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.

Scale Economies and Consolidation in Hog Slaughter

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Introduction

U.S. meat and livestock sectors have been transformed in the last two decades, in three important dimensions. First, livestock feeding has consolidated, as producers that fatten cattle, hogs, and poultry before their sale to slaughter plants have grown fewer but substantially larger. Second, far fewer packing plants now slaughter livestock, and those plants are more specialized and much larger than slaughter plants in the past. Finally, contractual relations between producers and meatpackers are changing, with less reliance on spot markets and more reliance on longer term contractual relationships.

Consolidation has led to sharply increased concentration in cattle slaughter, and persistent concerns over the future of competition in that industry (USDA, 1996). But hog slaughter has also consolidated, with a sharp shift of output toward large plants, and concentration has begun to increase in that sector as well. This study describes the process of consolidation in hog slaughter, and identifies the role of slaughter scale economies in driving that process.

Two previous studies investigate the importance of scale economies in hog slaughter. Ball and Chambers (1982) analyzed aggregate annual data for all meat products for the period from 1954 through 1976. They report evidence of scale economies, but their estimates vary widely from year to year. Melton and Huffman (1995) analyzed aggregated annual data for hog slaughter for the period from 1963 through 1988. They also report evidence of scale economies, but their estimates also vary widely over time, at times taking on inadmissible values (with increases in output leading to declines in total cost). With highly aggregated time series data, it may be difficult to disentangle the separate effects of scale, capacity utilization, and technological change.

Our analysis differs from prior studies in three crucial respects. First, it covers more recent data, with a period of analysis extending from 1963 through 1992. Second, it controls for differences in the mix of products at slaughter plants; product mixes, and their associated in-plant functions and costs, vary across plants and over time. Finally, we use data from individual slaughter establishments; with a wide cross section of plants in each observed year, we are better able to identify the extent of scale economies in any year, and to estimate shifts in scale economies between years.

The following section describes the process of consolidation in hog slaughter, and compares the process to that in cattle slaughter. We then summarize our model and data, and report our key findings for factor price effects, scale economies, the role of product and input mix, and technological change.

Consolidation in Hog Slaughter

Table 1 presents statistics describing recent consolidation in hog and in cattle slaughter, drawing on data from the Grain Inspection, Packers and Stockyards Administration (GIPSA) of the U.S. Department of Agriculture (1997). All meatpackers who purchase at least $500,000 worth of livestock annually must report to GIPSA, and reporting plants account for about 97 percent of commercial hog slaughter and 95 percent of commercial cattle slaughter.

Between 1977 and 1995, the number of GIPSA plants declined sharply, by about one half in hog slaughter and about two thirds in cattle slaughter, as plant sizes increased in each industry.

Plants that slaughtered over a million hogs annually accounted for 38 percent of all hog slaughter in 1977; just fifteen years later, large plants accounted for 86 percent of all commercial slaughter. By 1997, just 10 plants accounted for 40 percent of all hog slaughter (USDA, 1998). The shift to large plants was even more dramatic in cattle slaughter, with large plants accounting for just 12 percent of slaughter in 1977 and 67 percent in 1995.[1]

Fewer and larger plants mean increases in concentration, although at different rates in each industry. In cattle slaughter, the four firm concentration ratio increased from 28 in 1977 to 67 in 1995, an exceptionally large increase.[2] Concentration in hog slaughter increased more modestly, from 34 to 46. Differences in industry growth, when set against shifts of production to larger plants, may account for the differences in concentration change. Commercial cattle slaughter shows no increase since the early 1980's, and by 1995 was still considerably below 1970's slaughter volumes (table 1). But commercial hog slaughter has continued to grow through time, and mid 1990's volumes were considerably above prior years.[3]

Structural change in slaughter industries includes other important elements: changes in product mix, labor relations, and plant locations. Two decades ago, hog slaughter plants performed several related functions. They slaughtered hogs, cut up the carcasses, and then processed the pork into bacon, hams, sausages, and other products. But today, modern slaughter plants now specialize mainly in hog slaughter and carcass cutting; many traditional brand-name processors no longer slaughter hogs, but instead purchase cut-up carcasses from slaughter plants for processing.

Industry consolidation has been accompanied by important changes in labor relations. In 1980, 46 percent of workers in the meat products industry were union members, a figure that had remained stable through the 1970's.[4] In 1982, many unionized firms began to press for large reductions in base wages, from $10.69 an hour to $8.25, consistent with what was being offered in non-union plants. By 1987, after a series of lengthy strikes, plant closings, and deunionizations, union membership had fallen to 21 percent of the workforce, where it has remained through the most recent data (1997). Table 2 shows that nominal wages in meatpacking fell after 1982, and that real (inflation-adjusted) wages fell sharply. The distribution of wages also narrowed sharply: plants with more than 1,000 workers paid wages nearly 30 percent higher than plants with 100-999 workers in 1977, but that size differential shrank sharply by 1982 and disappeared by 1992.[5]

Meatpackers usually purchase hogs within localized markets--most procurement occurs within 150 miles of the slaughterhouse. For that reason, slaughter facilities locate near areas of hog production, which has undergone a dramatic consolidation in the last two decades. In 1978, about 4 percent of all hog farms could be classed as large, selling 1,000 head or more; they accounted for just over one third of all hog marketings. By 1992, large farms accounted for 15 percent of all hog farms, and they marketed nearly 70 percent of all hogs (McBride, 1995). Very large farms, those selling more than 5,000 head in a year, handled 28 percent of all hog marketings to slaughter plants in 1992, up from 7 percent 14 years before.

Many of the very large producers have located outside of the traditional region of hog production, the Corn Belt states of Minnesota, Iowa, and Illinois. The traditional region includes about one third of all U.S. hog farms and over 40 percent of hog marketings. But only 16 percent of the region's hog marketings come from farms of more than 5,000 head--most marketings come from farms selling between 500 and 5,000 head per year. By contrast, in the newly emerging Southeastern hog production region (the Carolinas and southern Virginia), nearly 80 percent of hog marketings come from farms that sell more than 5,000 head each.

A Model of Hog Packer Costs

The sharp shift of output to larger plants suggests that there may now be scale economies in slaughter as well as in hog production. To link scale and consolidation, we need a model that estimates the extent of scale economies across a wide range of plant sizes, and not simply at mean plant sizes. Moreover, we need a model that can test for scale-increasing technological change; for scale to drive consolidation, large plants should have larger cost advantages in the 1990's than in the 1960's and 1970's.

An analysis of scale economies must take account of product mix. During the period of consolidation, slaughter plants shifted to specialize in slaughter and simple fabrication. Reduced processing lowered plant costs and plant input demands; if product mix and plant size are related, then failure to control for mix will bias estimates of scale economies.

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.

For our purposes, we need a statistical cost function that does the following:

a) estimates plant level scale economies, and allows the effect to vary with plant size;

b) estimates the effects of product and input mix on costs;

c) identifies the effects of input prices on cost, and allows the effects to vary with plant size;

d) allows effects to vary over time, as a way to capture technological change.

We use the well-known translog cost function, defined as follows:

$$
\begin{aligned}
1)\qquad \ln C = {} & \alpha_0 + \Sigma\beta_i \ln P_i + (½)\Sigma\Sigma\beta_{ij} \ln P_i \ln P_j \\
& + \gamma_1 \ln Q + (½)\, \gamma_2 (\ln Q)^2 + \Sigma\gamma_{1i} \ln Q \ln P_i \\
& + \Sigma\delta_k \ln Z_k + (½)\, \Sigma\Sigma\delta_{kl} \ln Z_k \ln Z_l \\
& + \Sigma\Sigma\delta_{ik} \ln P_i \ln Z_k + \Sigma\delta_{1k} \ln Q \ln Z_k \\
& + \Sigma\alpha_n T_n + \Sigma\Sigma\alpha_{in} \ln P_i T_n + \Sigma\alpha_{1n} \ln Q\, T_n + \Sigma\Sigma\alpha_{kn} \ln Z_k T_n.
\end{aligned}
$$

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.

The translog allows for a variety of possible production relationships including varying returns to scale, nonhomothetic production, and nonconstant elasticities of input demand. We can obtain greater efficiency in estimation by estimating the optimal, cost-minimizing input demand, or cost-share, equations jointly with the cost function. Those equations are the derivatives of total cost with respect to each input price, and share parameters with the cost function:

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

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; the other coefficients capture changes in the estimated factor share over time, and as factor prices, output, and plant characteristics move away from sample mean values. Since 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 hog slaughter plants produce a wide variety of products, and the mix of products has changed over time. Our data source defines several different product categories, including carcasses, hides, primal and fabricated cuts, processed pork products, 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 many plants do not produce all outputs, and logs are undefined at zero, the translog functional form cannot directly be adapted to the multiproduct approach.

Instead, we followed an approach used in the estimation of transportation cost functions, where output is defined simply as ton-miles (examples include Allen and Liu, 1995, for trucking, and Caves, Christensen, Tretheway, and Windle, 1985, for railroads). But tonmiles can be produced in many ways. The network can route output to many different locations, as opposed to operating a few through routes, or output can be routed in many small deliveries, as opposed to a few 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.

We define a single output, pounds of meat shipped, but we add production characteristics to the equation (this is where the Z vector comes from). Our estimating equation includes a measure of product mix, one minus the share of processed products in output (processed pork products include things like sausage and ham products). This measure will always be defined in the translog, as processed products never take up all of output. Because hide and byproducts are produced in nearly fixed proportions to the number of hogs slaughtered, those shipments account for nearly constant shares of total output. As a result, the measure varies primarily in proportion to the share of pork processing in a plant's output; increases in processing mean declines in the share of carcass and cut-up carcasses. As processing increases, for a given volume of hogs slaughtered, total costs should also increase. Note that the measure itself is an inverse measure of processing: costs should fall as the measure increases (some plants produce no processed products, so we need to use the reciprocal measure in order to define it in the translog).

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 less than 1 suggest the presence of economies of scale, while estimated values that exceed

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. The parameters on the interaction terms between Q and T (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 processing. Define Zp as our measure of product mix (one minus the output share of processed products). 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 reductions in processing on costs in 1992, given the physical volume of output, at sample means for all variables. The interaction terms on T show how that elasticity changes as one moves back in time. Finally, 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.

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

We observe slaughter plants operating in seven different years: 1963, 1967, 1972, 1977, 1982, 1987, and 1992. The model allows for the possibility of 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 between each first order parameter and each of six different dummy variable (one for each 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

We use data from the U.S. Census Bureau's Longitudinal Research Database (LRD). The LRD details the records of individual establishments reported in the Census of Manufactures, and covers plants reporting in 1963, 1967, 1972, 1977, 1982, 1987, and 1992. LRD hog slaughter plants are not identical to the universe of plants reporting to GIPSA, and summarized in table 1. GIPSA records all plants that (i) slaughtered hogs and (ii) purchased at least $500,000 in livestock. Our LRD file covers plants for whom (i) manufacturing is the primary line of business; (ii) hogs are the primary live animal input; (iii) Census reporting rules require the filing of detailed data (practically, at least twenty employees); and (iv) reported data meet standards for internal consistency. Census and GIPSA files overlap for midsized and large commercial plants, but the LRD file omits a variety of very small plants and other small plants with highly diversified operations (multispecies, or multiple businesses). The data covered a total of 1,142 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 the most general functional form that we estimated, and is referred to as Model IV. We also estimated several more restrictive forms, in order to test the assumptions of the model. Model I allows for no technological change and no plant characteristics; in other words, all Model IV 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 (product and input mix), 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 also tested two slightly more restrictive versions of Model IV. Model IVA drops all input mix variables (in practice, they are jointly significant but not individually so). Finally, we test for homotheticity by estimating Model IVB, which includes the Z and T vectors but forces 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 first applied Gallant-Jorgenson goodness of fit tests to distinguish among the different functional forms. Table 3 describes the models and summarizes the results of the G-J tests. The most restrictive model (I) was decisively rejected in favor of Model II, which added measures of output and input mix. In turn, Model II was decisively rejected in favor of Model III, which allows all 1st order coefficients to vary over time. Finally, Model IV added a dummy variable for single establishment firms, which is also interacted with the first order coefficients; Model III was rejected in favor of the more flexible Model IV.

Table 3 also reports tests of two further restrictions on Model IV. 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. Model IVB imposes homotheticity, and is decisively rejected in favor of the more flexible form. 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 it allows all first order coefficients to vary over time.

Tables 4 and 5 report the coefficient results from Model IV. For ease of exposition, table 4 reports first order coefficients for 1992 and the first order time shifters for earlier years, while table 5 reports coefficients on the quadratic and interaction terms and repeats the 1992 first order coefficients.

Factor price effects

Table 6 reports mean factor shares, calculated using estimated Model IV parameter values and mean 1992 data values. They therefore differ slightly from the first order factor price coefficients in table 4, which are factor shares based on sample mean data values. Live animal and meat inputs account for just over 74 percent of costs (with live animals accounting for almost all of that), while labor carries an 11 percent factor share, other materials 7.8 percent and capital

6.7 percent. The capital share grew over time at the expense of other factors (table 4). The animal share increases with output, set off against declines in the shares of labor and capital (table 5).

The skewed distribution of factor shares carries some important implications. First, changes in hog prices must be a dominant factor driving short run changes in manufacturing costs and wholesale pork prices. Second, as long as the prices paid for hogs are invariant to plant size, substantial scale economies in slaughter and fabrication processes will translate into small scale economies in total costs, because total costs will be dominated by hog purchase expenses. Third, wage changes will lead to small product price changes, because wages form such a small share of total costs. Finally, wage changes that are not passed through as product price changes can lead to large changes in returns on invested capital, since labor and capital each form small shares of total cost.

Price elasticities of input demand, along with Allen elasticities of substitution, are also reported in table 5, using mean 1992 data values. All four inputs have downward sloping demand curves--the estimated elasticities are negative at the mean. The estimated price elasticity of demand for labor is quite close to the estimate reported by Melton and Huffman (1995), while the elasticity on capital is relatively price sensitive. Note that the demand for animal inputs, given meat output, is extremely inelastic--the price elasticity of demand is close to zero, and there is essentially no substitution between hogs and labor or between hogs and other materials. There does appear to be some degree of substitution between hogs and capital, reflecting perhaps opportunities to use capital equipment to increase yields of meat from hog carcasses.

Our findings are quite similar to those observed in cattle slaughter (MacDonald, Ollinger, Nelson, and Handy, 1998). There, the livestock factor share is about 12 percentage points higher, and the labor, capital, and other materials shares are correspondingly lower. The factor share of capital also grew through time, and estimates of own price demand and substitution elasticities are quite close

Economies of Scale

Recall that our measure of scale economies is the elasticity of total cost with respect to output. The first order coefficient on output in Model IV was 0.926, suggesting economies of scale in 1992 at the sample mean plant size (table 4). The coefficient was significantly below one, and the year shifters suggest that scale economies became more important through time--prior year shift terms are positive and significant. In particular, there appeared to be a steady increase in scale economies from the 1960's to the 1970's and 1980's, and then another important increase by 1992. The coefficient on squared output is positive and statistically significant, suggesting that scale economies get smaller as plants get larger.

Table 7 provides more precise evidence by reporting cost elasticities for plants at different points of the plant size distribution and at different technology vintages (that is, different years). We chose three years-1992, 1977, and 1963. In each year, we selected the mean plant size (output level) for that year, the sample mean plant size, and a relatively large plant-at the 95th percentile for that year. Because of the changes in the size distribution of plants noted earlier, mean and large plants in 1992 are considerably larger than the corresponding 1977 plants, which are in turn larger than the 1963 plants.

For each plant size, table 7 calculates cost elasticities for three different vintages of technology, 1963, 1977, and 1992. We can then observe the degree to which estimated economies of scale vary by size of plant for a given year, and by year for a given size of plant. Four patterns stand out in the table.

First, there are modest scale economies.[7] Average sized plants in each year operate in the range of increasing returns--estimated scale parameters were less than one. Scale economies should be modest, because the slaughter process that generates scale economies accounts for a small share of total costs (that is, the animal share is large).

Second, technological change has led to greater scale economies--at any given plant size, one can look across a row and see that the cost elasticity fell from 1963 to 1977, and again from 1977 to 1992. Plants at the sample mean size were producing near constant returns in 1963, but by 1992 would be clearly in a range of increasing returns.

Third, the largest plants in each year (those at the 95th percentile of each year's size distribution) were operating at an output level near constant returns. Looking down the diagonal, 95th percentile plants had cost elasticities of 0.98 in 1992, 0.99 in 1977 and 1.01 in 1963.

Finally, plant sizes changed to take advantage of scale economies. The largest 1992 plants would have been too large in 1977 or 1963, operating in a range of decreasing returns in the technologies of those years (looking across the row for 1992 95th percentile). Similarly, plants at the 1963 95th percentile would have clearly been too small to take advantage of all scale economies in the 1992 technology.

Note that mean wages fell between 1982 and 1992, by 5.5 percent (table 2). By itself, that shift should have reduced costs by about 0.6 percent, given labor's factor share. But the size differential in wages also disappeared. In 1977, large plant wages were 30 percent higher than wages at smaller commercial plants; that gap translates into a 1977 cost differential of 3.8

percent, substantially attenuating large plant scale advantages. In the next fifteen years, those pecuniary scale diseconomies disappeared as the size differential in wages went to zero, reinforcing the effect of changing technological scale economies.

Production Characteristics

Hog plants slaughter hogs and cut up the carcasses into primals, but many also perform further processing of cutup carcasses into hams, sausages, and other products. Our measure of product mix (1 minus the share of ham and sausage products in plant shipments) aims to capture some important distinctions among plants. The measure should be closer to one in plants that specialize more in slaughter and cutup.

The coefficient on PMIX is negative and marginally significant for 1992--plants that do less processing have lower costs, all else equal (table 4). The coefficient value is not particularly large, again because hog expenses account for so large a share of the total, while processing costs account for small shares. A typical change in product mix toward less processing (from the median 1992 value to the 75th percentile) would lead to a 1.5 percent reduction in total costs, and therefore in average costs per pound. Changes toward less processing also have effects on factor shares, although only the term involving labor is statistically significant (see the interaction terms with PMIX in table 5). Labor and other materials account for smaller cost shares in plants that do little processing, as one would expect.

The interaction term between product mix and output is negative, small, and not nearly significant. Thus the data provide no evidence that costs can be reduced by combining processing with slaughter in large establishments; scope economies would also be inconsistent with the observed shift toward separation of slaughter and processing in the hog sector.

Our input mix variable is the value share of hogs in total animal and meat inputs, as distinct from purchased carcasses or, in some plants, from other species. The coefficient on IMIX in 1992 is positive, although small and not statistically significant. Note that the year shifts are all negative, generally significant, and usually large enough to make the full effect negative in the relevant year (table 4). That pattern probably reflects changes in input mix over time. In 1977, for example, the median value of IMIX was 90 percent and the 75th percentile value was 100 percent, but the 25th percentile value was 59 percent. That is, many plants specialized only in hogs, but a substantial fraction of sample plants also purchased many carcasses, presumably for processing operations. As the industry changed over the next 15 years, the distribution of IMIX values narrowed, to a 1992 median of 98 percent and a 25th percentile value of 91 percent. Given the narrow variance of IMIX values in 1992, it shouldn't be surprising that IMIX has no significant effect on costs in 1992. In earlier years, with a wider variation in input mix choices, plants that specialized in hog slaughter more clearly realized lower costs.

Few of the individual coefficients involving IMIX and PMIX are statistically significant. That may reflect multicollinearity between the two measures; plants that purchase carcasses are also likely to do more processing, and when one variable is dropped, coefficients on the other gain significance. But importantly, scale economies may be underestimated if product and input mix variables are omitted. The estimated scale elasticity measure rises, by 0.01 to 0.02, for each year when PMIX and IMIX are left out of the estimation. The joint tests of significance (table 3) strongly support the inclusion of both measures in the model; as a result, we believe that the best measures of economies of scale are obtained when controls for product and input mix are retained in the model.

Finally, note that none of the first order year intercepts in the model are large, none are statistically significant, and there is no particular sign pattern (see the intercepts in table 4). Temporal changes in slaughter industry costs are accounted for by changes in factor prices (in particular, by hog prices), changes in input and product mix, and by changes in scale economies.

Conclusions and Implications

There are modest but extensive scale economies in hog slaughter. Technological change and changes in the labor market have led to greater available scale economies over time, and packers have reacted quite rapidly, building new plants and expanding old ones to take advantage of scale. The industry's largest plants produce today at output levels near constant returns to scale, but most plants have not exhausted available slaughter economies; in consequence, we are likely to see continued cost pressures on small and mid-sized plants.

But the cost advantages held by large plants are not particularly large. Small plants survive, and consolidation is staved off, in many industries with larger scale economies than those found in meatpacking (see, generally, the discussion in McKinsey Global Institute, 1993, or its related summary in Baily and Gersbach, 1995). Consolidation in hog slaughter has followed from a rapid shift of plant sizes to take advantage of new scale economies, and the intensity of industry competition may have had much to do with the rapidity of that shift.

Footnotes

1. GIPSA data measure the share of the key input, hogs or cattle, accounted for by large plants. Data from the U.S. Census Bureau measure consolidation based on value of shipments, and show similar trends. MacDonald, Ollinger, Nelson, and Handy (1998) provide more detail.

2. Cattle slaughter plants tend to specialize in steers and heifers or in cows and bulls, because of differences in meat outputs, animal shapes, and slaughter technology between the two types. Consolidation and increased concentration has been even more dramatic in steers and heifers.

3. In turn, changes in commercial slaughter results from changes in domestic meat consumption, net meat exports, and changes in meat yields from animals. Each industry saw small rises in net exports. Cattle yields rose noticeably after 1977, while beef consumption fell sharply, placing sharp downward pressure on the derived demand for cattle. By contrast, pork consumption rose in line with population growth while meat yields rose only slightly; the net effect was modest increases in the derived demand for hogs.

4. 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).

5. This summary draws on several articles in the *Monthly Labor Review*, a publication of the Bureau of Labor Statistics, and on more detailed data in MacDonald, Ollinger, Nelson, and Handy (1998). The Census Bureau wage data in table 2 refer to SIC 2011, which includes all cattle, hog, and lamb slaughter plants. The more aggregated data allows us to disclose greater detail by size category, and our analysis of LRD data leads us to conclude that we lose little information by aggregating in this case.

6. Each of these choices represents the best fitting option. We also tried a multiple product cost function, with separate entries for pounds of carcass, fabricated, and processed products, while setting zero outputs to low but positive values. But that form did not provide as strong a fit as our preferred alternative, and we are wary of inserting arbitrary values into our model. Finally, 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.

7. No guide in economics defines "small" scale economies. But see Scherer and Ross (1990, p.115), who would see the scale economies reported in table 6 as small but not uncommon.

Table 1: Structural Change in Cattle and Hog Slaughter Plants

	1977	1982	1987	1992	1995
Slaughter Plants	-Number of Plants Purchasing More Than $500,000 in Livestock-				
Hogs	469	466	352	300	245
Cattle	814	632	474	342	279
Large Plant Importance	-Large Plant Share of Slaughter Reported to GIPSA-				
Hogs	38	59	72	86	86
Cattle	12	28	51	61	67
Concentration	-Four Largest Firms' Share of Slaughter Reported to GIPSA-				
Hogs	34	36	37	44	46
Cattle	28	32	54	64	67
Commercial Slaughter	-Millions of Animals, Three Year Average-				
Hogs	76.1	87.1	82.9	92.0	94.8
Cattle	41.4	35.8	36.0	33.0	35.5

Notes: Concentration, plant count, and large plant data are from U.S. Department of Agriculture, Grain Inspection Packers and Stockyards Administration (GIPSA). Large cattle plants are those who slaughter at least 500,000 cattle a year, while large hog plants slaughter at least one million hogs annually. Commercial slaughter data are from U.S. Department of Agriculture, National Agricultural and Statistics Service (NASS).

Table 2: Hourly Production Worker Wages in Slaughter Plants

	1967	1972	1977	1982	1987	1992
Employment Size Class	-Dollars per Hour (nominal)-					
Less than 100	2.66	3.71	5.84	6.78	7.30	7.91
100-999	3.21	4.40	6.51	9.38	8.38	8.67
1,000 or More	4.04	5.33	8.44	10.00	8.50	8.65
Industry-wide mean	3.36	4.51	6.86	9.06	8.27	8.56
	-1992=100-					
Consumer Price Index	23.8	29.8	43.2	68.8	81.0	100

Notes: Wage data are from Census of Manufactures, production worker payroll divided by hours. The data refer to SIC 2011, which includes cattle, hog, lamb, sheep, and calf slaughter plants.

Table 3: Tests of Model Selection, Hog Slaughter Cost Function

Comparison, Unrestricted vs. Restricted	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	98
III vs. II	Model III adds 1st order time shifters	42	66.18	89
IV vs. III	Model IV adds single establishment dummy to III	7	18.48	36
IV vs. IVA	Model IVA drops input mix from IV	19	36.19	109
IV vs. IVB	Model IVB imposes homotheticity on IV	3	11.34	136

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

Table 4: Hog 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	-.1034	-.0180	-.0188	.0315	.0436	.0006	-.0327
	(.0363)	(.0423)	(.0413)	(.0413)	(.0418)	(.0441)	(.0429)
PLAB	.1127	.0112	.0218	.0180	.0151	.0158	-.0007
	(.0081)	(.0089)	(.0090)	(.0093)	(.0093)	(.0096)	(.0099)
PMEAT	.7263	.0373	.0642	-.0036	.0339	.0032	-.0103
	(.0420)	(.0455)	(.0458)	(.0467)	(.0475)	(.0506)	(.0529)
PMAT	.0805	.0184	.0211	.0105	.0087	.0088	.0056
	(.0059)	(.0065)	(.0065)	(.0067)	(.0068)	(.0070)	(.0072)
PCAP	.0805	-.0668	-.1081	-.0249	-.0577	-.0277	.0054
	(.0449)	(.0486)	(.0490)	(.0499)	(.0509)	(.0541)	(.0566)
Q (lbs)	.9259	.0597	.0641	.0418	.0290	.0398	.0368
	(.0184)	(.0212)	(.0210)	(.0214)	(.0217)	(.0221)	(.0218)
PMIX	-.0346	.0110	.0088	-.0339	.0005	-.0167	-.0221
	(.0236)	(.0191)	(.0212)	(.0206)	(.0191)	(.0187)	(.0194)
IMIX	.0326	-.0130	-.0503	-.0420	-.0447	-.0851	-.0623
	(.0284)	(.0267)	(.0267)	(.0280)	(.0270)	(.0293)	(.0295)

Note: Results of estimation of translog cost function for hog 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 5: Hog 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	.1127	.0606	-.0931	.0216	.0109	-.0248	-.0030	.0004	-.0150
	(.0081)	(.0044)	(.0043)	(.0020)	(.0035)	(.0015)	(.0010)	(.0010)	(.0047)
PMEAT	.7263		.1349	-.0721	.0302	.0346	.0022	.0074	-.0056
	(.0420)		(.0132)	(.0028)	(.0142)	(.0060)	(.0042)	(.0045)	(.0210)
PMAT	.0805			.0566	-.0060	-.0025	-.0010	.0028	-.0042
	(.0059)			(.0017)	(.0024)	(.0010)	(.0007)	(.0008)	(.0034)
PCAP	.0805				-.0305	-.0073	.0018	-.0068	.0248
	(.0449)				(.1006)	(.0064)	(.0045)	(.0046)	(.0224)
Q (lbs)	.9259					.0246	-.0030	.0058	.0197
	(.0184)					(.0053)	(.0030)	(.0043)	(.0123)
PMIX	-.0346						-.0043	.0028	-.0023
	(.0236)						(.0040)	(.0017)	(.0107)
IMIX	.0326							-.0023	.0215
	(.0284)							(.0027)	(.0139)
EST1	-.0214								
	(.0268)								

Note: Quadratic (on diagonal) and interaction terms from estimation of translog cost function. First order terms from table 3 are repeated in first column.

Table 6: Mean Input Shares and Elasticities in Hog Slaughter

	Input Price Variables			
	PLAB	PMEAT	PMAT	PCAP
Input Shares	.1121	.7426	.0779	.0674
ϵii	-0.347	-0.076	-0.196	-1.385
σij (Allen)				
PLAB	-3.098	-0.118	3.475	2.443
PMEAT		-0.102	-0.246	1.602
PMAT			-2.510	-0.143
PCAP				-20.55

Note: All values are calculated using mean 1992 data values and parameters from tables 3 and 4. 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 7: Cost Elasticities for differing plant sizes and technology vintages.

	Technology Vintage		
Plant Size	1992	1977	1963
Sample Mean	0.926	.9549	.9856
1992 Mean	0.956	0.985	1.016
1992 95th Percentile	0.983	1.012	1.043
1977 Mean	0.924	0.953	0.984
1977 95th Percentile	0.958	0.987	1.017
1963 Mean	0.911	0.946	0.971
1963 95th Percentile	0.950	0.979	1.009

References

Allen, W. Bruce, and Dong Liu, "Service Quality and Motor Carrier Costs: An Empirical Analysis", Review of Economics and Statistics 77 (November, 1995): 499-510.

Baily, Martin Neil, and Hans Gersbach, "Efficiency in Manufacturing and the Need for Global Competition", Brookings Papers on Economic Activity: Microeconomics (1995): 307-347.

Ball, V. Eldon, and Robert G. Chambers, "An Economic Analysis of Technology in the Meat Products Industry", American Journal of Agricultural Economics 62 (November, 1982): 699-709.

Caves, Douglas W., Laurits R. Christensen, Michael W. Tretheway, and Robert J. Windle, "Network Effects and the Measurement of Returns to Scale and Density for U.S. Railroads", in Andrew F. Daughety, ed., Analytical Studies in Transport Economics (Cambridge, U.K.: Cambridge University Press, 1985).

Curme, M.A., Barry T. Hirsch, and David A. McPherson, "Union Membership and Contract Coverage in the United States, 1983-1988," Industrial and Labor Relations Review 44 (October, 1990): 5-30.

Gallant, A. Ronald, and Dale W. Jorgenson, "Statistical Inference for a System of Simultaneous, Non-Linear, Implicit Equations in the Context of Instrumental Variable Estimation," Journal of Econometrics 11 (1979): 275-302.

Kokkelenberg, Edward C., and Donna R. Sockell, "Union Membership in the United States, 1973-1981," Industrial and Labor Relations Review 38 (July, 1985): 497-543.

MacDonald, James M., Michael E. Ollinger, Kenneth E. Nelson, and Charles R. Handy. Consolidation in U.S. Meatpacking. U.S. Department of Agriculture. Economic Research Service. Agricultural Economics Report No. xxx. Forthcoming, 1997.

McBride, William D., U.S. Hog Production Costs and Returns, 1992: An Economic Basebook, U.S. Department of Agriculture, Economic Research Service, Agricultural Economic Report No. 724. November, 1995.

McKinsey Global Institute, Manufacturing Productivity . Report prepared by the McKinsey Global Institute with the assistance of Martin Baily, Francis Bator, Ted Hall, Robert Solow, and the University of Groningen. McKinsey & Co., Washington, DC. October 1993.

Melton, Bryan E., and Wallace E. Huffman, "Beef and Pork Packing Costs and Input Demands: Effects of Unionization and Technology", American Journal of Agricultural Economics 77 (August, 1995): 471-485.

Scherer, F. Michael, and David Ross, Industrial Market Structure and Economic Performance (Boston: Houghton Mifflin Co., 3rd Edition, 1990).

Stevenson, Rodney, "Measuring Technological Bias", American Economic Review 70 (March, 1980): 162-173.

U.S. Department of Agriculture, Agricultural Marketing Service. Concentration in Agriculture: A Report of the USDA Advisory Committee on Agricultural Concentration. Washington, DC. June, 1996.

U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration, Packers and Stockyards Programs. Concentration in the Red Meat Packing Industry. Washington, DC. February, 1996.

U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration, Packers and Stockyards Programs. Packers and Stockyards Statistical Report, 1995 Reporting Year. GIPSA SR-97-1. September 1997.

U.S. Department of Agriculture, National Agricultural Statistics Service. Livestock Slaughter: 1997 Annual. Washington, DC. March 1998.

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 animal inputs, divided by total pounds of meat and animal 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 hog slaughter plant in a year. Product mix (PMIX) is Q minus pounds of processed pork (SIC 20116 and 20117), divided by Q. Input mix (IMIX) is the pounds of live hog inputs purchased by a plant in a year, divided by the combined pounds of hog and meat inputs.