Chapter 7

Hog Slaughter Cost Estimation

We apply the models described in chapter 5 to the analysis of costs at hog slaughter plants; the data cover Census plants reporting in the years 1963, 1967, 1972, 1977, 1982, 1987, and 1992, and include a total of 1,142 plant observations over the 7 census years. Our primary goals are to identify the extent of scale economies in slaughter, to determine whether scale became more important over time, and to estimate the effect of product mix on plant costs.

Model Selection

We followed the same approach used in chapter 6 for the estimation of cattle slaughter cost functions, applying Gallant-Jorgenson tests to distinguish among different functional forms. Table 7-1 provides descriptions of the tested models, while table 7-2 summarizes the results of the G-J tests. The results mirrored the findings for cattle slaughter in that the most general model (IV) provided statistically significant improvements in fit over each of the more restrictive models.

As in the cattle models, the most restrictive model (I) contained four factor prices (labor, capital, animal inputs, and other materials) and the physical volume of output, but no time shifters and no measures of output or input mix. Model I was decisively rejected in favor of model II, which added measures of output and input mix. Model II was then compared with model III, which represents technological change by allowing all first-order coefficients to vary over time. Model III added 42 new estimated parameters to the cost function, but that more flexible model provides an improvement in fit, at a 99-percent level of significance. Finally, model IV adds a dummy variable for single-establishment firms, and is favored over the less flexible model III.

Table 7-2 also reports tests of two additional restrictions on model IV. Model IVa drops the terms involving input mix (that is, sets coefficients to zero), but the restrictions are strongly rejected—it is important to account for differences in the mix of animal and meat inputs. Model IVb imposes homotheticity, under which factor proportions are invariant to levels of output. G-J tests decisively reject homotheticity. The best model (IV) is nonhomogeneous and nonhomothetic; 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.

Summary of the Best Model

Table 7-3 reports all first-order coefficients for 1992 and first-order time shifters for earlier years, while table 7-4 repeats the 1992 first-order coefficients and reports coefficients on the quadratic and interaction terms. In table 7-3, the first-order coefficients can be interpreted as factor shares at the sample mean. Animal and meat inputs accounted for just under 73 percent of hog slaughter costs in 1992 (recall that in cattle slaughter this share was larger, 83 percent). Labor accounted for 11 percent of costs, while capital and other materials each accounted for 8 percent in 1992. The capital share rose sharply after the late 1970's, while all other factor shares fell. Table 7-4 also reports some important interactions of factor shares with output.

The skewed distribution of factor shares carries the same implications for hog as for cattle slaughter. First, as long as the prices paid for hogs are invariant to plant size, substantial scale economies in slaughter and fabrication will translate into small scale economies calculated on total costs, because total costs will be dominated by hog purchase expenses. Second, 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.

Table 7-5 reports price elasticities of input demand 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 close to that

Table 7-1—Hog slaughter cost function models, by goodness of fit

Model	Description	G-J statistic	Parameters estimated
I	Translog, factor prices and output only	3940	15
II	Adds product and input mix to I	3838	28
III	Adds first-order time shifts to II	3720	70
IV	Adds single-establishment dummy to III	3684	77
IVa	Drops input mix variables from IV	3793	58
IVb	Imposes homotheticity on IV	3820	74

Source: Authors' estimates, based on models and data described in text.

Table 7-2—Tests of model selection, hog slaughter cost function

	Test statistics[1]		
Comparison	d.f.	Critical value@ 99	Chi-square
II vs. I	13	27.69	98
III vs. II	42	66.18	89
IV vs. III	7	18.48	36
IV vs. IVa	19	36.19	109
IV vs. IVb	3	11.34	136

[1] Chi-square statistics are the difference in G-J statistics in models reported in table 7-1. Degrees of freedom (d.f.) are the differences in the number of estimated parameters.

Source: Authors' estimates, based on models and data described in text.

reported in chapter 6 for cattle plants (-0.294) and just below the estimate reported by Melton and Huffman (-0.373), while the elasticity on capital is rather price sensitive. As with cattle, 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, perhaps reflecting the use of capital equipment to increase yields from hog carcasses.

Economies of Scale

Our measure of scale economies is the elasticity of total cost with respect to output. Values less than 1 denote economies of scale—total costs increase less than proportionately with increases in output, so that average costs decline as output increases. Conversely, values over 1 show diseconomies of scale (larger plants have higher average costs than smaller plants).

Estimated cost elasticities can vary with the size of plant and with the year (as technology changes). Table 7-6 reports elasticities for plants of different sizes and at different years. In each year (1992, 1977, and 1963), we selected the mean plant size (output level) for that year, and output levels for a relatively large plant (at the 95th percentile of the GIPSA plant size distribution). Because of growth in plant sizes noted in chapter 3, mean and large plants in 1992 are considerably larger than the corresponding 1977 plants, which are in turn larger than the 1963 plants. We also include a seventh plant size—that at the overall sample mean.

For each of the seven plant sizes, table 7-6 presents calculated cost elasticities for three different vintages of technology, those estimated for 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.

First, the data show evidence of modest scale economies. Average sized plants in each year operate in the range of increasing returns—estimated scale parameters were less than 1. Second, technological change has led to greater scale economies—at any given plant size, the scale parameter falls 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 in a range of increasing returns. Third, the largest plants in each year, given that year's technology, were operating at an output level near constant returns (95th percentile plants had scale parameters 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 with the technology vintages of those years (looking across the row for 1992 95th percentile). Similarly, plants at the 1963 mean or the 1963 95th percentile would have been too

Table 7-3—Hog slaughter cost function parameters: first-order terms and year shifts[1]

Variables	First-order 1992	Change from 1992 1963	1967	1972	1977	1982	1987
		Coefficients (standard errors)					
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)

[1] 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.

small to take advantage of all scale economies in the 1992 technology.

To facilitate comparisons with other methods, we calculated a slaughter cost per head from our model. We started with the mean 1992 hog price of $43.03 per hundredweight (Iowa-Southern Minnesota slaughter hog series). Using estimated model IV coefficients, we calculated the animal share of total costs for a large 1992 plant (4 million head annually)—80.7 percent of total costs, if all 1992 plants paid the same factor prices. Slaughter costs at that plant, 19.3 percent of total costs, would then be 23.9 percent of hog prices, or $10.28 per hundredweight. With a 250-pound hog, that would translate to predicted slaughter costs of $25.70 per head. In turn, 1992 slaughter costs were about $3.50 per head higher at a plant handling 2 million hogs a year, $8.80 higher at a plant handling 1 million hogs a year, and $14.85 higher at the sample mean plant, handling 400,000 head per year. Those estimates compare to Hayenga's (1998) estimates, based on surveys of plant managers, of $23 per head for large plants in 1996-97. Hayenga's estimates are based on operation at full capacity in 1996-97, while ours embody actual 1992 utilization, technology, and factor prices; average costs can rise noticeably as production falls short of capacity.

We are aware of one other statistical study of scale economies in hog slaughter (Melton and Huffman 1995, or M&H). Comparisons are difficult because M&H used aggregate 1963-88 time series data to analyze temporal variations in value added, while we analyze variations in total cost across many plants over 1963-92. They used an unusual output specification, including number of head, average live weight, and number of plants as separate variables. With three separate and unrelated proxies for output, it is hard to define an appropriate cost elasticity, and hard to interpret any proxy-specific elasticity.

M&H estimate an average value-added cost elasticity of 0.79, with respect to number of head while holding weight and plants constant. If value added (slaughter/fabrication cost) averages 25 percent of total costs, then that estimate would correspond to a total cost elasticity of 0.948, which is quite close to our estimate (0.953) for average size plants at the 1977 midpoint of their data (table 7-6). But their estimated cost elasticities vary widely from year to year, with 10-percent increases in slaughter numbers being asso-

Table 7-4—Hog slaughter cost function parameters: higher order terms[1]

Variables	First-order	Interactions with: PLAB	PMEAT	PMAT	PCAP	Q (lbs)	PMIX	IMIX	EST1
					Coefficients (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)								

[1] Quadratic (on diagonal) and interaction terms from estimation of translog cost function. First-order terms from table 7-3 are repeated in first column.

ciated with 20-percent declines in total (not average) processing costs in some years, and 20-percent increases in others. M&H also report significant neutral technological change, with steady large trend decreases in costs (5-9 percent per year in value added, or 1 to 2 percent per year in total costs), whereas our cost declines operate entirely through scale economies, factor prices, and mix variables. Increases in output should not reduce total costs, and we suspect that the M&H data set does not adequately allow for changes in technology, scale, and product mix. We believe that our results are more consistent with observed structural change, and that the panel nature of our data, as well as our output measures, allows for improved results.

Wages and Pecuniary Scale Diseconomies

Industry average wages fell by 5.5 percent between 1982 and 1992 (table 4-8). That decline 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 23 percent higher than the industry mean. At a mean 1977 labor share of 12.8 percent (table 7-3), that gap translates into a 1977 cost differential of 2.9 percent, substantially attenuating large plant scale advantages, and for the largest 1992 plants, creating diseconomies of scale under 1977 wages and technology.

The wage premia in table 4-8 are drawn from aggregated data for all meatpacking plants. Because of the importance of this issue, we looked more closely at hog plant wages. While we cannot (for confidentiality reasons) detail breakdowns of wages by plant size, we can report regression results. We ran wage regressions for each census year, using average hourly production worker wages at each hog slaughter plant as our dependent variable. We regressed the natural log of wages on IMIX and PMIX, plant size expressed as number of head (in natural logs), and plant location.[27] Table 7-7 reports selected results from regressions for four census years. Coefficients on plant size were large, positive, and statistically significant through

[27] We used regional dummy variables for plant location, with the regions being Eastern Corn Belt (IL, IN, MI, OH, and WI), Western Corn Belt (IA, KS, MN, MO, ND, NE, SD), Southeast (FL, GA, KY, NC, SC, TN, VA), Northeast (CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT), and the rest of the country. We chose a log-linear specification because it clearly gave the best fit; in particular, the size-wage relation was best represented by a log-linear functional form.

Table 7-5—Mean input shares and elasticities in hog slaughter[1]

Item	Input price variables			
	PLAB	PMEAT	PMAT	PCAP
Input shares	.1121	.7426	.0779	.0674
$\in_{ii}$	-0.347	-0.076	-0.196	-1.385
σ_{ij}				
PLAB	-3.098	-0.118	3.475	2.443
PMEAT		-0.102	-0.246	1.602
PMAT			-2.510	-0.143
PCAP				-20.55

[1] All values are calculated using mean 1992 data values and parameters from tables 7-3 and 7-4. Own-price input demand elasticities ($\in_{ii}$) are calculated holding output and other factors constant, while the elasticities of substitution (σ_{ij}) are calculated using Allen's formula.

Table 7-6—Cost elasticities for differing plant sizes and technology vintages[1]

Plant size	Technology vintage		
	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

[1] 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.

1982. Moreover, unreported coefficients on the Eastern and Western Corn Belt locations were positive, significant, and large. Predicted wages there were substantially higher than in the Southeast and the rest of the country.

The lower panel of table 7-7 summarizes the estimated premia, reporting regression-based predicted hourly wages at Western Corn Belt (WCB) plants for 4 years and three different size categories: 400,000 head per year (sample mean), 1 million head (a large plant for 1977) and 4 million head (a large plant for 1992). Compared with the sample mean plant, wages at the million-head plant were consistently 9-12 percent higher through 1982, and predicted wages at the largest plant were 24-33 percent higher. Now note the regional effect of locating in the Southeast (bottom row); WCB wages are consistently about 50 percent higher than predicted Southeastern wages through 1982. Size and location premia eroded in the unreported 1987 regression, and then disappeared entirely in the 1992 regression—there are no statistically significant differences in 1992 predicted wages, and the coefficient on size is small and not significant. Early size and location premia represent a pecuniary scale diseconomy. In the 1980's and 1990's, those diseconomies disappear, reinforcing the effect of changing technological scale economies; their disappearance coincides with sharp increases in plant sizes.

Product and Input Mix Effects

These effects are more complicated in hog slaughter than in cattle slaughter, where slaughter and carcass fabrication into boxed beef predominate (there is also processing of byproducts such as hides, blood, and organs, but we model these as occurring in fixed proportions with slaughter). Hog plants slaughter hogs and cut up the carcasses into primals, but many further process 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 1 in plants that specialize more in slaughter and cutup.

The coefficient on PMIX is negative and marginally significant for 1992 (table 7-3)—plants that do less processing have lower costs, all else equal.[28] The coefficient value is not particularly large because processing costs account for small shares of total costs. 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 affect factor shares, although only the term involving labor is statistically significant (see the interaction terms with PMIX in table 7-4). Labor and other materials account for smaller cost shares in plants that do little processing, while animals and capital hold larger shares.

The interaction term between product mix and output is negative, small, and not nearly significant. That is, the data provide no evidence that costs can be reduced

[28] Note that this measure carries a different interpretation than the PMIX measure in cattle. Here increases in PMIX mean less processing; there increases in PMIX mean more processing and fabrication.

Table 7-7—Selected results from plant average wage regressions, by plant size and location[1]

Item		1963	1972	1982	1992
Coefficient and t statistic on ln (# of head)		.094 (8.40)	104 (7.54)	.122 (6.93)	.019 (0.91)
Plant characteristics:		Predicted wages			
Head	Location	*Dollars per production worker hour*			
400,000	WCB	3.08	5.04	12.17	8.08
1 million	WCB	3.36	5.54	13.61	8.22
4 million	WCB	3.83	6.40	16.11	8.44
4 million	South	2.59	4.20	10.83	8.02

[1] Based on regressions of plant average production worker wages (in natural logarithms) on plant size (number of head, in logs). The model also included controls for input mix, product mix, and plant location (Eastern Corn Belt, Western Corn Belt (WCB), Northeast, South, and rest of country).

by combining processing with slaughter in large establishments. That result is reassuring, since evidence of scope economies would clearly have conflicted 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 (table 7-3), generally significant, and usually large enough to make the full effect negative in the relevant year. 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 large volume of carcasses, presumably for processing operations. As the industry changed over the next 15 years, the distribution of IMIX values narrowed, to a median of 98 percent and a 25th percentile value of 91 percent. Given the narrow variance of IMIX values in 1992, it should not be surprising that IMIX has no significant effect on costs in 1992. In earlier years, with a wider variation in input mix, plants that specialized in hog slaughter 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 also do more processing (if one variable is dropped, coefficients on the other gain significance). Furthermore, it appears that scale economies may be underestimated if the 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 7-2) strongly support the inclusion of both measures in the model; as a result, we believe that economies of scale are best measured when controls for product and input mix are retained.

Conclusion

As in cattle, our estimated cost function finds small but important economies of scale at hog slaughter plants. Technological change and a flattening of the size-wage relation led to greater available scale economies over time, and plants adjusted quickly, growing to take advantage of scale. The industry's larger plants produce at output levels near constant returns to scale, but they have not exhausted available slaughter economies; in consequence, we are likely to see continued cost pressures on smaller and medium-sized hog slaughter facilities.

The mix of products and inputs at hog slaughter plants has changed, and plants today are mostly specialized, with a focus on a single species and relatively little processing. Our simple measures of product and input mix have significant associations with plant costs, so it is important to control for product and input mix when estimating scale economies and technological change.

We note one other striking similarity with the cattle results. 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 intercept row in table 7-3). Changes in slaughter costs appear to be fully accounted for by changes in factor prices (in particular, by hog prices), changes in input and output mix, and shifts in plant size to take advantage of scale economies. In turn, productivity growth in hog slaughter operations appears to be driven largely by scale economies.