Consolidation in the Meat Sector

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Slaughter industries are consolidating, as the number of firms falls and plant sizes grow. Related changes are occurring in upstream livestock production sectors: large cattle feedlots and hog farms account for sharply growing shares of livestock sales. As in poultry, new contractual relationships have begun to replace spot market cash transactions for cattle and for hogs. Those sharp structural changes have raised concerns about market power, pollution control, and the reliability of traditional price reporting sources. This is a research conference, aimed at encouraging evaluation and discussion of research methods, data sources, and results.

Topics covered at the conference include the following:

* The existence, extent, and effects of market power in livestock and meat industries; Causal factors in consolidation, such as scale and scope economies, mergers, changes in product mix, innovation, and changes in contractual relations;

* Vertical coordination, as compared to spot markets for transferring livestock, including summaries of recent developments and implications for location, for product characteristics, and for price discovery;

* Externalities associated with consolidation, including the effects of larger animal production facilities on pollution and the effects of local control regulations on consolidation.

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Scale Economies, Product Innovation, and Consolidation in Cattle Slaughter

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Introduction

Meatpacking has undergone a dramatic consolidation. According to the *Wall Street Journal*, the four largest firms handled 36% of all steer and heifer slaughter in 1980; by 1994, three firms, IBP, Excel, and Monfort, handled 81% (Ingersoll, 1996). Concentration increases of that speed and magnitude are quite extraordinary, and have led to considerable controversy concerning the potential exercise of packer market power in cattle procurement.

Congressional hearings were held in 1985 and in 1990; each focused on low cattle prices and rancher losses, but the later hearings emphasized packer concentration, and in particular the growing control of the three majors. After the 1990 hearings, Congress mandated a study of industry pricing by the Department of Agriculture. The Department contracted with several groups of academic researchers, and the resulting analyses found only limited evidence of any market power based on 1992 data (U.S. Department of Agriculture, 1996); the results are consistent with other studies. When the USDA study was released in early 1996, cattle prices had again reached a low point, with substantial rancher losses, while packer profits were said to be near record highs (Feder, 1995). The Secretary of Agriculture then appointed an Advisory Committee on Agricultural Concentration to review the USDA report and other evidence, and to hold public hearings. On the basis of the hearings, the Committee reported that "There is widespread belief in excess packer concentration and in the use of this concentration to depress prices paid to producers" (USDA, Agricultural Marketing Service, 1996). After release of the Committee's report, the Secretary announced plans to sharply expand the Department's program

of beef and livestock price reporting, and to review the Department's enforcement procedures and authority under the 1921 Packers and Stockyards Act.

Media reports emphasize the role of mergers in increasing packer concentration an in allowing for the potential exercise of market power. While the major packers have each acquired other packers, acquisitions are often followed by plant closings and by shutdowns for extensive investment and redesign; industry mergers may therefore be a consequence of consolidation, rather than a cause.

The purpose of this study is to investigate the role of scale economies and technological change in driving consolidation. We make use of a distinctive dataset, based on records of individual cattle slaughter plants, maintained in the Longitudinal Research Database (LRD) of the U.S. Bureau of the Census. LRD files cover plants from 1963 through 1992, and thus allow for analysis of changes over time as well as size related differences at a point in time. The detailed information in the files allows for a crucial step in the analysis, the separate identification of the roles of changes in input and product mixes, output volumes, factor prices, and technology, as factors driving industry costs.

The next section summarizes the industry's dramatic consolidation. We then describe our statistical cost model and data sources; we use the model to evaluate the importance of scale economies. Finally, we report the results of our estimation, and draw implications.

Consolidation in Cattle Slaughter

We rely primarily on two sources for evidence on consolidation. All meatpackers that purchase at least $500,000 of livestock annually are required to report information to the Grain

Inspection, Packers and Stockyards Administration (GIPSA), a USDA regulatory agency. GIPSA collects data on the physical flows of different animal types to meatpacking plants, and those records provide good detail for the period between 1980 and 1995.

The second source is the LRD files assembled from plant reports to the Census of Manufactures. Our LRD files cover slaughter plants that primarily handle cattle, while exempting plants with less than 20 employees from detailed reporting. The records provide data on financial flows (value of shipments, expenditures) and physical volumes of inputs and outputs for Census years from 1963 through 1992, and thereby offer a longer view than GIPSA data. The two sources cover the same large and midsized plants, but differing reporting rules cause them to diverge on very small plants. GIPSA rules exempt plants accounting for about 5.1% of 1992 commercial cattle slaughter, while Census procedures exempt plants accounting for 5.5%.

Table 1 summarizes developments.[1] Each source reports sharp declines in plant numbers in the overlap period of 1982-92; GIPSA plant numbers declined through 1995, while Census numbers declined since 1963.[2] Large plants--those slaughtering more than half a million cattle annually--took rapidly growing shares of output. They slaughtered 28% of all cattle in 1982; by 1995, large plants handled 67%. Moreover, cattle slaughter plants tend to specialize in the slaughter of either steers and heifers or cows and bulls, because of differences in animal shapes, production processes and meat products, and large plant dominance in steer and heifer slaughter grew even more dramatically, from 36% in 1982 to 83% in 1995.[3]

The dramatic shift to large plants mirrors a dramatic increase in market concentration: the four firm concentration ratio in cattle slaughter rose from 32 in 1982 to 67 in 1995, while that in steer and heifer slaughter rose from 41 to 79.[4] Increased concentration came about as production

shifted to large plants, in the face of no growth in industry output (table 1).

Consolidation in cattle slaughter featured three other important changes--in the mix of products shipped from slaughter plants, in plant location, and in labor relations. Twenty five years ago, most cattle slaughter plants were "carcass" plants--they sold whole or half carcasses to other meat processors, wholesalers, or retailers who then separated the carcasses into retail cuts of meat.[5] But since then, slaughter plants have also moved into carcass fabrication, cutting them into "boxed beef" and ground beef products.Table 1 shows that boxed beef accounted for only 9.3% of packer shipments in 1963, but accounted for more than half of 1992 shipments.

In boxed beef production, carcasses are chilled at the plant for a day after slaughter, and are then moved onto a "fabrication" line where they are cut into wholesale and retail cuts of meat. The vacuum-wrapped cuts are then packed in boxes, and the boxed beef is shipped to wholesalers, processors, and retailers. Those buyers purchase boxed beef because slaughter plants can fabricate carcasses at lower costs than they can, and because centralized fabrication also saves on transport costs; slaughterhouses can more efficiently direct the parts of the carcass to the appropriate users. Fabrication lines typically use as much labor and capital as a slaughter line alone--thus, total plant costs are noticeably higher at combination slaughter-fabrication plants than at slaughter only plants. Moreover, fabrication is more likely to be done at larger plants, complicating the estimation of scale relationships.

Slaughter plants locate near cattle feedlots, because they obtain most of their livestock from feeders within 150 miles of the plants. In the 1960's and early 1970's, many feedlots were located in the Corn Belt and west coast as well as in the Great Plains. Since then, commercial cattle feeding has consolidated: about 200 large Plains feedlots today handle more than half of all

steer and heifer sales to slaughterhouses. Table 1 shows that over two thirds of slaughter shipments originated in the Plains in 1992, up from just over one quarter in 1963.

In 1980, 46 percent of workers in the meat products industry were union members, a figure that had remained stable through the 1970's.[6] In the early 1980's, many unionized firms began to press for large reductions in base wages, from $10.69 an hour to $8.25, consistent with wages in non-union plants. After a series of lengthy strikes and plant closings, union membership had by 1987 fallen to 21 percent of the workforce, where it has remained through the most recent data (1997). Hourly industry wages fell sharply after 1982 (dramatically, in real terms); moreover, size related wage premiums eroded, and by 1992 large plants no longer paid higher wages than smaller plants (table 1).

A Model of Meatpacker Costs

The evidence suggests that there may now be substantial scale economies in cattle slaughter, and we would like to identify their extent and importance. We need a model that estimates the size of scale economies over a wide range of plant sizes, not only among small plants, and that allows us to identify scale-increasing technological change. We also need a to account for multiple outputs, because production shifted to boxed beef while also shifting to large plants. Fabrication increases plant costs and input demands, and if fabrication and plant size are related, any analysis of scale economies needs to take account of product mix.

During consolidation, real wage rates fell sharply, especially at larger plants. We would like to estimate the effects of wage changes on plant costs, in order to identify the role of labor market changes in consolidation. Since the effects are likely to vary with plant production

processes (labor should account for a larger share of total costs in plants that do processing, for example), we need to account for differences in labor demand across plants.

In order to analyze packer costs and the role of scale economies, we need a flexible functional form that allows for changes over time in scale relationships, changes in relative factor prices, and multiple outputs. We use the well-known translog cost function, defined as follows:

1) $$\ln C=\alpha_0 + \Sigma\beta_i \ln P_i + (\tfrac{1}{2})\Sigma\Sigma\beta_{ij} \ln P_i \ln P_j + \gamma_1 \ln Q + (\tfrac{1}{2})\, \gamma_2 (\ln Q)^2 + \Sigma\gamma_{1i} \ln Q \ln P_i + \Sigma\delta_k \ln Z_k + (\tfrac{1}{2})\, \Sigma\Sigma\delta_{kl} \ln Z_k \ln Z_l + \Sigma\Sigma\delta_{ik} \ln P_i \ln Z_k + \Sigma\delta_{1k} \ln Q \ln Z_k + \Sigma\alpha_n T_n + \Sigma\Sigma\alpha_{in} \ln P_i T_n + \Sigma\alpha_{1n} \ln Q T_n + \Sigma\Sigma\alpha_{kn} \ln Z_k T_n.$$

where C is total cost, P is a vector of factor prices (labor, animal and meat materials, capital, and other materials), Q is output, Z is a vector of plant characteristics, T is a vector of dummy variables for each Census year (with 1992 as the base), and where ln is the logarithmic operator.

We estimate the cost function jointly with the optimal, cost-minimizing input demand, or cost-share, equations. Those equations are the derivatives of total cost with respect to each input price, and share parameters with the cost function:

2) $$(\partial \ln C)/(\partial \ln P_i) = (P_i X_i)/C = \beta_i + \Sigma\beta_{ij} \ln P_j + \gamma_{1i} \ln Q + \Sigma\delta_{ik} \ln Z_k + \Sigma\alpha_{in} T_n$$

Because we follow standard practice and normalize all variables (dividing them by their

mean values before estimation), the first order terms (the β_i) can be interpreted as the estimated cost share of an input at mean values of the right hand side variables. Since the factor shares must sum to one, we drop the capital share equation to avoid a singular covariance matrix. Each equation in the system could be estimated separately by ordinary least squares, but in order to take account of likely cross equation correlation in the error terms, we again follow standard practice by using a nonlinear iterative seemingly unrelated regression procedure.

Measuring Output in the Cost Function

Modern slaughter plants produce many products, and the mix has changed over time. LRD files define several different product categories, including carcasses, hides, primal and fabricated cuts (boxed beef), ground beef, and byproducts. Each category is itself an aggregate--carcasses may be whole, or in halves or quarters, and fabricated products may cover a wide variety of different cuts.

There are a several ways to include multiple products in a cost function. In principle, we could simply convert Q in the cost function to a vector, with output of each product represented separately in the vector. But since few plants produce all products, and logs are undefined at zero, the translog functional form cannot directly be adapted to the multiproduct approach.

Instead, we follow an approach used in the estimation of cost functions for freight transportation; we define a single output, pounds of meat shipped, but we then add production characteristics to the equation (this is where the Z vector comes from).[7] Our estimating equation includes a measure of product mix (PMIX), one minus the share of carcasses in the value of output. This measure will always be defined in the translog, as carcasses never take up all of

output. Because hide and byproducts are produced in nearly fixed proportions to the number of cattle slaughtered, those shipments account for nearly constant shares of total output. As a result, the measure varies primarily in proportion to the share of boxed beef in a plant's output; increases in boxed beef mean declines in the share of carcasses. As fabrication increases, for a given volume of cattle slaughtered, labor, capital, and materials usage should also increase.

The estimated cost function yields a natural measure of scale economies, the elasticity of total cost with respect to output, Q:

3) $$\epsilon_{CQ}=(\partial \ln C)/(\partial \ln Q)=\gamma_1 + \gamma_2 \ln Q + \Sigma\gamma_{1i} \ln P_i + \Sigma\delta_{1k} \ln Z_k + \Sigma\alpha_{1n} T_n$$

Values of the cost elasticity, ϵ_{CQ}, that are less than 1 suggest the presence of economies of scale, while values in excess of 1 show diseconomies of scale. The first order term, γ_1, can be interpreted directly as the 1992 estimate of scale economies for plants at the sample mean size. Parameters on the interaction terms between Q and the T vector (the α_{1n}) show how the mean cost elasticity changes through time, while the parameter on the ln Q term ($\gamma 2$) shows how the elasticity varies as we move away from the mean plant size to larger or smaller plant sizes.

We can also define a cost elasticity with respect to changes in product mix. Define Zp as our measure of product mix (one minus the output share of carcasses). Then the product mix cost elasticity is:

4) $$\epsilon_{CZp} = (\partial \ln C)/(\partial \ln Z_p) = \delta_p + \Sigma\delta_{kp} \ln Z_k + \Sigma\delta_{ip} \ln P_i + \delta_{1p} \ln Q + \Sigma\alpha_{pn} T_n.$$

The first order term, δ_p, provides a direct measure of the effect of fabrication on costs in 1992, given the physical volume of output, at sample means for all variables. The interaction terms on T (the time periods) capture first order changes as one moves back in time, while the coefficient on physical output, δ_{1p}, provides a direct estimate of scope economies; positive values suggest that the effect of increases in processing on costs is smaller in bigger plants, while negative values suggest that increased processing is more costly in bigger plants.

The final estimating equation includes two other Z variables, input mix (IMIX) and a dummy variable for single plant firms (EST1). IMIX is the share of cattle in combined live animal and purchased meat input costs. Some slaughter plants purchase additional carcasses from other slaughter plants as inputs to fabrication lines. Plants with significant amounts of purchased meat may have different cost structures than plants that only buy live cattle.

We observe slaughter plants operating in seven different years: 1963, 1967, 1972, 1977, 1982, 1987, and 1992. The model allows for technological change by allowing certain parameters to be time varying (Stevenson, 1980). In particular, all first order parameters are allowed to vary by adding interaction terms with each of six different temporal dummy variables--the T vector (one for each Census year, with 1992 as the base). Because of concerns with multicollinearity, quadratic and interaction terms were not allowed to vary with time.

Data and Variable Definitions

The LRD contains records from individual establishments reported in the Census of Manufactures, and covers plants reporting in 1963, 1967, 1972, 1977, 1982, 1987, and 1992. Our dataset consists of LRD plants whose primary product class was SIC 20111 (beef), who reported

complete input and output data (very small plants were exempted from reporting requirements), and whose records met consistency requirements (for example, between cattle and meat inputs and meat outputs). The dataset included 2,541 plant observations over the seven Census years.

Individual LRD records provide detailed establishment information on product types, quantities, and revenues, material input quantities and expenditures, employment and payroll, and ownership and location. Quantity (Q), product mix (PMIX), input mix (IMIX), and single establishment (EST1) variables were defined above. The model also includes factor prices, for labor (PLAB), meat and animal inputs (PMEAT), other material (PMAT), and capital (PCAP). Precise definitions and sources are in appendix A.

Model Selection

The model summarized in equation (1) is our most general functional form, and is referred to as Model IV. We also tested the assumptions of the model with several more restrictive forms. Model I allows for no technological change and no plant characteristics; in other words, all variables from the Z and T vectors are dropped, and all α and δ coefficients are set to zero. Model II generalizes Model I by adding two variables from the Z vector (PMIX and IMIX), and estimating the relevant δ coefficients; Model II still includes no technological change, by omitting all T vector variables and thereby setting all α coefficients to zero. Model III adds technological change (the T vector) but continues to omit the single establishment dummy.

Model IV estimates all coefficients in equation 1. We finally tested two more restrictive versions of Model IV. Model IVA drops all input mix variables, and Model IVB tests for homotheticity by forcing factor shares to be invariant to output (that is, the model drops the

interaction terms between output, Q, and factor prices, the P vector).

We used Gallant-Jorgenson (1979) chi-square tests to distinguish among among different functional forms, in table 2. Model I, the most restrictive, was decisively rejected in favor of Model II, which added measures of output and input mix to factor prices and output. Model II was in turn strongly rejected in favor of Model III, which allows all 1st order coefficients to vary over time. Finally, Model III was rejected in favor of Model IV, which added a dummy variable for single establishment firms, interacted with all first order coefficients.

Table 2 also reports tests of the two further restrictions on Model IV, and rejects each. Model IVA drops all terms involving input mix, but the restrictions are strongly rejected--it's important to account for differences in the mix of animal and meat inputs. G-J tests also decisively reject homotheticity in the test of Model IVB versus IVA..

The selected model (IV) is nonhomothetic and nonhomogeneous; it includes measures of product and input mix as well as a shift variable for single establishment firms, and allows all first order coefficients to vary over time. Table 3 reports Model IV first order coefficients for 1992 and all first order time shifters for earlier years, while table 4 repeats the 1992 first order coefficients and reports coefficients on quadratic and interaction terms.

Factor Price Effects

Table 5 reports factor shares calculated at mean 1992 sample values, and are therefore slightly different from the 1st order coefficients in table 3. Factor shares in cattle slaughter are highly skewed--animal and meat inputs account for just over 86% of costs at 1992 means, while labor and other materials each account for between 5 and 6%, and capital accounts for just over

3%. Over time, the animal input share fell, while capital's grew sharply from a small base, and labor and material shares showed hardly any change (table 3). Estimated capital shares are consistent with the findings of Melton and Huffman (1995), who report a mean 1963-88 capital share of 15.6% of beef value added, which would equate to a 2.65% share of total costs, assuming our overall sample mean estimate of the cattle share of 83% (table 3).

This is a distinctive feature of slaughter industries; rarely does a material input account for such a large share of costs. Three important implications follow.[8] First, changes in cattle prices must be a dominant factor driving short run changes in manufacturing costs and wholesale meat prices. Second, there must be some strong limits to the effects of slaughter scale economies on costs, since the processes that drive scale economies are limited to the cooperating inputs of labor, capital, and other materials that together make up only a fifth to a tenth of total slaughter costs. Third, changes in industry wages can have only small effects on product prices, not because the demand for labor is particularly price-insensitive (it isn't), but rather because labor accounts for such a small share of total costs.

Note the own price demand elasticities reported in table 5, calculated at mean 1992 data values. That for animal and meat inputs is essentially zero--calculated to be 0.0001. Given meat output, demand for animal and meat inputs does not change at all as animal prices change. In short, one can feasibly estimate "value added" cost functions on the assumption of separability between animals and other inputs, as in Melton and Huffman (1995): animal input demand appears unresponsive to changes in other factor prices.

Other input demands are downward sloping. The own price elasticity for labor is estimated to be -0.294 in 1992, quite close to the estimate (-0.373) reported by Melton and

Huffman (1995) for the mean of their 1963-1988 data based on aggregate time series. The labor demand elasticity is quite close to the estimated elasticity of demand for other materials (-0.274), while that for capital is substantially larger (-1.028).

Economies of Scale

In table 3, the first order coefficient for Q is .93--at the sample mean, a 1 percent increase in output, holding factor prices and plant characteristics constant, is associated with a 0.93 percent increase in total costs. The result implies modest scale economies in 1992, that are statistically significant; that is, the coefficient is significantly less than one. Now look across that row: the coefficient rises, by increasing and statistically significant amounts, as we move back toward 1963 from 1992. Estimated scale economies in cattle slaughter, at the sample's mean plant size, became more important, modestly but steadily, through time.[9]

Table 6 presents estimated cost elasticities in a different way, for various representative plant sizes and for different years. The top row repeats information that can be gleaned from table 3, by presenting the estimated cost elasticities for a plant at the sample mean size, calculated for 1992 and 1963. But plants in 1992 were generally much larger than the sample mean size, so we recalculate the 1992 cost elasticity for the mean size plant in 1992 and for a relatively large 1992 plant, one at the 95th percentile of the 1992 size distribution. We also calculate elasticities for the typically smaller plants of 1963, again using the mean and 95th percentile sizes for that year.

The table shows that scale economies became more important between 1963 and 1992; the largest plants in 1963 produced at a point near constant returns, with an estimated cost

elasticity of 0.981 (lower right corner of table 6). But in the 1992 technology, the large plants of 1963 fell noticeably short of constant returns, with a cost elasticity of 0.944.

Plants grew dramatically between 1963 and 1992; a plant at the 95th percentile of the 1992 plant size distribution produced five times as much meat as a plant at the 1963 95th percentile (in fact, the large 1963 plant would be below the 1992 mean). Part of that growth probably reflected attempts to realize scale economies. But notice that the large 1992 plant still falls short of constant returns, with a scale parameter of 0.961. That estimate suggests that further consolidation in slaughter is likely, because the largest plants have not exhausted scale economies. Recent trends confirm that view. GIPSA data show a continuing sharp shift of output toward even bigger slaughter plants after 1992; plants that slaughtered over one million cattle accounted for 34 percent of cattle slaughter in 1992, but 55 percent in 1995 (USDA, 1997).

Our estimates of scale economies hold factor prices constant. But changes in industry labor relations provided further advantages to size. In 1977, wages at large slaughter plants (1,000 or more employees) were 30% above those in other commercial slaughter plants (table 1). With labor accounting for 8.1% of costs in 1977 (table 3), that size differential would translate into a 2.4% cost disadvantage for large plants. In the 1980's, industry wages fell, reducing slaughter costs; moreover, the size differential disappeared, and large plant wages now matched those in smaller plants (table 1). In the 1980's and 1990's, the disappearing size differential effectively reinforced technological change in providing new economies of scale.

Production Characteristics

In table 3, the first order coefficient on product mix (PMIX, the noncarcass share of plant

shipments) is positive and significant, while that on its square is positive and highly significant. Holding the physical volume of output constant, increases in fabrication are associated with cost increases. We ought to see that result, if higher values of PMIX imply more fabrication, and therefore more labor, capital, and materials.[10]

We can calculate the effects of likely changes in PMIX on average costs, using the approach taken for scale economies above. Estimated average costs rise by about 3.2%, for a plant at the 95th percentile of the size distribution, as the plant goes from minimal fabrication (PMIX=.38) to extensive fabrication and minor carcass shipments (PMIX=.90).[11]

Interaction terms of PMIX with factor prices are all highly significant (table 4). As fabrication becomes more important, labor shares grow while animal shares shrink. If PMIX is picking up fabrication, that is what we ought to see; slaughter/fabrication plants use more labor, capital, and materials to transform carcasses into meat cuts, but do not use more animals. Finally, note the interaction with output (Q); the negative and marginally significant sign gives evidence of scope economies, in that the scale parameter gets smaller (steeper, or further below one) as PMIX gets larger. The effect, however, is small: a plant at the 75th percentile of the 1992 size distribution (about 1/3 as large as a plant at the 95th percentile) would incur additional estimated fabrication costs of 3.6 cents per pound in going from minimal to extensive fabrication, compared to 3.2 cents per pound for a plant at the 95th percentile.

Most individual coefficients involving input mix (IMIX, the share of animals in meat and animal inputs) are small and not significant, although the G-J tests in table 2 favor retaining the measure. There are three exceptions. The quadratic term on IMIX squared is small but positive and statistically significant. The coefficient on the interaction term with the price of labor is

negative, while that on capital is positive, with each being highly significant. Labor shares are lower, and capital shares are higher, in plants that use higher ratios of animal to meat inputs.

Consider changes in the model's intercept over time, in table 3. None of the coefficients are significant, and they show no consistent sign pattern. By implication, there are no temporal changes in slaughter costs that are not picked up by movements in factor prices, scale, and product mix effects. The results suggest that much of the industry's productivity growth is accounted for by scale economies: through changes in the estimated scale parameter and through increases in plant size to take account of scale economies.

The results show that it is important to account for plant differences in the mix of outputs and inputs when analyzing costs. Mixes vary widely across plants and over time, and have important direct effects on cost. Because larger plants produce greater proportions of boxed beef, omission of product mix measures can lead to biased estimates of scale economies; and because product mix has changed through time, omission can lead to biased estimates of the extent of technical change and productivity growth.

Discussion

Cattle slaughter exhibits modest but extensive scale economies: modest in that large plants maintain small cost advantages (1 to 3 percent) over smaller plants, but extensive in that scale economies extended throughout the range of 1992 plant sizes.

Production shifted sharply to large plants in the 1980's and 1990's--by 1997, 14 plants accounted for half of all cattle slaughter (USDA, 1998). The timing of this shift matches the technological shift, shown in table 3, toward more pronounced scale economies, a shift that

began in the early 1970's and continued through to the 1990's. Moreover, plant diseconomies due to size related wage premia peaked in 1977, then eroded sharply before disappearing by 1992; concentration in cattle slaughter remained stable until 1977, and increased sharply thereafter. The evidence strongly suggests that scale economies in slaughter, and the disappearance of wage-based diseconomies, drove consolidation.

The effects of consolidation show up in aggregate USDA data on the farm to wholesale price spread for choice beef, which reflects transportation, slaughter, and fabrication costs (Nelson and Hahn, 1998). Adjusted for inflation, the spread fluctuated during the 1970's, but fell steadily and sharply from 1979 through 1992, the period of sharpest consolidation.[12]

Consolidation, reflecting plant level scale economies, is clearly not the sole factor driving the concentration of production among a few firms. The industry's largest plants each account for about 5% of all steer and heifer slaughter, so that the industry could in principle contain a fairly large number of one and two plant firms. Concentration is high partly because the most efficient plants are large, but also because the three leading firms each own multiple plants; factors such as mergers, firm level scale economies (and the absence of managerial diseconomies), and the transfer of organizational capital may each play roles here.

But technological and organizational factors cannot be a complete explanation. For modest scale economies to lead to consolidation as rapid and massive as that in meatpacking, the industry must also have had strong price competition. Small, less efficient plants don't exit because larger plants have slightly lower costs: they exit because product prices fall below their own average variable costs. For product prices to be below small plant costs, they must in turn be quite close to large plant unit costs, because we find small differences between small and large

plant costs.

Studies of cattle pricing find little market power, using several different approaches. First, studies of the interegional linkage of cattle prices find very rapid price transmission (Hayenga, Koontz, and Schroeder, 1996). While rapid transmission of price shocks can occur under market power, the findings imply that buyers and sellers are quite sensitive to price signals. Second, traditional structure-performance studies relate regional differences in cattle prices to regional concentration differences; they typically find very small effects of concentration on price, and sometimes find that larger plants pay higher prices for cattle (Marion and Geithman, 1989; Azzam and Anderson, 1996; Texas A&M Agricultural Market Research Center, 1996). Third, other studies rely on recent techniques relating prices to estimates of marginal factor costs, and find no more than small divergences from competitive pricing (Morrison, 1998). Finally, the labor strife during that period also suggests strong price competition. While unionized plants had substantially higher wages than nonunion plants in the 1970's, the effect on costs was small because the share of wages in total costs was small. For small cost differences to have led to plant closures and lockouts, unionized plants would have to have been under strong competitive price pressures from nonunion plants.

Recent game-theoretic analyses argue that intense price competition can lead to greater concentration in homogeneous good industries (Sutton, 1991). The evidence for U.S. meatpacking supports that conjecture, and suggests that high packer concentration has not yet limited competition in the industry; on the contrary, intense price competition may have accelerated consolidation.

Footnotes

1. MacDonald, Ollinger, Nelson, and Handy (1998) contains a more complete description of consolidation in cattle and in hog slaughter.

2. GIPSA reports more plants, because the agency records all plants that slaughter any cattle, while our LRD file omits multispecies plants for whom cattle are incidental.

3. LRD data agree with GIPSA, and show a shift to large plants beginning in the early 1970's.

4. Census Bureau CR4 in cattle slaughter products (SIC 20111-beef) increased to 71% in 1992 from 25% in 1977, by far the largest increase for any Census product class in any similar time span. Shipments concentration exceeds cattle concentration because leading firms buy steers and heifers and produce boxed beef. The four digit Census industry (SIC 2011-meatpacking) includes hog, cattle, and lamb slaughter plants. We believe, due to differences in slaughter technology and meat demand, that the four digit classification is too broad an industry definition.

5. Of course, the whole animal was used, then as now. Plants ship byproducts--hides, blood, bonemeal, internal organs, and trimmings--that are separated during slaughter, and are used to make clothing, pharmaceuticals, sporting goods, animal feeds, and food products.

6. Unionization data are drawn from the Current Population Survey, which defines industries at the three digit level. Meat products (SIC 201) includes red meat and poultry slaughter and processing. See Kokkelenberg and Sockell (1985) and Curme, Hirsch and McPherson (1990).

7. Transportation studies use ton-miles as output. But tonmiles can be produced in many ways: a network may route output to many different locations, as opposed to a operating a few through routes; or the output can be routed in many small deliveries, as opposed to a smaller number of large shipments. Transport cost functions often include measures of route and output

characteristics in the cost function, in order to capture the effect of characteristics on costs (see Allen and Liu, 1995, or Caves, Christensen, Tretheway, and Windle, 1985).

8. The skewed distribution of factor shares gives rise to some violations of monotonicity conditions. Specifically, predicted factor shares for capital are negative in 9 percent of observations, and other materials factor shares are negative for 12 percent of observations. The violations occur among the smallest plants, and early in the period.

9. The data imply substantial scale economies in slaughter costs, exclusive of animal purchase expenses. That sample mean cost elasticity would be about 0.80--as output increased by 1%, costs for the labor, capital and non-animal materials used in slaughter would increase by 0.8%.

10. We experimented with several alternatives. We tried other indicators of product characteristics (such as one minus boxed beef), and we tried a multiple product cost function, with separate entries for pounds of carcass and pounds of boxed beef (setting zeroes to low but positive values). But those forms provided weaker fits, and we did not want to insert arbitrary values into our model. We also tried a measure based on the relative value of output, with those plants obtaining a higher value of shipments per pound of output in any year assumed to have a more complex product mix. All product mix and multiple product measures gave similar qualitative results, but our final choice provided a better fit to the data and a more direct interpretation.

11. Costs exclusive of animal purchase expenses would therefore rise by about 30%, if animal purchase expenses were 90% of total costs in a plant with minimal fabrication.

12. Farm to wholesale spreads rose sharply between 1992 and 1995, driving some of the controversy described in the introduction; however, spreads fell back again in 1996 and 1997.

Table 1: Selected Characteristics of Consolidation in Cattle Slaughter

Measure and Source	1972	1977	1982	1987	1992	1995
Number of Plants	-Number of Plants Reporting-					
GIPSA	n.a.	814	632	474	342	279
LRD	782	598	391	265	215	n.a.
Large Plants' Share	-Percent of Cattle Bought by Plants Slaughtering More than 500,000-					
Cattle, GIPSA	n.a.	12	28	51	61	67
Steers and Heifers, GIPSA	n.a.	28	36	63	76	83
Market Concentration	-Percent Held by Four Largest Slaughter Firms-					
Cattle, GIPSA	n.a.	n.a.	32	54	64	67
Steers and Heifers, GIPSA	n.a.	n.a.	41	67	78	79
Beef Shipments, LRD	30	25	44	58	71	n.a
Commercial Cattle Slaughter	-Three Year Moving Average-					
All Cattle, NASS	35.0	41.3	35.8	36.0	33.0	35.5
Product Mix	-Percent of SIC 20111 Value of Shipments in Boxed Beef-					
Boxed Beef %, LRD	15.5	30.1	39.5	43.2	56.2	n.a.
Plant Location	Percent of SIC 20111 Shipments from Great Plains-					
Great Plains, LRD	45.4	44.8	59.1	62.6	68.1	n.a.
Hourly Wages, by Plant Size	-Nominal Payroll per Production Worker Hour, SIC 2011-					
More than 999 Employees	5.33	8.44	10.04	8.50	8.65	n.a.
100-999 Employees, Census	4.40	6.50	9.38	8.38	8.67	n.a.

Sources: GIPSA refers to Grain Inspection, Packers and Stockyards Administration, USDA; NASS refers to National Agricultural and Statistics Service, USDA; LRD refers to Longitudinal Research Database, U.S. Census Bureau, and Census refers to published Census of Manufactures reports, U.S. Census Bureau.
Notes: 1963 wages use 1967 data on hours per production worker to adjust 1963 data on annual payroll per production worker to payroll per production worker hour.

Table 2: Tests of Model Selection, Cattle Slaughter Cost Function

Comparison, unrestricted vs. restricted model	Comments	Test Statistics		
		d.f	critical value @ .99	Chi-square
II vs. I	Model I has factor prices and output only; Model II adds product and input mix.	13	27.69	72
III vs. II	Model III adds 1st order time shifts to Model II.	42	66.18	425
IV vs. III	Model IV adds single establishment dummy to III.	7	18.48	28
IV vs. IVA	Model IVA drops input mix variables from IV.	19	36.19	56
IV vs. IVB	Model IVB imposes homotheticity on IV	3	11.34	21

Notes: Chi-square statistics are the difference in Gallant-Jorgenson statistics between models.

Table 3: Cattle Slaughter Cost Function Parameters: First Order Terms and Year Shifts

	Coefficients and Standard Errors						
	1st Order	Changes from 1992					
Variables	1992	1963	1967	1972	1977	1982	1987
Intercept	-.2857	-.0016	-.0181	.0224	.0601	.0154	.0487
	(.0288)	(.0324)	(.0318)	(.0325)	(.0321)	(.0333)	(.0350)
PLAB	.0816	-.0054	.0014	.0044	-.0011	-.0014	-.0017
	(.0052)	(.0055)	(.0056)	(.0057)	(.0058)	(.0061)	(.0064)
PMEAT	.8371	.0233	.0125	.0144	.0258	.0148	.0031
	(.0081)	(.0088)	(.0088)	(.0091)	(.0091)	(.0098)	(.0102)
PMAT	.0510	.0050	.0087	.0088	-.0024	-.0026	-.0022
	(.0032)	(.0088)	(.0034)	(.0035)	(.0036)	(.0038)	(.0040)
PCAP	.0303	-.0228	-.0226	-.0189	-.0223	-.0108	.0008
	(.0083)	(.0089)	(.0089)	(.0092)	(.0093)	(.0099)	(.0103)
Q (lbs)	.9322	.0370	.0382	.0179	.0109	.0088	.0075
	(.0140)	(.0158)	(.0156)	(.0159)	(.0164)	(.0169)	(.0173)
PMIX	.0409	-.0131	-.0103	- .0058	.0114	- .0086	.0129
	(.0114)	(.0106)	(.0104)	(.0104)	(.0104)	(.0112)	(.0113)
IMIX	.1534	-.0916	-.0869	-.0658	.0071	-.0014	-.2593
	(.1647)	(.1636)	(.1636)	(.1646)	(.1729)	(.1674)	(.1997)

Note: Results of estimation of translog cost function for cattle slaughter plants, 1963-1992. Since all variables are standardized at their means, first order coefficients can be interpreted as elasticities at the sample means, while year shifts capture shifts in those elasticities over time.

Table 4: Cattle Slaughter Cost Function Parameters: Higher Order Terms

Variables	1st order	Interactions with: PLAB	PMEAT	PMAT	PCAP	Q (lbs)	PMIX	IMIX	EST1
				Coefficients and standard errors					
PLAB	.0817	.0380	-.0612	.0070	.0162	-.0214	.0053	-.0167	-.0145
	(.0052)	(.0027)	(.0026)	(.0009)	(.0017)	(.0008)	(.0004)	(.0018)	(.0026)
PMEAT	.8371		.1189	-.0435	-.0142	.0265	-.0051	-.0015	.0151
	(.0081)		(.0037)	(.0011)	(.0027)	(.0011)	(.0006)	(.0028)	(.0041)
PMAT	.0510			.0369	-.0004	.0013	-.0007	-.0014	.0035
	(.0032)			(.0006)	(.0010)	(.0005)	(.0002)	(.0011)	(.0016)
PCAP	.0303					-.0064	.0006	.0190	-.0041
	(.0083)					(.0012)	(.0006)	(.0024)	(.0041)
Q (lbs)	.9322					.0105	-.0023	-.0040	-.0075
	(.0140)					(.0031)	(.0014)	(.0065)	(.0077)
PMIX	.0409						.0108	-.0001	-.0017
	(.0114)						(.0017)	(.0019)	(.0046)
IMIX	.1535							.0136	.0030
	(.1647)							(.0077)	(.0249)
EST1	-.0284								N.A.
	(.0161)								

Note: Quadratic (on diagonal) and interaction terms from estimation of translog cost function. First order terms from table 6-4 are repeated in first column.

Table 5: 1992 Mean Input Shares and Elasticities

	Input Price Variables			
	PLAB	PMEAT	PMAT	PCAP
Input Shares	.0587	.8622	.0550	.0301
ϵ_{ii}	-0.294.	0.0001	-0.274	-1.028
σ_{ij} (Allen)				
PLAB	-5.01	-0.209	3.167	10.170
PMEAT		0.0001	0.083	0.453
PMAT			-4.98	0.789
PCAP				-34.10

Note: All values are calculated using mean 1992 data values and parameters from tables 2 and 3. The own price input demand elasticities (ϵ_{ii}) are calculated holding output and other factors constant, while the elasticities of substitution (σ_{ij}) are calculated using Allen's formula.

Table 6: Estimated Cost Elasticity Coefficients, by Plant Size and Year.

	Technology Vintage	
Plant Size	1992	1963
Sample Mean	0.932	0.969
1992 Mean	0.946	0.983
1992 95th Percentile	0.961	0.998
1963 Mean	0.925	0.962
1963 95th Percentile	0.944	0.981

Notes: The coefficients report the percentage change in total costs corresponding to a 1 percent change in output, for plants of differing sizes and technological vintages.

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Appendix A: Data Definitions and Sources for the Cost Analysis

All variables are derived from the Longitudinal Research Database (LRD) maintained at the Center for Economic Studies of the U.S. Census Bureau. Total cost (COST) is the sum of labor, meat, material, and capital input costs. Meat input prices (PMEAT) are defined as expenses for meat and cattle inputs, divided by total pounds of meat and cattle inputs. The price of labor (PLAB) is total plant labor costs (payroll plus supplemental labor expenses) per employee. The price of physical capital (PCAP) is defined as (OPPORTUNITY +NEW)/CAPACITY, where OPPORTUNITY is the sum of equipment and structures book values multiplied by their respective rental prices, NEW is the cost of new equipment and structures, and CAPACITY is equipment and machinery book value. The materials price (PMAT) is total annual expenses for packaging, energy, and other nonanimal and nonmeat materials, divided by pounds of animal and meat inputs.

Output (Q) is defined as pounds of meat products (SIC 2011) shipped from the cattle slaughter plant in a year. Product mix (PMIX) is Q minus pounds of carcass shipments (SIC 20111-12 and 20111-14), divided by Q. Input mix (IMIX) is the pounds of meat inputs purchased by a plant in a year, divided by the combined pounds of live cattle and meat inputs.