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Abstract

Cost function analyses using data from the U.S. Bureau of the Census reveal substantial scale economies in chicken and turkey slaughter. These economies show no evidence of diminishing as plant size increases, are much greater than those realized in cattle and hog slaughter, and have resulted in a huge increase in plant size over the 1972-92 period. The findings also suggest that consolidation in the chicken and turkey slaughter industry is likely to continue, particularly if the growth in the demand for poultry diminishes.

Keywords: chicken slaughter, turkey slaughter, production costs, structural change

The research reported here is based on work performed as research associates at the Center for Economic Studies, U.S. Census Bureau.

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Summary

Substantial unexploited scale economies—the ability to reduce production costs by becoming larger—exist for both chicken and turkey slaughter manufacturing establishments. This could mean lower poultry prices, but it could also result in fewer plants and fewer firms in the future. Over the past 30 years, a doubling of U.S. chicken consumption and a huge increase in exports have helped limit consolidation pressure. However, if growth in demand were to stall, the industry would likely feel market pressure to consolidate. These results are based on cost function analysis using the Longitudinal Research Database from the Bureau of the Census. We examined changes in the structure of the poultry slaughter industry over the 1967-92 period. A unique feature of this analysis was our ability to account for changes in product mix. By including product mix in the model, very strong scale economies became evident that otherwise would have been masked.

The existence of scale economies has important public policy implications. Scale economies force relatively smaller plants to reduce costs by tightening worker and contractor performance standards, reducing wages, and/or increasing plant size. Stricter performance standards or lower wages may lead to disputes between management and workers and contractors; larger plant size means that greater volumes of poultry litter must be disposed of over the same confined area, increasing concerns about water quality and other types of environmental impacts. If smaller plants choose not to take steps to reduce costs, then they will likely be forced to exit the industry. Fewer and larger firms may prompt concerns about anticompetitive behavior.

Poultry manufacturers have responded to the existence of scale economies by becoming larger. Even though industry output tripled, the number of poultry slaughter and processing plants in 1992 was about the same as in 1967 and, by 1992, more than 80 percent of all chicken and turkey products were produced in large plants employing more than 400 workers. Less than a third of chicken and turkey production came from such large plants in 1967.

Larger plant size has not led to excessively high four-firm concentration ratios (the share of industry output held by the largest four firms). The chicken slaughter industry, but not the turkey slaughter industry, was slightly more concentrated in 1992 than in 1967, and most of the increase in concentration took place between 1977 and 1987. The top four chicken-slaughtering firms controlled only about 45 percent of total U.S. output in 1992. Economists generally believe that only when the four-firm concentration ratio exceeds 80 can firms raise prices with reduced fear of being underpriced by competitors.

Because large plants can produce poultry at a much lower cost than small plants, the magnitude of the cost savings gained by large plants is impressive. An average size plant producing mainly whole birds in 1992 had costs 13 percent lower than an average size plant in 1972. This cost savings partially explains why the retail price of whole chickens has dropped by about a third, in real dollars, over the last 20 years.

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1. Introduction

The emergence of the integrator-grower production system in the late 1950's and early 1960's, along with sharp growth in U.S. poultry consumption and exports, has dramatically changed poultry industry structure over the past three decades. A typical chicken plant in 1992 produced about five times more output than a plant in 1967 and, rather than producing mainly whole birds, had a product mix consisting of traypacks, cut-up and deboned poultry in bulk containers, and nuggets and other further-processed products.

A shift to larger average plant size can cause the number of plants to drop and the production share of the largest firms (concentration ratio) to rise because each plant then accounts for a larger share of industry production. However, the number of poultry slaughter and processing plants in 1992 was about the same as in 1967, and the four-firm industry concentration ratio rose only for chicken slaughter, not turkey slaughter, and, only for chicken over the 1977-87 period to about 45, a level not particularly high compared with other manufacturing industries. By contrast, similar increases in plant size for cattle and hog slaughter coincided with a much larger increase in the four-firm concentration ratio in cattle and a 75-percent reduction in the number of hog and cattle slaughter plants. Economists generally believe that when the four-firm concentration ratio exceeds 80, large firms can raise prices with less fear of competitors' taking away market share by selling a similar product at a lower price. Increased prices are possible because there are fewer competitors to try to underprice the product.

A primary goal of this report is to estimate the extent to which larger poultry plants can produce products at a lower cost than smaller ones (scale economies). Scale economies combined with other production-related changes, such as changes in product mix, affect production workers through changed opportunities, retailers and wholesalers through changes in product mix, and consumers through changes in poultry prices and product variety. A better understanding of scale economies and, more generally, structural change allows one to make inferences about the future of the poultry industries. A clear understanding of scale economies is particularly important for assessing market competition. For example, substantial scale economies can explain why small producers have been forced to exit an industry. Alternatively, the absence of scale economies in an industry with only a few large producers may prompt one to be more concerned about anticompetitive behavior.

Increases in scale economies have other public policy implications. The need to continuously reduce production costs to capture the cost savings of large plants raises worker safety and compensation concerns for farmers who raise chickens and turkeys and for slaughter plant workers. Additionally, large slaughter plants require a vast number of live birds, which generate an enormous amount of animal waste. Historically, chicken and turkey farmers and slaughter plants have spread poultry waste on nearby farms as fertilizer. Since bird farmers typically locate within 20 miles of slaughter plants, they have been disposing of a growing volume of animal waste within a confined area. In some parts of the country, the animal wastes pose no environmental threat, but in other, more environmentally sensitive areas, the high concentration of animal wastes has resulted in nitrogen and phosphates leaching into ground water or washing into streams, causing water quality problems and environmental degradation.

The policy issues described above concern the effects of the modern integrated poultry production plant. This report aims to assess the causes of structural changes by using a unique dataset to describe and to explain the process of consolidation. In particular, this report examines several innovations that may have created scale economies and changed product mix and affected slaughter costs and consolidation among slaughter firms.

Chapter 2 briefly summarizes the relevant developments in U.S. poultry consumption and production. Chapter 3 provides the key statistics summarizing structural changes. It also defines market concentration and presents changes from 1963 through 1992. We show that large plants account for growing shares of chicken and turkey slaughter over this period and that the rate of plants leaving the industry (exits) is less rapid than for cattle slaughter. As industry structure changed, so did plant operations. Chapter 4 discusses changes in grower-integrator contractual relationships, seasonality of production, plant output mix, poultry meat input mix, location, and labor force. Chapter 5 describes how confounding effects, changes in product mix or live bird prices, are controlled in cost function analysis. Chapters 6 (chicken) and 7 (turkey) contain the results of statistical analyses, and chapter 8 provides concluding comments.

Scale economies are found to exist over a range of large plant sizes. Controlling for plant product mix proves to be critically important. Plants that do more fabrication and processing of whole birds have higher costs, but also receive higher prices for output. The omission of product mix in an econometric analysis may lead to inaccurate productivity estimates if different product mixes require different levels of inputs.

The report relies on a unique data source, the Longitudinal Research Database (LRD) from the Bureau of the Census. The LRD details the records of individual establishments reported in the Census of Manufactures (Census). The LRD data used for this manuscript includes all plants reporting to the Census in each of the 5-year censuses: 1972-92 for chicken and 1967-92 for turkey (data from the 1997 Census will be processed for the LRD too late for this report). Census data prior to 1967 were excluded because there are no data on further-processed products and State-inspected poultry plants were not required to meet the more rigorous Federal food safety standards.[1] After 1963, Congress mandated that State plants meet Federal standards, perhaps causing many plants to leave the industry. Data from the 1967 Census were also excluded from chicken slaughter cost estimates because chicken traypack data, an important component in production costs, were not collected in that survey year.

LRD data provide detailed information on the physical quantities and dollar amounts of many different products shipped by slaughter plants, physical quantities and prices paid for materials, and employment and average wages for each establishment. The file also notes ownership and location information. Because the LRD contains data on individual plants over several Censuses, researchers can make comparisons for different plants during the same year, and can also trace changes in product and input mixes, costs, and concentration over time.

Researchers can use LRD data only for research purposes, and may not divulge information on any individual plant or firm, and may publish only aggregated information. This report therefore identifies aggregated statistical data and the coefficients from regression analyses covering hundreds of establishment records. Any references to specific company or plant names are based on publicly available information, and not on any Census source.

[1] Under current Federal food safety standards, red meat and poultry plants must be inspected by either Federal or State Food Safety Inspectors prior to the sale of finished products. A s of 1999, only federally inspected plants can ship products across State lines. Inspection standards are made uniform by legislation requiring State food safety inspection programs to be certified by the Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture (USDA).

2. Changes in Poultry Demand

Per capita poultry consumption has grown consistently over the last 40 years (table 2.1) and now exceeds beef and pork consumption. During the 40 years preceding 1950, however, poultry consumption varied between 15 and 25 pounds per capita and, on average, amounted to about 20 pounds per capita, a level about one-third that of either beef or pork. The highest consumption occurred during WWII because, due to its secondary status in the American diet, poultry was not covered by rationing.

During the pre-1950 period, farmers viewed poultry raising as a way either to produce eggs or to put spilled grain, grass, and insects around the farm yard to productive use. Chickens for consumption were either those not needed for egg production or surplus animals. Chickens intended for egg production were hatched in the early spring, and, since many young males were not needed for production, they were slaughtered together with cull hens during the summer months. Large numbers of hens were slaughtered in the late fall when seasonal egg production dropped off. Some hens and a couple of roosters were often held over to hatch out new chicks the next spring.

The integrated structural form for producing chickens emerged during the 1950's and 1960's. In this integrated form, the chicken slaughter plants and feed mills are owned by a single firm and make contractual chicken-supply arrangements with chicken growers who agree to raise baby chicks provided by the slaughter plants and then return them to the plant after the grow-out period. This arrangement permits a steady supply of live chickens for slaughter and allows the chicken integrators to control the quality of incoming birds (see chapter 4 for a more detailed discussion). Bugos asserts that this highly integrated structure, in which growers provided uniform-quality birds combined with ever-increasing line speeds and more efficient feeding operations, enabled chicken slaughter plants to realize scale economies over the 1950-60 period (Bugos et al.).

Chicken quality also changed dramatically as specialized meat-type chicken breeds began to dominate chicken production. Before 1952, most chicken meat came from mature hens used for egg production, but by 1960, young chickens raised for meat consumption (broilers) made up nearly 85 percent of chicken purchases, and, by 1999, close to all chicken purchases. Broilers tend to have moister, more tender chicken meat and larger breast portions than birds intended for egg production.

The building of more highly specialized broiler processing plants in the 1960's drove down prices by enabling faster line speeds. Chicken-manufacturing yields also improved as plants installed chicken cut-up lines that better utilized whole birds that could not meet USDA-inspected Grade A standards and as chicken breeders developed larger birds, which have lower labor costs per pound than smaller ones.

Chicken consumption over the 1960-77 period was stimulated by a decline in its price from one-half that of beef to about one-sixth and by the introduction of popular new products, such as traypacks (table 2-1). After 1977, chicken marketers emphasized the lower saturated fat content of chicken relative to beef and introduced a stream of new products ranging from deboned ready-to-cook products to luncheon meats to chicken nuggets and patties for restaurant use. Marketers also introduced chicken products to nontraditional vendors, such as fast food restaurants. Today, fast food restaurants sell huge quantities of chicken in many forms, including breaded chicken parts, nuggets, patties, breast filets, tenders, and popcorn chicken.[2] Many of these products are also available in the frozen food section at grocery stores. Marinated whole birds have become popular items for takeout meals at both fast food restaurants and supermarket delis, and probably account for the increase in the percentage of birds sold whole at retail between 1995 and 1997 from about 12.5 percent to 13.2 percent, a reversal of at least a 35-year trend toward fewer whole birds.

The transformation of chicken production from a simple slaughter and package operation into more specialized processing operations is evident from whole-bird consumption patterns. As shown in table 2-2, whole broilers accounted for over 87 percent of the birds consumed in the United States in 1962, but only about 13 percent by 1997. This shift away from whole birds toward more convenient products enabled broiler production to grow by about 5 percent per year over the last 40 years.

[2] Company records indicate that McDonald's introduced Chicken McNuggets throughout the United States in 1983 and that, by 1984, McDonalds had become the second-largest purveyor of chicken in the world.

Marketing efforts to segment the chicken market encouraged export growth and more use of further processing. Domestic consumers prefer breasts and other white meat and are willing to pay much higher prices for these products than for whole birds or dark meat (thighs and drumsticks). Responding to these preferences and the increased demand for further-processed products, chicken producers attached cut-up operations to the end of slaughter lines, reserved breasts and other white meat for domestic consumption, moved much of the dark meat into the export market, and used the remainder for further processing.

The growth in exports was a sharp change from the past. As recently as 1975, the export market amounted to no more than 200 million pounds and had never been more than 5 percent of production. However, exports doubled in 1976 from 1975 levels and grew each year through 1981. Slow production growth in 1982 and 1983 (table 2-3) restricted broiler meat availability, limiting exports. Since 1984, exports have increased every year, reaching 4.7 billion pounds and 17 percent of production in both 1997 and 1998 (table 2.1).

Increased further processing came a little later for the turkey industry, with most of its growth coming in the 1980's. Turkey consumption was less than 3 pounds per capita in the 1930's and 1940's, but doubled by 1960, as turkey firms developed specialized bird breeds that yielded more breast meat. By 1980, consumption had risen to 10 pounds, and, with the introduction of turkey luncheon meats, turkey ham, sausages, and deli products, consumption grew to 18 pounds in the early 1990's (table 2-1).

Fast food and restaurant markets have not been nearly as receptive to turkey as to chicken, but the export market has been an important outlet for dark turkey meat (thighs and drumsticks), with Mexico being the leading market. A large quantity of mechanically separated turkey meat is also exported to both Mexico and Russia. Turkey exports were particularly strong during the 1990's, reaching a level of about 10 times that of the 1980's.

Branded products have been important for both chicken and turkey producers. In the late 1960's, some of the leading poultry companies established their own processing plants and started marketing branded products in addition to private and store brands. Consumers perceived the branded products to be of higher quality than private labels, permitting a significant price premium. The presence of branded, private, and further-processed product markets permitted chicken slaughter plants to use birds that did not meet USDA Grade A standards for further processing; birds that just meet Grade A specifications for private

Table 2-1: Poultry consumption, prices, and exports, 1960-99

Product	1960	1963	1967	1972	1977	1982	1987	1992	1997	1999
					Retail pounds					
Per capita consumption										
Chicken[1]	27.8	30.8	32.4	41.7	40.2	47.0	57.4	67.8	72.7	78.8
Turkey	6.3	6.9	8.7	9.0	8.8	10.6	14.7	17.9	17.6	17.8
Beef	64.2	69.9	78.8	85.1	91.5	76.9	73.7	66.3	66.9	65.4
					December price					
Retail prices[2]										
Chicken	41.0	40.0	37.4	41.2	57.7	68.2	73.6	87.9	100	106[3]
Turkey	55.3	49.1	47.2	56.7	83.0	89.2	89.3	93.0	106	n.a.
Beef	80.2	78.4	85.8	238	309	467	486	287	280	301
Consumer Price Index	3.37	3.27	2.99	2.39	1.65	1.04	0.88	0.71	0.62	n.a.
					Million pounds					
Net exports										
Chicken[4]	137	157	88	100	349	524	767	1,530	5,043	4,421
Turkey	24	31	49	36	54	51	33	202	605	400

n.a. = not available.
[1] Includes broilers and mature hens.
[2] Prices are whole fryers for chickens, young hens for turkeys, and weighted composite of Choice beef for beef.
[3] Year average.
[4] Includes broilers and mature hens.
Sources: Published in various issues of *Livestock, Dairy, and Poultry Situation and Outlook*, USDA, ERS. Early data also in *Poultry Yearbook* and *Red Meat Yearbook*, USDA, ERS.

Table 2-2: Poultry sales, 1963-97

Raw product	1963	1967	1972	1977	1982	1987	1992	1997
	Percent of total slaughter production							
Cut-up and deboned								
Chicken	15.2	21.9	29.6	38.2	48.1	56.1	78.2	86.9
Turkey	3.4	6.8	16.7	22.5	29.9	36.6	55.1	n.a.
Whole birds								
Chicken	84.8	78.1	70.4	61.8	51.9	43.9	21.8	13.1

Sources: Economic Research Service, *United States Egg and Poultry Statistical Series, 1960-90* (U.S. Department of Agriculture, 1991); National Turkey Federation, unpublished survey data and National Chicken Council, Marketing Practices Surveys, for various years.

brands; and birds of the highest quality for their own branded products.

Attempts to differentiate the branded products from competitors' products have included more expensive packaging, more appealing skin color through the use of feed ingredients, and advertising campaigns stressing the high quality of the product. Skin color does not in itself add to quality, but it does serve as an indicator of whether the bird was raised with a modern feeding technology that does deliver higher quality, and, thus, skin color became associated with quality characteristics. As additional producers adopted modern feeding practices, color was no longer a unique indicator. However, brand names had been established by then and carried a perception of higher quality.

Table 2-3: Bird size and amount slaughtered, 1960-98

	Liveweight per bird		Number of birds slaughtered		
Year	Broilers	Turkeys	Broilers	Mature hens	Turkeys
	Average pounds		*Million birds*		
1960	3.36	15.06	1,534	110	71
1963	3.47	16.13	1,835	129	82
1966	3.49	16.63	2,242	151	103
1969	3.60	17.84	2,516	154	95
1972	3.73	18.17	2,936	186	121
1975	3.76	17.75	2,922	176	119
1978	3.89	18.87	3,516	191	132
1981	4.01	19.07	4,076	202	166
1984	4.17	19.80	4,273	187	164
1987	4.29	20.31	4,971	198	231
1990	4.37	21.25	5,841	181	271
1992	4.51	21.71	6,425	177	281
1994	4.63	22.70	7,072	168	279
1996	4.78	23.65	7,546	154	292
1998	4.86	24.63	7,838	170	273

3. Concentration and Consolidation in Poultry Slaughter

Concentration in the poultry slaughter industry has increased over the years, but is not particularly high relative to other manufacturing industries. The top four firms control less than half of the final product market. More dramatic has been the growth in plant size. In 1972, plants with over 400 employees accounted for approximately a fourth of chicken and turkey output, but by 1992, the share controlled by these large plants had increased to over 80 percent. This shift to much larger plant sizes suggests that scale economies are important. Changes in industry concentration and plant size are documented in this chapter. Later, we empirically measure the extent of scale economies and assess their role in encouraging the growth of plant size.

Concentration

The four-firm concentration ratio measures the share of industry output held by the four largest producers and is widely used as a summary indicator of structural change.[3] Table 3-1 gives four-firm concentration ratios for chickens and turkeys based on the Longitudinal Research Database (LRD) plant-level data.

Industry categories are defined by the Standard Industrial Classification (SIC), a hierarchical coding for products and establishments in the economy. Establishments that primarily slaughter poultry and produce further-processed poultry products are assigned to the four-digit class "2015." In this report, plants with over 50 percent of their output from chicken slaughter products were assigned the five-digit code "20151," and those with over 50 percent of their output from turkey slaughter products were given "20153." Plants that produce only further-processed products, such as luncheon meats, frankfurters, and poultry hams, were assigned "20155."

Concentration in chicken slaughter rose sharply between 1977 and 1987, but remained constant thereafter. Similarly, turkey slaughter concentration increased substantially between 1963 and 1972 and then stabilized. Poultry processing concentration has varied over the 1963-92 period with no clear trend.

With concentration ratios below 50, neither chicken nor turkey slaughter nor poultry processing have particularly high concentration ratios relative to other manufacturing industries.[4] By contrast, MacDonald et al. (1999) report that the beef slaughter concentration ratio now exceeds 70 on a value of shipment basis and almost 80 for steers and heifers on an animal basis. Hog slaughter concentration is similar to chicken and turkey.

Economists often link differences in plant size and demand conditions to differences in concentration ratios. All four slaughter industries have shifted to larger plants, suggesting that four-firm concentration ratios should be similar across industries if there were no demand differences. However, consumption of chicken and turkey has been rising, and pork consumption has held steady since the 1970's, while per-capita beef consumption has declined by almost 30 percent from its peak in 1977 to 1999.

Heffernan et al. (1999) report higher concentration ratios for chicken (about 35 versus 42 percent in 1986 and 45 versus 41 percent in 1992) and lower concentration ratios for turkey (about 31 versus 38 percent in 1987 and 35 versus 45 percent in 1992) than those reported here. Heffernan et al.'s data come from surveys conducted by the National Chicken Council and *Turkey World* magazine. These surveys differ from Census surveys in that responses are voluntary for industry surveys and mandatory for Census, meaning that Census data include many more respondents. Additionally, Census data are based on the value of shipments, a measure that reflects both pounds of output and the price of that output, whereas Heffernan's data are based on pounds of ready-to-cook broilers and liveweight turkeys.

[3] There are many potential concentration measures. The four-firm ratio is commonly used and has been calculated by statistical agencies for several decades.

[4] The use of Census data results in some double-counting because it is based on the value of plant (establishment) shipments. For example, suppose that a firm operates a chicken slaughter plant and then ships whole birds to another of its own plants for cutting up and packaging. Assume that this second plant also packages birds slaughtered in its plant. At the firm level, the whole birds from the first plant are counted as one output and then counted again as another output when the second plant cuts them up and packages them.

Table 3-1: Four-firm concentration ratios in poultry slaughter and processing[1]

Census year	Chickens	Turkeys	Poultry processing
		Percent	
1963	14	23	52
1967	23	28	49
1972	18	41	35
1977	22	41	48
1982	32	40	37
1987	42	38	36
1992	41	45	46

[1] Values are based on total value of shipments.
Source: Longitudinal Research Database, U.S. Dept. of Commerce, Bureau of the Census.

Table 3-2: Share of industry value of shipments by large plants in poultry industry

Census year	Chickens	Turkeys	Poultry processing
		Percent	
1963	d	d	d
1967	29	16	d
1972	34	15	41
1977	45	29	51
1982	65	35	53
1987	76	64	65
1992	88	83	71

Cells labeled “d” contain data that cannot be disclosed, in order to retain respondent confidentiality. Large plants are defined as those with more than 400 employees.
Source: Longitudinal Research Database, U.S. Dept. of Commerce, Bureau of the Census.

Consolidation into Large Plants

Bugos (1992) links the adoption of the integrated production form to the near doubling of mean plant size and greater scale economies in chicken slaughter over the 1947-63 period. Under the integrated form, slaughter plants own the feed mills and provide chicks or poults, medicines, veterinary services, and other inputs to contract growers who return the birds to the plant after a grow-out period.

Bugos also indicates that by 1968, the basic automated slaughtering process had been established. In this process, live birds enter the plants; are slaughtered and cleaned; pass through an ice bath; are refrigerated and wrapped; and are either shipped or cut-up, deboned, or otherwise processed. The adoption of slaughtering innovations combined with the addition of cut-up, tray-pack, and further-processing operations increased slaughter plant line speeds and product complexity and led to continuous increases in plant size (see table 3-2, where the left-hand column contains the seven Census years beginning in 1963, while the interior cells indicate the share of industry output coming from plants with more than 400 employees).[5] From 1967 to 1992, the share of output held by plants with over 400 employees more than tripled in chicken slaughter and more than quintupled in turkey slaughter. The table also shows that the large-plant share of output almost doubled in poultry processing between 1972 and 1992.

Plant Entry and Exit

New technologies can come from within the industry through plant innovations or plant or firm expansions or from outside the industry through firm entrants. The LRD permits one to examine plant and firm entry and exit because each observation in the LRD includes plant and firm identification numbers.[6] These data characteristics allow us to (1) contrast plant entrants with plant acquisitions, and (2) compare the impacts of firm entrants and firm expansions.[7]

The 1967-92 period is characterized by high plant entry and acquisition rates, varying from about 10 to 30 percent of the total number of plants during each Census period (table 3-3). But these plant entrants did not survive for long. Between 60 and 70 percent of all plant entrants failed within two Census periods, perhaps because they were too small (table 3-4). A firm would buy a production plant only if it could be operated profitably, and, thus, would likely buy only plants

[5]The Census Bureau has for many years reported plant-level data on value of shipments by employment size (average number of employees over the course of a year). That measure is used here to maintain comparability. The 400-employee cut-off point for large plants is used in order to meet Census Bureau confidentiality requirements.

[6] Since these data codes do not vary from Census to Census and do not change with either name changes or business organization changes, plant or firm entry is known to have occurred if a plant or firm identification number appears in one Census but not in the preceding one. Existing plants and firms have identification codes in both the current and preceding Censuses.

[7] Plant entrants are new plants of new firms and new plants of existing firms. Plant acquisitions are existing plants bought by existing firms and existing plants bought by new firms. Firm entrants include those new firms that either buy existing plants or establish new plants. Firm expansions occur when existing firms buy existing plants or establish new plants.

Table 3-3: Number of entrant types in chicken and turkey slaughter and processing industries

Entrant type (initial stock)	1963	1967	1972	1977	1982	1987	1992
Entry plants							
New plants of new firms with less than 25 workers.	25	7	5	d	d	d	5
New plants of new firms with more than 24 workers	295	33	71	20	17	25	17
New plants of existing firms with more than 24 workers	—	12	12	20	7	17	37
New plants' share (%) of all plants	—	16.3	31.9	13.6	9.0	18.8	26
Acquired plants							
Number of existing plants with more than 24 workers bought by existing firms.	—	17	48	24	23	19	11
Number of existing plants with more than 24 workers bought by new firms	—	7	6	13	32	41	31
Plant acquisitions as a share (%) of all plants	—	7.5	19.6	12.6	20.7	26.9	18.5
New or existing plants of new firms							
New or existing plants of new firms with more than 24 workersa	—	47	82	33	49	66	48
New or existing plants of new firms as a share (%) of all plants	—	14.7	29.7	11.2	18.4	29.6	21.1
New or existing plants of existing firms							
New or existing plants of existing firms with more than 24 workers	—	29	60	44	30	36	48
New or existing plants of existing firms as a share (%) of all plants.	—	9.1	21.7	15.0	11.3	16.1	21.1
Total number of plants	320	276	294	266	223	227	270

Chicken industry refers to SIC 20151, turkey industry to SIC 20153, and poultry processing to SIC 20155.
Confidentiality concerns prevent disclosure of entries labeled "d."
Source: Authors' tabulations, using the Longitudinal Research Database (LRD) at the Center for Economic Studies, U.S. Dept. of Commerce, Bureau of the Census.

that had reached a size at which their production costs were about the same as those of their competitors (minimum efficient scale). Failed plants would be smaller since they may have underestimated minimum efficient scale.[8] Overall, the data indicate a dynamic industry in which there is considerable shifting of plant ownership, new plant construction, and firm entry.

Tables 3-3 to 3-5 contain several dimensions of entry in the poultry industry. Data are aggregated to the entire poultry industry level so as to avoid disclosure of confidential information. Only plants with 25 employees or more are examined in detail because confidentiality concerns prevent the disclosure of data for plants with fewer than 25 employees.

Table 3-3 shows how the number of plant and firm entrants varied for new and acquired plants and for new and existing firms over each Census period during the 1963-92 period. Interior cells show the number of new plants or firms from one Census period to the next. Looking at the first row under the left column headed "Entry plants," the table shows that there were only 7 new firms with new plants with fewer than 25 employees over the 1963-67 period, and only 5 over the 1967-72 period. Subsequent numbers of new plants could not be disclosed because of an insufficient number of observations. Of particular interest are sections showing new or existing plants of new firms and new or existing plants of existing firms. They show that the number of firm entrants was at least equal to the number of existing firm expansions (through either a new plant or an acquisition of an existing plant) in all Census years except 1977, suggesting a very fluid industry in which new firms continue to enter.

Plants survive from one period to the next if they continue to operate under the same ownership. Thus, exit refers to plants, not firms, and can occur due to plant closure, a change in product line to products outside of the industry, or sale. Closed facilities may be reopened under new owners, and, if that were to happen, would be reported later as a plant entry. Table 3-4 identifies

[8] This failure rate is not particularly high relative to other industries and is lower than that for cattle and hog slaughter, which had failure rates approaching 90 percent. The difference is likely due to demand changes.

the rate of failure for plants with 25 or more employees. Cells in the interior of the table show the percent of plants surviving from the Census year indicated in the second column to the Census year indicated in the top row. All diagonal terms are 100 because diagonal cells match identical years, e.g., the 1963 Census column intersects the horizontal 1963 Census line.

The second cell of the first data row indicates that about 48 percent of all 1963 plants survived under the same ownership until 1967, and the third cell indicates that about 29 percent survived until the 1972 Census. After 1967, about two out of every three plants failed in the first 5 years after entry, but then this rate of decline tailed off dramatically. Failure rates in the first 5 years are comparable to those that occurred in cattle and hogs, but the modest decline in poultry plant failure after the first 5-year period contrasts with continued sharp declines (failure rates of about one out of two plants) during the second 5-year period for cattle and hogs.

Table 3-5 is constructed like table 3-3 except that the interior cells indicate the market share of plants that entered the industry between Census years. For example, the first cell in the second interior row indicates

Table 3-4: Survival of cohort plants with more than 24 workers in chicken and turkey slaughter and processing plants

Cohort	1963	1967	1972	1977	1982	1987	1992
				Percent of plants surviving from entry year			
1963 (initial stock)	100	47.8	29.2	19.0	11.5	6.1	3.1
1967	0.00	100	18.2	d	d	d	d
1972	0.00	0.00	100	57.7	39.4	29.6	23.9
1977	0.00	0.00	0.00	100	35.0	30.0	d
1982	0.00	0.00	0.00	0.00	100	35.3	35.3
1987	0.00	0.00	0.00	0.00	0.00	100	28.0
1992	0.00	0.00	0.00	0.00	0.00	0.00	100

The chicken industry refers to five-digit SIC 20151, the turkey industry refers to SIC 20153, and the chicken processing industry refers to SIC 20155.
Entries labeled “d” represent shares that could not be disclosed due to confidentiality restrictions.
1963 plants include all plants in the sample.
Source: Authors’ tabulations, using the Longitudinal Research Database (LRD) at the Center for Economic Studies, U.S. Dept. of Commerce, Bureau of the Census.

Table 3-5: Market share of new plants with over 24 workers in chicken and turkey slaughter and processing industries

Plant type	1967	1972	1977	1982	1987	1992
			Market share of plant entrants			
New plant of new firm	8.5	24.2	3.3	3.1	5.5	1.7
New plant of existing firm	d	d	6.8	d	3.6	13.7
New plant market share[1]	8.5	24.2	10.1	3.1	9.1	15.4
			Market share of acquired plants			
Existing plant bought by existing firm	10.1	24.5	9.8	8.5	6.8	d
Existing plant bought by new firm	d	d	5.7	13.7	18.8	9.1
Total plant acquisitions	10.1	24.5	15.5	22.2	25.6	9.1
			Market share of new or existing plants of new firms			
New or existing plants bought by new firms[1]	8.5	24.2	9.0	16.8	24.3	10.8
			Market share of new or existing plants of existing firms			
New or existing plants bought by existing firms[1]	10.1	24.5	16.6	8.5	10.4	13.7

Chicken industry refers to five digit SIC 20151, turkey industry refers to SIC 20153, and poultry processing industry refers to SIC 20155.
[1]Does not include entries labeled “d.”
Source: Authors’ tabulations, using the Longitudinal Research Database (LRD) at the Center for Economic Studies, U.S. Dept. of Commerce, Bureau of the Census.

that new plants of new firms over 1963-67 had an 8.5-percent market share in 1967. Notice that, like cattle and hogs, the market share of plant acquisitions generally exceeded the relatively small market share of plant entrants. Since there was no apparent change in market share, it appears that the basic location and facilities of existing plants were compatible with low-cost production. We explore geographic shifts and changes in production outputs and inputs in more detail in the next chapter.

Conclusion

The shift to large plant size in chicken and turkey slaughter industries over the 1967-92 period was accompanied by an increase in industry concentration that was much more moderate than that reported by MacDonald et al. (1999) for cattle slaughter. Additionally, with plant and firm entry rates exceeding those for cattle and hog slaughter, the poultry industry appears to be more open and entrants able to survive longer than in cattle and hog slaughter (see Ollinger et al., 1996). Most likely, the relatively high share of output produced by large plants in the presence of relatively low industry concentration and the relatively high entry and survival rates stem from increases in demand. Over the 1977-99 period, per capita poultry consumption doubled, while per capita beef consumption dropped about 30 percent.

4. Structural Change: Plant Operations and Locations

Many factors contributed to the growth in poultry plant size over the 1963-92 period. Bugos, Lasley et al., and others cite historical evidence that poultry contracting led to the production of high-quality, uniform-size chickens that could be processed into chicken traypacks, whole broilers, and cut-up and deboned poultry at high rates.

Higher quality birds, combined with a shift in consumer tastes favoring greater poultry consumption, led to a host of new products, ranging from chicken nuggets to chicken traypacks and deboned chicken. Production of the new raw products generally took place in slaughter plants, which added cut-up and processing lines to the end of existing slaughter lines. Further-processed products, e.g., poultry sausages, luncheon meats, and other cooked or otherwise processed raw poultry, were sometimes produced in slaughter plants, particularly for turkeys, but were usually produced in independent plants that received raw poultry from slaughter facilities.

Traditionally, turkey plants faced highly seasonal demand with most production occurring in the last quarter of the year. The shift in consumer tastes toward greater year-round turkey consumption, however, permitted turkey plants to stabilize production, and, thus, avoid production cutbacks and expansions. Generally, stabilizing production rates would be expected to lower production costs because plants would be able to avoid the costs of hiring, training, and laying off employees and starting up and shutting down facilities.

Competitive forces required poultry plants to seek locations that had access to low-cost grain and had optimum climatic conditions, the key inputs to raising poultry, because live-bird inputs comprise the biggest production cost for poultry producers. For chicken production, the low-cost region turned out to be the Southeastern States, where grain costs were relatively low and environmental conditions were ideal. For turkey production, the low-cost regions were the North and South Central States.

In this chapter, we discuss grower contracts, detail the shifts in input and product mixes, investigate the seasonality of turkey production, examine geographic production areas, and consider worker wages. The impact of changes in input and product mixes and production seasonality on plant costs is assessed in later chapters.

Grower Contracts

Bugos et al. argue that the development of specialized poultry breeds and improved feeds, veterinary services, and medicines after World War II greatly reduced the costs of raising chickens and led to the growing of chickens under contract in large confined chicken houses. During the 1950's and early 1960's, it was mainly the feed dealers, seeking to increase the volume of their business, who encouraged contracting. They used contracts to extend credit to growers who suffered financial losses after a bad production batch. Eventually, contracting came to dominate the broiler sector, but under a slightly different framework.

Low-cost chicken production requires a large supply of uniform-size birds. These requirements for birds could be met by the large automated chicken-growing facilities coming on stream in the late 1950's and early 1960's only if growers increased capital investments; incurred substantial short-term financing costs for feed, medicines, chicks, poults, and other inputs; and refined their management skills. Under these high-risk conditions in which a bad batch could easily bankrupt a chicken farmer, growers could be reluctant to undertake chicken farming in the absence of coordinated relationships and cause insufficient chicken supplies for slaughter plants.

In the vertical coordination framework of poultry contracting, integrators accept much of the risk of poultry growing in exchange for greater control over both the quality and quantity of the birds. The usual terms of the contract are such that the integrator provides growers with chick or poult hatchlings and feed from integrator-owned hatcheries and feed mills, and veterinary services, medication, part of the fuel, some litter, and field supervisors to monitor operations. Ownership of the breeding stock, chicks and poults, and most other inputs enables an integrator to develop poultry breeds specifically to meet its market needs and to better control bird production quantities, quality, and costs. The contract grower provides housing, equipment, labor, water, and all or part of the fuel and litter.

Integrators establish contracts with numerous growers, usually located within 20 miles of the plant, who raise the birds until ready for shipment. Integrators control their poultry supply either by increasing or decreasing the number of chicks or poults they place for "grow-out." They may also drop growers in the event of a market downturn. Growers located the farthest from either the slaughter plant or the feed mill face the greatest possibility of being dropped because of higher transportation costs to or from the manufacturing plant.

In their contractual relationship with growers, integrators usually agree to pay a pre-established fee per pound for live broilers plus a bonus or penalty for performance relative to other growers. This performance bonus is based on the difference between the actual grower settlement cost and the average settlement costs of all growers harvesting their flocks at that time. The total grower payment is a function of the number of chicks placed at a grower, kilocalories per unit of feed provided, and the live pounds at harvest, and is determined mainly by the feed-conversion ratio and losses due to disease or environmental conditions.

Knoeber and Thurman (1996) reason that growers make major investments in poultry housing and other facilities, with little ability to either diversify or control all outcomes, thereby exposing themselves to: exogenous risks from increases in broiler and feed prices, adverse weather, and other factors; chicken management risks arising from grower decisionmaking; and supply and demand risks due to consumer market turns. Integrators, on the other hand, are owned by investors who are able to reduce their risk by holding a diversified portfolio of investments. These different capacities to mitigate risk provide the opportunity for a contractual relationship in which the party best able to bear a type of risk accepts it.

Using well-accepted economic theory, Knoeber and Thurman argue that integrators take on broiler and feed price risks by designing contracts in which only chicken yields and not broiler and feed prices matter in the calculation of the grower bonus, suggesting that the variable part of grower payments depends only on production outcomes and not on input and output prices. Additionally, integrators bear common uncontrollable (exogenous) production risks, such as weather, by basing grower payments on chicken yields relative to other growers.[9] Chicken growers, on the other hand, bear production risks arising from their own discretionary management decisions. The integrator bears all of the risks of a short-term price change affecting feed and broiler prices. Supply and demand risks are borne by both the integrator and the grower. The integrator risks reduced output, and the grower bears the risk of not having his contract renewed.

Knoeber (1989) uses economic theory to assert that grower contracts may be a superior organization form over spot-market purchases because there are very few growers and very few integrators, giving rise to a lot of uncertainty over the supply and demand of live chickens. Williamson (1983) argues that, under these conditions, contracts are needed to reduce the threat of either a lost market for live chickens for the grower or an insufficient supply of live chickens for the integrator. The contract, however, could be either with integrator-employees on integrator-operated farms, i.e., a single plant with plant-owned farms, or with nonemployee contractors.

Williamson (1983) asserts that rapid productivity changes and the potential effect of exogenous shocks, such as temperature changes, lead to a high degree of outcome uncertainty, suggesting that company-owned farms would dominate production. However, the grower-contract form dominates in the chicken industry.

Knoeber (1989) explains that contracts that require the grower to provide costly housing strongly discourage poor performance by creating a bond with the integrator in which there is a self-selection of high-quality growers, i.e., only a grower who is confident of growing chickens profitably will incur the necessary capital costs. For the grower, integrator compliance with the contract is ensured because cheating any single grower leads to higher bonus payments to other growers and no greater remuneration to the integrator.[10] Additionally, since all growers are compensated with the same formula, the integrator must offer all growers the contract terms demanded by the highest cost grower in order to obtain sufficient bird inputs.[11]

[9] Presumably, regional disease outbreaks and temperatures affect growers similarly, suggesting that weight gains (losses) due to these factors should be similar for all growers and thus would not be considered in the bonus payment.

[10] A lower payment to one grower in a tournament in which growers compete for the same pool of money regardless of payment to any single grower means that other growers receive higher payments than they would otherwise obtain.

[11] Contracts with consistently poor-performing growers, like a poorly performing employee, would likely be terminated. However, contract termination for arbitrary reasons appears unlikely because such measures would discourage new growers from making an investment in bird-growing facilities unless the contract terms offered ample payments for arbitrary integrator decisions. Since the same contract would have to be offered to all growers, arbitrary terminations would likely lead to higher bird-contracting costs for the integrator.

Table 4-1 Grower-contract production dwarfs integrator-owned production in chicken, but not in turkey, slaughter[1]

	Coordinated chicken				Coordinated turkey			
Year	Integrator-owned	Grower-contract production	Grower-contract marketing	Total	Integrator owned	Grower-contract production	Grower-contract marketing	Total
	Percent							
1955	2.0	87.0	1.0	90.0	4.0	21.0	11.0	36.0
1960	5.0	90.0	1.0	96.0	4.0	30.0	16.0	50.0
1965	5.5	90.0	1.5	97.0	8.0	35.0	13.0	56.0
1970	7.0	90.0	2.0	99.0	13.0	42.0	18.0	73.0
1975	8.0	90.0	1.0	99.0	20.0	47.0	14.0	81.0
1977	10.0	88.0	1.0	99.0	28.0	52.0	10.0	90.0
1980	n.a.	n.a.	n.a.	n.a.	28.0	52.0	10.0	90.0
1982	12.0	87.0	0.0	99.0	28.0	54.0	8.0	90.0
1990	n.a.	n.a.	n.a.	n.a.	28.0	55.0	5.0	88.0
1994	14.0	85.0	0.0	99.0	32.0	56.0	5.0	93.0

n.a. = not available.
[1]Integrator-owned is poultry that is raised by the integrator. Production contracts are contracts in which the integrator provides the chicks or poults, feed, etc. to the grower who owns the building and manages the flock during their grow-out period. Marketing contracts are agreements in which a grower agrees to sell an entire batch of live birds to a slaughter plant. The grower provides his (or her) own chicks or poults, feed, and other inputs.
Source: George B. Rogers, "Poultry and Eggs," in *Another Revolution in U.S. Farming?* Ed. by Lyle P. Schertz, ERS, USDA, AER-441, 1979; Manchester (1999).

Turkey slaughter plants also developed integrated supply networks, but not to the same extent as chicken slaughter plants. Table 4-1 illustrates the degree to which contract production and owner-integrated production co-exist in the United States. The interior cells show that 14 percent of chickens and 32 percent of turkeys were grown on integrator-owned farms in 1994.

Table 4-1 also shows that, as early as 1955, about 90 percent of all chickens were purchased under grower contracts, but that only about one-fifth of turkeys were purchased in this fashion, and that grower contracting in turkey production more than doubled between 1955 and 1977.[12] Knoeber (1989) attributes differences in the extent of contracting for chickens and turkeys to the number of growers participating in compensation tournaments. He suggests that turkey production requires fewer growers, making a compensation scheme based on performance relative to average production less workable. Unfortunately, data limitations prevent us from exploring this hypothesis.

[12] Alden Manchester (personal communication) points out that contract production can occur in which there are very few growers. For example, a *Turkey World* magazine article points out that two growers supply all the turkeys to an integrator in South Carolina.

Input and Product Mix

Increased line speeds permitted huge increases in average plant size for both chicken and turkey integrators, but required millions of uniform-size birds. Since the integrated form of production and automated slaughter systems were well established by the 1960's (Bugos et al.), there were only modest changes in the composition of bird inputs, i.e., live chickens versus live turkeys or unprocessed chicken meat, after 1967 (table 4-2).

In contrast to bird inputs, poultry output changed dramatically after 1960 as poultry consumption soared and product type shifted from primarily whole birds to poultry traypacks, semi-prepared chicken parts for use in restaurants, chicken nuggets and patties, and other poultry products. These demand changes led to a major shift in plant product mix, with processed chicken output (chickens in Styrofoam traypacks and further-processed products) as a share of total output more than doubling (table 4-3) and cut-up and deboned chicken as a share of total chicken output climbing by 300 percent (table 2-2) over the 1967-92 period. Over the same period, further-processed turkey products as a share of output more than doubled (table 4-3) and cut-up and deboned turkey as a share of total output rose by 700 percent (table 2-2).

Large chicken slaughter plants produced about six times as many consumer traypacks as a share of output than did their middle-size competitors in 1972 and about three times as much in 1992 (table 4-4), suggesting that there may be economies-of-scope in traypack production.[13] We further examine this issue in chapter 6. Table 4-4 also indicates that traypacks as a share of chicken production dropped in large plants but that the average volume of traypacks per plant rose.

[13]Economies of scope are said to exist when a plant produces two or more products at a lower cost than if those products were produced separately in single-product plants.

Table 4-2: Both chicken and turkey slaughter plants specialize in one primary bird species

Census year	Liveweight chicken inputs in chicken industry	Liveweight turkey inputs in turkey industry
	Percent of pounds of total meat inputs	
1967	83.0	93.8
1972	96.5	97.6
1977	95.7	97.2
1982	99.6	98.7
1987	99.9	99.9
1992	99.0	100.0

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

Presumably, bulk cut-up and deboned chicken as a share of chicken output rose as chicken traypacks declined because of increased exports to Russia and a surge in shipments to plants that produce ground chicken, nuggets, and other processed chicken.

Like the large chicken slaughter plants, large turkey slaughter plants produced substantially more further-processed products than their smaller competitors (table 4-5). One plausible explanation is a desire to fill excess capacity with nonseasonal products. The increase in turkey parts and further-processed turkey occurred in both large and medium-size plants and mirrored a shift in consumer demand.

Seasonality

A major production problem for turkey slaughter plants prior to the 1970's arose from the seasonality of demand due to the much higher consumption during the end-of-the-year holiday season than during other parts of the year. Since turkey is a perishable product, seasonality of demand means that production also has to be seasonal, which would require excess plant and grower capacity during much of the year. This excess capacity normally implies higher production costs and should encourage plants to try to balance production

Turkey industry marketing programs led to the introduction of turkey traypacks and luncheon meats and other further-processed products. This, combined with

Table 4-3: Slaughter plant product mix requires fewer whole birds as it becomes more complex

Product mix	1963	1967	1972	1977	1982	1987	1992	1997
				Percent of total slaughter production				
Poultry in Styrofoam traypacks								
Chicken	n.a.	n.a.	13.9	15.8	20.5	24.2	21.9	24.3
Sausage, lunch meat, and other further-processed products (from cut-up, deboned, or whole birds)								
Chicken	n.a.	n.a.	2.7	2.1	5.1	6.5	9.6	11.4
Turkey	n.a.	n.a.	10.4	14.6	19.3	16.2	22.2	20.6
Bulk domestic: Cut-up, deboned, and whole birds in large containers								
Chicken	97.4	98.9	82.3	78.7	69.9	64.6	60.8	46.0
Turkey	97.7	97.4	87.7	82.7	78.7	82.9	73.6	68.2
Bulk export: Cut-up, deboned, and whole birds in large containers								
Chicken	2.6	1.1	1.1	3.4	4.5	4.7	7.1	18.3
Turkey	2.3	2.6	1.9	2.7	2.0	0.9	4.2	11.2

n.a. = not available.
Sources: U.S. Dept. of Commerce, Bureau of the Census, Longitudinal Research Data Base, 1963-97; U.S. Dept of Agriculture, Economic Research Service, *United States Egg and Poultry Statistical Series, 1960-90,* 1991; National Turkey Federation and the National Chicken Council for 1992 and 1997 raw bird processing data.

increased poultry consumption due to health concerns and declining prices, enabled turkey producers to reduce production seasonality. Table 4-6 illustrates these changes for four major animal slaughter industries. Using a ratio of production workers in the first quarter to production workers in the last quarter of each year from 1963-92 as a measure of seasonality, the table shows that production schedules were approximately in balance for cattle, hogs, chickens, and poultry processing. There was a sharp change in seasonality for turkeys, however, rising from 0.38 in 1963 to almost completely in balance in 1992.

Lasley et al. (1983) assert that the shift to a more balanced production schedule required very little expansion of existing facilities and resulted in higher annual capacity utilization rates. Greater in-plant processing, however, required plants to either add cut-up and processing operations to the end of existing production lines or build entirely new processing facilities. As we later see, turkey slaughter plants chose both options.

In terms of production costs, higher capacity utilization means that greater output can be produced with existing equipment. Additionally, the integrated poultry system relies on a continuous flow of young turkeys for lowest cost production, meaning that if growers have excess capacity for much of the year, they would likely demand a premium price for stopping and starting their growing operations. Similarly, workers would likely demand a wage premium as compensation for working only on a temporary basis. As a result, for turkey slaughter plants, poultry meat input costs and labor costs should decline as production schedules become more balanced. We investigate costs associated with turkey seasonality in chapter 7.

Plant Location

Prior to World War II, the Delmarva Peninsula (Delaware, Maryland, and Virginia) chicken growers dominated the northeastern broiler market and produced a majority of the chickens raised in the United States. During World War II, however, the Government required Delmarva growers to sell their output to military bases near Washington, DC, leaving the northeastern market open to other producers. Southern firms filled the market void and retained their market position thereafter.

Structural changes in the poultry industry, combined with increasing consumer demand for poultry products,

Table 4-4: Chicken traypack production in the chicken Industry, 1972-92

Year	Output share and mean production of chicken traypacks					
	Large plants (400 or more employees)		Medium plants (100-399 employees)		Small plants (up to 99 employees)	
	Percent of output	*Mean lbs (millions)*	*Percent of output*	*Mean lbs (millions)*	*Percent of output*	*Mean lbs. (millions)*
1972	30.4	20.9	5.4	1.9	11.2	0.9
1982	26.5	32.2	5.2	2.7	10.8	1.4
1992	20.5	33.2	7.1	3.7	N.A.	N.A.

N.A. = not available.
Source: Longitudinal Research Database, U.S. Dept. of Commerce, Census Bureau.

Table 4-5: Turkey parts and processed poultry production in turkey industry, 1982 and 1992

Year	Mean production and output share of turkey parts and processed poultry					
	Large plants (400 or more employees)		Medium plants (100-399 employees)		Small plants (up to 99 employees)	
	Percent of output	*Mean lbs (millions)*	*Percent of output*	*Mean lbs (millions)*	*Percent of output*	*Mean lbs. (millions)*
1982	37.3	31.0	26.1	9.1	d	d
1992	58.5	87.4	28.5	16.3	d	d

“d” means that data could not be disclosed due to confidentiality concerns.
Source: Longitudinal Research Database, U.S. Dept. of Commerce, Census Bureau.

brought further concentration of chicken production in the Southeast and turkey production to the Middle South States (tables 4-7, 4-8, and 4-9). Note that slightly different regional definitions are used in each table.

The increase in chicken production in the Southeast from 55.7 percent of total U.S. production in 1963 to 65.4 percent in 1992 (table 4-7) came mainly at the expense of the category called Rest of the U.S. More dramatic than this regional shift is the change in the number of counties in which chickens are raised commercially. McBride (1997) found that the number of counties with farms that sold broilers declined by about 45 percent over the 1969-92 period and that the mean number of chickens per farm more than tripled to 237,000 head. He also found that 50 percent of broiler production came from 51 counties in 1992 versus only 37 in 1969.

Lasley et al. (1988) attribute locational changes to differences in feed costs, indicating that feed costs per pound of chicken produced were almost the same in 1972 in the Southern, Northeastern, and West Coast States, but that, by the early 1980's, the Southern States had $0.05 per-pound lower costs than the other regions. Despite this cost difference, close proximity to the large consumer markets in the Northeast for central Atlantic chicken producers and the west coast for southwestern chicken producers encouraged continued production in those regions.

Table 4-6: Seasonality differs substantially only for turkey slaughter plants prior to 1987

Year	Cattle slaughter	Hog slaughter	Chicken slaughter	Turkey slaughter	Poultry processing
			Ratio		
1963	.98	1.00	.94	.38	N.A.
1967	.99	1.00	.97	.45	N.A.
1972	.97	.98	.92	.50	.89
1977	.97	.98	.96	.53	.89
1982	1.02	1.01	1.00	.79	.91
1987	.92	.96	.96	.92	.96
1992	.96	.94	.90	.97	.95

Table units are ratio of production workers during the first quarter of the year (Jan.-March) to production workers during the last quarter of the year (Oct.-Dec.).
Source: Longitudinal Research Database, U.S. Dept. of Commerce, Bureau of the Census.

Table 4-7: Most chicken slaughter products are produced in the Southeast

Year	Southeast	Central Atlantic	Southwest	Rest of U.S.
	Market share of chicken slaughter industry on pounds of output basis			
1963	55.7	14.9	10.0	19.4
1967	55.8	14.7	8.4	21.1
1972	59.9	11.6	8.5	20.0
1977	62.8	14.7	10.5	12.0
1982	62.1	16.4	13.3	8.2
1987	68.2	15.6	9.8	6.4
1992	65.4	15.1	10.8	8.7

Notes: The Southeast includes AL, AR, GA, FL, LA, MS, NC, SC, TN; Central Atlantic includes DC, DE, MD, VA, and WV; Southwest includes TX, OK, AZ, NM, and CA; and, Rest of U.S. is all other States.
Source: Longitudinal Research Database, U.S. Dept. of Commerce, Bureau of the Census.

Table 4-8: Most turkey slaughter output is concentrated in the Middle South States

Year	Middle South	North Central	Rest of U.S.
	Market share of turkey slaughter industry pounds output		
1963	16.3	46.1	37.6
1967	31.0	33.2	35.8
1972	31.1	38.2	30.7
1977	36.6	40.5	22.9
1982	41.4	34.7	23.9
1987	51.1	31.1	17.8
1992	51.9	33.4	14.7

Notes: The Middle South includes AR, GA, MO, NC, SC, TN, and VA; North Central includes IL, IN, IA, MI, MN, ND, NE, OH, SD, and WI; and, Rest of U.S. includes all other States.
Source: Longitudinal Research Database, U.S. Dept. of Commerce, Bureau of the Census.

Table 4-9: Further-processed poultry output in the chicken and turkey slaughter regions

Year	Southeast	North Central	Rest of U.S.
	Market share of pounds of further-processed poultry output		
1972	25.3	49.3	25.4
1977	31.5	37.1	31.4
1982	37.9	35.4	26.7
1987	38.9	30.9	30.2
1992	43.7	30.8	25.5

Notes: The Southeast includes AL, AR, GA, FL, LA, MS, NC, SC, TN, and VA; North Central includes IL, IN, IA, MI, MN, ND, NE, OH, SD, and WI; and, Rest of U.S. includes all other States.
Source: Longitudinal Research Database, U.S. Dept. of Commerce, Census Bureau.

The South Central States' share of slaughtered turkeys doubled from 1963 to 1967, and then rose by another two-thirds from 1967 to 1992. The North Central region's market share, after losing almost 13 percent between 1963 and 1967, has held steady since then, while market share in the rest of the country continuously dropped and now accounts for only 15 percent. Lasley, Henson, and Jones (1983) suggest that lower heating and ventilation costs and the proximity to the grain-producing areas give South Central States an edge in turkey production over the States outside of the North Central region. The North Central region has even lower feed costs than South Central States, but higher environmental control expenditures.[14]

Further-processing firms located their plants near the main poultry-growing regions of the Southeast and Middle South (chickens and turkeys) and North Central (turkeys) regions. Most of the change over the 1972-92 period came as the Southeast / Middle South regions increased their market share to over two-fifths of total output. This gain came at the expense of the North Central Region, which dropped from about one-half to three-tenths of total processed poultry production. Further processing in the rest of the country remained fairly constant. Although precise cost differentials are not available, proximity to slaughter plants and, perhaps, lower labor costs likely contributed to poultry processor locational choice.

The shift to greater regional concentration in poultry production matches what occurred in cattle and hog slaughter. MacDonald et al. indicate that beef production in the 15 largest cattle slaughter States rose from about 68 percent of the U.S. total to 85 percent between 1963 and 1992, while hog production in the 12 largest hog slaughter States increased from about 64 to 75 percent.

[14]Death due to heat stress is a major temperature-related cost of turkey production and is much more likely to occur in the South than in the North Central region. Chickens, by contrast, thrive in the warmer climates of the South. Thus, North Central poultry growers can compete much more effectively against South Central poultry growers in turkeys than in chickens.

Wages

Using mainly nonunion labor in rural areas, poultry producers have been able to compensate workers with far lower wages than red meat producers pay. Table 4-10 shows average wages per production worker (wages) by year and plant size for both red meat and poultry producers.

Table 4-10: Average hourly wages in meatpacking, by year, industry, and plant size

Industry code and number of employees	1967	1972	1977	1982	1987	1992
			Payroll per production-worker-hour ($)			
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
Consumer Price Index	1.00	1.25	1.82	2.89	3.40	4.20

Wages are production worker payroll divided by production worker hours.
Red meat producers are mainly cattle and hog slaughter plants. Poultry producers are mainly chicken and turkey slaughter and processed-poultry producers.
Source: Census of Manufactures, Industry Series, for relevant years.

Wage differentials were most striking over the 1967-77 period when wages in red meat were almost twice as high as those in poultry. After 1977, the wage gap began to narrow, largely because of a faster rate of increase in poultry wages. For example, from 1977-92, average poultry industry nominal wages more than doubled, but red meat nominal wages rose by only about 28 percent overall and declined by about 5 percent after 1982. Adjusted for consumer prices, real poultry wages have remained almost constant over the 1967-92 period, while beef slaughter wages have plummeted.[15] Notice also that the wages paid to workers in the largest red meat plants were much higher than in small plants until 1992, when there was almost no difference. Wages between large and small poultry plants have been about the same.

[15] The Consumer Price Index is widely considered to overstate inflation; thus, real wages likely declined much more modestly in red meat slaughter and not at all in poultry.

5. Analyzing Poultry Slaughter Plant Costs: The Model

Production by large chicken and turkey slaughter plants as a share of total output sharply increased while the number of plants with fewer than 100 employees dropped to almost zero between 1967 and 1992. Over the same time period, plant product mix shifted from whole-bird products to traypacks, cut-up and deboned products, and frankfurters, luncheon meats, and other further-processed products. Greater plant size and additional plant processing likely affected factor demand because greater size and additional processing require more bird and labor inputs. Econometrically, changes in factor demand imply that cost analyses must take product mix into account.

Price changes for liveweight bird and unprocessed poultry (poultry input meat) can affect estimated scale economies and the demand for labor and other factors of production through substitution effects. If poultry input meat prices are a small share of total plant costs, then substitution effects would have a small impact on plant costs. Census data reveal, however, that the cost of live birds dominates production expenses, so cost analyses must distinguish between poultry meat input prices and other factor prices. Note that poultry meat input prices include the costs of feed, medicine, chicks and poults, grower payments, etc., regardless of whether birds are purchased from an independent grower or come from a contractor.

A Functional Form for Cost Estimation

The translog cost function used in this report includes variables for factor prices, plant size, poultry meat input mix, bulk output share, time shifts, seasonality, whole-bird output share, and type of plant (single or multi-establishment firm). This cost function model is both flexible and general, and (a) estimates the effect of plant size on costs; (b) controls for differences in share of primary input meat (chicken or turkeys) and product mix; (c) identifies the effect of factor prices on cost, and allows those effects to vary with plant size; (d) evaluates the importance of production seasonality; and (e) permits technological shifts over time. A second-order, four-factor, longrun cost function is defined as follows:

$$\begin{aligned}
\operatorname{Ln} C = {} & \alpha_0 + \sum_i B_i \ln P_i + \frac{1}{2}\sum_i \sum_j B_{ij} \ln P_i P_j \\
& + \gamma_Q \ln Q_Q + \frac{1}{2}\gamma_{QQ}(\ln Q)^2 + \sum_i \gamma_{Qi} \ln Q \ln P_i \\
& + \sum_k \delta_k \ln Z_k + \sum_i \sum_k \delta_{ik} \ln Z_k \ln P_i \\
& + \sum_k \delta_{Qk} Z_k \ln Q + \sum_k \sum_l \delta_{kl} \ln Z_k \ln Q \\
& + \sum_m \rho_m T_m + \sum_i \sum_m \rho_{im} T_m \ln P_i \\
& + \sum_m \rho_{Qm} T_m \ln Q + \sum_k \sum_m \rho_{mk} T_m Z_k + \xi
\end{aligned} \tag{5.1}$$

where C is total costs, P is factor prices, Q is output, Z is a vector of plant characteristics, T represents dummy variables for each Census year (with 1992 and the base), and ln is the logarithmic operator.

The translog cost function is flexible in that it allows for a variety of possible production relationships, including returns to scale, optimal factor shares that vary with the level of output (nonhomotheticity), and nonconstant elasticities of factor demand. The cost function can be estimated directly, but parameter estimates are often inefficient because of multicollinearity among explanatory variables. Gains in efficiency can be realized by estimating the factor demand equations (cost-share equations) jointly with the cost function. The equations are obtained from the derivatives of the total cost function with respect to each price (equation 5.2).

$$\begin{aligned}
\frac{\partial \ln C}{\partial \ln P_i} = \frac{P_i X_i}{C} = {} & \mathrm{B}_i + \sum_j \mathrm{B}_{ij} \ln P_j + \gamma_{Qi} \ln Q \\
& + \sum_k \delta_{ik} \ln Z_k + \sum_m \rho_{im} T_m
\end{aligned} \tag{5.2}$$

All variables are normalized (i.e., divided by their mean values before estimation); thus, the first-order terms (the β_is) can be interpreted as the estimated cost-share of factor i at mean values. The other coefficients capture changes in the estimated factor shares with changes in other prices, plant output, and other model components. Price elasticities of factor demand can be derived from the coefficients and variables in the share equations.

Cost-function symmetry and homogeneity of degree one can be imposed in order to gain improvements in efficiency (Berndt, 1991). Symmetry means that the coefficients on all interaction terms with identical components are equal (that is, the coefficients $\beta_{ij} = \beta_{ji}$, $\delta_{ki} = \delta_{ik}$, $\rho_{im} = \rho_{mi}$, and $\rho_{km} = \rho_{mk}$ for all i, j, k, and m). The omitted variables are not reported because they are implied. Homogeneity of degree one means that if all factors are doubled, then output would also double. This characteristic means that the number of parameters that must be estimated would be reduced because some parameters can be derived from combinations of others. It requires the following:

$$\sum B_i = 0, \sum B_{ij} = \sum B_{ji} = \sum \gamma_{Qi} = \sum \delta_{ik} = \sum \rho_{im} = 0 \tag{5.3}$$

Measuring Output

Bugos reports a rapid convergence toward use of the integrator organizational form of contracting poultry growing, and almost complete industry convergence by 1967. Other sources reveal a shift in product output mix from whole birds to cut-up and deboned poultry packed in bulk containers, traypacks, and further-processed products (table 4-6); more homogeneous poultry meat input mix, i.e., liveweight of single-species birds versus multiple-species birds and unprocessed poultry meat inputs (table 4-2); and less production seasonality in turkeys (table 4-6).

New plants were sometimes built to accommodate broader product lines and faster line speeds, but usually cut-up and deboning, packaging, and, to a lesser degree, further-processing operations were added to existing whole-bird production lines, raising both the cost and value of a single pound of poultry output. These changes are accounted for by including the following variables as plant characteristics (the Z vector in equation 1): bulk output share (BULK), whole-bird output share (WHOLE), poultry meat input mix (BIRD), seasonality of production (SEASON), and single-plant firm status (MULTI).

The failure to account for product mix variables in a cost model leads to a specification error and inaccurate cost estimates. Suppose two plants slaughter the same number of chickens, but one produces traypacks and the other produces whole birds. Both plants will have the same physical quantity of output, and, using the estimated coefficients from a regression not controlling for differences in product mix, will have the same predicted costs. Yet, the traypack plant will hire more workers, carry a larger investment in structures and equipment, use more energy and materials, and, in general, have higher costs than the whole-bird plant because it will conduct more processing per pound of chicken.

Cost-function analysis provides a framework for accommodating differences in product mix by extending the cost function to the multiproduct framework (Baumol, Panzar, and Willig, 1982). In this framework, Q in the cost function is converted to a vector, with pounds of each output represented separately.[16] But since many plants produce zero amounts of some outputs, and logs are undefined at zero, the translog functional form cannot directly be adapted to a multiproduct poultry slaughter model.

Instead, the approach taken is one commonly used in the extensive literature on cost-function estimation 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 for trucking (Allen and Liu, 1995), for airlines (Baltagi, Griffin, and Rich, 1995), and for railroads (Caves, Christensen, Tretheway, and Windle, 1985). But the simple measures can be produced in a variety of ways; for example, costs incurred in producing the same simple output can vary if the transport network goes to many different locations (as opposed to operating only a few through routes) or if the output is shipped 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.

Two product-mix variables are included in the model: bulk output share and whole-bird output share. The use of these variables depended on data availability. Census data contain several broad product classes for each chicken slaughter plant, including wet- and dry-ice broilers and cut-up parts packed in bulk containers, chicken traypacks, other broilers and old hens, roasters and capons, frankfurters and other further-processed products, and nonclassified items. Turkey slaughter

[16] 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.

categories include roaster birds, whole young birds, whole old birds and turkey parts packed in bulk containers, further-processed products, and nonclassified items. Using these data, we defined bulk output share as one minus the combined shares of traypack and further-processed poultry shipments for chicken slaughter and one minus the share of further-processed poultry products for turkey slaughter. These measures were never zero because traypacks and further-processed poultry as shares of total output were never one and thus were always defined (there were no logs of zero). Since the residual of cut-up and deboned poultry and whole birds packed in wet or dry ice in bulk containers divided by total output (bulk output share) requires fewer inputs than traypacks and further-processed products, total costs should drop as bulk output share increases.

Census data do not distinguish between cut-up and deboned poultry (parts) and whole birds packed in bulk containers; yet there was a sharp increase in parts production at chicken slaughter plants over the 1963-92 period (table 2-2), and most of these parts were shipped in bulk to other countries as exports, to retailers and wholesalers for repackaging, or to further-processors for the production of poultry hams, sausages, etc. Since parts production is a more labor-intensive operation than simple whole-bird production, plant costs would likely be biased upward without controlling for it; thus, publicly available annual poultry parts data were used to construct a variable defined as one minus parts share of output.[17] The residual, mainly whole birds, is indistinguishable between plants; thus, two plants are assigned the same whole-bird share if they exist in the same year even if one plant produces almost no parts and the other plant produces almost all parts. Despite this shortcoming, whole-bird share does accommodate the temporal changes in product mix toward greater poultry parts production.

The final regression excludes the quadratic whole-bird share term because it does not vary across plants. The final regression also excludes the interaction of whole-bird share with bulk output share and poultry meat input mix terms because these variables had no effect on model fit.

Several other product mix variables that could either replace or supplement bulk output share were tried. These included one minus byproducts; one minus broiler parts and whole birds packed in wet or dry ice; and, one minus further-processed poultry for chicken slaughter plants. We also tested a measure based on the assumption that the value of shipments per pound of output has a more complex product mix. None of these specifications provided as good a model fit as that obtained with bulk output share. A multiple-product cost function with separate entries for pounds of whole birds, and traypacks and further-processed products (setting zero values to low but positive values) was also tried, but it was rejected because it did not provide as strong a fit as the preferred alternative, and it required the use of arbitrary zero values.

Census data provide information on the types of poultry used as production inputs. This poultry could be in the form of raw, unprocessed poultry input meat or the liveweight of whole chickens or turkeys. Some plants slaughtered both chickens and turkeys, others only chickens or turkeys, and some slaughtered both birds and used raw unprocessed poultry. Differences in poultry meat input mix may cause costs to rise if it means less plant specialization, or it may cause prices to drop if it means less processing effort; thus, we have included the variable BIRD in the model. We did not use liveweight turkey as a share of total poultry input meat for turkey slaughter because it was not significant.

Technological change, permitting increases in line speeds and improvements in other operations, likely reduced slaughter plant costs over time, suggesting the need for time-shift variables. However, the use of annualized whole-bird output share prevents the use of time-shift variables and their corresponding time-varying parameters because there is insufficient model variance due to the presence of two industry-level variables: time shifters and whole-bird output share. Failure to control for industry technological change may bias results, but, since the basic integrator system of production was well-established by 1967 (Bugos), the amount of bias should be modest. Additionally, many of the changes after 1967 came in the form of greater processing at the plant level, as well as faster line speeds, which are accounted for in the bulk output share, whole-bird output share, and production output variables, while changes in prices are accounted for with the factor price terms.

There was a major shift in both the chicken and turkey industries away from single-plant firms to multiplant firms over the 1967-92 period; thus, we included a dummy variable (MULTI) for single-plant firm status. However, since it was not significant to model fit for either turkey or chicken slaughter, it does not enter the

[17] Plant-level data for turkey parts exist only for 1987 and 1992 and, thus, could not be used in the analysis.

final regression equation. There was also a change toward balanced year-round production in turkeys (table 4-2). This change implies that plants were operating their facilities at capacity on a year-round basis by 1992. To account for any effects on plant costs, a seasonality variable (SEASONAL) is included.

Measures of Scale and Scope Economies

The elasticity of total costs with respect to output provides a natural measure of scale economies by showing how costs change as plant size increases. Mathematically, it is defined as the derivative of the cost function with respect to output:

$$\in_{CQ} = \frac{\partial \ln C}{\partial l Q} = \gamma_Q + \gamma_{QQ} \ln Q + \sum_i \gamma_{Qi} \ln P_i + \sum_k \delta_{Qk} Z_k + \sum_m \rho_{Qm} T_m \quad (5.4)$$

where values of the cost elasticity, $\in_{CQ}$, that are less than 1 show scale economies and values above 1 show scale diseconomies. For example, a value of .90 indicates that costs increase by 0.9 percent for every 1.0-percent increase in output (average costs fall as output increases). Because the variables are all divided by their sample means before estimation, the first-order term, δ_Q, can be interpreted as estimated scale economies for plants at the sample mean size.

Equation 5-4 allows the estimated cost elasticity to vary with single-plant firm status, whole-bird output share, time, bulk output share, poultry meat input mix, seasonality, output, and factor prices. The parameter on the lnQ term (γ_{QQ}) shows how the elasticity varies with plant output, and the parameters on the factor price terms show how scale economies vary with factor prices. The other coefficients illustrate how scale economies vary with plant characteristics.

The cost elasticity with respect to changes in bulk output share indicates how changes in bulk output share affect costs, i.e., a 1-percent change in the bulk product output share leads to a corresponding percentage change in costs:

$$\in_{CB} = \frac{\partial \ln C}{\partial \ln B} = \delta_B + \sum_k \delta_{kB} \ln Z_k + \sum_j \delta_{jB} \ln P_j + \delta_{QB} \ln Q + \sum_m \delta_{mB} T_m \quad (5.5)$$

The first-order term in the cost elasticity, δ_B, provides a direct measure of the effect of increases in the bulk product share of output on production costs at the sample mean. The other terms show how elasticity changes with various firm characteristics (single-plant firm status, whole-bird output share, poultry meat input mix, seasonality, and bulk output share), factor prices, production output, and time. The coefficient on physical output, δ_{QB}, provides a direct estimate of scope economies: negative values suggest that average costs decline as plant size increases for a given bulk output share, and positive values suggest that average costs rise.

Measures of Factor Substitution and Demand

The translog functional form can be used to derive the own- and cross-price elasticities of factor demand and the Allen elasticities of factor substitution. These elasticity estimates allow examination of industry responsiveness to changes in public policy or the industrial environment.

The own-price factor demand elasticity indicates how a given change in the price of factor j affects demand for factor j. A cross-price elasticity shows how a given percent change in the price of factor j affects demand for factor k. A positive sign means that the two factors are complements, and a negative sign indicates that they are substitutes. The Allen elasticity of factor substitution indicates the degree to which a given percent change in factor k can substitute for a percent change in factor j—a higher positive number indicates greater substitutability.

The factor demand own- and cross-price elasticities for any factors i and j are equal to:

$$\in_{jj} = \frac{(\Phi_{jj} + S_j^2 - S_j)}{S_j} \quad (5.6)$$

and

$$\in_{jk} = \frac{(\Phi_{jk} + S_j S_k)}{S_j} \quad (5.7)$$

and the Allen partial cross elasticities of factor substitution can be written as

$$\sigma_{jk} = \frac{(\Phi_{jk} + S_j S_k)}{S_i} S_j \quad (5.8)$$

where the S represents a factor share of the jth or kth factor, and Φ_{jk} is the coefficient on the kth factor price for the jth factor; it is also the coefficient on the interaction term between the jth and kth factor prices in the cost equation 5.1. The coefficient Φ_{jj} is the coefficient on the jth factor's price in the demand equation for that factor, and it is also the coefficient on the squared factor price term in the cost function. Since predicted factor shares may vary with output, factor prices, and plant characteristics, estimates of equations 5.6-5.8 should use fitted shares at representative data. Reported elasticities should also use representative values, which can vary with data.

Estimation and Tests for Model Selection

The longrun cost function is estimated jointly in a multivariate regression system with the four factor demand equations. Since the factor shares add to one, the capital share equation is dropped to avoid a singular covariance matrix. All dependent and explanatory variables are normalized by their sample means; thus, first-order coefficients can be interpreted as elasticities at sample means. Each equation in the system could be estimated separately by ordinary least squares, but to account for likely cross-equation correlation in the error terms, we used a nonlinear iterative, seemingly unrelated regression procedure.

The translog functional form used to estimate plant costs is a second-order Taylor expansion that is a very general functional form that can be specified in various ways to capture an array of potential cost effects. Different specifications allow for alternative ways in which factors can be combined, and a wide range of options by which input and output mixes can affect costs. A Gallant-Jorgenson likelihood ratio test was used to evaluate whether a selected variable affects production costs. A likelihood ratio test is preferable to single-variable statistical significance because translog cost functions have many interaction terms for each explanatory variable, making any single variable a poor measure of variable importance. Hypotheses are tested by comparing a model containing a variable of interest to a model in which that variable is excluded (the restricted model). If the difference in the Gallant-Jorgenson statistic exceeds a critical value, then the hypothesis that the test variable does not affect costs is rejected.

A number of model variations were examined. Model I excludes all plant characteristics and product mix effects, i.e., their corresponding parameters are zero. The remainder of the models test whether various plant characteristics and time affect plant costs. Model II adds bulk output share and poultry meat input mix to Model I for chicken slaughter and bulk output share and seasonality for turkey slaughter. Model III adds whole-bird share to Model II. This model gives the best fit of the data for both chickens and turkeys. Model IV adds seasonality for chicken slaughter and poultry meat input mix for turkey slaughter to Model III and Model V adds single-plant firm status to Model III. Model VI omits poultry meat input mix for chickens and seasonality for turkeys from Model III; Model VII leaves out bulk output share from Model III. Model VIII adds time shifts to Model II. Time shifts could not be included in Model III because both the time shifters and whole-bird output share are constant across plants in a given year, causing model failure.

We examined homotheticity of Model III with Model IIIB by forcing the model to be invariant to output by setting all ρ_{Qj} coefficients to zero. That is, the model drops the interaction terms between output, Q, and factor prices, the P vector.

Data and Variable Definitions

Table 5-1 provides definitions of model variables. All data except the whole-bird output share term come from Bureau of the Census microdata from the 1967-92 Census of Manufactures. Explanatory variables include factor prices (labor, poultry meat input, other material, and capital) and plant output. To these standard explanatory variables we add bulk output share, poultry meat input mix, seasonality, whole-bird share, single-plant firm status, whether the plant is part of a multiplant firm, and time-shift variables.

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

Whole-bird output share is defined as one minus the industry bird parts production as a percent of total industry production. Costs should drop as the percentage of whole birds rises because there are fewer processing requirements per pound of poultry for whole birds than for bird parts.

Bulk output share in chicken slaughter is defined as one minus the share of chicken traypacks and further-processed products. An increase in its value suggests a less complex finishing operation in which plants slaughter chickens and pack them as either whole birds or parts in bulk containers. Bulk output share in turkey slaughter is defined as one minus further-processed turkey products and includes turkey whole birds, parts, and byproducts. An increase in bulk output share should reduce costs because it implies a change to a less complex production operation.

Poultry meat input mix is liveweight chicken as a percent of all liveweight poultry and pounds of unprocessed poultry for chicken slaughter and liveweight turkey as a percent of liveweight poultry and pounds of unprocessed poultry for turkey slaughter. The closer poultry meat input mix is to one, the more likely the plant specializes in the use of its primary poultry meat factor (the slaughter of either chickens only or turkeys only).

Seasonality is defined as total number of employees in the first quarter of the year divided by the total number of employees in the fourth quarter of the year and is used to control for seasonal variation in output, such as the demand for turkeys at the end of the year. As this percentage rises, production becomes less seasonal (it never goes beyond approximately 1.0).

Seasonal plants may require excess plant capacity and/or excess grower capacity to accommodate their needs. Capital investment for these plants is largely for capacity to satisfy the end-of-the-year holiday season and the plants sit idle during much of the year.[18]

[18] Capital costs may not be larger for a seasonal plant than for a year-round plant because these nonseasonal plants must produce non-whole-bird products during the first quarter of the year, meaning that they may have higher capital costs due to additional processing machinery.

Table 5-1: Cost function variable definitions

Independent variables	
PLAB	price of labor = (total plant labor costs) / (total employees)
PMEAT	poultry meat input price = (liveweight poultry costs + unprocessed poultry meat input costs) / (liveweight poultry pounds + unprocessed poultry meat input pounds)
PMAT of	cost of other material inputs = (energy costs + packing and packaging cost + other material costs) / (pounds liveweight poultry + pounds of unprocessed poultry)
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 minus all retirements. Machinery (Building) rental prices (Bureau of Labor Statistics) are costs per dollar of machinery (buildings) expenditure.
Q	output of poultry products, in thousands of pounds
BULK	bulk output share = 1 - TRAYPACK% - PROCESSED% for chicken and 1 - PROCESSED% for turkey. TRAYPACK% = (pounds of chicken traypacks) / (pounds of total poultry shipments) and PROCESSED% = (pounds of further-processed poultry, such as poultry sausages) / (pounds of total poultry shipments)
BIRD	poultry meat input mix = (liveweight chicken pounds) / (liveweight poultry pounds + unprocessed poultry pounds) for chicken and (liveweight turkey pounds) / (liveweight poultry pounds + unprocessed poultry pounds) for turkey.
SEASON	seasonality = ratio of first quarter total employees to fourth quarter total employees
WHOLE	whole-bird output share = 1 - (pounds of cut-up and deboned poultry) / (industry pounds of production)
MULTI	one for single-plant firms and zero otherwise. Shows shift for ownership type.
TIME	one in Census year i and zero in other years for all Census years 1972-87 for chicken, and 1967-87 for turkey; 1992 is suppressed, making all results in the context of 1992 values.
Dependent variables	
COST	sum of labor, meat, materials, and capital factor costs
LABOR%	(salary and wages + supplemental labor costs) / COST
MEAT%	(purchased poultry costs + packed meat costs) / COST
MAT%	(energy costs + packing and packaging cost + other material costs) / COST
CAPITAL%	(OPPORTUNITY + NEW) / COST. See above for definitions.

6. Chicken Slaughter Cost Estimation

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

Model Selection

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

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

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

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

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

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

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

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

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

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

Summary of the Best Model

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Own-Factor Price and Allen Elasticities

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

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

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

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

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

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

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

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

Scale Economies

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Technological Change

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

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

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

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

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

Conclusion

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

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

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

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

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

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

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

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

7. Turkey Slaughter Cost Estimation

Structural changes in the turkey slaughter industry were remarkably similar to those in the chicken slaughter industry. During the 25 years prior to 1992, total turkey production more than tripled and an average turkey plant's share of output from further-processed turkey products more than quadrupled to about 18 percent (Census estimates).

In this chapter, a translog cost model is used to examine scale economies in turkey slaughter. The data include all plants with more than 50 percent of their output from turkey slaughter products that reported turkey slaughter product shipments in the Census of Manufactures for 1967, 1972, 1977, 1982, 1987, and 1992—a total of 314 plants.

Model Selection

The procedures and table formats that were used in chapter 6 are also employed in this chapter. Table 7-1 contains the model description, the G-J statistic, and the number of parameters estimated for eight variations of the cost model. Table 7-2 includes information used to evaluate model fit.

Models are rejected or not rejected based on the manner in which they affect model fit and their consistency with economic theory. As shown in table 7-2, Model II has a better fit than Model I, and Model III has the best fit of the data. Thus, bulk output share, seasonality, and whole-bird output share significantly affect plant costs, but single-plant firm status and turkey meat input mix do not. Although seasonality does not meet the rejection threshold of a 99-percent level of confidence, it does meet the less restrictive criterion of a 95-percent level. It is retained in order to illustrate that more balanced production schedules do affect plant costs, although only in a small way.

Table 7-1: Goodness- of-fit statistics for the turkey slaughter cost function models

Model	Description	G-J statistic	Parameters estimated
I	Translog, factor prices and output only	1133	15
II	Adds plant bulk output share and seasonality to I	1100	28
III	Adds whole-bird output share to II	1076	33
IV	Adds poultry meat input mix to III	1086	41
V	Adds single establishment to III	1071	38
VI	Removes seasonality from III	1092	26
VII	Removes plant bulk output share from III	1111	26
VIII	Adds time to model II	1051	53
IIIH	Imposes homotheticity on III by removing factor price and output interaction terms	1096	30

Notes: There are 314 observations in the 1967, 1972, 1977, 1982, 1987, and 1992 Censuses.

Model VIII was rejected for reasons similar to those given for chicken slaughter, i.e., results suggest regressive technical change. If time-shift variables are included in the model, the whole-bird output share variable must be excluded because it and the time-shift variables are constant across plants in any given year, resulting in insufficient model variance and model collapse. However, if whole-bird output share is excluded, the temporal shift in production from whole birds to cut-up and deboned turkey over the 1967-92 period (table 4-4) is not accounted for and estimated production costs rise. We discuss this in more detail below.

The homotheticity assumption, i.e., factor shares do not vary with plant output, is imposed on Model III by removing the interactions between output and the three relevant factor prices from the model. Results of Model III versus Model IIIH suggest that the standard translog model is not homothetic, meaning that large and small plants use different proportions of labor, capital, and materials in their production technologies.

Summary of the Best Model

Tables 7-3 and 7-4 show the estimated coefficients of Model III and are organized like tables 6-3 and 6-4 for chicken. First-order coefficients can be interpreted as factor shares at the sample mean. Accounting for 66 percent of turkey slaughter costs in 1992, turkey meat inputs (PMEAT) dominate total plant costs and are similar, but somewhat smaller than chicken meat inputs. Turkey slaughter has a substantially higher share of other materials and modestly lower shares of labor and capital than chicken slaughter. These differences may be due to the relatively higher level of further processing in turkey slaughter (table 4-4).

The skewed distribution of factor shares gives rise to monotonicity violations. The estimated capital share was negative for about 6 percent of the plants, and the

Table 7-2: Hypothesis tests for the turkey slaughter cost model

Maintained hypothesis	Tested hypothesis	Parameter restrictions	Chi-square @ .99	Chi-square statistic	Status of tested model
Model II	Model I	13	27.7	33	Reject
Model III	Model II	5	15.1	24	Reject
Model IV	Model III	8	20.1	-10	Not Reject
Model V	Model III	5	15.1	5	Not Reject
Model III	Model VI	7	18.5	16	Reject[1]
Model III	Model VII	7	18.5	35	Reject
Model VIII	Model II	25	44.3	49	Reject[2]
Model III	Model IIIH	3	11.3	20	Reject

[1] Test hypothesis was rejected at the 95% level of confidence.
[2] Model VIII was rejected because it does not account for the shift to more cut-up and deboned turkey and less whole-bird production over the 1967-92 period, and very likely gives misleading results.
Notes: There are 314 observations in the 1967, 1972, 1977, 1982, 1987, and 1992 Censuses. Chi-square statistic is G-J statistic of tested hypothesis minus G-J statistic of maintained hypothesis.

Table 7-3: Turkey slaughter cost function parameter estimates: First-order terms and factor price interaction terms

	Interacted with				
Variable	1st order	PLAB	PMEAT	PMAT	PCAP
	Coefficients and standard errors				
Intercept	-0.208***	-	-	-	-
	(.018)				
PLAB	.131***	.053***	-.061***	-.008**	.017**
	(.005)	(.012)	(.010)	(.004)	(.007)
PMEAT	.662***		.161***	-.089***	-.011
	(.007)		(.013)	(.005)	(.007)
PMAT	.191***			.103***	-.006
	(.004)			(.003)	(.0035)
PCAP	.016***				-.0002[1]
	(.005)				
BULK	-.029				
	(.033)				
SEASON	.021				
	(.017)				
Q (lbs)	.919***				
	(.025)				
WHOLE	-.128**				
	(.050)				

* significant at 90% level;
** significant at 95% level;
*** significant at 99% level.
[1] Standard error could not be estimated.
Note: Translog cost function estimation for turkey slaughter, 1967-1992. There are 314 observations. Since all variables are standardized at their means, first-order coefficients can be interpreted as elasticities at the sample means.

Table 7-4: Turkey slaughter cost function parameter estimates: First-order terms and bulk output share,seasonality, output, and whole-bird output share interaction terms

	Interacted with				
Variable	1st order	B	S	Q	W
	Coefficients and standard errors				
Intercept	-0.208***	-	-	-	-
	(.018)				
PLAB	.131***	-.0082***	.0023	-.015***	.002
	(.005)	(.0026)	(.002)	(.005)	(.016)
PMEAT	.662***	.0081***	-.0061**	.0178***	.018
	(.007)	(.003)	(.003)	(.006)	(.019)
PMAT	.191***	-.0067***	.002	.0042	.004
	(.004)	(.002)	(.002)	(.004)	(.011)
PCAP	.016***	.0068***	.0018	-.007	-.022
	(.005)	(.002)	(.002)	(.005)	(.014)
BULK	-.029	-.002	-.004	-.002	-
	(.033)	(.008)	(.003)	(.007)	
SEASON	.021		.005	-.0015	-
	(.017)		(.005)	(.008)	
Q (lbs)	.919***			-.025	-.039
	(.025)			(.027)	(.056)
WHOLE	-.128**	-			
	(.050)				

* significant at 90% level;
** significant at 95% level;
*** significant at 99% level.
Note: Results of estimation of translog cost function for turkey slaughter plants, 1967-92. Since all variables are standardized at their means, first-order coefficients can be interpreted as elasticities at the sample means. Quadratic (on diagonal) and interaction terms from estimation of translog cost function.

estimated other materials share was negative for about 7 percent of the plants. Estimated labor and turkey meat input factor shares were never negative.

The interaction terms show how estimated elasticities (and factor shares) vary with movement away from sample means. Since bulk products require less labor and packaging materials than further-processed products, the coefficients on the interactions of plant bulk output share (BULK) with the prices of labor (PLAB) and other materials (PMAT)—mainly packaging materials—should have negative signs, and turkey meat inputs (PMEAT), positive signs. Results (table 7-4) are consistent with these hypotheses.

The coefficients for the interactions of output (Q) and factor prices (table 7-4) show how prices vary with plant size. For example, since the coefficient of the labor and output interaction term is negative, plants use relatively less labor as output grows, but there is less of a labor reduction for turkeys than for chickens. Interpreting results in this manner suggests that the labor share declines and the turkey meat factor share rises about 0.15 percent for each 10-percent increase in output. Results also suggest that the labor share of costs drops and the turkey meat factor cost share rises as industry whole-bird share of output rises.

The cost of birds as a share of total input costs is much higher than for other factors in turkey slaughter, and with the same implications as in the chicken slaughter industry. First, if total costs are dominated by meat purchase expenses, then substantial scale economies in slaughter and processing translate into small scale economies calculated on total costs. Second, wage changes will lead to small retail-price changes because wages are 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 because the labor share of costs is six times larger than the capital share.

Own-Factor Price and Allen Elasticities

Cost function coefficients are used to calculate own- and Allen price elasticities (table 7-5). Own-price elasticities indicate how factor demand changes with prices, holding output constant. For example, own-price elasticities for labor (table 7-5) show that a 10-percent increase in the price of labor leads to a 4.6-percent decline in the demand for labor. The demand for labor is more sensitive to factor prices and demand for capital is less sensitive in turkey slaughter relative to chicken slaughter. Like chicken, the factor demand curves have downward slopes (all elasticities are negative), but the own-price elasticity for turkey meat is more inelastic, i.e., a change in price leads to smaller changes in quantity demanded. Compared with cattle and hog slaughter, own-price elasticities for turkey slaughter are much less inelastic. These differences may be due to differences in turkey-growing technologies compared with animal-growing operations for chickens, cattle, and hogs. Of the four industries, chicken slaughter plants have the greatest ability to control the relationship between meat factor prices and purchase decisions because they can directly influence purchase price through contractual specification of a growing technology. Turkey plants have less influence because more growers are independent, and cattle slaughter plants have the least control because slaughter plants must purchase animals at market prices. Thus, if chicken-growing technology changes, then chicken meat factor prices change for one plant, but if cattle-raising technology changes, all cattle slaughter plants are affected.

Positive Allen elasticities indicate substitutes, and negative elasticities indicate complements. The reported elasticity of 0.293 for labor and turkey meat inputs and 0.671 for labor and materials (table 7-5) means that 1-percent increases in each of these factors, holding output constant, results in 0.3- and 0.7-percent decreases in the demand for turkey meat inputs. All other Allen elasticities, except for capital and turkey meat inputs and capital and other materials, are substitutes—an outcome similar to that in the chicken industry.

Table 7-5: 1992 own-factor price and Allen elasticities evaluated at the sample mean for turkey slaughter

	Factor price variables			
	PLAB	PMEAT	PMAT	PCAP
Estimated factor shares	.131	.662	.191	.016
ϵ_{ii} (own-factor price)	-0.464	-0.094	-.269	-0.998
σ_{ij} (Allen)				
PLAB	-3.548	0.293	0.671	8.922
PMEAT		-0.143	0.294	-0.020
PMAT			-1.408	-0.813
PCAP				-62.86

Note: All values are evaluated at the sample mean using parameters from table 7-3. The own-price input demand elasticities (ϵ_{ii}) are calculated holding output and other factors constant, while the elasticities of substitution (σ_{ij}) are calculated using Allen's formula.

Scale Economies

The cost elasticity is estimated with equation 5-4 using the coefficients of the first-order output term and the second-order output term (table 7-4). Interactions between output and other model variables are ignored because competitive forces drive factor prices to similar levels and the other variables have very small coefficients.

The cost elasticity at sample mean prices and output is 0.919 (the first-order coefficient for Q in table 7-4). Holding all firm characteristics constant at their sample means, a 1-percent increase in output leads to a 0.919-percent increase in total costs.

Cost elasticities, an average cost index, and processing costs for various plant sizes are reported in table 7-6. The third column illustrates very sharp growth in mean turkey plant size, increasing by about 600 percent from 1967 to 1992. However, the mean turkey plant size was still only about 80 percent as large as the mean chicken plant size in 1992.

The final three columns of table 7-6 give cost elasticity, average cost index, and processing costs as a share of total costs for various plant sizes. As with chicken slaughter, increasing returns to scale exist throughout the size range examined, and also grow in magnitude, dropping from 0.936 for a plant that is half the sample mean plant size to 0.884 for a plant that is four times larger than the sample mean plant size. These strong scale economies result in a 17-percent cost advantage for the largest plants relative to sample mean plants and in a continuous decline in the processing share of total costs. The cost differentials are consistent with the near-disappearance of small plants and likely contributed to the increase in mean plant size over the 1967-92 period.

The sign on the coefficient of output interaction with output (table 7-4) is negative, suggesting that increasing returns become stronger with size and that plant size will continue to increase. Possible constraints on plant size that are not captured by the cost function include a lack of a suitable number of growers and laborers and environmental issues. However, no hard data are available to examine the issue empirically.

Turkey slaughter is much less automated than chicken slaughter because turkeys are less likely to be of uniform size; thus, there is not so great a need to have plants specialize by turkey size and end use. Environmental issues are important and become an issue in regions with susceptible watersheds. However, appropriate site selection can permit slaughter plants to avoid environmental degradation. For example, turkey slaughter plants have not been located in the Delmarva Peninsula, but are concentrated in the North and South Central regions.

Alice Johnson of the National Turkey Federation (interviewed May 10, 1999) suggested that a lack of turkey growers and low-cost labor may limit plant size. She asserted that the financial risks of raising turkeys are greater than for chickens because turkeys are much more susceptible to disease and heat stress due to their longer grow-out period and greater size. She also claimed that turkey growers need greater financial resources than chicken growers because (1) turkeys require larger housing facilities and greater environmental controls; (2) turkeys generate more variable cash flows because flock sizes must shrink during the summer months in order to reduce the threat of heat stress, and then be expanded rapidly to meet market demands for the holiday season; and (3) turkey growers must carry excess capacity during much of the year because of varying flock size. This greater financial risk of turkey growing relative to chicken growing requires turkey slaughter plants to bear greater financial risks by owning a greater share of bird-growing operations than chicken slaughter plants do, but would seem to have little effect on plant size.

Labor shortages may play a larger role than the nature of grower contracting in limiting turkey plant size. Turkey plants must locate in rural areas that are not environmentally fragile in order to have access to turkey meat inputs and to avoid high environmental

Table 7-6: Estimated cost elasticity and average cost index by plant size for turkeys

Plant size	Plant size to sample mean	Plant size to 1967 mean	Plant size to 1992 mean	Elasticity	Avg. cost index*	Process cost
Million lbs.		*Ratio*				*Percent*
21.9	0.50	1.37	0.19	0.936	1.05	35.0
43.7	1.00	2.74	0.38	0.919	1.00	33.8
87.4	2.00	5.48	0.75	0.902	0.89	32.6
174.8	4.00	10.96	1.51	0.884	0.83	31.3

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

control costs. These rural areas tend to have a limited labor supply. Johnson argued that since plants cannot raise wages for new hires without raising the wages for all employees, the marginal cost of hiring additional workers is very high. Although this phenomenon may also exist in chicken slaughter, its impact is likely more severe with turkeys because of the turkey industry's greater reliance on manual labor.

A large share of turkey products are sold as branded or further-processed products, requiring turkey breeds with different qualities. Since some of these turkey breeds vary substantially in size, managers must match turkey breeds with specialized plants that are able to slaughter them. This need for specialization and a limited market may result in plant sizes with a substantial degree of increasing returns to scale.

Consider how much labor and turkey meat factor costs would have to rise to offset the cost savings resulting from scale economies. Suppose that the largest turkey plants produce at a level of eight times the sample mean plant size (this is about three times greater than the 1992 mean plant size). Assuming that model coefficients do not change as plant size exceeds the limit of the dataset, a doubling of plant size leads to a decline in the average cost index to 0.759 or about an 8-percent decrease in costs from a plant that is four times the sample mean plant size. Given that the turkey meat factor share of costs is about 66 percent and the labor share of costs is about 13 percent, this means that turkey meat factor prices would have to rise by about 13 percent, or labor costs would have to rise about 64 percent to offset the gains accruing to scale economies. If the limiting factor is the size of final product market—either because the product is branded or otherwise limited—then cost savings in production would be offset by higher marketing costs.

Table 7-7 shows a comparison of cost elasticities and a cost index for four animal slaughter categories. The cost elasticity valued at the sample mean for turkeys (0.919) is higher than for chickens (0.901), but lower than for cattle slaughter (0.953) and hog slaughter (0.926). Thus, scale economies are greater for turkeys than for either cattle or hogs but less than for chickens. Cost elasticities grow dramatically for chicken and turkey relative to cattle and hogs as plant size increases; thus, large chicken and turkey plants have much lower costs relative to their sample mean plants than is the case for cattle and hog slaughter plants.

Table 7-7: Cost elasticities and cost index comparisons for four slaughter industries

Comparison type	Chicken	Turkey	Cattle	Hogs
Cost elasticity (sample mean)	.901	.919	.932	.926
Cost elasticity (4 times mean)	.852	.884	.947	.960
Average cost index*	.850	.828	.929	.946

* Four times mean plant size relative to sample mean plant size.

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

Plant characteristics important to turkey production costs include bulk output share (BULK), whole-bird output share (WHOLE), and seasonality of production (SEASON). Bulk output share is defined as one minus the share of further-processed turkey products. Bulk products include whole turkeys, cut-up and deboned turkey, and miscellaneous byproducts.[22] Products not defined as bulk include frankfurters and other sausages, luncheon meats, and other cooked products. The production of bulk products requires fewer inputs to convert a pound of turkey into a finished product; thus, plant production costs and the labor share of total costs should decline as the bulk output share rises. The coefficients on the bulk output share and the interactions of the bulk output share with PLAB, PMEAT, PMAT, and PCAP are consistent with these hypotheses. They show that (1) production costs decline as the bulk output share rises and, (2) a plant that produces mainly bulk products has lower labor and materials shares of costs and greater turkey meat and capital factor shares of costs than a plant that produces mainly luncheon meats and other further-processed turkey products.

Equation 5.5 is used to see how much average costs change as the bulk output share changes. The elasticity of costs with respect to bulk output share at sample mean prices and output ($\in_{CM}$) is -0.029 (table 7-8), meaning that a 1-percent increase in the bulk output share leads to a 0.029-percent decline in turkey slaughter plant operating costs. To see how average costs change as the bulk output share varies, average costs at sample mean prices and output for plants having bulk output shares of 20, 50, and 80 percent of the sample mean bulk output share are evaluated (table 7-8). Plants with sample mean output and factor prices, which produce about 80 percent of the sample mean

[22] Plant-level data for turkey parts are available only from the 1987 and 1992 Censuses and, thus, cannot be used in the analysis.

bulk product share of output, have 0.5-percent higher production costs than identical plants with a bulk share at the sample mean. Plants with 20 percent of the sample mean bulk product share have about 3-percent higher costs than plants with sample mean bulk output share. These changes in bulk output share may cause substantially lower cost increases than for chicken slaughtering, perhaps because turkey slaughter already requires more labor per bird for slaughtering than does chicken and, thus, proportionately less additional labor for further processing. As with chicken slaughter, processing costs drop as bulk output share rises.

One explanation for larger plants' having a greater share of output from turkey parts and further-processed products than smaller plants (table 4.5) is the existence of economies of scope. However, since the interaction of the bulk output share with output (next to last column of table 7-4) is negative and insignificant, there is no such evidence (it would have to be positive and significant).

The negative coefficient for whole-bird output share (table 7-4) shows that a rise in the whole-bird share of output leads to a downward shift of the total cost function. There are also small but insignificant increases in the shares of labor and meat costs. Coefficients on the interactions of whole-bird output share with factor prices suggest that the capital share of costs drops, and the labor, turkey meat factor, and materials shares increase as the whole-bird output share rises.

To see how much average costs change as the whole-bird output share varies, we evaluated average costs at the sample mean for plants having whole-bird shares that are 20, 50, 80, and 120 percent of the sample mean whole-bird share (table 7-9). Plants with 120 percent of the sample mean whole-bird share have 0.5-percent lower average production costs and a 0.3-percent higher processing cost share than do plants at the sample mean plant size.

Now consider the bias caused by ignoring bulk output share and whole-bird output share effects. If both plant bulk output share and whole-bird output share are omitted (Model I, table 7-1), the coefficient on the output term (cost elasticity at sample mean prices and output) is 0.977, but if bulk output share and whole-bird output share are included, the coefficient drops to 0.919. If the last pound of turkey cost $0.50 to produce, these scale economy estimates mean that the estimated costs of producing the next pound of turkey would be $0.488 without a control for bulk output share and whole-bird output share or $0.459 with controls. This $0.029-per-pound estimation bias strongly affects plant profitability when considered in the context of a plant producing 200 million pounds of turkey each year.

The greater degree to which chicken and turkey slaughter plants process bird carcasses into finished

Table 7-8: Estimated turkey cost elasticity and the associated cost index for selected bulk shares at industry mean values

Bulk share	Bulk share to sample mean	Bulk share to 1972 mean	Bulk share to 1992 mean	Elasticity	Cost index*	Process cost
Percent		*Ratio*				*Percent*
17.9	0.20	0.18	0.21	-0.026	1.030	35.1
44.8	0.50	0.45	0.54	-0.028	1.014	34.4
71.6	0.80	0.72	0.87	-0.029	1.005	34.0
89.5	1.00	0.90	0.10	-0.029	1.000	33.8

* Index based on sample mean values with only bulk output share changing.

Table 7-9: Estimated cost elasticity and the associated cost index for selected whole-bird shares using industry mean values

Whole-bird share	Whole-bird share to sample mean	Whole-bird share	Whole-bird share to 1972 mean	Elasticity to 1992 mean	Cost index*	Process cost
Percent		*Ratio*				*Percent*
15.5	0.20	0.17	0.34	-0.128	1.048	36.7
38.8	0.50	0.41	0.86	-0.128	1.020	35.0
62.0	0.80	0.66	1.38	-0.128	1.006	34.2
77.5	1.00	0.82	1.73	-0.128	1.000	33.8
96.9	120.0	1.03	2.16	-0.128	0.995	33.5

* Values are based on sample mean values. Only whole-bird share of output changes.

and semi-finished products suggests that controlling for bulk output share and whole-bird output share is more important to these industries than it is for cattle and hog slaughter (table 7-10). The cost elasticities for chickens and turkeys drop by about 5.5 percent after including both bulk output share controls, while the cost elasticities for cattle and hogs decline by only about 1.5 percent. These comparisons suggest that ignoring product mix significantly biases the results of all models, but the bias is much greater in chicken and turkey than in cattle and hogs.

Turkey slaughter plants have traditionally had stronger demand during the end-of-the-year holiday season than during other seasons. This seasonality of demand can impose a cost of either carrying excess capacity or of paying high variable costs during peak demand periods. Turkey plants reduced seasonality over the 1967-92 period (table 4-2), suggesting that lower costs may have resulted. However, production seasonality was found to have a very modest impact on model fit (tables 7-2, 7-4), and is retained only to illustrate its modest impact.

Other plant characteristics were also examined but did not improve model fit. These include single-plant firm status, and liveweight turkey input mix. The insignificance of single-plant firm status suggests that plant technology is similar regardless of firm type. Turkey meat input mix may not have contributed to model fit because live turkeys accounted for most inputs throughout the study period (table 4-2). Alternative specifications for the bulk output share variables were also tried, but none improved on bulk output share.

Implications of the results of product mix effects are important and similar to chicken. The effects of change in product mix must be separated from the effects of plant size because turkey plants increased turkey processing while simultaneously increasing plant size. Simple cost functions that do not account for product mix will confuse product mix effects with size-related effects and likely understate scale economies.

Table 7-10: Cost elasticities for four slaughter industries at the sample mean for models with and without controls for bulk share and whole-bird shares

Cost elasticity comparison	Chicken	Turkey	Cattle	Hogs
Cost elasticity with control for product mix (bulk output share for chicken and turkey)	.901	.919	.932	.926
Cost elasticity without control for product mix (bulk output share for chicken and turkey)	.953	.977	.959	.980
Difference	.052	.058	.027	.054

Technological Change

Technological change over the 1967-92 period consisted of changes in product mix and materials- and labor-saving innovations. The model controls for changes in product mix with the bulk output share and whole-bird output share terms. It also controls for size-related technological change with the output term and accounts for some labor and material efficiency gains through coefficients on wages and chicken meat factor prices. However, the model does not directly account for other disembodied technological change.

A model employing technology variables (time-shift variables), but no whole-bird output share term (Model VIII, table 7-2), was found to improve model fit over a model consisting of factor prices, plant output, seasonality, and factor and bulk output share (Model II, table 7-2). However, this model was rejected because, as with the chicken model, most interaction terms are statistically insignificant; the model is barely statistically significant; and, worse, there is no way to control for whole-bird output share because both it and the time-shift variables are constant across plants, causing insufficient model variance and model collapse. Since the change in cut-up and deboned turkey as a share of output rose from less than 10 to over 50 percent in the 1967-92 period and since processing cut-up and deboned turkey is more labor intensive than whole-bird production, excluding whole-bird output share likely leads to serious specification errors.

Table 7-11 shows that Model VIII cost estimates are 7 percent higher than the preferred model (Model III) at a size that is twice the sample mean (about 75 percent of the 1992 mean size). Estimates from Model I (basic model) and Model II (controlling for bulk output share and seasonality only), at twice the size of the sample mean plant, were 8.5 and 6 percent higher than estimates from Model III.

A comparison of estimates from Model VIII for various Census periods (table 7-12) shows that intercept terms shift upward over time and scale economies are completely exhausted by 1992 (the coefficient on Q is about 1.04). Additionally, estimates at twice the sample mean plant size suggest that it was about 21 percent less costly to produce turkey in 1967 than in 1992 and that average costs rose from 1967 to 1982 and then stabilized thereafter—never falling to the same cost level as what existed in 1967. These results are inconsistent with other data that show that plant size increased by over 600 percent over the 1967-92 period; such inconsistencies lead one to conclude that Model VIII suffers from severe specification error.

In summary, Model VIII was rejected because (1) it is only marginally significant (table 7-2) and (2) comparisons with other models and the existence of regressive technological change suggest that serious specification errors exist. This finding does not imply that technological change did not occur. Quite to the contrary, technological change has had a profound effect on shaping the turkey slaughter industry. However, technological change has been captured through variables other than time. The model accounts for changes in product mix with the bulk output share and whole-bird output share terms, size-related change with the output term, and labor and poultry production changes with labor and meat costs.

Conclusion

The main purpose of this chapter is to assess the role of scale economies and product mix on turkey slaughter plant production costs. Results suggest a cost structure similar to that of chicken slaughter plants in that substantial scale economies exist and product mix, i.e., bulk output share and whole-bird output share, significantly affects plant production costs. Plants that are four times larger than the sample mean plant size realized a 17-percent reduction in costs, and plants twice as large as the sample mean plant size had a 10-percent reduction. Higher transportation costs, environmental and labor constraints, and plant specialization by bird type may inhibit additional plant size growth, but this is uncertain because there is no hard evidence to support any of these hypotheses. Thus, the question of the extent of scale economies will require further research.

Model fit might be improved with additional data. Turkey slaughter plants produce three main product classes: consumer-ready whole birds, parts, and further-processed products; cut-up and deboned turkey packed in bulk containers; and whole birds packed in bulk containers. Plant-specific data were available only for the further-processed products. Industry-level data were used to account for temporal changes in cut-up and deboned turkey, but these data cannot account for some plant-level differences.

The use of whole-bird output share as a control for product mix effects prevented the use of time-shift variables to account for disembodied technological change because the model collapses if both time shifters and industry-level whole-bird output share variables are included in the same model. Whole-bird output share rather than time-shift variables was used because cost estimates were consistent with economic theory, whereas, the time-shift model provided perverse results suggesting regressive technological change. Results from a model containing control variables for bulk share of output, whole-bird output share, and seasonality but no time shifters show large scale economies that likely led to the 600-percent increase in turkey plant size from 1967 to 1992.

Table 7-11: Turkey cost and elasticity ratios of models I, II, and VIII relative to model III at sample mean and twice sample mean values for 1992

Model	Model cost estimate relative to Model III at sample mean	Model cost estimate relative to model III at twice sample mean	Elasticity
	Ratio	*Ratio*	
I	1.030	1.085	0.977
II	1.023	1.060	0.958
III	1.000	1.000	0.919
VIII	0.992	1.070	1.048

Table 7-12: 1972-87 turkey cost and elasticity ratios of model VIII for 1967-87 relative to model VIII for 1992, evaluated at sample mean and twice sample mean values

Census year	Model VIII costs at sample mean for 1967-87 relative to model VIII costs for 1992	Model VIII costs at twice sample mean for 1967-87 relative to model VIII costs for 1992	Model VIII elasticity at sample mean for 1967-87 relative to model VIII elasticity for 1992
1967	0.916	0.788	0.795
1972	0.971	0.872	0.851
1977	1.026	0.934	0.870
1982	1.050	1.010	0.947
1987	1.150	1.004	0.952
1992	1.000	1.000	1.000

8. Conclusions

Overall conclusions of this study are presented in three areas. First, the extent of structural change in chicken and turkey slaughter is discussed. Next, the major findings are presented. Finally, the two are linked by discussing the impact of industry cost structure on structural change.

Structural Change in Chicken and Turkey Slaughter

Major structural changes occurred in poultry slaughter as the market share for large chicken plants doubled to about 88 percent of output and the market share for large turkey plants quintupled to about 83 percent between 1972 and 1992. As poultry plant size grew, the number of growers dropped by about 33 percent, and their average size almost tripled.

The shift to larger poultry plants likely contributed to a tripling of the four-firm concentration ratios in chickens and a doubling of the four-firm concentration ratios in turkeys. However, concentration remains modest—the four largest plants control less than 50 percent of output in both industries. The dramatic rise in domestic and export demand over the 1963-92 period may have restrained the industry from greater concentration.

The shift to large production facilities convinced most chicken slaughter plants to become integrated with poultry growers to ensure an ample supply of high-quality birds. Under the integrated form, integrators are able to control both the quality and supply of poultry inputs by providing contract growers with chicks, medicines and vaccines, feed, management assistance, and veterinary services. The growers contribute housing, care for the chickens, and usually pay part of the fuel bill. Turkey slaughter plants differ in that many either purchase turkeys from independent growers, own their growing facilities, or have contract growers.

Changes in poultry plant product mix were quite dramatic over the 1963-92 period. Whereas a typical plant in 1963 sold the whole bird to a retailer or wholesaler, typical plants in 1992 converted some birds into whole birds, but mainly sold cut-up and deboned birds in consumer traypacks, as restaurant products, or for further processing into luncheon meats and other further-processed products. More quantitatively, by 1992 over 70 percent of chicken production consisted of cut-up and deboned chicken for use in consumer-ready traypacks, restaurant products, and further-processed poultry. Similarly, over 17 percent of the output from turkey plants was further processed and almost half of production was either further processed, cut-up, or deboned. Output consisted almost exclusively of whole birds.

The shift to further processing was particularly important in turkey slaughter. In the 1960's, most turkey was consumed during the last quarter of the year. This seasonality in demand required many turkey growers to almost halt bird production during the first quarter and then gradually build up for the peak demand during the end-of-the-year holiday season. This cyclical process required plants to carry excess capacity, giving them an incentive to fill off-season production capacity. Many turkey slaughter plants responded by producing turkey parts and further-processed products.

The changes in factory output were accompanied by geographic shifts to the Southeast in chickens and the Middle South in turkeys. A number of factors likely contributed to this shift but were not examined in this report.

Cost Structure

Results from a translog cost function show that substantial unexploited scale economies exist in both chicken and turkey slaughter, suggesting that plant size will continue to increase. In chicken slaughter, scale economies have enabled plants operating at four times the sample mean size to produce chicken at a cost about 15 percent less than a plant operating at the sample mean size. Similarly, turkey plants that are four times the sample mean size have costs about 17 percent less per pound than plants at the sample mean size.

Failure to account for product mix was shown to have a substantial effect on results. If neither bulk output share nor whole-bird output share were included in the model, estimated scale economies were almost constant, but after accounting for product mix, very strong scale economies become evident. Although similar effects were detected for cattle and hog slaughter (MacDonald et al.), the product mix effects are much stronger for chicken and turkey slaughter.

Increased conversion of whole birds into parts and further-processed products may suggest economies of scope. However, results do not suggest a decline in the cost of producing further-processed products as plant size increases. Rather, results show that the bulk output share and the whole-bird share of output strongly affect total costs, but that these costs are independent of plant size.

Elasticity estimates derived from the estimated parameters suggest that poultry slaughter plants can more readily substitute labor for material, and that their demand for (poultry) meat inputs drops much more sharply as (poultry) meat factor prices rise than in red meat slaughter. We speculate that these differences arise because, due to contract growing, live bird prices vary across poultry plants, whereas most cattle are purchased at market prices from independent feedlots.

Live bird costs constituted about two-thirds of total production costs, suggesting that prices paid by consumers will drop only modestly even with large improvements in labor productivity. This does not mean that improved productivity will not generate higher profits. Rather, the small capital factor share suggests that improvements in labor productivity have a dramatic impact on return on invested capital.

It was not possible to account for disembodied technological change because time-shift variables used to control for temporal changes and the whole-bird output share term are constant across plants for any given year, causing insufficient model variance and model failure if both are included in the same model. A model leaving out whole-bird output share and including the time-shift variables was rejected because it exhibited regressive technological change, i.e., costs rose over time. The model including whole-bird output share, on the other hand, was retained because its results were consistent with economic theory.

Costs and Plant Size

Results indicate that substantial scale economies exist in chicken and turkey slaughter, i.e., larger plants produce poultry products at lower costs than smaller plants do, and scale economies are still not fully exploited. These unexploited scale economies are much stronger than for cattle and hogs, but, unlike them, show no signs of decreasing with plant size.[23]

The increase in plant size over the 1972-92 period coincided with an increase in four-firm concentration ratios only in chickens and, in that industry, only over the 1977-87 period. By contrast, similar increases in plant size driven by more modest scale economies for cattle slaughter coincided with a sharp increase in four-firm concentration levels. Differences in changes in concentration ratios could be attributed to many factors, such as differences in demand, differences in labor costs across plants, etc.

[23] Factors such as market demand, transportation costs, and environmental and legal restrictions are not controlled in the translog cost function; thus, these constraints can limit plant size before scale economies are completely exhausted.

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