might be expected, the Y_H to total output ratio is very constant, averaging around 6 percent. The M_O to total M ratio also is quite consistent at about 2 percent (although plants producing more Y_F have greater packaging and other materials costs).

Finally, consider the ratios of inputs to output and capital values – the **Y,K ratios** in Table B1. Note that plants with high M_B levels tend to have low capital-to-output ratios, as do plants associated with most firms in the Plains region. These low K, Y ratios are striking in that they are associated with the largest plants. This provides some indication that larger plants are more efficient in terms of output production – the very basis for cost economies. Labor intensity is much more consistent across plants, although high for plants in the East, and low for plants with no sales of fabricated products.

Overall, considerable variation, but also strong similarities appear in the data across categories, firms, and regions. This suggests that estimation of input and output patterns in the industry may usefully be carried out by pooling these data, while recognizing the differences in structure that cause variations, such as specialization in particular types of outputs or inputs. The legitimacy of pooling these data, while recognizing between-plant differences, is validated by model results. Although dummy variables reflecting categories, firms, and regions are statistically significant, they are not large in magnitude. And the results for various specifications and data sub-samples provided a very robust story about production structure in this industry.