Consolidation in U.S. Meatpacking. By James M. MacDonald, Michael E. Ollinger, Kenneth E. Nelson, and Charles R. Handy. Food and Rural Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 785.

Abstract

Meatpacking consolidated rapidly in the last two decades: slaughter plants became much larger, and concentration increased as smaller firms left the industry. We use establishment-based data from the U.S. Census Bureau to describe consolidation and to identify the roles of scale economies and technological change in driving consolidation. Through the 1970's, larger plants paid higher wages, generating a pecuniary scale diseconomy that largely offset the cost advantages that technological scale economies offered large plants. The larger plants' wage premium disappeared in the 1980's, and technological change created larger and more extensive technological scale economies. As a result, large plants realized growing cost advantages over smaller plants, and production shifted to larger plants.

Keywords: Concentration, consolidation, meatpacking, scale economies, structural change.

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Summary

U.S. meatpacking has been transformed in the last two decades. Far fewer meatpackers now slaughter livestock, but their plants are much larger. Consolidation toward larger plants led to sharply increased concentration in cattle slaughter and persistent concerns over the future of competition in that industry. Hog slaughter has also consolidated, with important shifts toward larger plants and increased concentration.

Consolidation in slaughter features three other important elements: changes in plant location, product mix, and labor relations. Consolidation brought geographic changes in slaughter plants, which followed changes in the location of animal feeders. Cattle slaughter shifted to the Great Plains from the Corn Belt, while hog slaughter shifted west within the Corn Belt and from the Corn Belt to the Southeast.

In the early 1970's, cattle plants were usually slaughter-only, shipping carcasses to wholesalers and retailers for processing into retail products. Hog slaughter plants often had extensive processing facilities for production of bacon, hams, and sausages. Today, large cattle plants, and most large hog plants, slaughter and cut up carcasses into smaller cuts for shipment to wholesalers, retailers, and specialized meat processors. Product mix influences costs, and mixes vary widely across plants and over time. Because product mixes are correlated with plant size (larger cattle plants produce almost all boxed beef, for example), their omission in models can lead to biased estimates of scale economies and of the extent of technological change and productivity growth.

Our statistical analysis aims to uncover the causes of consolidation into larger plants, particularly the roles played by technological change and scale economies. Two distinct scale concepts are important: technological scale economies, relating to economies of resource use as plant sizes increase; and pecuniary scale diseconomies, relating to changes in labor compensation as plants grow bigger. We find extensive technological scale economies in hog and in cattle slaughter in 1992, and those scale economies have become more pronounced over time. Scale economies are small—the industry's largest plants can deliver meat to buyers at costs 3-5 percent below those of plants only a quarter as big—but cost advantages extend over the entire range of plant sizes.

Wages rose sharply with plant size in the 1960's and 1970's, and those wage premiums generated a pecuniary scale diseconomy that largely offset the cost effects of technological scale economies. But changes in labor relations accompanied industry consolidation—strikes, plant closings, and deunionization struggles at slaughter plants in the 1980's led to sharp declines in union membership and in average hourly wages. Moreover, the wage distribution narrowed sharply as the large plant wage premium disappeared. Without that pecuniary diseconomy, and with growing technological scale economies, large plants realized growing cost advantages over smaller plants, and production shifted to larger plants.

We argue that slaughter concentration has increased for three reasons: (1) shifts in scale economies provided larger plants with modest cost advantages; (2) aggressive price competition forced prices to quickly move near the costs of the low-cost market participants; and (3) slow demand growth limited the number of efficient large plants in the market. For hogs, scale economies and strong price competition also forced small plants to exit the industry, but modest demand growth has allowed for more plants and lower concentration.

Chapter 1

Introduction

The U.S. meatpacking industry consolidated rapidly in the last two decades, as today's leading firms built very large plants and many independent packers disappeared. Today, four firms handle nearly 80 percent of all steer and heifer slaughter; just two decades ago, concentration was less than half as high. Although it has not grown as rapidly, concentration in hog slaughter has also increased, and today the top four firms handle over half of all slaughter.

Consolidation raises a host of policy issues. With few competitors, meatpackers may be able to reduce prices paid to livestock producers, and they may be able to raise meat prices charged to wholesalers and retailers. Indeed, livestock prices have been at the center of several recent lawsuits, congressional hearings, and Federal investigations.[1]

Related consolidation has occurred in livestock production: large cattle feedlots and hog farms account for high and growing shares of livestock sales, and their expansion is closely linked to the presence of large slaughter facilities nearby. Consolidation in production may worsen water pollution and odor problems, and has spurred intense debate over environmental policies in more than 20 States.

Slaughterhouses have always been risky places to work, and plants today rely on large workforces of immigrant workers to operate slaughter and fabrication lines.[2] As a result, slaughter plants frequently attract the scrutiny of job safety regulators and immigration authorities. Finally, a concentrated system of large plants and livestock producers may require a different set of regulatory strategies for reaching food safety goals than would an industry with many small producers and slaughter plants (MacDonald et al., 1996).

Policy issues tend to address the effects of consolidation, whereas this report aims to assess causes. We use a unique and valuable data set to describe and to explain consolidation.[3] In particular, we examine how several innovations may have reduced slaughter costs and promoted consolidation among slaughter firms. Changes in slaughter plant technology may have created scale economies, altered the mix of slaughter plant products, and changed the location and operations of cattle and hog producers (which may affect the optimal location, scale, and operations of slaughter plants). In addition, changes in labor relations have led to reductions in wages and may have created additional scale economies. We believe that it is crucial to understand the causes of slaughter industry consolidation when fashioning appropriate public policies to deal with its effects.

The report relies on a unique data source, the U.S. Census Bureau's Longitudinal Research Database (LRD). The LRD details the records of individual establishments reported in the census of manufactures, for the years 1963, 1967, 1972, 1977, 1982, 1987, and 1992 (1997 census data will be processed too late for this report). The files detail the physical quantities and dollar sales of many different products sold from slaughter plants, the physical quantities and prices paid for material inputs, and employment and average wages for each establishment. The files also note ownership and location for each establishment. Because the LRD covers several censuses, we can make comparisons across plants at a point in time, as well as over time.

[1] For a summary, see Feder (1995), or the report of the Secretary of Agriculture's Advisory Committee on Agricultural Concentration (1996).

[2] For a discussion of the transformation of rural communities, and the associated impacts on job injury risks and immigration rules, see Hedges and Hawkins (1996).

[3] A companion report (Ollinger et al., 1999) analyzes the poultry sector.

While researchers can access individual LRD establishment records for research purposes, they may not divulge information on an individual plant or firm, and may publish only aggregated information. This report therefore presents aggregated statistical data and the coefficients from regression analyses covering hundreds and, in most cases, thousands of establishment records. Any references to specific company or plant names are based on publicly available records, and not on any census source.

Chapter 2

The Setting

Developments in Meat Consumption and Livestock Production

Cattle and hog slaughter plants operate in conjunction with meat buyers and with livestock suppliers. Over the years covered by this study (1963-92), the economics of slaughter industries have been affected by some important developments in meat consumption patterns and in methods of livestock supply. [4]

Changes in Meat Consumption

Meat consumption patterns changed markedly in the last quarter century, shifting from red meats, and particularly beef, to poultry (table 2-1). Beef consumption dropped from 84.7 pounds per person in 1971-75 to 66.3 pounds by 1991-95. Over the same period, per capita pork consumption changed little from 51.9 pounds in 1971-75 to 52.1 pounds in 1991-95. In contrast, poultry consumption rose sharply. Per capita chicken consumption nearly doubled, from 36 pounds in the early 1970's to almost 70 pounds in 1995, while turkey consumption (not shown) jumped from 8 pounds in 1970 to 18 pounds in 1995.

The shifts derive from trends in relative prices among meats, health concerns, and the development of many new poultry products. But the changes forced slaughter industries to adapt. With declining per capita consumption, growth in beef demand, and consequently growth in demand for slaughter cattle, could come only from growth in population and in exports.

The U.S. population grew about 1 percent per year during 1970-95 or, compounded, 28 percent over the entire period. Coupled with declining per capita consumption and only a slight increase in net beef exports, total U.S. demand for beef showed little growth.[5] But changes in animal production meant that constant beef demand could be met with fewer animals. Beef yields rose to almost 700 pounds per carcass in the early 1990's from just over 600 pounds two decades before; consequently, cattle slaughter (numbers) fell by 13 percent between the late 1970's and the early 1990's.

Hog yields grew slightly during the period, as did net pork exports, while per capita consumption showed little change. The net effect was modest growth (15 percent) in annual hog slaughter over the two decades; that is, demand for slaughter hogs grew, but by less than 1 percent per year.

Poultry stands in stark contrast. Growth in broiler size (average meat yields from a broiler grew by nearly 20 percent) also limited the growth in demand for slaughter livestock. But growth in population, exports, and per capita consumption caused broiler slaughter to jump from 2.9 billion animals a year in the early 1970's to 6.6 billion in the early 1990's.

Later chapters will show that dramatic structural changes affected each of the slaughter industries during the period, as production shifted to larger plants. But those shifts occurred in the face of widely varying economic environments. In cattle, production shifted to larger plants in the face of declining demand for slaughter cattle; the result was sharp declines in plant numbers and sharp increases in concentration. By contrast, shifts to larger plants in poultry slaughter accom-

[4] We emphasize the developments that affect slaughter plant economics. More complete descriptions of meat consumption and livestock production can be found in Crom (1988), McBride (1997), USDA (1995), and Putnam and Allshouse (1997).

[5] Net exports refer to exports minus imports, measured in quantities (rather than in dollar values). During the period, net exports grew from -7 to -4 percent; that is, exports grew faster than imports, creating some net demand growth for U.S. beef.

Table 2-1—From meat demand to livestock slaughter

Variables driving livestock demand	Annual average 1971-75	1976-80	1981-85	1986-1990	1991-95
			Percentage increase		
U.S. population growth	1.04	1.07	0.93	0.94	1.04
Per capita consumption:			*Pounds*		
Beef	84.7	85.6	78.1	72.5	66.3
Pork	51.9	50.1	51.8	50.4	52.1
Chicken	36.8	42.8	48.3	55.8	66.4
Net meat exports:			*Percent of domestic supply*		
Beef	-7.0	-7.7	-6.4	-5.7	-4.0
Pork	-2.3	-1.3	-3.6	-5.3	-1.7
Chicken	+1.3	+4.8	+3.9	+4.9	+8.7
Average carcass size:			*Dressed weight, pounds*		
Cattle	612	615	632	666	699
Hogs	169	170	173	178	182
Broilers	3.74	3.88	4.10	4.31	4.45
Commercial slaughter:			*Million animals*		
Cattle	36.6	38.3	36.3	35.0	33.3
Hogs	81.3	82.7	86.2	84.5	93.0
Broilers	2,889	3,575	4,198	5,223	6,580

Sources: Putnam and Allshouse, 1997; USDA, ERS, 1995.

modated growing demand, so fewer plants exited and concentration changed little.[6] With slow but positive demand growth for hogs, shifts to larger plants resulted in plant exits and some increase in concentration, but nothing like the sharp consolidation in cattle slaughter.

The Supply Chain: Cattle Production

Cattle slaughter plants usually specialize in one of two types of cattle. Of the 35.7 million cattle slaughtered in 1996, 28.3 million were steers and heifers, while the rest were cows and bulls. Plants specialize because the animals have different shapes that require different settings for slaughter line equipment, and because the animals provide different meat products. Steers and heifers are fed a concentrated diet of corn rations before slaughter, producing a more marbled cut of beef that is preferred for taste. Cows, fed on grass and forage, produce leaner meat that is usually mixed with trimmings from steer and heifer carcasses to produce ground beef.

Cows sometimes move through feedlots before going to slaughter plants, but more often move directly to plants from dairy farms and beef cow-calf operations. Because of that, cow and bull sales and slaughter plants are widely distributed across the country. Texas accounted for 12 percent of the Nation’s 1996 cow and bull sales, and 15 other States, from all regions of the country, each accounted for at least 1 percent. Because sales are distributed over a wide geographic area, slaughter plants tend to be smaller than steer and heifer plants (larger plants would require uneconomically large catchment areas).

The animals that steer and heifer plants eventually purchase are first calved on a wide variety of farm operations spread across the country. Most producers are quite small. Calves are usually weaned from cows when they weigh about 400 pounds. Of those that are to be grown out for beef, 80 to 90 percent are placed

[6] Turkey slaughter also increased sharply, for similar reasons. Annual slaughter numbers in the early 1990’s were 130 percent above those of two decades earlier, following sharp increases in per capita consumption and more modest growth in population and exports. Meat yields from turkeys rose 20 percent.

in growing operations (many of which are integrated with cow-calf operations), where they add weight while pasturing on grass and roughage. Feeder cattle often move among growing operations, and to many different locations around the country, as pasture and forage conditions vary.

Feeder cattle commonly move to feedlots when they weigh between 500 and 750 pounds. The animals remain in feedlots until they reach market weights of 950 to 1,250 pounds, and are sold to slaughter plants. Feedlots, and hence steer and heifer plants, are geographically concentrated. According to an annual USDA survey, 75 percent of all packer purchases of steers and heifers in 1996 came from just five States in the Great Plains—Colorado, Nebraska, Kansas, Oklahoma, and Texas (USDA, 1998).

Feedlots cover a wide range of sizes, but sales to packers are increasingly dominated by large commercial feedlots in which almost all feed is purchased (rather than grown onsite), almost all labor is hired, and the animals are confined to a relatively small area. A 1992 USDA survey of the largest steer and heifer plants shows they bought cattle from many different sellers—19,395 of them.[7] Most sellers (89 percent) were small farmer-feedlots—seasonal operations with capacity below 1,000 head, which are part of a diversified farm business. But, on average, the survey's farmer-feedlots sold less than 200 cattle each in 1992, in 2 to 3 transactions, and together those sellers accounted for only 14 percent of the cattle purchased in the survey.

Packers purchased far more animals from very large commercial feedlots; 150 sellers in the 1992 survey sold over 32,000 cattle each, and together accounted for 43 percent of all cattle purchased by the packers. These large commercial feedlots sold an average of 65,000 animals each in 1992, in over 400 different transactions.[8] Almost all were located in the Great Plains.

[7] Those plants slaughtered 23.1 million cattle, 87.6 percent of all commercial steer and heifer slaughter in that year. The relevant survey data were collected by USDA's Grain Inspection, Packers and Stockyards Administration (GIPSA), as summarized in Texas Agricultural Market Research Center (1996).

[8] Another 144 sellers, which each sold more than 16,000 cattle to the largest plants, accounted for 3.3 million head. The remaining 28.8 percent of steer and heifer sales came from 1,873 smaller commercial feedlots.

In the mid-1970's, large commercial feedlots accounted for less than a quarter of total steer and heifer sales. Since then, their growth has paralleled that of large slaughter plants. Technological innovations—such as feed additives, computerized onsite feedmills and feeding operations, and improved transportation—have heightened economies of size in cattle feeding (Glover and Southard, 1995). By building a large slaughter plant among a network of large feedlots, plant managers can ensure a steady supply of animals and can maintain high capacity utilization throughout the year. The economics of slaughter plant operation and pricing are intertwined with large feedlot operations and pricing.

The Supply Chain: Hog Production

Meatpackers usually purchase hogs locally—within 150 miles of the slaughterhouse—so facilities consequently locate near hog farms, much as cattle slaughter plants locate near cattle feedlots. But hog finishing is not as geographically concentrated as cattle feeding. While the five largest cattle-feeding States form a contiguous region accounting for three-quarters of fed cattle sales, the five largest hog-finishing States form two distinct regions (the Western Corn Belt and the North Carolina-Virginia area), and together account for just over 60 percent of hogs marketed to slaughterhouses.

Hog production falls into several distinct phases: production of breeding stock, feeder pig production, and finishing. While hog producers usually maintain their own female breeding stock, most boars are supplied by specialized commercial breeders. In the next two stages, some producers specialize in either feeder pig production or finishing, with hogs transferred between the two stages in a commercial transaction. But most operations are farrow-to-finish.

Hog production at the latter two stages has undergone a dramatic and ongoing consolidation, represented by a shift toward larger production establishments and toward long-term contractual arrangements among the production stages and between production and slaughter. In 1978, 96 percent of all hog farms sold less than 1,000 head, and together accounted for just under two-thirds of all hog marketings. By 1997, 77 percent of all farms sold less than 1,000 head, but they accounted for only 5 percent of marketings (Lawrence, Grimes, and Hayenga, 1998). The very largest farms, those selling more than 50,000 head a year, handled 37 percent of all hog marketings in 1997, up from 7 percent only a decade before. Of those producers, 18 sold at least 500,000 head in 1997, and those accounted for nearly one-quarter of all marketings. Very large hog producers are highly specialized, purchasing feed rather than growing it, and are frequently linked to slaughterhouses through contractual agreements or common ownership.

With hog production increasingly divorced from corn and soybean production, large operations could locate virtually anywhere in the country. Many of the very large hog farms have located outside of the traditional region of hog production—the Corn Belt States of Minnesota, Iowa, and Illinois—which 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 selling at least 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 (North and South Carolina and southern Virginia), nearly 80 percent of hog marketings come from farms that sell more than 5,000 head each. Similarly, very large producers underlie the expansion of the hog industry in Oklahoma and proposals for expansion in Utah and other nontraditional States. Large hog operations can bring odor and water problems, and may threaten small operations; as a result, hog farm location has become a political and regulatory battleground in many States (Johnson, 1998; Drabenstott, 1998). Location of new hog production facilities may shift significantly in the near future, depending on how these issues are resolved.

Economies of size can account for much of the growth in hog farm size (McBride, 1995). Production costs per hog drop sharply as annual marketings increase to 1,000 head, and continue to decline, but more slowly, as size increases past that level. In turn, unit production costs decline largely because of improved feed efficiency and labor productivity on larger hog farms.

Economies of scale in hog and cattle slaughter emerged in the 1980's and 1990's. The largest slaughter plants in 1992 held significant cost advantages over smaller plants. Growth in slaughter plant size may be related to shifts in the size and location of hog producers and cattle feeders. Economies of scale in slaughter apply only if plant operators have access to an assured steady supply of cattle or hogs; large plants quickly lose any cost advantages if they cannot operate near full capacity. By locating among a network of large producers, and by forming long-term relationships with those producers, slaughter plants may reduce the risks associated with building and operating large plants.

Chapter 3

Concentration and Consolidation in Livestock Slaughter

Concentration in cattle slaughter increased dramatically in the last two decades, and three firms now dominate the industry. Market concentration in hog, chicken, and turkey slaughter is not particularly high when compared with other manufacturing industries, but has increased over the years. Large plants now dominate production in all major slaughter sectors, and consolidation among large plants over the past two decades is a major cause of increased concentration.

Concentration

The four-firm concentration ratio measures the share of an industry's output held by the four largest producers in the industry.[9] Changes in four-firm ratios are widely used as summary indicators of structural change.

Using Census Bureau data, table 3-1 reports concentration ratios for cattle, hogs, chickens, and turkeys. The ratios measure the four largest firms' share of the dollar value of shipments from plants in each slaughter class.[10]

Four-firm concentration in cattle slaughter remained stable from 1963 through 1977, then rose from 25 percent in 1977 to 71 percent in 1992 (table 3-1). The Census Bureau publishes four-firm concentration ratios for about 1,000 different product classes, and many of the series go back to 1947. The change in cattle slaughter concentration is unique: no other product class shows as dramatic an increase in any 15-year period.

Concentration in hog slaughter remained stable from 1963 through 1987, but then increased sharply between 1987 and 1992. Concentration in chicken slaughter rose sharply from 1977 to 1987, but has since remained stable. Similarly, turkey slaughter became much more concentrated between 1963 and 1972, and then stabilized (table 3-1). Of the four classes, only cattle could be described as having unusually high concentration today, when compared with other manufacturing classes.[11]

Census data are subject to two potential problems. First, they measure concentration as the value of plant (establishment) shipments. But suppose that a firm operated a plant that only slaughtered cattle and then shipped the carcasses to a second plant that both slaughtered cattle and also cut up carcasses into boxed beef. The Census approach would count the value of shipments from both the slaughter-only plant and the fabrication plant. But since fabrication plant shipments already include the value of shipments from the slaughter-only plant, the Census measure double-counts shipments among slaughter plants, and this approach may overstate the value of shipments from the combined firm and thus exaggerate industry concentration. Second, Census measures may be too broad. Cattle plants specialize within species; the largest plants slaughter only steers and heifers, while other plants specialize in cows and bulls. Not only do the plants use different techniques, but the meat outputs are not ready substitutes: steer and heifer meat is

[9] There are many potential concentration measures. The four-firm ratio is easy for statistical agencies to compute and provides confidentiality to individual firms. For those reasons, the measure has for several decades been calculated for many industries by Federal statistical agencies.

[10] The classes are defined by the Standard Industrial Classification (SIC), a hierarchical coding for products and establishments in the economy. Establishments that primarily process food products are assigned to the two-digit SIC code "20"; those food processors that specialize in meat slaughter and processing are assigned to the three-digit class "201." Establishments that slaughter any live cattle, hogs, horses, or sheep and lambs are then assigned to the four-digit industry "2011"(those that process or slaughter poultry are assigned to "2015"). Finally, slaughter products from these plants are assigned to five-digit product classes: "20111" for cattle, "20114" for hogs, "20151" for chickens, and "20153"for turkeys. Our concentration measures are based on shipments from establishments assigned to the five-digit slaughter product classes.

[11] About 10 percent of U.S. manufacturing industries are more concentrated than cattle slaughter, while the other three slaughter classes are close to the mean for manufacturing.

Table 3-1—Four-firm concentration ratios, shipments basis, in four slaughter industries

Census year	Slaughter industry: Cattle	Hogs	Chickens	Turkeys
1963	26	33	14	23
1967	26	30	23	28
1972	30	32	18	41
1977	25	31	22	41
1982	44	31	32	40
1987	58	30	42	38
1992	71	43	41	45

Source: Longitudinal Research Database, U.S. Bureau of the Census.

used in steaks and roasts while leaner cow meat is more often combined with steer trimmings to make ground beef. It may be useful to measure concentration on a narrower basis.

Table 3-2 provides a check on the Census Bureau data, with data collected by USDA's Grain Inspection, Packers and Stockyards Administration (GIPSA). That agency reports data for some precisely defined slaughter classes, such as steers and heifers, and for one precisely defined steer and heifer slaughter product—boxed fed beef. The GIPSA data are calculated on a quantity basis, the share of animals procured for slaughter by the largest firms (for boxed beef, the measure is the share of boxed beef output). The timing also differs from Census; GIPSA measures begin in 1980, but are produced in each year, and the most recent as of this writing was 1997. The GIPSA data are in some cases more direct measures than the Census concepts, and the two series provide checks on each other.

GIPSA and Census data tell the same story. Concentration in GIPSA cattle slaughter measures increased dramatically, more than doubling after 1980 (table 3-2). Concentration is especially high in steer and heifer slaughter, and shows the most dramatic increase there. And concentration in boxed beef production is equally dominated by the four largest steer and heifer slaughter firms (83 percent of output). GIPSA data, like Census, show the same recent increase in hog concentration, as well as a high level of concentration in sheep and lamb slaughter, with a sharp increase between 1982 and 1987 (we gathered no Census data on sheep and lamb slaughter).

Census and GIPSA concentration measures are similar for hog slaughter, but GIPSA cattle concentration falls consistently below the Census measures. GIPSA cattle concentration should be lower, partly because of Census double-counting, but also because the four largest firms receive higher prices for their meat products than other firms do and therefore hold higher shares of (value of) shipments than of animals. Smaller firms are more likely to slaughter lower valued cows, and less likely to slaughter higher valued steers and heifers; higher animal prices lead to higher meat prices. Moreover, large plants also do more in-plant fabrication, breaking carcasses down into boxed beef and fetching higher product prices.

Consolidation Into Large Plants

Concentration could increase because of mergers among many independent firms, or because plants become larger. Over the last 25 years, large plants have become vastly more important in slaughter industries, as evidenced by two different measurement bases.

GIPSA data sort cattle slaughter plants by size; the largest slaughter more than half a million cattle in a year, while large hog plants slaughter more than a mil-

Table 3-2—Four-firm concentration ratios, animal input basis, in slaughter classes

Year	Slaughter class: Cattle: Cows/bulls	Steers/heifers	All	Boxed fed beef	Hogs	Sheep and lambs
	Ratio					
1980	10	36	28	53	34	56
1982	9	41	32	59	36	44
1987	20	67	54	80	37	75
1992	22	78	64	81	44	78
1997	31	80	70	83	54	62

Source: U.S. Department of Agriculture (1999).

Table 3-3—Percent of animals slaughtered in large plants

Report year	Slaughter classes, and size cutoff[1]					
	All cattle	Steers/heifers		Cows/bulls	Hogs	Sheep/lambs
	(>500,000)	(>500,000)	(> 1 million)	(>150,000)	(>1 million)	(>300,000)
	Percent					
1977	12	16	nr	10	38	42
1982	28	36	nr	15	59	73
1987	51	63	31	20	72	84
1992	61	76	34	38	86	74
1997	65	80	63	57	88	71

[1] The size cutoff, in parentheses, refers to the number of animals slaughtered annually.
nr = not reported.
Source: U.S. Department of Agriculture (1999).

lion. Notions of "large" can change over time; the agency did not separately report cattle plants that slaughtered more than a million animals until 1987; by 1997, 14 plants were in that newly established category.

The emergence of large plants is quite striking. In 1977, 84 percent of all steer and heifer slaughter occurred in plants that slaughtered less than half a million a year. By 1997, plants in that category saw their share drop to 20 percent, while 63 percent of slaughter occurred in plants that slaughtered more than a million steers and heifers (table 3-3). In hog slaughter, large plants handled 38 percent of all slaughter in 1977, but 88 percent by 1997.

Census data report on the value of shipments by employment size of firm. We use that basis here, to maintain some comparability to other Census industries. We define large plants as those with at least 400 employees, in order to meet Census confidentiality rules.

Table 3-4—Share of industry value of shipments in large plants (> 400 employees)

Census year	Slaughter industry			
	Cattle	Hogs	Chickens	Turkeys
	Percent			
1963	31	66	d	d
1967	29	63	29	16
1972	32	62	34	15
1977	37	67	45	29
1982	51	67	65	35
1987	58	72	76	64
1992	72	86	88	83

d = cannot be disclosed, due to confidentiality concerns.
Source: Longitudinal Research Datafile, U.S. Bureau of the Census.

Census measures are not directly comparable with the GIPSA series, but they show the same trend. Large-plant shares in all four categories (cattle, hogs, chickens, and turkeys) increased dramatically during 1963-92 (table 3-4). GIPSA data generally show a much sharper increase than Census data. Since the GIPSA data are based on the number of animals, while Census data use an employment cutoff, the contrast suggests a substantial increase in labor productivity at large plants. Each source shows sharply increased concentration in cattle slaughter, and a more recent concentration in hogs.

Conclusion

The evidence shows a dramatic consolidation of slaughter in large plants in all four animal classes. That pattern suggests that scale economies may be important in slaughter industries, and that something happened to make scale economies more important in recent years. Later in this report, we explore those issues with statistical cost models. We estimate the extent of scale economies in slaughter, and identify a growing importance of scale economies.

A second interesting pattern stands out. Dramatic consolidation among large plants in four slaughter industries led to dramatic concentration increases in just one—cattle slaughter. Changes in concentration have been far more modest in hog, chicken, and turkey slaughter. Demand growth has likely played a role here. As chapter 2 shows, per capita poultry consumption has grown sharply in the United States over the last two decades, while per capita pork consumption has grown modestly and beef consumption has been flat. When combined with modest export and population growth, the cattle slaughter industry has faced very slow to declining demand growth. When set against shifts to large plants, the results should be increased concentration.

Appendix 3A: Sources of Establishment Data for Livestock Slaughter

Three Federal agencies—USDA's Grain Inspection, Packers and Stockyards Administration (GIPSA) and Food Safety and Inspection Service (FSIS), and the Bureau of the Census (U.S. Department of Commerce)—report data on animal slaughter. Each has different goals, which lead to different methods of data collection. In general, the three agencies report data from the same set of large and medium-sized plants, but differ substantially in their coverage of very small plants.

GIPSA is a regulatory agency whose mission is to guard against anticompetitive, deceptive, and fraudulent practices in the pricing and movement of livestock and meat products. FSIS is also a regulatory agency, whose primary activity is inspection of meat and poultry sold in interstate commerce, primarily to ensure animal and human health. The Census Bureau, as part of its census of manufactures, aims to measure the economic characteristics—such as sales, costs, and employment—of meat and poultry industries. Different agency missions lead to different reporting requirements.

GIPSA data are based on reports from slaughtering meatpackers operating in commerce in the United States. Small packers (who purchase $500,000 or less of livestock annually) are exempt from GIPSA reporting requirements. We can assume that plants that slaughter fewer than 10 steers or 90 hogs a week (roughly) are omitted from GIPSA reports, as are plants that do not purchase livestock for slaughter but instead perform custom slaughter services for livestock owners. For reporting plants, GIPSA obtains data on livestock volumes by plant, species, and location of seller.

All plants that slaughter or process meat to be sold in interstate commerce are subject to Federal safety inspection. FSIS reports therefore cover a wide range of plant sizes, but do not cover plants that sell only within States, exempting many very small plants but still capturing more small plants than GIPSA. In support of its regulatory responsibilities, FSIS obtains useful summary data on livestock volumes by plant and species.

The census of manufactures reports data from all plants whose primary business is manufacturing. As a result, facilities that do some animal slaughter, but that are primarily in retailing or wholesaling or other nonmanufacturing activities, are not reported in the census of manufactures. Of those whose primary business is manufacturing, the Bureau assigns all plants that do any red meat slaughter to SIC code 2011, meatpacking, even if they are primarily active in meat processing. Plants that only process meat, conducting no slaughter on premises, are assigned to SIC code 2013, meat processing. The Bureau has an additional small business exemption for some data: plants with fewer than 20 employees are not required to make detailed reports. The Census Bureau counts those plants, but does not obtain detailed information on slaughter volume from them. Thus, Census procedures likely count more small plants than GIPSA, but exempt more volume.

How do the three sources compare? In general, aggregated numbers are quite similar, because the three sources cover a common set of large plants. For example, appendix table 3-1 compares total slaughter volumes for 1992. USDA's National Agricultural Statistics Service (NASS) estimates the total commercial slaughter of cattle and hogs. Federally inspected slaughter totals (FSIS) account for 97.6 percent of total commercial cattle and hog slaughter—the difference presumably slaughter in State-inspected plants. GIPSA totals sum to 94.9 percent of total commercial cattle slaughter, and 96.5 percent of total commercial hog slaughter, with the differences reflecting slaughter by exempt entities—very small plants. Finally, Census totals, which exempt establishments primarily outside of manufacturing and exempt very small plants from detailed reporting of species volume, capture 94.5 percent of commercial cattle slaughter and 91 percent of hog slaughter.

The three series can disagree widely on plant counts, because very small plants make up substantial shares of any plant count. For example, all three agencies report substantial declines in plant numbers between 1977 and 1992 (appendix table 3-2): Census red meat slaughter plants declined by 46.4 percent, GIPSA by

Appendix table 3-1—Slaughter volumes, by reporting system (1992)

Plant category	Cattle		Hogs	
	Number	Percent of commercial	Number	Percent of commercial
All commercial plants	32,874	100.0	94,889	100.0
Federally inspected	32,094	97.6	92,611	97.6
Reporting to GIPSA	31,200	94.9	91,550	96.5
Census, SIC 2011	31,068	94.5	86,308	91.0

Sources: U.S. Department of Agriculture (1997), and Longitudinal Research Database, U.S. Bureau of the Census.

43.1 percent, and FSIS by 33.1 percent. But the absolute levels differ sharply. The Census reports over twice as many plants as GIPSA does, and is mostly higher than FSIS counts. This is because the Census approach counts more small plants than GIPSA does while its exempt plants (those outside of manufacturing that may do some slaughter) may overlap with the plants that FSIS does not count (those that slaughter but do not sell in interstate commerce).

Comparisons are more difficult at the species level. GIPSA and FSIS count plants as cattle slaughter facilities if they slaughter any cattle, even if they primarily slaughter other species such as hogs. They then report the same facilities as hog slaughter plants if they slaughter any hogs. Census counts exempt very small plants from reporting livestock volumes, so they are not captured in counts of cattle or hog slaughter plants. Furthermore, for purposes of counting plants, we count a plant as a cattle (hog) slaughter plant only if its primary activity is cattle (hog) slaughter. That is, we count Census plants only once, while GIPSA and FSIS plants may be counted several times when summing slaughterers of particular species.

Appendix table 3-2—Livestock slaughter establishments, by reporting system, 1977-96

Year	Reporting system		
	GIPSA	Federally inspected	Census, SIC 2011
		Number	
1977	1,000	1,682	2,590
1982	884	1,688	1,780
1987	722	1,483	1,434
1992	569	1,125	1,387
1996	418	988	nr

Sources: U.S. Department of Agriculture (1997), and Longitudinal Research Database, U.S. Bureau of the Census.

Thus, Census reports the fewest plants (appendix table 3-3) because it does not count very small plants and because we assign a plant to one species only. GIPSA counts are higher because that agency assigns plants to more than one category and because it probably counts more very small plants. Finally, FSIS reports on more very small plants, for these purposes, than either of the other agencies, and also assigns plants to more than one species category. Still, the three sources all show large declines in the number of slaughter plants over time.

The empirical analyses in this report are primarily based on data reported by the Census Bureau establishments in appendix table 3-3 (exceptions are some aggregated data from GIPSA records). We hence omit many very small establishments. However, those establishments account for very small shares of industry production.

Appendix table 3-3—Slaughter plants, by species and by reporting system

Year	Cattle			Hogs		
	Census	GIPSA	FSIS	Census	GIPSA	FSIS
			Number			
1963	1,817	nr	nr	1,410	nr	nr
1967	1,031	nr	nr	797	nr	nr
1972	782	920	nr	575	594	nr
1977	598	814	1,568	404	469	1,231
1982	391	632	1,506	325	466	1,344
1987	265	474	1,317	214	352	1,182
1992	215	342	971	182	300	921
1996	nr	274	812	nr	232	770

nr = not reported
Census refers to Census of Manufactures (“cattle” covers plants primarily producing in SIC 20111, while “hogs” covers plants primarily producing in SIC 20114).
Sources: U.S. Department of Agriculture (1997), and Longitudinal Research Database, U.S. Bureau of the Census.

Chapter 4

Structural Change

Location and Plant Operations

Industry consolidation involves more than changes in concentration and plant sizes. Other dramatic changes affect product and input mix, industry location, and the organization and compensation of workforces at slaughter plants.

Today's largest cattle slaughter plants operate in a limited geographic area: Nebraska, Kansas, eastern Colorado, and the Texas Panhandle. These plants typically slaughter 4,000 to 5,000 cattle a day, and also fabricate carcasses into smaller cuts, which are then distributed directly to wholesalers and retailers.

In the past, large hog plants also processed carcasses into hams, bacon, other cured products, and sausages. Today, they are more likely to simply slaughter hogs and cut up the carcasses, selling the meat to processing plants. Hog slaughter is not as geographically concentrated as cattle. New plants are tied to large hog feeding operations, and as those have spread through several rural areas of the country, so have slaughter plants.

Product Mix

Twenty-five years ago, most cattle slaughter plants were "carcass" plants, selling whole or half carcasses to other meat processors or to retailers who then separated the carcasses into retail cuts of meat. Then as now, the whole animal was used. The plants shipped hides, blood, bonemeal, internal organs, and trimmings. These byproducts, separated from carcasses during slaughter, were used to make clothing, pharmaceuticals, sporting goods, animal feeds, and food products. But since the 1970's, slaughter plants have also moved into the further fabrication of carcasses, cutting them up into "boxed beef" and ground beef products.

In boxed beef production, carcasses are chilled at the slaughter plant for a day after slaughter, then moved onto a "fabrication" line where they are cut into wholesale and retail cuts of meat, vacuum-wrapped, packed in boxes, and shipped. Increasing volumes are exported, usually to Asia. Boxed beef bound for Asian markets is usually shipped by truck or rail from the plants to West Coast ports for shipment.

Fabricated beef products (cut-up carcasses) accounted for only 9.3 percent of the value of shipments from beef slaughter plants in 1963, but represented over 56 percent of all shipments by 1992 (table 4-1). Large plants particularly drove this trend: boxed beef accounted for over 70 percent of large plant shipments in 1992, but less then a fifth of shipments from other plants. As a result, boxed beef production is noticeably more concentrated than cattle slaughter as a whole.

Twenty-five years ago, hog plants were far more complex operations than cattle plants. They slaughtered hogs, cut up the carcasses, and then processed the pork into bacon, hams, sausages, and other products. More recently, processing has shifted to specialist plants, and slaughter plants, like cattle, specialize mainly in slaughter and carcass cutting. Cut-up carcasses (the equivalent of fabrication at cattle plants) account for a growing share of hog slaughter plant shipments, more than half in 1992 (table 4-2). As with cattle, fabrication is far more prevalent, and increasingly so, at large slaughter plants.

Table 4-1—Growing importance of boxed beef production at cattle slaughter plants

Year	Boxed beef shipments as a share of total shipments: Industry average	Large plants[1]	Other plants
	Percent		
1963	9.3	8.1	9.8
1972	15.5	22.7	12.1
1982	39.5	51.9	26.6
1992	56.2	71.6	17.2

[1] More than 400 employees.
Source: Longitudinal Establishment Datafile, U.S. Census Bureau.

Many traditional brand-name processors no longer slaughter hogs, but instead purchase cut-up carcasses for processing into bacon, hams, and other branded products. In 1982, these specialist (nonslaughter) plants accounted for 43 percent of bacon, ham, and other cured pork shipments (that is, plants that didn't slaughter had 42.8 percent of shipments). By 1992, these plants handled almost two-thirds of the cured business (table 4-3), and even more of sausage products.

Meat processors, wholesalers, and retailers purchase boxed beef and cut-up pork because slaughter plants can fabricate carcasses at lower costs per pound. Fabrication also saves on transport costs compared with shipping whole or half carcasses. Processors, wholesalers, and retailers would often use only part of a carcass, shipping remaining parts out to other processors and to rendering plants. Slaughterhouses can more efficiently direct the parts of the carcass to the highest value users.

Table 4-2—Growing importance of cut-up carcass production at hog slaughter plants

Year	Cut-up carcass shipments as a share of total shipments		
	Industry average	Large plants[1]	Other plants
	Percent		
1963	27.5	30.9	20.8
1972	33.2	34.9	30.4
1982	34.9	36.7	31.2
1992	52.4	57.0	24.1

[1] More than 400 employees.
Source: Longitudinal Establishment Datafile, U.S. Census Bureau.

Table 4-3—Share of processed pork products by specialist plants

Year	Share of processed pork shipments from nonslaughter plants	
	Bacon, ham, and other cured pork[1]	Sausage and similar products
	Percent	
1982	42.8	55.9
1987	51.5	70.5
1992	63.1	77.0

[1] The "Bacon..." column reports the share of shipments in SIC codes 20116 (slaughter plants) and 20136 (nonslaughter) that are produced in 20136 plants. The "Sausage..." column reports 20137 shipments (nonslaughter) as a percentage of the sum of 20117 (slaughter plants) and 20137.
Source: 1992 Census of Manufactures, Industry Series, Meat Products. U.S. Census Bureau.

Input Mix

In the 1960's, many large slaughterhouses handled multiple species—for example, many slaughtered cattle and hogs. Some, particularly those with cattle and hog slaughter capabilities, also operated processing lines, producing bacon, hams, and sausage products. Those plants have largely disappeared in favor of specialized operations. In 1963, species other than cattle accounted for almost half of animal inputs at large cattle plants (more than 400 employees)—effectively, most were multi-species plants. Hog and chicken slaughter plants also had significant shares of other species (table 4-4). By 1992, large plants specialized in single species. Now, plants even specialize within species; the largest cattle plants slaughter only steers and heifers, while cows and bulls are slaughtered in separate plants.

Plant Location

Consolidation intensified geographic concentration in cattle slaughter, although not in hogs. For each Census year, tables 4-5 (cattle) and 4-6 (hogs) show regional shares of the value of shipments from slaughter plants (we use slightly different regional definitions in each table).

Cattle slaughter shifted strongly to the Great Plains from the rest of the country, mostly from the Corn

Table 4-4—Share of animal input costs by primary species at large slaughter plants[1]

Year	Cattle	Hogs	Chickens
	Percent of primary species in animal input costs		
1963	52.5	84.5	d
1967	60.2	79.0	83.0
1972	67.6	90.9	96.5
1977	81.3	94.3	95.7
1982	92.1	93.4	99.6
1987	99.2	97.4	99.9
1992	100.0	98.9	99.0

[1] More than 400 employees.
d = cannot be disclosed in order to preserve respondent confidentiality.
Source: Longitudinal Establishment Datafile, U.S. Bureau of the Census.

Belt, which had accounted for the largest regional share of cattle slaughter in the 1960's (table 4-5). Shifts in slaughter location mirror the geographic shifts in cattle feeding described in chapter 2. In the 1960's and early 1970's, many cattle feedlots were located in the Corn Belt and West Coast as well as in the Great Plains. Since then, commercial cattle feeding has consolidated into fewer but larger operations, primarily in the Great Plains.

Hog slaughter remains concentrated in the Corn Belt, though shifting west within that region (table 4-6). Southeastern slaughter grew erratically from 1963 to 1992, while production in the Northeast and the rest of the country fell sharply.[12] Hog slaughter is also closely tied to the location of hog production, which is in a state of flux. The Corn Belt is the traditional site for hog production, on farms that typically combined crop production (corn, soybeans) with hog operations. Large hog slaughterhouses could locate in the Corn Belt, among a dense network of farms, and ensure themselves of steady supplies of hogs through cash purchases throughout the region. As noted in chapter 2, most hogs are now produced in large hog operations—those marketing more than 5,000 head/year accounted for nearly two-thirds of all 1997 marketings. Large hog operations are increasingly located in many different States.

[12] Southeastern slaughter has continued to grow rapidly since 1992.

Table 4-5—Shares of cattle slaughter output, by region and year[1]

Year	Corn Belt	Great Plains	West	Rest of U.S.
	Percent			
1963	41.7	27.1	16.2	11.5
1967	39.0	32.5	16.3	9.8
1972	30.9	45.4	14.1	8.1
1977	31.4	44.8	14.3	7.1
1982	24.3	59.1	10.5	4.2
1987	20.9	62.6	11.0	3.1
1992	17.1	68.1	10.4	1.9

[1] Great Plains includes TX, OK, KS, CO, NE, ND, and SD. Corn Belt States are MN, IA, MO, IL, WI, MI, IN, and OH. The West includes all States west of the Great Plains.
Source: Longitudinal Establishment Datafile, U.S. Census Bureau.

Wages and Labor Force Characteristics

Industry consolidation has been accompanied by important changes in labor relations in meatpacking. In 1980, 46 percent of workers in the meat products industry were union members, a figure that had remained stable through the 1970's.[13] Most unionized slaughter plant workers belonged to the United Food and Commercial Workers (UFCW) union, whose base wage rate was $10.69 an hour in 1982. In that year, many unionized firms began to press for large reductions in base wages,

[13] Unionization data come from questions asked in 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).

Table 4-6—Shares of hog slaughter output, by region and year[1]

Year	Eastern Corn Belt	Western Corn Belt	Southeast	Northeast	Rest of U.S.
			Percent		
1963	24.6	39.2	12.6	9.4	14.1
1967	21.4	41.4	14.3	8.0	14.9
1972	25.8	38.9	15.7	6.6	12.9
1977	26.1	39.5	16.8	4.8	12.8
1982	23.6	42.1	17.9	3.9	12.5
1987	20.4	49.6	19.6	2.0	8.5
1992	19.5	55.9	14.8	2.5	7.3

[1] Eastern Corn Belt is IL, IN, MI, OH, and WI, while Western Corn Belt is IA, KS, MN, MO, ND, NE, and SD. Southeast is FL, GA, KY, NC, SC, TN, and VA; Northeast is CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, and VT. Rest of U.S. therefore is AL, MS, LA, as well as the West and Southwest.
Source: Longitudinal Establishment Datafile, U.S. Census Bureau.

to $8.25 an hour, consistent with what was being offered in non-union plants. The union at first acceded to wage cuts, but by 1984 adopted a strategy to vigorously contest them, in the view that large wage cuts at older unionized plants only postponed plant closings. Between 1983 and 1986, there were 158 work stoppages in cattle and hog slaughter plants, involving 40,000 workers. There were lengthy strikes, plant closings, and deunionizations at some ongoing and reopened plants.[14] By 1987, union membership had fallen to 21 percent of the workforce, and has remained at that lower level through the most recent data (1997); wage reductions were imposed in most plants, and wages have risen only modestly since then.

Declining unionization coincided with changes in slaughter plant demographics. Immigrants, primarily from Southeast Asia, Mexico, and Central America, make up large and growing shares of the workforces at both hog and cattle slaughter plants. This has led to striking transformations in the rural communities that must provide schooling and social services to the workers and their families (U.S. General Accounting Office, 1998).

Most plant workers today perform routinized tasks in either the slaughter or the fabrication department. Meatpacking work is hard and often hazardous; the use of knives, hooks, and saws in noisy surroundings on slippery surfaces presents the risk of cuts, lacerations, and slips. The nature of the work also creates the risk of repetitive stress injuries, and the plant environment can lead to pathogen-related illnesses. As a result, meatpacking has had the highest rate of occupational illnesses and injuries of all U.S. industries. During the late 1980's, on-the-job injury and illness rates in meatpacking rose sharply to a peak in 1991 of 45.5 for every 100 workers. Since then, worker safety statistics have improved, and the most recent Bureau of Labor Statistics data report that 30 out of every 100 employees were injured or sickened on the job in 1996.[15]

Perhaps because of the job hazards and workforce demographics, labor turnover in meatpacking is quite high, and in some establishments can reach 100 percent in a year as workers move to other employers or return to their native countries. The frequent movement of immigrant workers among plants and communities limits union opportunities to organize, but also reflects immigration problems—district officials of the Immigration and Naturalization Service estimate that as many as 25 percent of the workers at meatpacking plants in Iowa and Nebraska were illegal aliens (U.S. General Accounting Office, 1998).

Declines in unionization and increases in the use of immigrant workers coincided with sharp declines in real wages (table 4-7). In 1977, mean wages rose steadily with plant size in cattle and hog slaughter plants (SIC 2011), a pattern typical for manufacturing (Brown, Hamilton, and Medoff, 1990). The largest (1,000 or more employees) plants' average hourly wages were 23 percent above the industry average, 30 to 45 percent above wages at small (less than 500 employees) plants, and more than double the wages of workers in poultry slaughter plants. Five years later, plants with 1,000 or more workers paid average wages of $10 an hour, still 10 percent above the industry average, 20 to 40 percent above small plant wages, and almost twice the average wage in poultry plants. But by 1992, wages in large cattle and hog plants had fallen sharply in nominal terms and dramatically in real terms.[16] Moreover, the plant size differential had disappeared; the largest plants paid wages no different from those offered in any of the plants with 100 or more employees, and wages were only 17 percent higher than those earned in poultry slaughter plants.

[14] This summary draws on several articles appearing in the *Monthly Labor Review*, a publication of the Bureau of Labor Statistics of the U.S. Department of Labor.

[15] The injury data refer to SIC 2011, all red meat slaughter plants.

[16] The Consumer Price Index (CPI) increased by 131 percent between 1972 and 1982, and by another 45 percent between 1982 and 1992. In 1992 dollars, large plant wages would have been $17.89 an hour in 1972, and the real 1972-1992 decline would amount to over 50 percent, with most of that concentrated in 1982-92. The CPI is widely considered to overstate inflation; if that's true, then our adjustment overstates the size of the real wage decline, although it does not affect comparisons across plants or slaughter classes within a year. If we accept the Boskin Commission's estimate of CPI overstatement—1.1 percent per year—then the 20-year decline in real wages at the largest cattle and hog plants would have been 40 percent.

Table 4-7—Average hourly wages in meatpacking, by year, industry, and plant size

Industry and plant size (no. workers)	1967	1972	1977	1982	1987	1992
			Dollars per hour[1]			
SIC 2011 (Red meat):						
0-19	2.50	3.74	6.26	5.35	6.06	7.17
20-99	2.70	3.71	5.69	6.88	7.79	8.23
100-249	2.90	4.01	5.96	8.23	7.77	8.77
250-499	3.29	4.36	6.33	9.43	8.40	8.46
500-999	3.45	4.82	7.06	10.13	8.90	8.76
1,000 or more	4.04	5.33	8.44	10.00	8.50	8.65
Industry average	3.36	4.51	6.86	9.06	8.27	8.56
SIC 2015 (Poultry):						
0-19	1.92	2.50	3.37	5.00	5.78	6.81
20-99	1.81	2.78	3.38	5.10	5.77	8.10
100-249	1.76	2.42	3.52	5.23	6.33	7.16
250-499	1.72	2.40	3.43	4.98	5.96	7.33
500-999	1.79	2.35	3.48	5.14	6.17	7.39
1,000 or more	n.a.	n.a.	3.74	4.91	6.30	7.38
Industry average	1.76	2.40	3.48	5.06	6.16	7.37

[1] Wages are production worker payroll divided by production worker hours.
n.a. = not available.
Source: Census of Manufactures, *Industry Series*, for relevant years.

Chapter 5

Analyzing Packer Costs

The Model

Dramatically increased concentration in cattle slaughter (and increased concentration in hog slaughter) has coincided with the ascendance of large plants in each industry. This suggests that new scale economies may have emerged and driven the increase in concentration. For scale economies to drive consolidation, they must adhere through a range of plant sizes, and not simply appear among very small plants. Moreover, for scale economies to drive increases in concentration, technological change should be scale-increasing—the largest plants should have cost advantages in the 1990's that are larger than those observed in the 1960's and 1970's.

Increased concentration in cattle and hog slaughter occurred along with other developments. Cattle plants moved toward fabrication of carcasses into boxed beef, while hog plants moved from extensive further processing (into hams, sausages, and the like) toward slaughter and simple fabrication. Since fabrication raises plant costs and alters input demands, cost analyses need to take account of product mix. More important, as larger plants often do more fabrication, any analysis of scale economies needs to take account of product mix.

Finally, real wages fell from 1977 to 1992, while wage premiums paid by large plants disappeared. We aim to estimate the effects of wage changes on costs, and so need to separately identify the effects of changes in scale economies and relative wages on large plant costs.

We need a statistical cost model that will allow us to estimate the extent of scale economies over a wide range of plant sizes, and that allows us to identify scale-increasing technological change. The model should identify the effects of factor price changes on costs, and should allow the effects of scale, factor prices, and product mix to change through time.

A Functional Form for Cost Estimation

For our purposes, we need to estimate a statistical cost function that:

(1) estimates the effect of plant scale on costs, and allows the effect to vary with plant size;

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

(3) identifies the effects of input prices on cost, allowing those effects to vary with plant size; and

(4) allows the above effects to vary over time as a way to capture technological change.

We chose a functional form that is widely used in empirical analyses of costs—the translog cost function. The translog is defined as follows:

$$\begin{aligned} \ln\ C = {} & a_0 + \sum b_i \ln P_i + (1/2)\sum\sum b_{ij} \ln P_i \ln P_j \\ & + g_1 \ln Q + (1/2) g_2 (\ln Q)^2 + \sum g_{li} \ln Q \ln P_i \\ & + \sum d_k \ln Z_k + (1/2)\sum\sum d_{kl} \ln Z_k \ln Z_l \\ & + \sum\sum d_{ik} \ln P_i \ln Z_k + \sum d_{lk} \ln Q \ln Z_k \\ & + \sum a_n T_n + \sum\sum a_{in} \ln P_i T_n + \sum a_{\ln} \ln Q T_n + \sum\sum a_{kn} \ln Z_k T_n \end{aligned} \tag{5-1}$$

where C is total cost, the P_i are factor prices (in this case, labor, animal and meat materials, other materials, and capital), Q is output, Z represents other plant characteristics, and T is a set of dummy variables for each census year (with 1992 as the base). All continuous variables are transformed to natural logarithms.

We observe slaughter plants operating in 1963, 1967, 1972, 1977, 1982, 1987, and 1992. The model allows for technological change 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). In the final form of the cost function, we used 4 factor prices, 3 Z variables, and 1 output variable, so that allowing for time-varying parameters added 48 new parameters to the model.

The translog is a flexible functional form that allows for many possible production relationships, including varying returns to scale, nonhomothetic production (that is, optimal input ratios that vary with the level of output), and nonconstant elasticities of input demand. One can estimate the cost function directly, but parameter estimates are often inefficient because of multicollinearity among the variables on the right-hand side. Gains in efficiency can be realized by estimating the optimal, cost-minimizing input demand, or cost-share equations jointly with the cost function. The equations are derived directly from the cost function as the derivatives of total cost with respect to each input price, and share parameters with the cost function:

$$(\partial \ln C)/(\partial \ln P_i) = (P_i X_i)/C = b_i + \sum b_{ij} \ln P_j + g_{li} \ln Q + \sum d_{ik} \ln Z_k + \sum a_{in}.T_n \qquad (5\text{-}2)$$

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 input i at mean values of the right-hand variables; the other coefficients capture changes in the estimated factor share over time, and as factor prices, output, and plant characteristics move away from their mean values.

Some restrictions can be imposed on the estimating equations in order to gain further improvements in efficiency (Berndt, 1991). For the cost function to be homogeneous of degree one in prices, the following restrictions must hold:

$$\sum b_i = 0, \quad \sum b_{ij} = \sum g_{li} = \sum d_{ik} = \sum a_{in} = 0 \qquad (5\text{-}3)$$

The restrictions reduce the number of parameters that must be estimated, since they imply that some parameters can be derived from combinations of others. Similarly, symmetry is also imposed on the model; under symmetry, the coefficients on all interaction terms with identical components are equal (that is, the coefficients $\beta_{ij} = \beta_{ji}$, and $\delta_{kl} = \delta_{lk}$, for all i,j and all k,l).

We estimate the longrun cost function jointly in a multivariate regression system with the four share equations. Since factor shares sum to one, we dropped the capital share equation to avoid a singular covariance matrix. Each equation could be estimated separately by ordinary least squares, but in order to take account of likely cross-equation correlation in the error terms, we follow standard practice by using a nonlinear iterative seemingly unrelated regression procedure.

Measuring Output

Modern slaughter plants produce many products. Our Census data for cattle slaughter plants define several product categories, including carcasses, hides, boxed beef, ground beef, and byproducts. Each category is itself an aggregate—carcasses may be whole or in halves or quarters, and boxed beef may come in a variety of different cuts.

Multiple outputs create challenges for cost analysis. Suppose two plants slaughter the same number of cattle, but one operates a fabrication line while the other produces only carcasses. They will produce the same physical quantity of output, and so a single product cost function will give them the same output level. But the fabrication plant will hire more workers, carry a larger investment in structures and equipment, and use more energy and materials than the carcass-only plant; it will have higher costs because it will be performing more processing of the carcass. The failure to account for product mix will, in this case, leave some variation in costs unaccounted for. But suppose that the plant that fabricates is also larger, in that it handles more cattle—typical for the modern slaughter industry. Then we may observe higher costs per steer at the larger plant—that is, apparent diseconomies of scale, driven by a failure to account for the different mix of products at the larger plant.

To include multiple products in the cost function, we could simply convert Q in the cost function to a vector, with pounds of each output represented separately in the vector.[17] But since many plants in the data set produce zero amounts of some outputs, and logs are

[17] See Morrison (1998) for an approach along these lines. Her data included more precisely defined outputs for a more limited set of plants, as well as a different functional form for cost estimation, and so was better suited to that method.

undefined at zero, the translog functional form cannot directly be adapted to the multiproduct approach.

Instead, we followed an approach that is commonly used in the extensive literature on the estimation of cost functions for transportation firms (railroads, trucking, airlines, shipping). In that literature, analysts often have simple measures of output, defined in terms of ton-miles (for freight) and passenger-miles (examples include Allen and Liu, 1995, for trucking; Baltagi, Griffin, and Rich, 1995, for airlines; Caves, et al., 1985, for railroads). But the simple measure can be produced in a variety of ways; for example, cost incurred in producing the same simple output can vary if the transport network routes to many different locations (as opposed to a operating a few through-routes) or if the output is produced in many small deliveries (as opposed to a smaller number of large shipments). Transport cost functions often include measures of route and output characteristics in the cost function, in order to capture the effect of network characteristics on costs.

We define a single output, pounds of meat produced, but we then add output characteristics to the equation (this is where the Z vector comes from). Our final equation includes a measure of product mix. For cattle, this is defined as one minus the share of carcass shipments in the value of a plant's output. The measure is always defined in the translog, because carcass shipments are never 100 percent of output (byproducts are always positive). Hide and byproduct shipments are nearly constant shares of total output, because they are produced in close to fixed proportions to the number of cattle slaughtered. As a result, the measure varies primarily in proportion to the share of boxed beef in a plant's output; increases in boxed beef mean declines in the share of carcass output. As the cattle product mix variable increases, we ought to see increases in total cost.

Our measure of product mix for hogs was one minus the share of processed products (sausage, hams, etc.) in output. This measure will again always be defined in the translog, as processed product never takes up all of output. This is an inverse measure of processing, and costs should fall as the measure increases.

Each of these choices represents the best fitting option, after some experimentation. We tried several different measures of product characteristics (such as one minus boxed beef). We also tried a multiple-product cost function, with separate entries for pounds of carcass and pounds of boxed beef (setting zero values to low but positive values). But that form did not provide as strong a fit as our preferred alternative, and we preferred not to insert 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.

Our final estimating equation includes two other variables in the Z vector, a measure of input mix and a dummy variable for single-plant firms. The measure of input mix is the share of live animals (primarily cattle and hogs) in combined live animal and purchased meat input costs. Some slaughter plants purchase carcasses and other meats from other slaughter plants to supplement their own slaughtered carcasses as inputs to fabrication lines. Plants with significant amounts of purchased meat may have different cost structures than plants that purchase no meats, because those plants will do proportionately more fabrication and less slaughter.

Measures of Scale and Scope Economies

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

$$\begin{aligned} \in_{CQ} &= (\partial \ln C)/(\partial \ln Q) = g_1 + g_2 \ln Q \\ &+ \sum g_{li} \ln P_i + \sum d_{lk} \ln Z_k + \sum a_{\ln} T_n \end{aligned} \quad (5\text{-}4)$$

Values of the cost elasticity, $\in_{CQ}$, that are less than 1 indicate economies of scale. For example, a value of 0.90 indicates that costs increase by 0.9 percent for every 1.0-percent increase in output (in turn, average costs fall as output increases). Values in excess of 1 show diseconomies of scale. Because the variables are all divided by their sample mean values before estimation, the first-order term, γ_1, can be interpreted directly as the 1992 estimate of scale economies for plants at the sample mean size.

Equation 5-4 shows the value of a flexible functional form for our purposes, because it allows the estimated cost elasticity to vary with changes in output, factor prices, plant characteristics, and time. The parameters on the interaction terms between Q and years (the α_{1n}) show how the mean cost elasticity changes through time, while the parameter on the the ln Q term (γ_2) shows how the elasticity varies as we move away from the mean plant size to larger or smaller plant sizes. Finally, the other coefficients allow the estimated degree of scale economies to vary with factor prices and other plant characteristics.

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

$$\in_{CZp} = (\partial \ln C)/(\partial \ln Z_p) = d_p + \sum d_{kp} \ln Z_k + \sum d_{ip} \ln P_i + d_{ip} \ln Q + \sum a_{pn} T_n \quad (5\text{-}5)$$

The first-order term in the cost elasticity, δ_p, provides a direct measure of the effect of increases in boxed beef production on costs in 1992, given the physical volume of output, at sample means for all variables. The interaction terms on T (the time periods) show how that elasticity changes as one moves back in time, while the coefficients on the Z interaction terms show how the product mix elasticity varies as product mix, input mix, and ownership type vary. Finally, the coefficient on physical output, δ_{1p}, provides a direct estimate of scope economies. Positive values indicate that expanding product mix is more costly, per pound, in larger plants than in small, while negative values indicate that expanding product mix is less costly in larger plants than in smaller plants.

Measures of Input Substitution and Demand

The translog functional form can be used to derive measures of substitution elasticities among inputs, as well as measures of own-price and cross-price input demand elasticities. Some models assume a particular structure of input demand in slaughter industries; for example, "value-added" cost function models assume that there is no substitution between animals and other inputs in the production of meat. Our specification allows us to test that assumption.

How is it possible to substitute other factors for animals in the production of meat? Of course, at any one plant, purchased carcasses can be substituted for animals in the fabrication process. But even without purchasing carcasses, yields—the amount of meat produced from a carcass of a given size—do vary across animals, plants, and time, and some of that variation may be systematic, due to more intensive use of labor, machinery, and other materials. On the other hand, variation in yields does not necessarily imply that variations in input prices were driving variations in input substitution. That is an empirical issue, and translog parameter estimates allow us to test for the actual existence of substitution, and to estimate its extent.

Substitution among labor, capital, and materials is more likely, and the translog estimates will allow us to identify the extent of substitution among those inputs, and to estimate price elasticities of input demand. In turn, those estimates can be used as parameters in models that aim to simulate the response of the industry to changes in public policy or the industrial environment.

The Allen partial elasticities of input substitution for any inputs i and j, as derived from the translog function, are equal to:

$$s_{ij} = (g_{ij} + S_i S_j)/(S_i S_j), \quad (5\text{-}6)$$

while price elasticities of input demand can be written as:

$$\in_{ij} = (g_{ij} + S_i S_j)/S_i \quad (5\text{-}7)$$

and

$$\in_{ij} = (g_{ii} + S_i^2 - S_i)/S_i \quad (5\text{-}8)$$

where the S's are the factor shares of the ith and jth inputs, and γ_{ij} is the coefficient on the jth input price in the demand equation for the ith input (equation 5-2); it is also the coefficient on the interaction term between the ith and jth factor prices in the cost equation (5-1). The coefficient γ_{ii} is the coefficient on the ith input's price in the demand equation for that input, and is also the coefficient on the squared input price term in the cost function. Because, according to equation 5-2, predicted factor shares will vary with output, time, factor prices, and plant characteristics, estimates of equations 5-6 to 5-8 should use fitted shares at representative data values, and reported elasticities are also representative values, which can vary with the data.

Data and Variable Definitions

Table 5-1 provides definitions for the variables in the translog longrun cost functions estimated for cattle and for hogs. All data are derived from the LRD files of the 1963-92 Census of Manufactures. Explanatory variables include input prices (labor, animals and meat, other material, and capital) and plant output. To these standard explanatory variables, we add product mix, input mix, time shifts, and establishment type variables.

Labor, meat, and other material input prices are defined in a conventional fashion. Following Allen and Liu (1995), we define capital input costs as the opportunity cost of investing in plant and equipment. This definition of capital is imperfect because existing machinery and building costs are reported at book rather than real values. Additionally, capacity is a measure of full capacity, and it is unlikely that all establishments are producing at full capacity for all years.

Product mix (PMIX) in cattle slaughter is defined as one minus the share of carcasses in total physical output; if the weight of hides and other byproducts can be thought of as varying in fixed proportions with total plant slaughter, then this measure should vary largely with variations in boxed beef production. The product mix variable in hog slaughter is one minus the quantity share of processed products (such as hams and sausages). Increases in this measure reflect shifts to less complex processing, and should result in lowered costs.

Table 5-1—Cost function variable definitions

Independent variables	
PLAB	Price of labor = (total plant labor costs) / (total employees).
PMEAT	Price of meat inputs = (purchased animal costs + packed meat costs) / (pounds of live animal meat inputs + pounds of packed meat inputs).
PMAT	Price of other material inputs = (energy costs+packing and packaging cost + other material costs) / (pounds live animal meat inputs + pounds packed meat inputs).
PCAP	Price of capital = (OPPORTUNITY + NEW) / CAPACITY, where OPPORTUNITY = (machinery rental price) * (machinery book value) + (building rental price) * (building book value); NEW is the cost of new machinery and buildings; CAPACITY is buildings and machinery book value. Note, machinery rental price is the industry-level cost per dollar of machinery expenditure; building rental price is industry-level cost per dollar of building expenditure.
Q	Output of meat products, in thousands of pounds.
PMIX (cattle)	Product mix: (1 - CARCASS%), where CARCASS% = (pounds of carcass shipments) / (total pounds of meat shipments).
PMIX(hogs)	Product mix: (1 - SAUSAGE%), where SAUSAGE% = (pounds of sausage and ham products) / (total pounds of meat shipments).
IMIX (cattle)	Input mix: (1 - CATTLE%), where CATTLE% = (pounds of live cattle meat inputs) / (total pounds of meat inputs).
IMIX (hogs)	Input mix: (HOGS%), where HOGS% = (pounds of live hog meat inputs) / (total pounds of meat inputs).
ESTAB1	One for single-plant firms and zero otherwise. Shows shift for ownership type.
Dependent variables	
COST	Sum of labor, meat, materials, and capital input costs.
LABOR%	(Salary and wages + supplemental labor costs) / COST.
MEAT%	(Purchased animal costs + packed meat costs) / COST.
MAT%	(Energy costs + packing and packaging cost + other material costs) / COST.
CAPITAL%	(OPPORTUNITY + NEW) / COST. See PCAP above for definitions.

Input mix measures (IMIX) also vary between cattle and hog models. In cattle, the measure is one minus the quantity share (in pounds) of cattle in total animal and meat inputs; that measure will move closer to one as the plant purchases more carcasses from other plants, or as it slaughters other species in addition to cattle. In hogs, the measure is simply the quantity share of hogs in animal and meat inputs, and will move closer to one as the plant specializes more in hog slaughter and purchases fewer carcasses.

Comparison to Other Econometric Models of Slaughter Industries

Our model differs in important respects from four other extant estimations of slaughter cost functions for cattle and hogs. In chronological order, the four are Ball and Chambers (1982), whose model covered the meat products sector for 1954-76; Melton and Huffman (1995), who analyzed costs in cattle and hog slaughter (separately) over 1963-88; Kambhampaty et al. (1996), who estimated a shortrun variable cost function using weekly data for 16 large cattle slaughter plants in 1992; and Morrison (1998), who used the same data source as Kambhampaty et al., to estimate a shortrun variable cost function using monthly data for 42 plants in 1992.

Four features combine to distinguish our study and allow us to investigate some issues that other studies cannot: (1) disaggregated plant-level data covering a wide range of plant sizes; (2) annual observations on plants covering census years between 1963 and 1992; (3) physical measures of output and measures of product and input mix; and (4) a translog specification that allows for technological change by allowing parameter values to shift over census years.

Ball and Chambers (1982) and Melton and Huffman (1995) each use samples that consist of annual time series observations on industry aggregates—for Ball and Chambers, the aggregate is all red meat slaughter and processing. As Ball and Chambers point out, it is quite difficult to disentangle economies of scale from technological change in aggregated time series models. Indeed, each reports estimates of economies of scale that jump very sharply from year to year. Kambhampaty et al. (1996) and Morrison (1998) use data on a relatively small number of large plants, observed at frequent intervals within a year. That data set is better suited to the analysis of pricing and capacity utilization than to economies of scale and technological change.

We contend that changes in product and input mix have been an important feature of technological change in the industry. For example, differences in boxed beef output across plants or over time will affect costs, and omission of a product mix measure will strongly affect estimates of scale economies if product mix is associated with plant size (as chapter 3 strongly suggests). Of the studies mentioned above, only Morrison (1998) accounts for differences in product mix. Kambhampaty et al. rely on a single-product output measure (chilled carcass weight), although the plants in the study produce sharply varying product mixes.[18] The two earlier studies do not control for temporal changes in product mix; chapter 3 shows that such changes were substantial in the periods under study, and correlated with growth in plant sizes.

[18] They do provide separate estimates for plants that specialize in carcass production and those with fabrication capability, but this approach limits the size of their already small sample of plants, and ignores the large differences in fabrication output among fabrication plants.

Chapter 6

Cattle Slaughter Cost Estimation

We use the cost model to analyze costs at cattle slaughter plants. The data cover Census cattle slaughter plants reporting in the years 1963, 1967, 1972, 1977, 1982, 1987, and 1992, and include a total of 2,541 useable plant observations over the 7 census years.[19] 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

The translog is a general functional form that can be specified in different ways to capture many potential cost effects. Alternative specific forms can allow for changes in cost relationships through time, for different ways in which inputs may be combined, or for different ways in which input and output mix can affect costs. We were not certain of the best form prior to estimation. Model selection tests help to choose the best fitting model among specific functional forms.

Tables 6-1 and 6-2 summarize the set of specific models, and the results of the Gallant-Jorgenson (G-J) tests used to distinguish among them. We began with the most restrictive (I), a translog cost function with four factor prices (labor, capital, animal, and material inputs) and the physical volume of output, but with no measures for input or output mix and no time shifters. It is restrictive in the sense that it imposes the assumptions that input and output mix have no effect on costs and that coefficients do not change through time (no technological change).

Model II adds input and product mix measures but not time shifters; model I is decisively rejected in favor of model II (table 6-2)—input and product mix measures provide statistically significant improvements in fit. Model III adds time shifters to model II; each first-order coefficient is allowed to take on different values in different census years. Model III adds 42 new parameters to be estimated (6 new years times 7 variables); G-J tests again favor the less restrictive model (III) over model II.

Model IV adds a dummy variable for single-establishment firms, and yields a statistically significant (though small) improvement in fit over model III. Models IVa and IVb impose new restrictions on model IV. Model IVa drops variables involving input mix, but that model is rejected; input mix variables, while individually not significant, together provide a statistically significant improvement in fit. Finally, model IVb imposes homotheticity, by eliminating the interaction terms between factor prices and output volume (forcing factor shares to be invariant with respect to output). J-G tests reject homotheticity, and Model IVb, in favor of model IV. The best fitting model (IV) shows the importance of input and product mix, and technological change in determining cattle slaughter costs.

Summary of the Best Model

Because of the large number of estimated coefficients in model IV, we have organized them into two tables. Table 6-3 reports first-order coefficients for 1992 and changes in those coefficients in earlier years compared with 1992. Because all variables were standardized on their means before estimation, first-order coefficients can be read directly as estimated elasticities at the sample mean. Table 6-4 repeats the 1992 first-order coefficients and coefficients for the quadratic and interaction terms, showing how estimated elasticities vary as one moves away from sample means.

Consider factor price effects. First-order coefficients in table 6-3 can be interpreted as factor shares at sample mean data values. Animal and meat inputs (in this sample, almost all animal) account for over 83 percent of plant costs in 1992, while labor (PLAB) and other materials (PMAT—primarily packaging) are each less than 10 percent. The animal input share fell over time,

[19] As is common with analyses of Longitudinal Research Data (LRD) files, we deleted observations on very small plants that did not report all data, and some other observations with clear reporting errors.

Table 6-1—Cattle slaughter cost function models, by goodness of fit

Model	Description	G-J statistic	Parameters estimated
I	Translog, factor prices and output only	8324	15
II	Adds product and input mix to I	8252	28
III	Adds first order time shifts to II	7827	70
IV	Adds single-establishment dummy to III	7799	77
IVa	Drops input mix variables from IV	7855	58
IVb	Imposes homotheticity on IV	7820	74

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

Table 6-2—Tests of model selection, cattle slaughter cost function

	Test statistics[1]		
Comparison	d.f.	Critical value@ 99	Chi-square
II vs. I	13	27.69	72
III vs. II	42	66.18	425
IV vs. III	7	18.48	28
IV vs. IVA	19	36.19	56
IV vs. IVB	3	11.34	21

[1] Chi-square statistics are the difference in G-J statistics in models reported in table 6-1. 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.

from just over 86 percent in 1977, while capital's (PCAP) grew substantially from a small base. Labor and material shares showed hardly any change.

Because factor shares must sum to one, we left capital out of the estimating equation, and recovered its value as 1 minus the sum of the other three factors. Using that approach, capital's share (PCAP) is less than 1 percent in 1963 and over 3 percent in 1992.[20] Estimated capital shares are consistent with Melton and Huffman (1995), who find a mean 1963-88 capital share of 15.6 percent of beef value added, which would equate to a 2.65-percent share of total costs (assuming our mean estimate that cattle purchase costs were 83 percent of total costs).

Many interactions on factor prices (table 6-4) are highly significant, and the coefficients can be used to make inferences about substitution among inputs (table 6-5). In particular, the own-price elasticity of demand for animal and meat inputs, 0.0001, is about as close to zero as one can get in these measures. Given meat output, demand for animal and meat inputs does not change at all as animal prices change. In short, one can feasibly estimate "value added" cost functions on the assumption of separability between animals and other inputs: that is, animal input demand is unresponsive to changes in other factor prices.

The labor demand elasticity is estimated to be -0.294 in 1992, close to the estimate (-0.373) reported by Melton and Huffman (1995) for the mean of their 1963-88 data based on aggregate time series. It is also close to the estimated elasticity of demand for other materials (-0.274), while that for capital is substantially larger (-1.028). Capital and labor appear to be substitutes in production, while substitution and cross-price elasticities between other input pairs is quite low. Table 6-5 also reports factor shares used in the estimation of 1992 elasticities. They are calculated at mean 1992 sample values for other variables, and are therefore different from factor shares in table 6-3, which are calculated at mean sample-wide values for other variables.

The factor share distribution identified here is a distinctive feature of slaughter industries. Rarely does a material input (in this case, cattle) account for such a large share of costs. The large share accorded to cattle inputs suggests that there are some important limits to the effect of slaughter scale economies on costs. The processes that drive scale economies are limited to the cooperating inputs of labor, capital, and other materials, which together make up only a fifth to a tenth of total slaughter costs.[21]

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

[21] Potential scale economies in slaughter plants arise from opportunities to achieve specialization of labor, and from opportunities to apply capital equipment in larger plants. But even if these strategies result in substantial reductions in slaughter and fabrication costs, those costs are small fractions of total plant costs, swamped by animal purchase costs.

Table 6-3—Cattle slaughter cost function parameters: first-order terms and year shifts[1]

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

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

Economies of Scale

Equation 5-4 shows how to use estimated coefficients to calculate an elasticity of total cost with respect to output—our measure of scale economies. Recall that it is:

$$\in_{CQ} = (\partial \ln C)/(\partial \ln Q) = g_1 + g_2 \ln Q + \sum g_{li} \ln P_i + \sum d_{lk} \ln Z_k + \sum a_{\ln} T_n \quad (5\text{-}4)$$

Variation in the Z variables (plant characteristics) is too small, when combined with the estimated coefficients (the δ_{1k}), to have any appreciable impact on calculated values for $\in_{CQ}$. Similarly, temporal variation in factor prices has no appreciable effect (the γ_{1i} coefficients essentially cancel one another out). As a result, the important coefficents in equation 5-4 are the first-order term, γ_1, the second-order coefficients on Q (γ_2), and the time shift coefficients (α_{1n}).

In table 6-3, the first-order coefficient for Q is 0.9322 (at the sample mean, a 1-percent increase in output—holding constant factor prices, product mix, and input mix—is associated with a 0.9322-percent increase in total costs). The result implies modest but statistically significant 1992 scale economies; that is, the coefficient is significantly less than 1. The coefficient rises, by increasing and statistically significant amounts, as we move back toward 1963 (table 6-3, row 6), when the cost elasticity was 0.97. Estimated scale economies in cattle slaughter became more important, modestly but steadily, through time.

In table 6-4, the first-order coefficient on Q is repeated in the first column. The coefficient on the interaction of Q with itself (Q squared) is positive and statistically significant: the cost elasticity gets closer to 1 as output gets bigger, but never reaches 1. The largest value for Q is just over 3, in 1992 (recall that we're dividing all variables by their means, and then taking logs). With a 1992 value of the first-order coefficient of 0.93 (table 6-3), the largest 1992 plants generate elasticities of just over 0.96, closer to constant returns than average sized plants, but still within the range of increasing returns to scale. Note that, in 1967 technology, the largest 1992 plants would have exhausted economies of scale, with an estimated value of $\in_{CQ}$ slightly in excess of 1.0 (.9322 + .0382 + [3 *.0105]).

Table 6-6 presents estimated cost elasticities for several representative plant sizes and for two different years.

Table 6-4—Cattle 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	.0817	.0380	-.0612	.0070	.0162	-.0214	.0053	-.0167	-.0145
	(.0052)	(.0027)	(.0026)	(.0009)	(.0017)	(.0008)	(.0004)	(.0018)	(.0026)
PMEAT	.8371		.1189	-.0435	-.0142	.0265	-.0051	-.0015	.0151
	(.0081)		(.0037)	(.0011)	(.0027)	(.0011)	(.0006)	(.0028)	(.0041)
PMAT	.0510			.0369	-.0004	.0013	-.0007	-.0014	.0035
	(.0032)			(.0006)	(.0010)	(.0005)	(.0002)	(.0011)	(.0016)
PCAP	.0303					-.0064	.0006	.0190	-.0041
	(.0083)					(.0012)	(.0006)	(.0024)	(.0041)
Q (lbs)	.9322					.0105	-.0023	-.0040	-.0075
	(.0140)					(.0031)	(.0014)	(.0065)	(.0077)
PMIX	.0409						.0108	-.0001	-.0017
	(.0114)						(.0017)	(.0019)	(.0046)
IMIX	.1535							.0136	.0030
	(.1647)							(.0077)	(.0249)
EST1	-.0284								
	(.0161)								

[1] Quadratic (on diagonal) and interaction terms from estimation of translog cost function. First-order terms from table 6-3 are repeated in first column.

The top row repeats information that can be gleaned from table 6-3, by presenting the estimated scale elasticities for a plant at the sample mean size, calculated for 1992 and 1963. But plants in 1992 were generally much larger, so we recalculate the 1992 cost elasticity for the mean size plant in 1992 and for a relatively large 1992 plant, one at the 95th percentile of the 1992 size distribution of plants reporting to GIPSA (that is, only 5 percent of plants produced more). We also calculate elasticities for the typically smaller plants of 1963, again using the mean and 95th percentile sizes, but this time from the 1963 size distribution.

The largest 1963 plants produced near constant returns (an estimated cost elasticity of 0.98—lower right corner of table 6-6) with 1963 technology. But in 1992 technology, the largest 1963 plants fell noticeably short of constant returns, with a cost elasticity of 0.944. Plants grew dramatically in the period; a large 1992 plant produced five times as much meat as a large 1963 plant (in fact, the large 1963 plant would be below the 1992 mean). Part of that growth probably reflected attempts to realize scale economies. But the large 1992 plant still falls short of constant returns, with a scale parameter of 0.961. That estimate suggests that further consolidation in slaughter is likely. Indeed, GIPSA data after 1992 show a continuing sharp shift toward the largest slaughter plants. Plants that slaughtered over 1 million cattle accounted for 34 percent of cattle slaughter in 1992 and 63 percent in 1997.

Changes in labor markets reinforced the growing importance of scale economies. Recall that large slaughter plants paid higher wages in the first decade of our study period—as much as 23 percent above the industry average and 33 percent above smaller commercial plants (table 4-8). Given the factor share of labor, that size differential would translate into a large plant cost disadvantage of 1.5 to 3.8 percent, attenuating the advantages of scale. But between 1977 and 1992, the size differential in wages disappeared, adding to the growing advantages of scale.

Plant Characteristics

In table 6-4, the first-order coefficient on product mix (PMIX, the noncarcass share of plant shipments) is positive and significant, while that on its square is positive and highly significant. Holding output constant, increases in the noncarcass share of output are associated with cost increases. The result is logical since

Table 6-5—Mean input shares and elasticities, 1992[1]

Item	Input price variables PLAB	PMEAT	PMAT	PCAP
Input share	.0587	.8622	.0550	.0301
$\in_{ii}$	-0.294	0.0001	-0.274	-1.028
σ_{ij}				
PLAB	-5.01	-0.209	3.167	10.170
PMEAT		0.0001	0.083	0.453
PMAT			-4.98	0.789
PCAP				-34.10

[1] All values are calculated using mean 1992 data values and parameters from tables 6-3 and 6-4. The 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.

higher values of PMIX imply more fabrication, and therefore more labor, capital, and materials.

For product mix (PMIX), the interaction terms with factor prices are all highly significant (table 6-4, column 7). As the noncarcass share gets larger, the share of costs accounted for by labor gets larger while that accounted for by animals gets smaller, also logical given the value added in fabrication.

We can show the effects of likely changes in PMIX on average costs, with the approach taken above for scale economies. Estimated average costs rise by about 3.2 percent, for a large plant (at the 95th percentile of the size distribution), as the plant goes from minimal to extensive fabrication (from PMIX of 0.38 to 0.90).[22] Finally the negative and marginally significant sign on the interaction of PMIX and output (Q) gives evidence of scope economies—the scale parameter gets smaller (steeper, or further below 1) as PMIX gets larger. But the effect is small: a plant at the 75th percentile of the 1992 size distribution (about a third as large as a plant at the 95th percentile) would incur additional fabrication costs of 3.6 cents per pound in going from minimal to extensive fabrication, compared with 3.2 cents per pound for a plant at the 95th percentile.

Most of the individual coefficients involving input mix (IMIX, the share of animals in meat and animal inputs) are small and not significant, although the G-J tests in table 6-2 favor retaining the measure. There

[22] In turn, average processing costs (value added) would rise by slightly over 30 percent, if animal acquisition costs were 90 percent of the total at the minimal plant and were unchanged as one moves to the extensive plant.

Table 6-6—Estimated cost elasticity coefficients, by plant size and year[1]

Plant size	Technology vintage 1992	1963
Sample mean	0.932	0.969
1992 mean	0.946	0.983
1992 95th percentile	0.961	0.998
1963 mean	0.925	0.962
1963 95th percentile	0.944	0.981

[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.

are three exceptions. The coefficient on IMIX squared is small but positive and statistically significant, suggesting that costs increase as the animal share increases above its mean, given output. The coefficient on the interaction term with the price of labor is negative, while that on capital is positive, with each highly significant. Labor shares are lower, and capital shares are higher, in plants that use higher ratios of animal to meat inputs.

Tables 6-3 and 6-4 also show that, all else equal, single-establishment firms have lower costs, as well as slightly different input shares (higher shares of animals and materials, and lower labor shares). Interpretation is difficult here—the coefficients could be picking up differences in accounting techniques; differences in product mix, input mix, or scale that our model does not capture; or real efficiency differences. Because these results are hard to interpret, we look at single-establishment variables as control measures, and other coefficients are not affected by their inclusion.

Finally, consider changes in the model's intercept over time, in table 6-3. None of the coefficients are significant, and they show no consistent sign pattern. By implication, there are no temporal changes in slaughter costs that are not picked up by movements in factor prices, scale, and product mix effects. This suggests that much of the cattle slaughter industry's productivity growth is accounted for by scale economies, either through changes in the estimated scale parameter or through increases in plant size to take advantage of scale economies.

What Do Other Studies Find?

Our findings for scale economies conflict with Ball and Chambers (1982) and with Melton and Huffman

Table 6-7—Comparing size-cost estimates in cattle slaughter

Head/year	Cost/head, including cattle acquisition W&S[1]	D&N	Census	Cost/head, slaughter & fabrication only W&S	D&N	Census
			Index			
175,000	102.3	101.4	104.3	116.9	111.2	130.7
300,000	101.2	100.6	101.5	109.3	104.3	110.7
425,000	100.0	100.0	100.0	100.0	100.0	100.0
850,000	98.7	98.4	97.9	90.4	87.1	85.0
1,100,000	97.7	98.0	97.3	82.6	84.4	80.7
1,350,000	97.5	98.0	97.0	81.3	84.4	78.6

1 "W&S" refers to estimates of Ward (1993), derived from Sersland; "D&N" refers to estimates derived from Duewer and Nelson (1991); "Census" refers to estimates derived from tables 6-3 and 6-4. In order to protect the confidentiality of Census data, the data are presented as index numbers, with 425,000 set to 100.

(1995). Each reports cost elasticities that range substantially above and below 1, with large economies of scale in some years and diseconomies in others. Ball and Chambers estimate a value-added cost function using annual data for the entire meat products sector (SIC 201). They report cost elasticities for the early 1970's, and find scale economies that are substantially larger than those reported here. Moreover, their estimates vary, as they report substantial diseconomies of scale for 1971. Melton and Huffman estimate a value-added cost function using aggregated annual data for beef and pork slaughter separately. They report economies of scale for 1975, and very large diseconomies of scale for the 1980's.

Each study used highly aggregated data that afforded limited opportunities to distinguish among capacity utilization, technological change, and the realization of scale economies, and neither attempted to control for changes in product and input mix over the period. Since large plants led the move to greater fabrication in beef (table 4-1), those plants would have begun to incur higher average costs per head than smaller slaughter-only plants, and analyses that fail to control for product mix would likely report evidence of diseconomies.

Kambhampaty et al. (1996) and Morrison (1998) estimate shortrun variable cost functions, and those data sets are poorly suited to estimation of longrun scale economies. Each finds important shortrun increasing returns to scale, in that average costs decline as output increases at plants within the year. In that respect, they support the assertions of Ball and Chambers (1982) and Ward (1990)—that capacity utilization is an important element in average costs at cattle slaughter plants.

Our findings on economies of scale are quite similar to the estimates reported for the simulation models of Duewer and Nelson (1991) and of Ward (1993), who reports the work of his student, Sersland (1985). The simulation models differ from our econometric model in one major respect: while our econometric estimates are based on the statistical estimation of cost functions using operating data from many plants, simulation models rely on idealized operations across a few standardized plant types. Sersland obtained her data from a mail survey of managers, who provided her with cost estimates for several specified plant types, while Duewer and Nelson constructed an engineering-economic model of costs at specified plant types, by building up from specified activities, input quantities, and input prices.

In table 6-7, we calculate indexes of average cost (per head), based on the data in Ward and in Duewer and Nelson, and compare them to calculations based on the models and data underlying this report. We separately report indexes for slaughter cost, which excludes purchase expenses for animals, and total cost, which includes animal expenses. All estimates were converted to index numbers to preserve Census confidentiality. Index numbers reveal no actual cost estimates, but show how estimated average costs change as plant size varies.[23]

23 We can use our model to estimate costs per head for a hypothetical plant. We first estimate the 1992 animal share of total costs for a large plant (1.1 million head annually, or 300 head per hour in a two-shift-per-day plant operated 40 hours per week). Then, using our census data for the mean 1992 animal factor price, we calculate total cost per pound and subtract the animal cost from that to get slaughter/fabrication cost per pound. We then multiply by the 1992 average meat yield (701 pounds) to estimate a cost per head. The resulting estimate, $59 per head, compares with D&N's estimate of $60 dollars per head at a similarly sized plant and Sersland's estimate of $55 (Ward, 1993). Our analysis is based on

We began with Ward, who derives a set of annual slaughter volumes from typical combinations of hourly slaughter speeds and daily shifts (the three smaller plants are assumed to operate single shifts, with correspondingly smaller investments in storage capacity, while the three larger plants are designed to operate two daily shifts). Each simulated plant performs slaughter and fabrication functions. For each simulated plant, we took Ward's slaughter/fabrication cost estimates, and then converted them to index numbers with his midpoint plant (425,000 head per year) set to 100.[24] To convert Ward's slaughter cost indexes to total cost indexes, we then made two assumptions about cattle prices: that cattle costs account for 86 percent of total costs at Ward's midpoint plant (consistent with the 1992 Census mean) and that all plants pay the same cattle prices. With those assumptions, we can derive an estimated cattle price from Ward's data, and then simply add that price to average slaughter fabrication costs to get average total costs.

Duewer and Nelson's size categories do not match up exactly to Ward's. For comparison, we interpolated average costs between Duewer and Nelson's output levels to get to costs for Ward's output levels.[25] We added in the estimated cattle price to get to total costs, and converted Duewer and Nelson's estimates to index numbers, with average costs at an output of 425,000 head set to the base of 100.

We next calculated a total cost index for our model, first converting our output measure (pounds of meat) to cattle numbers with the Census mean meat yield of 701 pounds per animal. We estimated total and average costs for a plant with output corresponding to 425,000 head per year, and set its index to 100. Finally, we used our estimated cost function to project how total and average costs would vary with output, holding other variables constant at 1992 means.

Average total costs fall with plant size in each model, but the declines are very modest (table 6-7). In particular, as we move to the largest plant from the midpoint plant, average total costs per head fall by 3.0 percent in the Census model, 2.5 percent in Ward, and 2.0 percent in Duewer and Nelson. Average total costs rise more sharply in the Census model as we move toward smaller plants from the midpoint plant (a 4.3-percent rise vs. 2.3 percent in Ward and 1.4 percent in D&N), suggesting more severe diseconomies of small scale.[26]

Average costs for slaughter/fabrication alone fall by around 20 percent from midpoint to largest plant (Census reports a 22.4-percent decline, compared with 18.7 percent for W&S and 15.6 percent for D&N). This comparison also points up one area of difference—the Census model reports continuing scale economies among the very largest plants, while D&N report constant returns among the largest plants.

Given the uncertainties involved in comparing econometric and simulation models, the two approaches still tell a common story regarding economies of scale in cattle slaughter. There are large scale economies in the slaughter and fabrication functions, the economies extend across a wide range of plant sizes, and they translate into modest but significant economies of scale when considering total costs (including animal procurement costs).

We can use table 6-7 to gauge the relative importance of technological and pecuniary scale effects. The table shows technological scale economies: given 1992 factor prices, total costs per head fall by 2 to 3 percent as we move from average sized to very large plants. Pecuniary diseconomies at larger 1970's plants (in the form of higher wages) increased large plant costs by 1.5 to 3.8 percent, compared with smaller plants. Pecuniary diseconomies were close in magnitude to technological economies, and their disappearance in

1992 factor prices and technology, while D&N's analysis is for 1988 and Sersland's for 1985. As noted above, our incremental cost of adding fabrication lines in a plant appears to be low, compared with the simulation studies. Nevertheless, our estimated costs are quite close, and provide further confidence for the econometric estimates.

24 The largest plant listed in table 6-7 matches the largest plants operating today, while plants that slaughter more than a million head accounted for just over half of all steer and heifer slaughter in 1996 (table 3-3). Plants slaughtering less than a half million accounted for nearly two thirds of 1982 slaughter and less than one fifth of 1996 slaughter.

25 We selected Duewer and Nelson's estimates corresponding to slaughter/fabrication operations, 40-hour work weeks, single shifts for smaller plants, and double shifts for larger plants.

26 Capacity utilization may play a role here. Ward (1990) and 1992 GIPSA data suggest that larger plants have systematically higher levels of capacity utilization, which would show up as part of scale economies in our econometric cost functions. Our cost estimates for Ward and D&N plants assume no differences in capacity utilization across plants. If we alternatively assume that small plants operate 32 instead of 40 hours per week, then the D&N index at the smallest plant size rises to 102.9, closing half the gap with the Census indexes.

the 1980's reinforced the effects of growing technological scale economies in providing cost advantages to large plants.

Conclusion

The estimated cost function finds small but important scale economies. They became more important through time, and extend throughout the range of plant sizes in the 1990's, suggesting that the largest plants continue to have cost advantages over smaller commercial operations. Wage-based pecuniary diseconomies limited the realization of technological scale economies in the 1970's, and their disappearance in the 1980's reinforced growing large-plant cost advantages. Changes in product mix, toward greater fabrication, have small positive effects on costs, and add slightly less to unit costs in larger plants. The results suggest that slaughter plants shifted to greater fabrication because they could do so at lower costs than carcass buyers (meat wholesalers and retailers) could, and that larger plants had greater fabrication advantages than smaller plants.

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
ϵ_{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 (ϵ_{ii}) are calculated holding output and other factors constant, while the elasticities of substitution (σ_{ij}) are calculated using Allen's formula.

Table 7-6—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.

Chapter 8

Conclusions

We organize our conclusions into three sections. First, we summarize our description of the extent of structural change in cattle and hog slaughter. Next, we discuss the major findings of the cost analyses, along with their implications for cost modeling in slaughter. Finally, we link the two by discussing the impact of industry cost structure on structural change.

Structural Change in Cattle and Hog Slaughter

Major consolidation occurred in each industry, as large plants supplanted small and now dominate production. In each case, the shift to large plants occurred quite rapidly, over a short time period—from 1977 to 1992. Consolidations on such a dramatic and rapid scale are quite rare in U.S. manufacturing.

Consolidation in slaughter proceeded apace with consolidation in related animal production sectors, as cattle feeding shifted toward large commercial feedlots and hog production shifted toward large hog farms. Because meatpacker procurement generally occurs over a limited geographic area, slaughter plants are closely linked to local feeding and finishing operations. As cattle feeding and hog production shifts geographically, slaughter plants follow. In new areas with limited networks of producers and slaughter plants, buyers and sellers are less likely to rely on spot market cash transactions to arrange for the transfer of animals, and more likely to use alternatives such as contracts and vertical integration.

In cattle slaughter, where the demand for cattle declined through time, consolidation was accompanied by sharp increases in market concentration, as the number of independent plants fell sharply. In hog slaughter, where the market grew slowly, concentration increased, but less so than in cattle. In poultry industries, where market growth was rapid, concentration changed little despite a consolidation of production in large plants.

Consolidation was accompanied by important changes in product mix in each industry. Large cattle plants now ship more output as boxed beef and ground beef instead of whole and half carcasses, thereby taking on tasks that had been performed in distribution facilities. Hog plants moved to perform a similar set of tasks, but from a different starting point. That is, hog slaughter plants now commonly perform slaughter and byproduct processing, and also cut carcasses up for shipment much like boxed beef. But many hog plants used to process carcasses into hams, bacon, sausages, and other prepared products. Specialist processors are more likely to perform those tasks today.

Slaughter Industry Cost Structure

Our cost analysis emphasized the estimation of economies of scale—the effects of plant size on unit costs. We found that scale economies were modest but extensive. The largest plants maintained only small cost advantages (1 to 3 percent) over smaller plants, but these modest scale economies appeared to extend throughout all sizes of 1992 plants (the last year of our cost data). The very largest plants in that year did not exhaust all possible scale economies. Still, scale economies were larger and more extensive at the end of the study period (1992) than in earlier years.

Large meatpacking plants traditionally paid higher wages than small, and this pecuniary diseconomy limited the technological cost advantages that scale economies offered large plants. However, size-based wage premia disappeared during the 1980's, reinforcing the effects of expanding technological scale economies.

The second major emphasis of our cost analysis was on product mix. Product and input mix influences costs, and mixes vary widely across plants and over time. Because product mixes are correlated with plant size (larger cattle plants produce greater proportions of boxed beef, for example), their omission in models can lead to biased estimates of scale economies and of the extent of technological change and productivity growth. Finally, our measures show that there may be small economies of scope in cattle slaughter, in that larger plants can combine slaughter and fabrication at lower cost than smaller plants.

The distinctive feature of slaughter plant operations, compared with other manufacturing operations, is the importance of materials, particularly animals, in total costs. By implication, labor, capital, and energy expenses form much smaller shares of costs in slaughter industries than elsewhere. It is this importance that ensures that scale economies have modest effects on costs, because scale economies primarily arise in the use of other inputs—labor, capital, and energy—at slaughter plants. Moreover, although there is some theoretical scope for substitution between animals and other inputs in the production of meat, our analyses show that there is virtually no actual substitution; one can reasonably estimate "value-added" cost functions for slaughter under the assumption of no substitution.

From Costs to Structure: Did Scale Economies Cause Consolidation?

Our evidence shows modest scale economies in cattle as well as hog slaughter: large plants can produce meat at slightly lower costs than small slaughter plants. These advantages became more important in the 1980's, as the industries consolidated and production shifted to large plants. That is, the existence of scale economies, and the timing of their appearance, suggests that consolidation occurred because of scale economies.

But scale economies cannot be a complete explanation for consolidation because the cost advantages held by large plants are not particularly large. Small plants appear to 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). For modest scale economies to lead to consolidation as massive as that in meatpacking, the industry was likely subject to strong price competition. That is, small plants will close if market prices are below small plant unit costs; for market prices to be below small plant costs, they must in turn be quite close to large plant unit costs, due to small differences between small and large plant unit costs.[29]

[29] Strictly speaking, average variable costs, but variable costs in meatpacking are very close to average total costs.

The labor strife of the 1980's, as reported in chapter 4, may also reflect strong price competition in the industry. While unionized plants had substantially higher wages than nonunion plants in the 1970's, the effect on costs would be small because the share of wages in total costs was small. For small cost differences to lead to plant closures and lockouts, the higher cost unionized plants would have to have been under strong competitive price pressures from the nonunion plants.[30]

Our conclusions about price competition in slaughter must be more speculative, because they are based not on our own work but on the published literature, with far more information for cattle than for hogs. The existing literature suggests that departures from competition in cattle slaughter have been small and rare. In competitive markets, product prices should equal marginal costs of production, while prices paid for inputs (like cattle) will equal the value of the input's marginal product. Attempts to measure departures from competition take two forms. Researchers may attempt to directly estimate the gap between prices and the corresponding competitive magnitudes (marginal costs or marginal value products), relying on the econometric estimation of demand and cost models. Alternatively, they may attempt to see if prices vary systematically with variations in competitive conditions, while trying to hold (or assuming) constant other cost and demand factors.

Most early studies took the latter approach. For example, Marion and Geithman (1989) examined how prices paid for slaughter cattle varied with buyer concentration across buying regions, while also controlling for interregional differences in labor costs and interseller differences in feedlot size. They found that buyers in more concentrated markets paid less for cattle, but that the differences were small: prices for cattle fell by 3.4 percent, at most, as one moved from the least concentrated to the most concentrated region. Other early studies, surveyed by Azzam and Anderson (1996) found similar results: concentration effects, if they existed, were small.

More recently, the Texas A&M Agricultural Market Research Center (1996) used far superior data to arrive

[30] Large plants may also realize marketing advantages over smaller plants through export markets and nationwide shipping. However, marketing advantages are difficult to identify in these data sets (or in other existing ones).

at a familiar conclusion. They were able to control for a wide array of cost, cattle characteristic, and demand measures, and found that prices paid for cattle in 1992 were lower in more concentrated regions, but that cattle prices fell by only 2.4 percent as one moved from the least to the most concentrated market. Moreover, the most concentrated regions in these studies are remote areas that host some relatively small plants. The less concentrated regions are the areas of consolidation of large plants in the Plains: there, prices are slightly higher.

Studies that rely on direct estimation of gaps between prices and corresponding competitive values reached similar conclusions. Those based on reliable estimation of demand and cost functions may disagree as to whether prices equal competitive magnitudes, but none found large departures of prices from those magnitudes. For example, Morrison (1998) found that product prices exceed marginal costs of production (the competitive magnitude) by a small gap, 5 to 10 percent, which indicates that plants had very limited market power in product (wholesale meat) markets. She further found that prices paid for animals in input (cattle) markets were not below competitive levels.

Finally, measures of farm-to-wholesale price spreads did not increase over time as concentration increased. The aggregate USDA measure of the farm-to-wholesale price spread for choice beef reflects transportation, slaughter, and fabrication costs (Nelson and Hahn, 1998). Adjusted for inflation, the spread fluctuated during the 1970's, but fell steadily and sharply from 1979 through 1992, the period of sharpest consolidation, even as plants added more fabrication and the attendant costs. Farm-to-wholesale margins did rise sharply between 1992 and 1995, but then fell back again in 1996 and 1997.

Several factors, whose effects are difficult to measure, may have helped to increase concentration in meatpacking—these include economies of operating multiple plants, large firm marketing advantages (particularly in exports), and mergers among packing firms. But if the pricing evidence is correct, then the following three measurable factors clearly combined to help increase concentration in cattle slaughter: (1) shifts in scale economies provided larger plants with modest cost advantages; (2) aggressive price competition forced prices to quickly move near the costs of the low-cost market participants; and (3) slow demand growth limited the number of efficient large plants in the market. In hogs, scale economies and strong price competition have also forced small plants to exit the industry, but faster demand growth allowed for more plants and lower concentration.

Our evidence suggests that once new and extensive scale economies emerged in meatpacking, intense price competition led to the exit of high-cost small plants, their rapid replacement by larger and more efficient plants, and significant increases in market concentration. The policy challenge for the future is to ensure that a result of the process, high concentration, does not erode a key contributing factor—price competition among packers. The analytical challenge is to continue to update the evidence so that we can effectively monitor competitive conditions in an industry that is now concentrated, and to ensure that we adequately understand the causes and effects of continued change in the industry.

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