6. Chicken Slaughter Cost Estimation

The chicken slaughter industry almost tripled its output to over 20 billion pounds between 1967 and 1992; chicken traypacks as a share of output increased from an unreported level to almost a quarter of industry output; and the average plant almost tripled its size and produced a more complex mix of outputs (USDA estimates based on Census data). In this chapter, we assess the extent of scale economies in slaughter and estimate the effect of changes in input and product mixes on plant costs. The data include 694 plants reporting that more than 50 percent of their output came from chicken slaughter products in the 1972, 1977, 1982, 1987, and 1992 Census of Manufactures.[19]

Model Selection

A Gallant-Jorgenson (G-J) likelihood ratio test was used to determine the model best able to explain plant production costs. Tables 6-1 and 6-2 summarize the set of functional forms and the results. Table 6-1 contains the G-J statistic for eight chicken slaughter model variations and the number of estimated model parameters. These data are used in table 6-2 to make model comparisons of the maintained hypothesis relative to a tested hypothesis. The number of restrictions is the number of variables left out of the tested hypothesis. The chi-square statistic is the difference between the G-J statistics of the two models.[20] The hypothesis that the restricted variables do not affect plant costs is rejected if the model chi-square statistic has a 99-percent level of confidence.

Hypothesis tests (table 6-2) are conducted by comparing the model fit of the test hypothesis to the maintained hypothesis. Model II adds to Model I 13 variables associated with bulk output share and poultry meat input mix. Since the chi-square statistic for the comparison of Models I and II exceeds the critical chi-square (DF, 99), the tested model (Model I) is rejected in favor of the maintained hypothesis (Model II). Other models, except Model VIII, were evaluated similarly. Of all the models tested (table 6-2), Model III provides the best fit of the data and allows one to conclude that plant product mix, poultry meat input mix, and whole-bird share of output significantly affect plant costs, but type of firm (single- or multi-establishment) and seasonality do not.

Model VIII was rejected because its results, suggesting that plant production costs rose over time, even though linespeeds were increased and labor-saving equipment was introduced, are inconsistent with well-accepted economic theory. We attribute this regressive technological change to a specification error caused by excluding whole-bird output share from the model. If time-shift variables are included in the model, the whole-bird output share variable must be excluded because both variables are constant across plants in any given year, causing the model to collapse. Yet, if

Table 6-1: Goodness-of-fit statistics for chicken slaughter cost function models

Model	Description	G-J statistic	Parameters estimated
I	Translog, factor prices and output only	2713	15
II	Adds bulk share and poultry meat input mix to I	2646	28
III	Adds whole-bird share to II	2629	33
IV	Adds seasonality to III	2630	41
V	Adds single establishment to III	2623	38
VI	Removes poultry meat input mix from III	2662	26
VII	Removes bulk share from III	2685	26
VIII	Adds time to Model II	2585	48
IIIH	Imposes homotheticity on III by removing input price and output interaction terms	2648	30

Note: There are 694 chicken slaughter observations in the 1972, 1977, 1982, 1987, and 1992 Censuses.

[19] Plant observations with either incomplete data or clear reporting errors were deleted. The analysis does not include data from before 1972 because chicken traypack production data were not reported.

[20] The difference in the values of the objective function equals $N^*S(\alpha, v)_R$ - $N^*S(\alpha^1, v^1)_u$, where $S(\alpha, v)_R$ is the minimum value of the objective function of the restricted model, $S(\alpha^1, v^1)_u$ is the minimum value of the objective function of the unrestricted model, and N is the number of observations. The value of the objective function is printed as output from the nonlinear estimation of the seemingly unrelated regression model in the SAS statistical package.

whole-bird output share is excluded, then the model does not control for the increase in labor, materials, and capital necessary to produce the higher value chicken parts that came to dominate plant product output mix by 1992, causing perverse results. This is discussed in more detail later in the chapter.

Homotheticity means that factor shares do not vary with plant output. Results show that the model is not homothetic, meaning that large- and small-plant technologies differ in that they use different proportions of labor, capital, and materials. Econometrically, it means that the interactions between Q (output) and the three relevant factor prices, PMEAT, PMAT, and PLAB, contribute to model fit.

Summary of the Best Model

The first column of table 6-3 contains the first-order coefficients, the diagonal terms are own-factor price quadratic terms, and the terms above the diagonal are interactions among factor prices. There are no terms below the diagonal because they are identical to those above it. The first column of table 6-4 repeats the first-order coefficients, and the remainder of the table includes the interaction terms of the nonprice variables and is constructed similarly to table 6-3. There are no interaction terms for either bulk output share (BULK) or poultry meat input mix (BIRD) with whole-bird output share (WHOLE) because they do not contribute to model fit. There also is no quadratic term for whole-bird output share because it is constant across plants in any given year.

The first-order coefficients can be interpreted as factor shares at sample means. They suggest that chicken meat inputs account for about 68 percent of plant costs, while labor (PLAB) and other materials (PMAT, primarily packaging) each are about 14 percent of costs. The sum of coefficients for the four-factor prices must equal one because the capital cost share equals one minus the sum of the other three factor shares.

Consider chicken slaughter results relative to those for cattle and pork slaughter. The cattle cost share is much higher (83.7 percent versus 66.2 percent), while the labor and other materials shares (8.2 percent and 5.1 percent, respectively) are much lower in cattle slaughter than in chickens. The capital share is about the same. Hog slaughter has cost shares intermediate to chicken slaughter and cattle slaughter.

Cost share differences are attributed to the product mix distinctions between red meat and chicken plants. Carcasses and large slabs of beef for boxed beef are still major products for cattle slaughter operations, whereas only about 20 percent of the chicken output is in a whole or near-whole form. Pork has more processing than beef but less than chicken. Chicken slaughter plants convert chicken not sold as whole birds into parts and deboned products. Some of these products go to consumers and restaurants, but most of the rest is packed in wet or dry ice and shipped either to further-processors or to export markets.

The skewed distribution of factor shares gives rise to some violations of monotonicity conditions. Predicted factor shares were negative for the following percentages of observations: 11 percent for capital; 5 percent

Table 6-2: Hypotheses tests for the chicken slaughter cost model

Maintained hypothesis	Tested hypothesis	Parameter restrictions	Chi-square @.99	Chi-square statistic	Status of tested model
Model II	Model I	13	27.7	67	Reject
Model III	Model II	5	15.1	17	Reject
Model IV	Model III	8	20.1	-1	Not Reject
Model V	Model III	5	15.1	6	Not reject
Model III	Model VI	7	18.5	33	Reject
Model III	Model VII	7	18.5	56	Reject
Model VIII	Model II	20	37.6	61	Reject*
Model III	Model IIIH	3	11.3	19	Reject

* Model VIII is rejected because it does not account for the trend toward more parts production and less whole-bird production over the 1972-92 period and, thus, very likely gives misleading results.
Note: There are 694 chicken slaughter observations in 1972, 1977, 1982, 1987, and 1992 Censuses. Chi-square statistic is G-J statistic of tested hypothesis minus G-J statistic of maintained hypothesis.

for other materials; 0 percent for poultry meat inputs; and 0.1 percent for labor. These violations are not at alarming levels for a data set containing a number of both very large and very small plants.

The interaction terms show how estimated elasticities (and factor shares) vary with movement away from sample means. The coefficients on the interactions of bulk output share with labor and chicken meat factor prices (PLAB and PMEAT) indicate that, as the share of bulk products rises, the labor factor share drops and the chicken meat factor share rises.

The coefficients for the interactions of production volume and factor prices (table 6-4) show how factor prices vary with plant size. Results show that plants use relatively less labor as output grows. Compared with cattle slaughter, the labor share change is similar, but the chicken meat factor share is about half as much, and the other material share is about twice as high.

Whole-bird output share is much like a declining trend term in that it decreases each year from 1972-92. The coefficient on the first-order term is negative, showing that costs decline as the industry's whole-bird share of output rises, while factor interaction terms indicate that labor's share of costs drops and chicken meat input's share of costs rises as the whole-bird output share rises.

The cooperating inputs of labor, capital, and other materials drive scale economies; yet, they make up only 30 percent of total costs. This relatively small share of costs for non-animal inputs and the large share of factor costs means that changes in poultry meat factor prices are a dominant factor driving shortrun changes in manufacturing costs and wholesale prices, and that scale economies have a limited effect. Also notice that the high shares of labor and other materials relative to capital mean that small changes in labor and capital cost factors have a large impact on returns to invested capital.

Table 6-3: Chicken slaughter cost function parameter estimates: First-order terms and factor price interaction terms

		Interacted with			
Variable	1st order	PLAB	PMEAT	PMAT	PCAP
	Coefficients and standard errors				
Intercept	-0.066***	-	-	-	-
	(.011)				
PLAB	.142***	.077***	-.081***	-.001	.005
	(.003)	(.008)	(.006)	(.002)	(.005)
PMEAT	.684***		.120***	-.075***	.036***
	(.008)		(.015)	(.003)	(.014)
PMAT	.142***			.085***	-.008***
	(.002)			(.002)	(.003)
PCAP	.032***				-.032[1]
	(.008)				
BULK	-.097***				
	(.017)				
BIRD	-.216**				
	(.109)				
Q (lbs)	.901***				
	(.015)				
WHOLE	-.067***				
	(.026)				

[1] Standard error could not be estimated.
Note: Translog cost function estimation for chicken slaughter, 1972-1992. Since all variables are standardized at their means, first-order coefficients can be interpreted as elasticities at the sample means. There are 694 observations.
* significant at 90% level; ** significant at 95% level; *** significant at 99% level.

Table 6-4: Chicken slaughter cost function parameter estimates: First-order terms and bulk share, chicken meat input mix, output, and whole-bird share interaction terms

		Interacted with			
Variable	1st order	Bulk	Bird	Q	Whole
	Coefficients and standard errors				
Intercept	-0.066***	-	-	-	-
	(.011)				
PLAB	.142***	-.0035***	.076***	-.022***	-.001
	(.003)	(.0009)	(.014)	(.002)	(.007)
PMEAT	.684***	.0001	.113***	.012*	.038*
	(.008)	(.003)	(.037)	(.007)	(.024)
PMAT	.142***	.0003	.035***	.003*	.001
	(.002)	(.0006)	(.009)	(.0016)	(.005)
PCAP	.032***	.0031	-.189***	.007	-.038*
	(.008)	(.003)	(.037)	(.007)	(.023)
BULK	-.097***	-.019***	-.029	.0005	
	(.017)	(.004)	(.044)	(.003)	-
BIRD	-.216**		-.206***	.041	-
	(.109)		(.057)	(.061)	
Q (lbs)	.901***			-.013	-.035
	(.015)			(.011)	(.026)
WHOLE	-.067***				-
	(.026)				

Note: Translog cost function for chicken slaughter plants, 1972-1992. Since all variables are standardized at their means, first-order coefficients can be interpreted as elasticities at the sample means. There are 694 observations.
* significant at 90% level; ** significant at 95% level; *** significant at 99% level.

Own-Factor Price and Allen Elasticities

Model coefficients are used to estimate the own-factor price and Allen elasticities, which can be used to make inferences about the effect of changes in factor prices on demand for own- and other factors of labor, poultry meat, other materials, and capital. For example, own-price elasticities for labor (table 6-5) imply that a 10-percent increase in the price of labor leads to a 3.1-percent decline in the demand for labor; and the Allen cross elasticity of labor and materials indicates that a 1-percent rise in labor usage results in a 0.9-percent decrease in use of other materials.

The own-price and Allen cross elasticities for chicken slaughter are remarkably similar to those for cattle slaughter (MacDonald et al.) for labor, material and capital. Meat elasticities for cattle, however, differ substantially. The own-price elasticity of cattle meat is almost zero (-.0001), while the own-price elasticity for chicken meat is -.140. These differences suggest that a 10-percent increase in cattle prices has almost no effect on the demand for cattle, but that a 10-percent increase in chicken meat prices reduces chicken meat demand by about 1.4 percent. Thus, "value-added" cost functions that ignore chicken meat inputs may give misleading results.

The much more sensitive response of chicken factor demand to prices (compared with cattle factors) may stem from greater integration of chicken slaughter plants and the more common production of brand name products. The price paid per pound of live chickens can vary among chicken slaughter plants because chicken growers for those plants may employ different growing technologies, i.e., the mix of feed, medicine, veterinary services, etc. If chicken meat factor prices for one chicken slaughter plant rise faster than for another, then those additional costs cannot be passed to the consumer. If the slaughter plant does raise its prices, demand for its products will drop and, likewise, demand for chicken meat inputs will drop. Cattle slaughter plants, on the other hand, purchase animals from feedlots that sell cattle to buyers at market prices. Thus, if growing technology changes for raising cattle, all cattle slaughter plants will be similarly affected.

Table 6-5: Own-factor price and Allen elasticities evaluated at the sample mean

	Factor price variables			
	PLAB	PMEAT	PMAT	PCAP
Estimated factor shares	0.150	0.733	0.112	0.025
ϵ_{ii} (own-factor price)	-0.313	-0.140	-.258	-1.964
ϵ_{ij} (Allen)				
PLAB	-2.206	0.164	0.929	2.108
PMEAT		-0.205	0.224	2.604
PMAT			-1.822	-0.818
PCAP				-59.999

Note: All values are evaluated at the sample mean using parameters from table 6-3. The own-price factor demand elasticities (ϵ_{ii}) are calculated holding output and other factors constant, while the elasticities of substitution (ϵ_{ij}) are calculated using Allen's formula.

Capital has more price sensitivity to quantity demanded than do either labor or other materials, decreasing 19 percent for each 10-percent increase in capital prices. Labor and other materials usage decrease 3 percent and 2.5 percent, respectively, for each 10-percent increase in prices.

The Allen cross-price elasticities indicate the degree of substitutability among factors. Table 6-5 shows that all factors, except capital and other materials, are substitutes and that substitution between capital and chicken meat inputs is strongest. Results for cattle are similar to chicken slaughter for meat inputs and labor. For chickens, a 10-percent increase in the chicken meat input share leads to a 1.6-percent decline in the labor factor share, while a 10-percent increase in cattle factor share leads to a 2.1-percent increase in labor factor share.[21]

Scale Economies

The elasticity of total costs with respect to output (equation 5.4) can be used to examine scale economies. Only the first- and second-order output terms and the interactions of output and whole-bird output share (tables 6-3 and 6-4) have a substantial effect. The second-order output term is particularly important in that it indicates the change in returns to scale as plant size increases. A negative sign suggests costs drop faster as plant size increases, i.e., an escalation of increasing returns; and a positive sign indicates

[21] One may argue that chicken slaughter is much more like hog slaughter because some plants in both industries produce sausages and other further-processed products. However, elasticities for hog slaughter are similar to those for cattle.

a diminishing degree of increasing returns with plant size. The whole-bird output share varies across time only, meaning that it does not affect scale economies across plants at any particular point in time. Factor prices, bulk output share and poultry meat input mix are also interacted with output, but their variances are very small and, thus, they can be ignored.

Inserting the coefficients from tables 6-3 and 6-4 into equation 5.4 yields an elasticity of total cost with respect to output of 0.901 at the sample mean (the first-order coefficient for Q in table 6-3), implying that substantial increasing returns to scale exist. This means that a 1-percent increase in output at constant factor prices, bulk output share, poultry meat input mix, and whole-bird output share is associated with a 0.901-percent increase in total costs and declining average costs. Scale economies at the sample mean for chickens is 0.901 versus 0.953 for cattle slaughter and 0.926 for hog slaughter, which suggests that much larger unexploited scale economies exist in chicken slaughter than in either cattle or hog slaughter. Moreover, the negative coefficient on the second-order output term for chicken indicates that increases in returns become greater as chicken slaughter plants increase in size, while the positive coefficient on the second-order terms for cattle and hogs suggests that increases in returns become smaller as slaughter plants increase in size.

Cost elasticities, an average cost index, and processing costs as a share of total costs for various plant sizes are reported in table 6-6. The leftmost column gives the plant size in millions of pounds of output, and the next three columns translate this plant size into sizes relative to the sample mean, the 1972 mean, and the 1992 mean. Notice how mean plant size changes from 1972 to 1992. Plants producing about 150 million pounds of output were about four times the 1972 mean plant size but equal to the 1992 mean plant size, i.e., 1992 mean plant size was about four times larger than 1972 mean plant size.

The final three columns of table 6-6 give the cost elasticity, average cost index, and processing share of costs for plant sizes that vary from half the sample mean plant size to about four times the sample mean plant size. Elasticity declines from 0.925 for plants that are half the size of the sample mean to 0.852 for plants that are four times the sample mean plant size, and the average cost index for the largest plants is almost 20 percent below that of the smallest plants. These cost differentials are consistent with the near-disappearance of small plants, likely contributed to the more than 300-percent increase in mean plant size over the 1972-92 period, and resulted in higher processing productivity that reduced the processing share of costs by over 2 percentage points.

The negative sign on the second-order output term suggests a continued increase in the degree of increasing returns. If this is true, why are there so many chicken slaughter plants? An answer to this question is beyond the scope of the data set, but a number of hypotheses have been proposed: a suitable number of growers, environmental constraints, access to labor, and higher risks of flock losses in more concentrated growing areas due to the risks of bad weather, diseases, and other exogenous factors.

No single factor was given by industry experts as a constraint on plant size. Dan Cunningham of the University of Georgia (interview on 1/26/99) suggests that neither a lack of growers nor concern for the environment has constrained plants in the northern Georgia chicken- growing area. Conversely, Bill Roenigk of the National Chicken Council (interview on 3/25/99) indicates that a lack of growers and environmental concerns have limited chicken production growth in the Delmarva Peninsula.

Table 6-6: Estimated cost elasticity, average cost index, and processing cost share for selected plant sizes, using industry mean values

Plant size	Plant size to sample mean	Plant size to 1972 mean	Plant size to 1992 mean	Elasticity	Avg cost index	Process cost
Million lbs.		——*Ratio*——				*Percent*
37.4	0.50	0.99	0.26	0.925	1.05	32.4
74.8	1.00	1.97	0.53	0.901	1.00	31.6
149.6	2.00	3.95	1.06	0.877	0.92	30.8
299.2	4.00	7.90	2.11	0.852	0.85	29.9

Notes: Values are based on sample mean values. Only size of operation changes.

As plants grow in size, they must supply additional growers with chicks, veterinary services, and other inputs. Since chicken feed comes from a centralized feed mill, chicks come from a hatchery, and mature birds are shipped to the slaughter plant after the grow-out period, transportation costs and bird losses due to the stress of transit can be substantial. Thus, plants do not typically enlist growers located more than 20 miles away from the plant.

Although growers could locate very close together because chicken houses are compact, environmental constraints can limit their concentration. The rigor of these environmental constraints likely relates to the susceptibility of water sources to contamination from bird feces, rural population proximity and density, and other factors. Grower concentration also makes the flocks of adjacent growers more susceptible to disease risk.

Roenigk also cites labor shortages and plant specialization by product and brand type (or bird size) as strong influences on plant size. Chicken slaughter and its attendant processing operations, in which whole birds are converted into chicken parts and deboned chicken, require many workers. Since chicken slaughter plants typically locate in rural areas, some may have to act as monopsonists in that they must increase all employee wages if wages are raised for new employees. Thus, they may suffer large labor cost increases for hiring more workers.

Modern high-speed chicken slaughter operations must have uniform-size chickens because changeovers require operational adjustments and shifting worker responsibilities, leading to sharply higher operational costs. However, the differentiated product market that chicken slaughter plants serve requires chickens of different sizes. Thus, low-cost operations require specialized plants to convert small chickens into chicken parts, medium-size birds into chicken traypacks, or large birds into deboned products. This fragmentation of production means that the marketing area of any given plant is greater than what would occur in the absence of such specialization, and it could make transportation costs to more distant markets prohibitive or require marketing costs that are greater than the cost savings obtained from a larger scale plant.

Consider how much labor and chicken meat input costs would have to rise to offset the potential gains stemming from scale economies. Suppose that the largest plants are about twice the size of the largest plants in 1992 (table 6-6). Assuming that elasticities do not change as plant size exceeds the limit of the dataset, a doubling of the largest plant size in table 6-6 leads to a decline in the average cost index to 0.763 or about a 10-percent decrease in costs. Given that the chicken meat input share of costs is about 68 percent and the labor share of costs is about 14 percent, this means that chicken prices would have to rise by about 15 percent or labor costs would have to rise about 70 percent to offset the gains accruing to scale economies. If the limiting factor were the size of final product market, either because the product is branded or otherwise limited, then cost savings in production would be offset by higher marketing costs. The increase in these marketing costs cannot be estimated since current marketing expenditures are not available.

Bulk Output Share, Whole-Bird Output Share, and Other Plant Characteristics

Plant characteristics important to chicken production costs are bulk output share (BULK), whole-bird output share (WHOLE), and poultry meat input mix (BIRD). Since bulk processing requires less labor than for traypacks and further-processed products, the labor share of total costs should decline as the bulk output share rises. Notice that the signs on plant bulk output share in the first column, the interaction of plant bulk output share with PLAB in the second column, and the interaction of bulk output share with itself are all negative (table 6-4), suggesting that costs and the labor share of plant costs both decline as the bulk output share rises.

Costs were also estimated for cases in which the bulk share of production is 20, 50, and 80 percent of the sample mean bulk share, i.e., 16.8 to 84 percent bulk shares, and all other variables are at sample mean values (table 6-7). As the bulk output share rises from 20 to 100 percent of the sample mean, production costs drop by about 13 percent. However, the processing cost share does not change because plants substitute more capital for labor, as illustrated in the negative coefficient of the interaction of labor and bulk output share and the positive sign on the interaction of capital and bulk output share (table 6-4).

One explanation for larger plants' having a greater share of output from traypacks than smaller plants (table 4-2) is the existence of economies of scope. If economies of scope do exist, then the interaction of the bulk output share and plant output (Bulk and Q in the next to last column of table 6-4) should be positive and significant. The coefficient is positive, but insignificant, suggesting modest, if any, economies of scope.

Average chicken production costs are hypothesized to decline as the whole-bird output share rises because parts production requires more labor and capital-intensive cut-up and deboning operations. A rise in the whole-bird output share means that costs should drop and that both the labor and capital shares of production costs should decline. Results reported in table 6-4 are consistent with this hypothesis (last column, table 6-4).

Costs are estimated for cases in which the whole-bird share of production is 20, 50, 80, and 150 percent of its sample mean of about 45.7 percent, i.e., 9.1 to 68.6 percent share of actual output. All other variables are at sample mean values (table 6-8). As the whole-bird output share rises from 20 to 150 percent of the sample mean bulk output share, the cost of production drops by about 13 percent and the processing share of costs declines by almost 8 percent.

Most of the individual coefficients involving poultry meat input mix are significant. Plants that use a higher share of liveweight chicken (versus unprocessed chicken) have a higher labor share of costs.

Failure to account for either bulk output share, poultry meat input mix, or whole-bird output share biases estimated scale economies. If bulk output share, poultry meat input mix, and whole-bird output share are omitted from Model III (Model I, table 6-1), or whole-bird output mix is left out of Model III (Model II, table 6-1), then the coefficient on the output term changes to 0.953 for Model I and to 0.931 for Model II from 0.901 for Model III. Using these estimated scale elasticities at the sample mean and assuming a pound of chicken costs $0.50 to produce, Model I and Model III imply that the next pound could be produced at $0.475 and $0.450 per pound, respectively. This $0.025-per-pound difference is substantial in the context of a production plant that may produce 300 million pounds of chicken each year; that observation leads to the conclusion that failure to account for product mix will hide the existence of scale economies.

Other plant characteristics including single-plant firm status and seasonality were also examined but did not improve statistical fit. The lack of significance of sin-

Table 6-7 Estimated cost elasticity and the associated cost index for selected bulk shares using industry- mean values

Bulk share	Bulk share to sample mean	Bulk share to 1972 mean	Bulk share to 1992 mean	Elasticity	Cost index[1]	Process cost[2]
Percent		———*Ratio*———				*Percent*
16.8	0.20	0.19	0.22	-0.066	1.145	31.6
42.0	0.50	0.49	0.54	-0.084	1.050	31.6
67.2	0.80	0.78	0.86	-0.093	1.021	31.6
84.0	1.00	0.97	1.08	-0.097	1.000	31.6

1 Index based on sample mean values with only bulk output share changing.
2 Although labor costs decline with more bulk output, capital costs rise. There is little change in the chicken meat input factor share.
Notes: Values are based on sample mean values. Only bulk output share changes.

Table 6-8: Estimated cost elasticity and the associated cost index for selected whole-bird shares, using industry mean values

Whole-bird share	Whole-bird share to sample mean	Whole-bird share to 1972 mean	Whole-bird share to 1992 mean	Elasticity	Cost index[1]	Process cost
Percent		———*Ratio*———				*Percent*
9.1	20.0	11.0	43.0	-0.216	1.114	37.7
22.9	50.0	27.0	106.0	-0.216	1.047	34.2
36.6	80.0	42.0	166.0	-0.216	1.015	32.4
45.7	100.0	53.0	208.0	-0.216	1.000	31.6
68.6	150.0	78.0	312.0	-0.216	0.974	30.0

Notes: Values are based on sample mean values. Only whole-bird share changes.

gle-plant firm status suggests that there are no positive or negative firm effects, i.e., plant technology is similar regardless of firm type. Seasonality does not play a major role in chicken slaughter because chicken was a major part of the American diet on a year-round basis throughout the time period studied. Alternative specifications for the bulk output share, including one minus byproducts, one minus bulk products, one minus further-processed products, a measure of the relative value of output, and a multiple-product cost function, were estimated but rejected because the chosen bulk output share variable provided a better statistical fit of the data.

Technological Change

Disembodied technological change is typically examined by using time-shift variables, but this approach was not possible because there was insufficient model variance if both whole-bird output share and the time-shift variables were included in the same model. This does not suggest that we did not control for technological change. Technological change consisted of both a shift in plant product mix and materials and in labor-saving innovations. Product mix technological changes were controlled with the bulk output share and whole-bird output share terms, and factor- and output-related changes were controlled with factor prices and the plant output variables.

A model including time-shift variables, but excluding whole-bird output share, was estimated and found to improve model fit over a model consisting of factor prices, plant output, bulk share of output, and poultry meat input mix (Model VIII of table 6-1). However, if time shifters are included in the model, there is no way to control for whole-bird output share because these data are available only on an annual basis and cause model collapse if they are included with the time shifters. Since whole-bird output share dropped from about 80 to 20 percent chicken parts over the 1972-92 period and chicken cut-up and deboning operations are labor-intensive, excluding whole-bird output share leads to a model with serious specification errors. Cost estimates using Model VIII at sample mean values are about 9 percent higher than estimated costs for plants evaluated at the sample mean for Model III in 1992. This estimated cost differential is more severe than any of the other model comparisons shown in table 6-9: Model I versus Model III and Model II versus Model III. Table 6-9 also shows differences in cost elasticity estimates arising from failure to account for bulk output share and poultry meat input mix, and whole-bird output share (Models I, II, and III).

Cost estimates of Model VIII for the years prior to 1992 relative to 1992 (table 6-10) show that costs are lower and cost elasticity is higher in all years except 1972. Since regressive technological change violates economic theory, Model VIII was rejected. Other models containing time-shift variables for various time periods were also tested and likewise rejected.

Conclusion

The principal goals of this chapter were to assess the role of scale economies and product mix in the production costs of chicken slaughter plants. Results suggest that substantial scale economies exist and are much greater than those in cattle and hog slaughter (MacDonald et al.). Plants that were four times larger than the sample mean realized about a 15-percent reduction in costs, and plants that were twice as large as the sample mean had a 7.3-percent reduction in costs relative to plants at the sample mean plant size. One puzzling aspect is the absence of evidence of a constraint to plant size. In the absence of a constraint, either old plants will be expanded, or new plants will be made much larger than older plants. Speculation suggests that higher transportation costs, environmen-

Table 6-9: 1992 cost and elasticity comparison of models I, II, and VIII relative to model III at sample mean values

Model	Model cost estimate relative to model III	Elasticity	Elasticity relative to model III
	Ratio		*Ratio*
I	1.005	0.953	1.058
II	1.024	0.930	1.032
III	1.000	0.901	-
VIII	1.096	0.900	1.000

Table 6-10: 1972-87 Cost and elasticity comparisons of model VIII at earlier years relative to model VIII at 1992 values at sample mean values

Census year	Estimated costs for model VIII over 1972-87 relative to estimated costs for model VIII, 1992	Cost elasticity comparison: model VIII, 1972-87, to model VIII, 1992
	Ratio	
1972	1.055	0.972
1977	0.916	1.048
1982	0.894	1.007
1987	0.928	1.010
1992	1.000	1.000

tal and labor constraints, and plant specialization by product market and bird type inhibit growth in plant size and force eventual diseconomies. However, we found no hard evidence supporting any of these hypotheses, and the question must be left to future research.

Whole-bird output share and bulk output share were found to affect plant production costs significantly. Estimated costs using models that do not control whole-bird output share and bulk output share indicate the presence of seriously biased estimates.

Data limitations prevented the specification of a model that controlled for all types of products. Chicken slaughter plants produce three main classes of product: consumer-ready products, such as traypacks and chicken hot dogs; cut-up and deboned chicken packed in bulk containers; and whole birds packed in bulk containers. Plant-specific data were available only for consumer-ready products, and only industry-level data were available to distinguish bulk whole birds from bulk cut-up and deboned chicken. Thus, whole-bird output share did not vary across plants.

Economists often use time-shift variables to distinguish general changes in the level of technology from one year to the next. However, the model collapses due to insufficient model variance if the time-shift and whole-bird output share terms are included in the same model. Whole-bird output share was used because estimated results were consistent with economic theory, and perverse results, suggesting regressive technological change, occurred if time-shift variables, rather than the whole-bird output share variable, were used.

Despite any shortcomings, to our knowledge, no poultry industry cost function using plant-level data has been published. Results show that chicken slaughter plants have reaped huge cost reductions from scale economies, while adding more complex processing operations.