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ANALYSIS OF THE U.S. PORK SECTOR

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ABSTRACT

FACTORS AND TRENDS OF REGIONAL SHIFTS OF PRODUCTION:

ANALYSIS OF THE U.S. PORK SECTOR

By

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Until the mid 20th century, the pork industry in the United States was characterized by production on numerous unspecialized small farms scattered across the rural landscape. The pork industry in the recent past has transferred into fewer, larger and specialized operations. The phenomenon of change is continuous. Historically, input availability, development of transportation systems, technological changes in production systems, government regulations and the consumer preferences have been driving changes in the pork industry. All these forces affect the competitiveness of one region relative to other regions. This dissertation examines the historical trends in the U.S. hog production and regional shifts of hog operations from traditional regions to the new regions. Relevant literature has been reviewed to identify the factors of regional shift. Three major factors: pork demand, variation in cost of production and processing, and government regulations are discussed in detail. The analysis is focused on how these forces affect the regional competitiveness of the pork industry and movement towards larger, specialized and geographically concentrated operations.

The pork industry, as influenced by its background is reviewed first. Trends in pork production, processing, and marketing and factors that may be directly or indirectly impacting industry structure are summarized. The theoretical aspects of meat demand are

discussed and regional pork demands are estimated using an econometric model. Costs of finishing pigs in different regions are estimated for small, medium and large operations in order to allow examination of competitiveness of feeding operations by size of operation. The study also analyzes the differences in federal and state regulations and develops an index to compare the relative stringency by production regions. Various technology options in manure management are briefly discussed. Based on these options and United States Environment Protection Agency data, compliance costs are analyzed for different sizes of operations. Finally, a mathematical programming model is used to analyze the effect of market forces on the pork industry structure.

The results of this study show that raising hogs in larger operations is less costly. Small-sized operations in some regions are still required to produce hogs to meet the demand for consumption and export. Although environmental compliance cost is considered one of the major factors of industry relocation, the analysis showed that the effect of such costs was minimal. Feed costs and transportation costs play a great role in location of production and processing.

The results also revealed that pork operations tend to locate near the populous areas to meet the consumer demand and at the same time minimize the transportation cost. Pressures from current and future environmental regulations, moratoria and scarcity of agricultural land for manure management tend to keep the hog operations away from high population areas. A future scenario analysis suggested that the western region of the U.S. would experience higher growth in pork production by the year 2010. The current trend of fewer and larger production units and location changes in the pork industry will continue in the future.

This work is dedicated to my parents, Mana Harka and Apsara Adhikari

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Chapter 1

I. Introduction

The U.S. pork industry is an important value-added sector in the agricultural economy. Annual farm sales (market hogs sold) usually exceed $11 billion, while the annual retail value of pork sold to consumers exceeds $30 billion. The pork industry supports over 600,000 jobs and adds approximately $27 billion in value to basic production inputs such as soybean and corn (National Pork Producers Council, 1999). The total U.S. hog population is about 60 million animals, with about 68 percent located in the Corn Belt area, where they have access to abundant supplies of feed grains and soybean meal. Another 20 percent of hogs are produced in the Southeast (Economic Research Service, 2000).

The pork industry is a complex system of producing, marketing, processing and distributing of pork and pork products. The production process uses many inputs (e.g., feedstuff, labor, capital, land, etc.) to produce live hogs. Similarly, processing and marketing processes require capital, labor and several other inputs. In the 1970s and 1980s, hogs were generally produced on farrow-to-finish farms. Although farrow-to-finish farms are still utilized, recently, hog production has shifted to specialized farms at four distinct sites, usually separated by location.

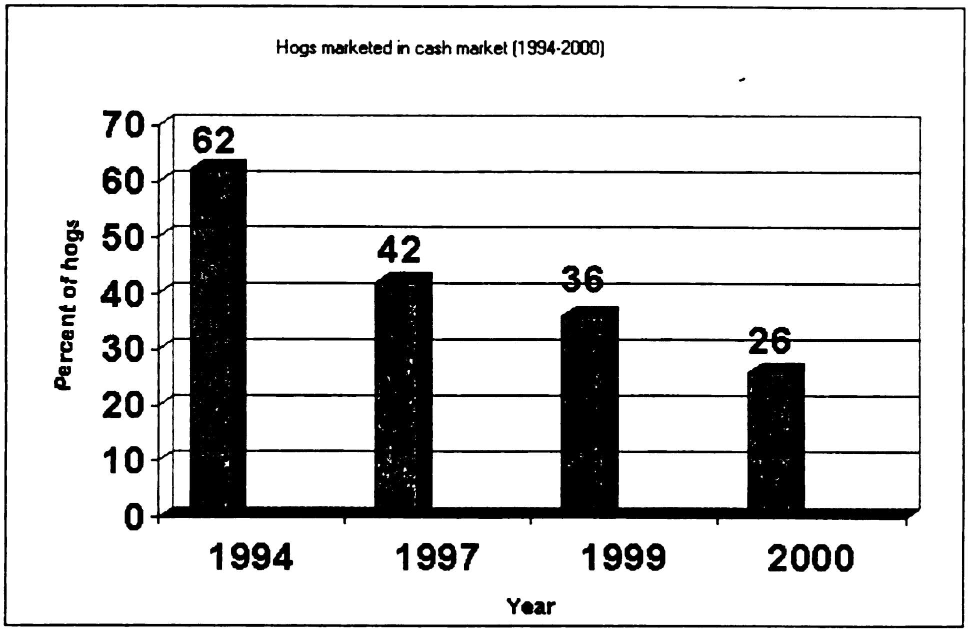
- Farrow-to-wean operation: Breeds pigs and ships 10 to 15 pound pigs to nursery operations.
- Farrowing-nursery operation: Breeds pigs and ships 40- to 60-pound "feeder" pigs to growing-finishing operations.

- Nursery operation: Manages weaned pigs (more than 10 to 15 pounds) and ships 40- to 60-pound "feeder" pigs to growing-finishing operations. The final product from nursery operation is the same as from the farrowing-nursery operation.
- Grow-finishing/feeder-to-finish operation: Handles 40 to 60 pound pigs and finishes these to market weights of about 250 to 265 pounds.

After pigs reach a weight of about 250 pounds, producers sell them at terminal markets or sell them directly to packers. Nineteen large packers surveyed in 1993 indicated that 87 percent of hog supplies came from the spot market (Hayenga et al., 1996). However, recently the market coordination method has changed dramatically. About two-thirds of all the hogs were sold to packers under a marketing contract in 1999 (Fig 1.1). Producers are increasingly shifting to contracts to decrease risks in the spot market, and packers are willing to offer these contracts to get the number and quality of hogs required. As presented in Fig. 1.1, the share of cash (spot) market transaction has declined sharply in recent years.

Sixty-two percent of total hogs marketed were sold in spot market in 1994 and the share decreased to 26 percent in the year 2000. If this trend is continued, contracts will eliminate the cash market (Feed-Stuff, March 13, 2000).

Figure 1.1: Share of cash (spot) market (1994-2000)

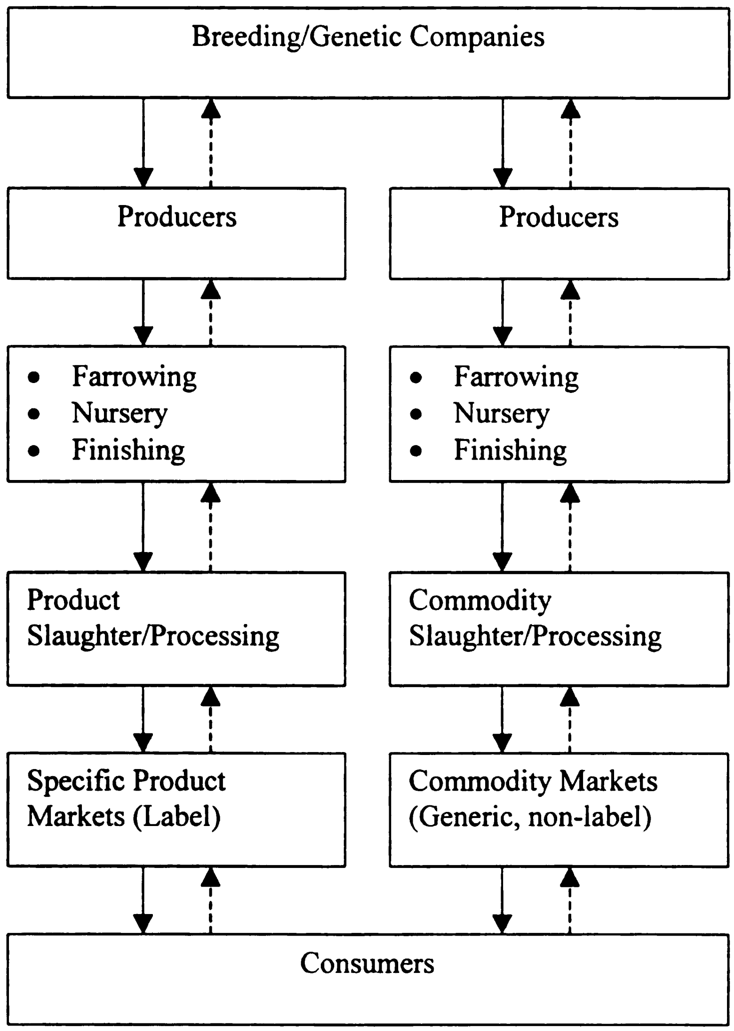


Source: Compiled from Feed-Stuff, March 13, 2000

There are two distinct production and marketing channels in the U.S. pork industry as represented by Figure 1.2. The first channel targets the specific product markets and the commodity markets are targeted by the second. Solid arrows indicate the product flow and broken arrows reflect feedback loops.

Both products oriented and commodities oriented production and marketing channels are in existence in the U.S. pork sector. Industrialized producers with processing and packing facilities dominate the specialty side, whereas independent producers without processing and packing facilities dominate the commodity side. The spot market is the dominant method of pricing in the commodity hog channel. The trend in U.S. agricultural production has been turning away from commodity production and towards product specialization.

Figure 1.2: Product flow and feedback channels in the pork industry



(Product flow and feedback)

1.1 Industrialization of agriculture

The changing nature of linkages between stages and consolidation of firms in the food production and distribution system has been referred to as the industrialization of agriculture (Boehlje and Schrader, 1998). Food production and distribution systems are experiencing structural changes. Linkages between the producers, input suppliers, and product buyers are important elements of structural change. In the production of agricultural products, the number of linkages has increased. "Most agricultural producers are sourcing more inputs from outside the farm and performing fewer activities or processes along the chain that result in the final food product" (Boehlje and Schrader, 1998).

According to the U.S. census data (1997), a typical U.S. farm produced just one or two farm products, whereas 90 percent of all farms in 1920 raised chickens, 75 percent raised at least one pig and 69 percent milked at least one cow. In 1997, just 5.3 percent farms raised pigs and 6.1 percent kept cows. Twenty chicken producers control 85 percent of all chicken production today, 3.5 percent of all cow/calf producers control 33 percent of the cow herd, two percent of all feedlots feed 85 percent of the feedlot inventory, seven percent of all dairy producers milk 59 percent of the dairy herd and seven percent of all hog producers produce 70 percent of the country's hogs.

1.2 Industrialization of the U.S. pork sector

During the 1950s, the broiler industry made its dramatic structural change towards vertical integration. Agricultural economists and industry experts believed that the pork industry would follow the broiler industry's vertical integration model. Traditional hog producers disliked this model and hog production has deviated from the broiler model (Rhodes, 1995). However, currently the structure of the U.S. pork industry is in rapid transition. During the 1980s and 1990s, major pork industry related technological advances benefited the pork industry. These advances allowed production to grow significantly in states not known previously for pork production. These technological advances resulted in cost efficiency by achieving a lower average cost of production and processing.

Applying new technology to existing firms may not be the best option[1]. Sometimes it is more efficient to start with complete new production units in order to capture the full benefits of the new technologies. As an analogy, consider the cost involved with upgrading an older version of a personal computer versus buying a newer version of a computer. Depending upon such factors as the age of the computer, the technology available, and the salvage value of the old computer; such a decision to replace may be optimal. It is often as expensive to upgrade a computer, as it is to buy a new one. Moreover, a new computer may have more capacities and computational power

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1. Many small and mid-size Midwest production facilities are of a size and technology that can continue to produce if capital and investment costs have already been recovered, but will not likely be profitable if major remodeling or upgrading of investments is necessary to remain in operation. Because of technological, size, environmental, or managerial conditions and limitations, many of these production facilities are likely to be

than the upgraded one. Similarly, much of the new pork production technologies cannot be fully implemented using the existing physical and human resources in traditional hog areas (Hurt et al., 1995). Technological advances lead to new types of production and processing facilities. This change encourages shifts of location to regions with advantages in the new types of units (Gillespie, 1996).

Large-scale hog production that utilizes new technologies has increased in the southern and western parts of the United States. These regions have competitive advantages in adopting the new types of production units. New operations have better arrangements with feed mills, packers, and other contractors to reduce production costs and improve risk management. Large operations have advantages over smaller operations (e.g., economies of scale). Lower cost and product differentiation are two basic types of competitive advantages (Porter, 1990), which encourage the shift to larger scale pork operations. These economic factors directly or indirectly contribute to the profitability of the industry and therefore drive spatial shifts of operations.

Locations where operating costs are lower and a favorable labor climate exists (i.e. high labor productivity, positive work attitude and low wage rates), can be dominant considerations for location decisions. Feed grains are the primary input for hog production and the transportation costs of bulky and heavy feed grains are generally high. Proximity to feed suppliers influences location decisions. Similarly, proximity to the markets is another important consideration since products of pork industry are bulky and involve high transportation costs.

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phased out of production rather than upgraded and modernized in place (Boehlje and Schrader, 1998)

Hog operations in the U.S. are not only getting larger, but are also moving to non-traditional pork states such as North Carolina, Arkansas, Utah, and Colorado where production has increased substantially. Production of hogs in North Carolina (currently the state with the second largest hog inventory) increased by 278 percent from 1987 to 1997. Iowa, still the number one state in terms of hog inventory, increased hog production by only 13 percent in the same period. In contrast, Illinois, formerly the second highest-ranking state in 1987, decreased its production by 17 percent (Table 3.2). The explosive growth of the hog industry, particularly in North Carolina and changes in industry structure, have raised the issue of social, economic and environmental sustainability with respect to the location and long term viability of the industry.

Expansion of the hog industry in the Southeast region (non-traditional region) may also slow in the future. The growing hog business and its malodorous by-products are raising eyebrows of regulators and environmentalists. Constraints such as higher costs associated with management of odor, flies and manure are important considerations in the hog industry expansion.

Consumer demand for more processed and specialized foods is another driving force for structural changes. Consumer preferences have changed toward meat products that are leaner, more consistent, and more convenient to prepare. Pork production and processing firms have built new alliances with hog breeders and producers to ensure breeding and production decisions that yield a superior product and meet consumer needs. This alliance results in an industry with a supply chain structure, where hogs are grown under contracts or by large integrated firms (Drabenstott, 1998). Vertical integration and contracts in production and marketing have become prominent in the pork industry, facilitating the transmission of consumers demand to the producers (Hennessy, 1996).

Public policies along with new technologies, and a favorable business climate are a few of the forces driving such changes (Gillespie et al., 1997). Public policies can encourage or discourage current or future market behaviors. Grants and subsidies, for example, provide incentives whereas regulations and standards are disincentives (Seidl and Grannis, 1998). Similarly, taxes, zoning, quotas, permits, research, and education are examples of public policy tools that play important roles in industry structure and performance.

1.3 Statement of problem

Pork producing operations in the U.S. are moving from the Corn Belt (traditional regions) to the Southeast, West and Southwest. In addition to spatial movement, the hog operations are growing in size, but shrinking in number. The trend of fewer but larger farms raising more hogs has been continuous for the last 50 years. This structural change affects farm communities, the environment, and pork consumers. The effect of the change has both positive and negative impacts on consumers and producers. Per unit cost of production has gone down lowering the price of pork for consumers. However, smaller producers may not be able to compete with larger producers, which would lead to further concentration in production. A study of the current market structure, economic motivations, and environmental constraints of the pork industry is required to model the regional distribution of hog operations. It is important to analyze the trends and factors of regional shifts of U.S. hog production so that policy makers and industry leadership will understand recent changes in pork production, and better anticipate further changes in the industry.

1.4 Objectives

1. Objective: To review the present supply and demand situation of the U.S. pork industry.

Related Concerns:

- What regional differences are there with respect to cost of pork production and processing?
- What regional differences are there with respect to demand for pork?

2. Objective: To study recent regional shifts in the U.S. pork industry.

Related Concerns:

- What are the temporal and spatial patterns of regional shifts in pork production and processing?

3. Objective: To predict the future locations of pork production and processing operations.

Related Concerns:

- What factors influence location of pork production and processing?
- What are the best locations for production and processing of hogs based on factors influencing supply and demand?
- Will the pork production and processing facilities continue to operate in existing locations?

1.5 Organization of dissertation

This study does not involve original data gathering or surveys, rather secondary data from different sources, particularly U.S. government documents, are used. The dissertation is organized into nine chapters. Chapter One is devoted to the introduction of the U.S. pork industry, problem statements and objectives and related concerns of the study. Chapter Two provides a literature review in which the concept of structural changes in agriculture including the pork industry is introduced. Chapter Three discusses the pork industry's historical perspective and recent trends in pork production, processing, and marketing. This chapter also summarizes the factors that might be directly or indirectly responsible to the structural changes in the pork industry.

Chapter Four summarizes the theory and application of demand system analysis. Three earlier estimated demand models are examined for their capability of explaining pork demand and the model that best estimates the pork demand is used for further analysis. Regional differences in pork consumption are also estimated based on demographic characteristics and disposable per capita incomes.

Chapter Five addresses the issues in the supply side of the pork industry. Detailed analysis of the cost of feeder-to-finishing operations is carried out. The main goal of this chapter is to analyze the competitive positions of different states/regions in pork production and processing. This analysis is the focal point of this study because the future of pork operations in one location lies on its cost competitiveness relative to operations in other locations.

Chapter Six evaluates the regulatory pressures that the pork industry is facing. State and federal environmental regulations are summarized and each state is assigned with an environmental stringency index. All the states are then classified into five different stringency groups based on their stringency indices. The U.S. Environment Protection Agency (EPA) proposed technology options for manure management. Tentative compliance costs attached with stringency indices and the technology options are assigned to each state. The compliance costs then are linked to the enterprise budgets developed in Chapter Five. Chapter Seven is the application of mathematical programming method to find the optimal locations of pig feeding operations and pork processing plants. This chapter utilizes all the components discussed in previous chapters that contribute to shape the pork industry. A linear programming approach is used to minimize the total costs of production, processing, and transportation under several constraints. Chapter Eight consists of results and discussion, and the sensitivity analyses of the results. Finally, summary and conclusions, and the limitations of the study are given in Chapter Nine.

Chapter 2

II. Literature Review

This section summarizes and discusses literature on structural changes in the agricultural sector in general and the pork industry in particular. The concept of market coordination system is introduced and the prevailing market coordination in the hog industry is discussed. This chapter gives insight into the nature and process of structural changes. A flow chart that depicts the concept and a process of spatial shift induced by technological change is discussed at the end this chapter. Since this dissertation analyzes various aspects (e.g. supply, demand, and government regulations) of hog industry, relevant literature is reviewed and cited beyond this chapter.

2.1 Industry structure

A growing economy is characterized by a decline in relative contribution of the agricultural sector. Slower rise in demand for food as compared to other goods and services contributes to this process. Rapid development of new farm technologies leads to expansion of food production per unit land and labor (Johnson, 1995). Technological developments increase total output per unit of land, but farm profitability may not increase due to lower prices received by farmers, which puts pressure on the agricultural sector.

Industrialization of the U.S. ag-economy is transforming farming from self-sufficient enterprises, to specialized and interdependent firms. The number of farms in the U.S. peaked during the Great Depression and has decreased ever since particularly during the 1970s and 1980s. The decrease in farm numbers exceeded 70 percent from

1969 to 1992 (McBride, 1997). One widely held view of the future of American agriculture is that it will continue the current trend toward fewer but larger farms, greater centralization, and vertical coordination (Stauber, 1994). Historically, the decline in number of farms is most prominent in the livestock sector.

The role of information and knowledge in the industrialization of the pork sector is important for business success. People with unique and accurate information and knowledge have increasing power and control of the sector. The capacity to capture profits and transfer risk comes from power and control (Boehlje and Schrader, 1998). The structure plays an important role in the process of transformation of information and knowledge among industry participants.

Industry structure can be defined in different ways. It may refer to the distribution of sales, revenues and profits; the importance of farm income; concentration of production in different regions; degree of specialization; ownership and control of inputs and outputs; and number and size of firms (Offutt et al., 1997).

Martin and Norris (1998) emphasize three different factors to describe the industry structure. These factors are: size of operation (number of head or acres of land); form of vertical coordination (coordinating mechanism spectrum ranging from spot market to complete ownership integration); and location of operations (shifts of animal production between regions and clustering of production within a region).

The U.S. pork industry has experienced dramatic restructuring during the 1980s and 1990s. It is undergoing increased consolidation of production units (decreased in number of farms but increased in the number of animals per farm), change in location of production within or between regions and change in coordination mechanisms. This restructuring is referred as industrialization of the pork industry. A variety of forces such as government intervention through policies designed to promote new technologies, and favorable business climates that allow entrepreneurs to combine low cost production with minimal regulation are cited as catalysts that cause industries to undergo rapid regional expansion (Gillespie et al., 1998). These factors vary among regions, states, and different counties, and therefore, influence industry structure.

2.1.2 Historical perspectives

The United States is one of the major pork producing countries in the world and its production accounts for 10 percent of the total world supply. The U.S. was the largest exporter of pork in 1997 followed by Denmark and Canada. The pork industry in the United States is an important sector of the economy. Over 17 billion pounds of pork were processed from about 92 million hogs in 1997 (USDA, 1997).

Hogs have been considered as a means to add value to corn. Therefore, the U.S. pork industry has been historically centered in Corn Belt states (Iowa, Ohio, Indiana, Illinois and Missouri), since corn is the primary input for hog production. These states contributed 72 percent of total hogs marketed in 1995 in U.S. However many pork operations have begun to move to new locations (toward the South) such as North Carolina and Oklahoma and the size of the operations is getting larger. The South's share of the national swine inventory rose from 15.8 percent in 1989 to 26.7 percent in 1996. Martin and Zering (1997) have described the process as following:

> "Fueled by technological change and economic opportunity,
> the historic patterns of geographic location, farm size,
> packing plant size, and organization of pork production are

> changing at exceptional rates in the United States and in the South. The number of swine farms keeps falling, with the majority of those exiting the industry keeping fewer than 1,000 head in inventory. In contrast, total inventory of farms with at least 2,000 head in inventory is growing rapidly."

The production and pork processing operations are not only moving, but also are departing from the small farm toward large and integrated operations. The output of the 20 largest packers represented 86.5 percent of 1993 hog slaughter and the 45 largest producers, each marketing more than 62,000 head in 1993, represented 13 percent of the total U.S. hog production (Lawrence et al., 1997). The share of total hog numbers held by large operations with 2,000 or more head went from 33 percent in 1993 to 37 percent in 1994 (Southard, 1995). According to recent data, 55 percent of all hogs were produced on farms with more than 2,000 animals, and 35 percent of all hogs were on farms with 5,000 or more hogs (Seidl, 1999).

From 1969 to 1992, the number of farms selling hogs decreased by 70 percent but average sales (undeflated) per farm increased by 300 percent during the period. The change in geographic distribution of pork operations during this period was also dramatic. North Carolina ranked eleventh in 1969 in hog production and it moved up to second place in 1992 surpassing the major hog producing states (Illinois, Minnesota, Indiana, Nebraska and Missouri). Changes in geographic concentration of production between 1969 and 1992 resulted in a decrease in number of pork producing counties in Iowa, Illinois and Indiana. Only a few counties in these states account for 25 to 50 percent of total sales. More counties from non-traditional hog production areas, primarily

North Carolina, Arkansas, Colorado, and California became part of the most concentrated areas of hog production (McBride, 1997).

One can ask, why do these dramatic changes in production, processing and marketing in the pork sector exist? Martin and Zering (1997) argue that the technological improvements have led to economies of scale in production. Furthermore, improved housing facilities, disease control measures, advances in nutrition, feeding regimes, and animal breeding have allowed large-scale, specialized pork production to prosper.

2.1.3 Vertical coordination system

Vertical coordination is the alignment of direction and control across segments of the production/marketing system (King, 1992). Firms enter into vertically coordinated relationships for several reasons: to increase efficiency, gain market advantage, reduce uncertainty and obtain or reduce the cost of financing (Mighell and Jones, 1963). Processors participate in vertical arrangements to assure the continuous supply of products with particular characteristics. Similarly, input suppliers also participate in these relationships to transfer/protect their technologies (Featherstone and Sherrick, 1992). The coordination can be achieved through direct market transactions and/or vertical integration (direct acquisition/ownership). The coordination system can be discussed in the following continuum based on the degree of coordination. The continuum ranges from the loosely coordinated spot market to the tightly coordinated vertical integration system.

2.1.3.1 Spot market

Spot market, also known as cash market, provides the exchange of commodities or financial instruments for immediate delivery. Prices and external control mechanisms are major factors for the coordination between the actors of economic exchange relationships. Spot markets are open, impersonal, and do not have contractual arrangements. These markets encounter difficulty in conveying the full message concerning attributes (quantity, quality, timing, etc.) of a product and characteristics of a transaction (Boehlje and Schrader, 1998). Coordination between the actors is achieved through the control mechanism that comes externally (from market forces) but sometimes an actor with market power can influence the market and specify some terms of exchange. Weaker actors who cannot influence the market can reserve the right to walk away from the exchange.

2.1.3.2 Contracts

Contracts are legally enforceable arrangements between individuals and/or firms involved in the transfer of goods and services. Economists have recognized the importance of risk in business arrangements. Kliebenstein and Lawrence (1995) argue that the primary reason for contractual arrangements (e.g. marketing contracts) in the hog industry is risk management. Production contracts help to reduce income risk and, therefore, contracts are generally helpful to risk-averse producers. New operators tend to have lower net worth and one might expect them to be more risk averse than existing producers (Gillespie et al., 1996).

2.1.3.3 Strategic alliances

The coordinating mechanism in which the parties involved in exchange relationships come together with mutual agreements. The coordination comes from common identifiable objectives, mutual control and decision-making processes, and sharing of risks and benefits. A breach of expectations by either party may terminate the alliance and it does not need legal or third party enforcement.

2.1.3.4 Formal cooperation

In the cooperation scheme, there is formal organization with distinct identity and internal control. Joint ventures, partial ownership relationships, clans, and other organizational forms requiring some level of equity commitment between the business partners form the formal cooperative arrangements (Wysocki, 1998). The control is decentralized among the parties and the ownership. Actors in this relationship maintain their identity and are able to walk away from the relationship if they wish. Agricultural cooperatives in the US are examples of formal cooperation.

2.1.3.5 Vertical integration

Vertical integration relies on centralized control to achieve coordination. Business decisions are made centrally which controls the operations. Single ownership may not result in vertical integration and generally vertical integration has multiple ownership structure. Lesser transaction costs than market exchange has become the conventional wisdom for vertical integration as suggested by Williamson (1979).

2.1.4 Coordination in pork sector

Production contracts in the pork industry are common mainly in areas of rapid expansion of operations. Producers provide labor, utilities and physical facilities and the contractor provides feed, pigs, veterinary care and market hogs after finishing. The contractor bears risks and keeps residual profits and losses. Contracts and vertical integration are important in obtaining consistent supplies of high quality pork. Coordination in production and marketing can improve the quality of hogs slaughtered and reduce the transactions costs. Genetics and weight determine the value of hogs received by packers. Use of long-term contracts reduces the sorting, measurement, grading and monitoring costs. In fiscal year 1996, Smithfield Foods Inc. obtained approximately 61% of its hogs through long-term agreements and integrated operations (Martinez et al., 1998).

From the early 1980s, hog production under contract became more widespread, mainly in the Southeast where larger companies followed the integrated broiler production model. Contracting is also growing in the Midwest, but this production arrangement is relatively new.

Asset specificity[2] in the production process is another incentive for contracts and vertical integration. Specific assets generate quasi-rent[3] streams because these assets are hard to substitute and rents are appropriated through opportunistic behaviors. Martinez et al. (1998) suggest that the long-term contracts and vertical integration may be helpful in reducing the potential for opportunism in the development of pork products with unique quality characteristics. If the packer lowers the premium, producers are left with the

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2. Specific assets are assets whose value is much greater in particular use compared to the next best alternative use.

alternative of accepting the premium or selling their product in spot market for no premiums. Legally enforceable long-term contracts provide protection against short-term opportunism.

2.1.5 Technology induced structural change

Methods of production improve over time. Development of new techniques, equipment, medicines and feeds make it feasible to handle more animals in one location than ever before. These new developments can be viewed as substitution of capital for labor. It is important to capture these improvements in the production process to be more profitable in business. Technological change is one of the driving forces for structural change (Reimund et al., 1981, Gillespie et al., 1997). The structural change model for agricultural sub-sectors has four dynamic stages.

1. Technological change
2. Shift in location of production
3. Growth and development and
4. Risk and transaction cost adjustment.

Advances in mechanical and engineering technologies has provided better housing environments for growing pigs. Continuous improvements in feeding and cleaning equipment increase labor and feed efficiencies. Similarly, advances in animal breeding, nutrition, and disease control are taking place continuously. Development in engineering and biological technologies have reduced the amount of time and feed required for raising pigs and has also reduced mortality. These technological changes have the following sequential structural impacts in the pork industry (Reimund et al., 1981):

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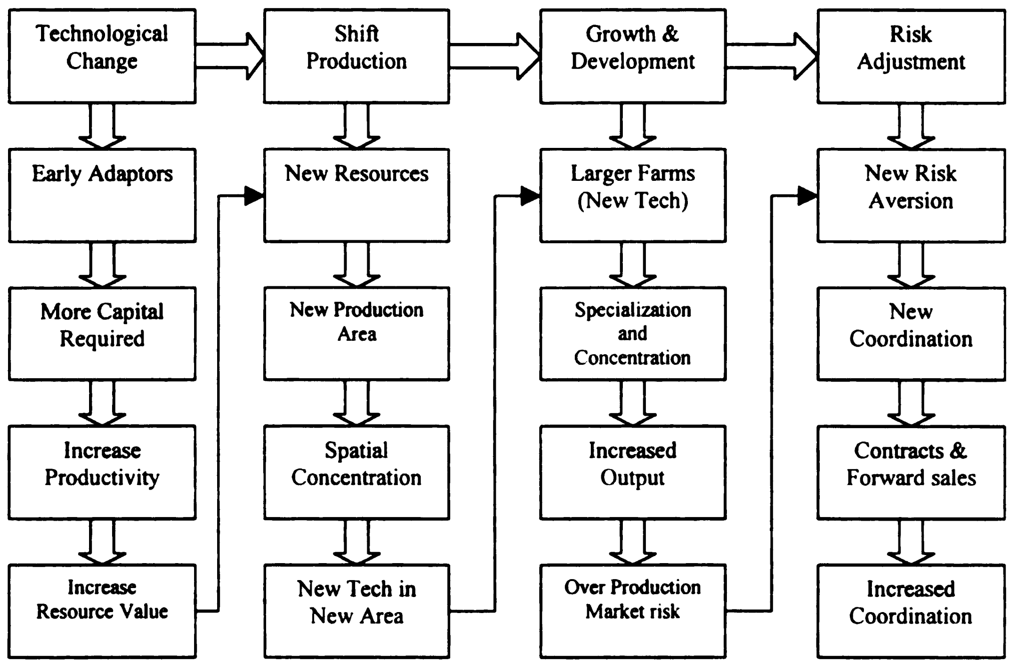
3 . Value of the assets in excess of the salvage value.

- The technology is employed by large producers and early adopters
- Requirement of capital increase to adopt new technology
- Land and labor productivity increase
- Development of economies of size
- Value of resources increases
- Shift in location of production

Fig. 2.1 outlines the process of the technology-led structural change model. A shift in production location brings new producers, and other resources into the sub-sector. Firms look for the production sites that have lower input prices to increase their net return to the investment. Production may be concentrated in the sites where pork production turns more profitable and hence the new technology is adopted in new areas. Innovative industries experience rapid growth and development.

Ex-post spot market introduces the opportunistic behaviors of market participants (e.g. meat packers and the producers). Ex-ante marketing arrangements prevent them from such behaviors. Larger and specialized farms produce a large volume of production and have less product diversification. Such farms may need to sell their products at a lower price in spot market if they did not have formal marketing arrangements before the production process. Due to productivity growth and specialization, industries become more risky (price risk). Recent trends of increasing the size of farms and rapid technological development results in increased risk in production and marketing. Production and marketing chains become more tightly coordinated to minimize the risk due to over-production and less diversification. Ex-ante contracts and vertical integration minimize the risk in the production marketing chain. Since this research is particularly interested in the shift in production location, changes in the industry beyond the shift in production locations will be only briefly discussed in this research project.

Figure 2.1: Conceptual structural change model



Source: Adapted from Reimond, Martin and Moore (1981) with modifications.

<u>Description of the conceptual model</u>

The meat packing industry in the U.S. has developed over the last 150 years in response to technological changes. In the process of development, the industry has moved from small, local butchers to central terminal stockyards to slaughterhouses. Large-scale hog production using the new technologies has increased in the southern and western regions. New operations are typically linked with a packer and or feed mill by contract or joint ownership agreement to reduce risk and transaction costs (Gillespie et al., 1996). A marketing structure with fewer, large-volume buying stations would be more operationally efficient.

The hog industry has passed through several vertical integration and horizontal merger waves in the past. Williamson (1989), Perry (1989) and Katz (1989) discuss the benefit and motivation for tighter vertical integration. Williamson argued that the main purpose of vertical integration is to minimize transaction costs. Perry has suggested transaction costs, technological changes, and market imperfection as major causes leading to vertical integration. Vertical integration can also spread the risks involved in production and marketing.

2.1.6 Government regulations and pork industry

In addition to labor force characteristics, input availability, and proximity to final markets, government intervention on different levels and issues can also influence the location of firms. Public policy tools can encourage or discourage current or future behaviors. Grants and subsidies from government provide incentives whereas regulations, standards and moratoria are disincentives (Seidl and Grannis, 1998). Similarly, taxes, zoning, quotas, permits, research and education are some public policy tools that play important roles in industry structure. Animal feeding operations generate manures that are rich in mineral nutrients such as nitrogen and phosphorus. Such nutrients are useful to the plants, but are detrimental to human health if the air and drinking water are contaminated. The loading of nutrients into water and air, as the impact of large hog feeding operations has generated debate in several state legislatures. The National Survey of Animal Confinement Policy (1998) under the auspices of the National Policy Education Committee has covered various aspects of government regulations. The regulations relevant to pork industry are analyzed and discussed in a separate section of this dissertation.

Chapter 3

III. Pork industry: trends in production and firm locations

The pork industry is reorganizing to meet the changing expectations of consumers. The industry has built new alliances with breeders, producers and processors to ensure superior pork products. The consequence of these arrangements is the development of a supply chain structure. Breimyer (1962) noted that crop, livestock, and marketing were three distinct economies in the U.S. agriculture and the livestock industry was an intermediate stage between a traditional agrarian structure and a modern industrialized model. The relative emphasis of crop and livestock within major production regions changed due to the industrialization of agriculture. In this chapter, the supply situation of pork with emphasis on historical trends is discussed. The spatial distribution of pork production is of primary interest in this research; therefore, the geographical concentration of hog production is analyzed.

3.1 Trend in number of hog farms and production in the U.S.

Since the beginning of the 20th century, the number of pig farms in the United States has been falling, but the average inventory per farm has risen steadily. In past decades, the number of farms, particularly the smaller farms (i.e., less than 100 head in inventory) has dropped sharply, but the number of farms keeping more than 1,000 head in inventory increased until 1992 and the number dropped slightly in 1997. The drop in the number of big farmers from 1992 to 1997 is the result of consolidation of bigger farms into larger operations. The data presented in Table 3.1 are helpful to explain the structural changes in the U.S. pork sector in terms of number and size of farms.

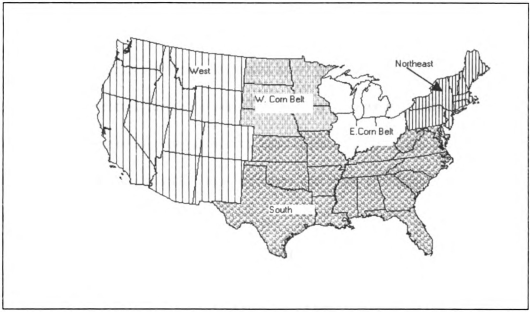
Table 3.1 Trends in number and size of hog farms (1959-1997)

Census Year	Total farms (in thousands)	Number of hogs sold per farm (in thousands)				
		1-99	100-199	200-499	500-999	1,000+
1959	1,273	1,018	161	81	10	1.5
1969	604	361	109	101	25	6.6
1978	470	281	69	74	30	15.8
1982	315	162	44	56	30	21.6
1987	239	110	33	45	27.5	23.9
1992	188	77	23	35	25	27.8
1997	110	43.7	9.6	15	12	21.7

Source: U.S. Census of Agriculture

Pork production operations are found in every state in the nation, but are not evenly distributed. Historically, pork production has been concentrated in the Corn Belt states in the North-central region. Iowa ranked number one in the nation in hog numbers with 26 percent of the nation's supply (Melvin, 1996). According to the 1999 December data, Iowa's share decreased to 24.6 percent, but still ranked number one in the nation in terms of total hog numbers. Production units in the 200 to 499 head of annual sales declined in 1970s. Similarly, production units in the 500 to 999 head of annual sales declined in 1980s. In 1978, the U.S. Census showed one-third of output produced by units marketing 1,000 head or more per year, but only seven percent by those large units marketing 5,000 head or more. In 1992, 1,000 head group marketed 69 percent and 5,000 head group was marketed at 28 percent (Rhodes, 1995).

Figure 3.1 The United States of America and geographical regions



In addition to size change, pork-producing operations locations have also been changing in the past 25 years. The North-central region remains a major production area, both in number of operations and number of animals, but there has been continuous growth in pork production in the Southeastern and Western Corn Belt regions[4] (Table 3.2). Table 3.2 shows the position of major pork producing states in terms of number of operations and hog inventory in different years. From 1978 to 1997, the number of hog operations decreased by 75 percent and the total number of hogs increased by six percent in the nation. The increase in the number of hogs during this period is dramatic in North Carolina (406 percent increase), but the number of operations decreased by 84 percent. The total number of hogs in Iowa remained nearly constant, but the number of hog farms

4 According to Bureau of Economic Analysis (1997) grouping of states in region
Northeast: ME, NH, VT, MA, RI, CT, NY, NJ, PA
Midwest (Eastern and Western Corn Belts): OH, IN, IL, MI, WI, MN, IO, MO, ND, SD, NE, KS
South: DE, MD, VA, WV, NC, SC, GA, FL, KY, TN, AL, MS, AR, LA, OK, TX
West: MT, ID, WY, CO, NM, AZ, UT, NV, WA, OR, CA, AL, HI (Fig. 3.1)

decreased by 70 percent. Illinois and Indiana experienced declining trends in both hog operations and inventories. In Montana, the number of hogs has decreased by 16 percent and the number of operations has decreased by 74 percent during the period. Similarly, in Michigan, the number of farms decreased by 67 percent and the number of hogs increased by 11 percent during the period. From this table we may conclude that the decrease in number of hog operations is drastic in most of the cases. Inventories of hogs have been increased dramatically in a few states and in most of the states it is either constant or it has decreased slightly.

Hog production is concentrated among the top five producing states (Iowa, North Carolina, Minnesota, Illinois, and Indiana). In 1997, these five states supplied about 70 percent of the total production. Iowa was the largest hog producing state, representing 24 percent of the U.S. hog inventory in 1997. The second largest producing state was North Carolina with about 16 percent of inventory. Despite North Carolina's large production share, the majority of commercial hog operations are still located in the Midwest, the traditional hog producing area. In 1997, Iowa had the most hog operations with 17,243. Other states with large numbers of hog operations included Minnesota (7,512), Illinois (7,168), Indiana (6,442) and Nebraska (6,017 operations).

Table 3.2 Number of operations[5] and hog inventory in selected states (1978-1997)

State	Number of operations			Number of hogs (Thousands)		
	1997	1987	1978	1997	1987	1978
Iowa	17,243	36,670	57,325	14,652	12,983	14,695
N. Carolina	2,986	6,900	18,846	9,624	2,547	1,901
Minnesota	7,512	16,042	25,703	5,722	4,372	4,089
Illinois	7,168	17,084	28,227	4,679	5,642	6,206
Indiana	6,442	14,834	22,141	3,972	4,372	4,160
Nebraska	6,017	13,363	20,532	3,452	3,944	3,723
Michigan	2,853	5,577	8,572	1,032	1,227	931

Source: U.S. Census of Agriculture 1982, 1987, and 1997

Historically, hogs have been raised on farms that produced corn and other crops. However, in the past three recent decades, farming has become more specialized. The size of production operation is growing rapidly and many small to mid-size farmers have abandoned raising hogs. The number of farms that sold hogs was 645,882 in 1969. The number reduced to 312,924 in 1982. This number was further reduced to 138, 690 in 1997 (Table 3.3). The share of hog slaughter rose from 34 percent in the top four firms in 1980 to 56 percent in 1998 (Carstensen, 2001).

5 The definition of a farm for census purposes was first established in 1850. It has been changed nine times since. The current definition, first used for the 1974 census, is any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the census year. The farm definition used for each US territory varies. The report for each territory includes a discussion of its farm definition.

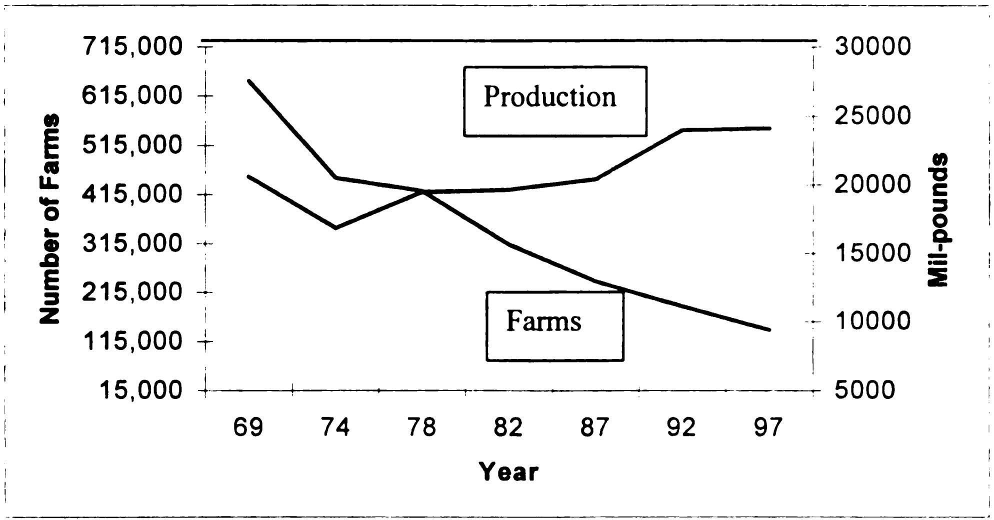
Table 3.3 Number of farms and per farm pig production 1969-97

Year	Farms (Sale hogs)	Live wt. (Mil. Pounds)	Head per farm (Average)
1969	644,882	20,600,325	138
1974	449,266	19,976,384	177
1978	422,873	19,466,200	214
1982	312,924	19,657,921	300
1987	236,973	20,408,228	403
1992	186,627	23,946,691	588
1997	138,690	24,094,229	1491

Source: Compiled from the U.S. Census of Agriculture Data

The number of farms with hog sales declined by about 78 percent between 1969 and 1997, but the total hog production increased by about 17 percent. The average number of hogs sold per farm jumped from 138 to 1491, which is over a ten-fold increase from 1969 to 1997 (Table 3.3). The increasing trend of production and decreasing trend of the number of farms can be represented from the following chart. The chart shows annual production of hogs in terms of total live weight and the number of farms for census years from 1969 to 1997.

Figure 3.2: Trends in pork production and number of pig farms in the U.S.



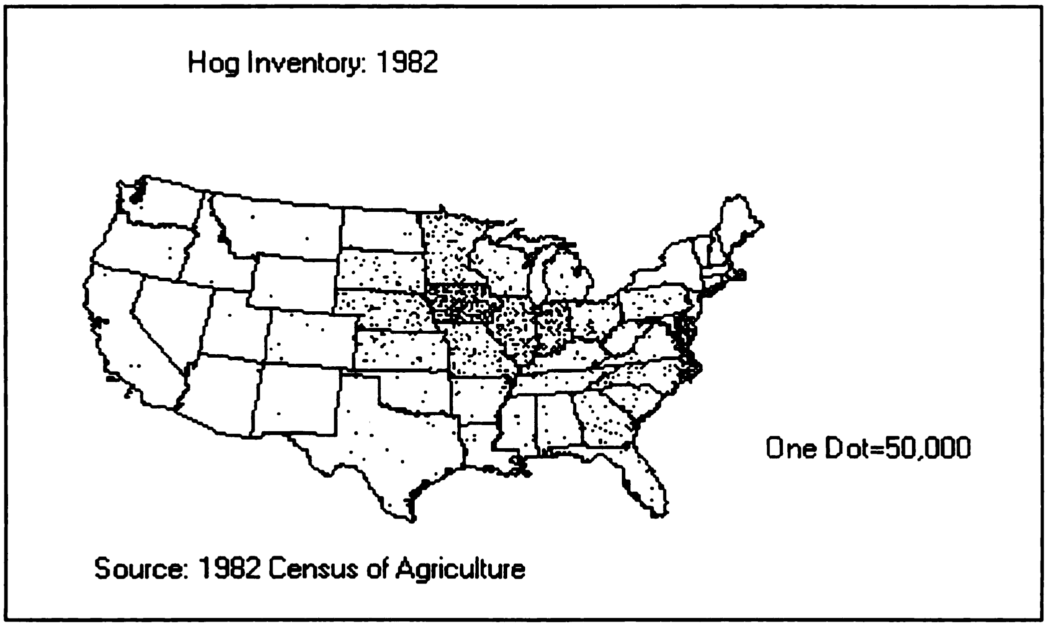
Source: Economic Research Service, U.S. Department of Agriculture

3.2 Increasing geographic concentration of production

Concentration[6] in hog industry refers to the inequality in the pork production among different geographic regions, states, and counties. Hog production was previously concentrated in the Corn Belt area since corn is the major feed grain for hogs. However, in the recent past decades, the pork industry has moved to new locations. Hog production has shifted from small, geographically dispersed operations to fewer, larger, and geographically concentrated operations. Further concentration of ownership and control is under way in the industry (Abdalla et al., 1995).

6 Concentration is defined as an increased proportion of production controlled by fewer firms.

Figure 3.3: Distribution of hogs in contiguous U.S. 1982 and 1997



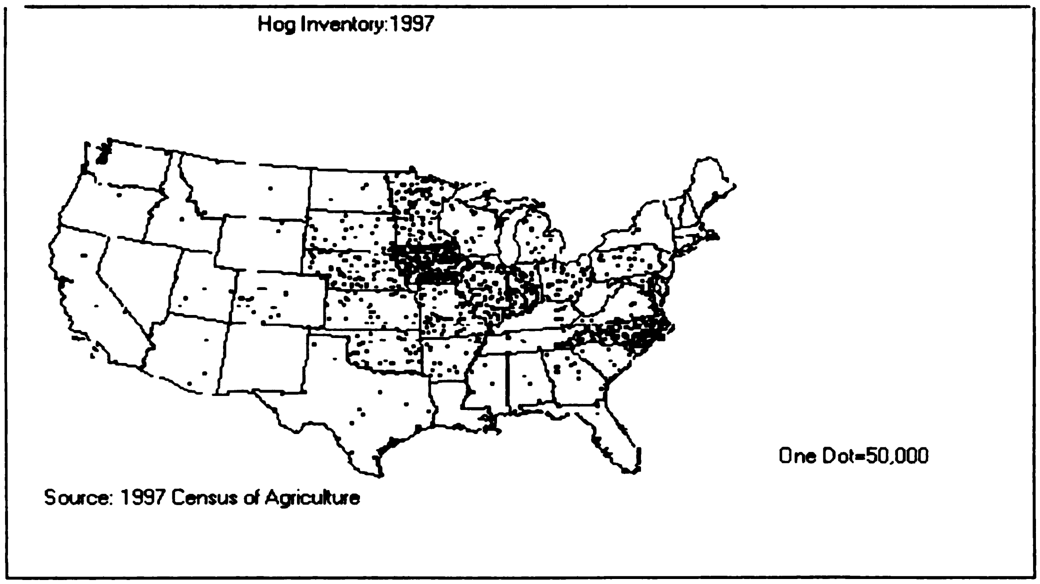


Table 3.2 and Fig. 3.3 show how the hogs are concentrated in fewer states. The states of Iowa, Minnesota, Illinois and Indiana (the traditional hog producing states) are still dominant in hog production. Fig. 3.3 also indicates the growth in hog production in South (vicinity of the state of North Carolina) and the West (e.g. the state of Colorado, Utah, and Arizona) from 1982 to 1997. The concentration in the state of North Carolina is remarkably higher.

As discussed earlier, production of hogs is concentrated in fewer operations. The number of hog operations in some states reduced dramatically in 1997 and the pork production is dominated by a fewer operations in limited areas. Most of the hog operations that have more than 200 hogs in their inventory are still located in traditional hog producing states. Few new emerging states such as North Carolina, Pennsylvania, Missouri, Oklahoma and Arkansas also have high concentration of big operations (Fig. 3.4 and Fig. 3.5).

There has been a major growth in pork production in the Southeast, particularly in North Carolina over time. In some counties, pork production has increased dramatically. Figure 3.5 depicts the concentration of hogs in U.S. counties. Out of the top 25 counties, 11 counties are from Iowa and eight counties are from North Carolina. This gives some idea of how the hog production is concentrated in these two states. Texas County in Oklahoma and Sullivan County in Missouri have seen a dramatic jump in production. These two counties jumped from 797 and 736 ranking in 1992 to the number three and number six top producers respectively in 1997.

Figure 3.4: Farms with 200 or more hogs and pigs inventory in 1997

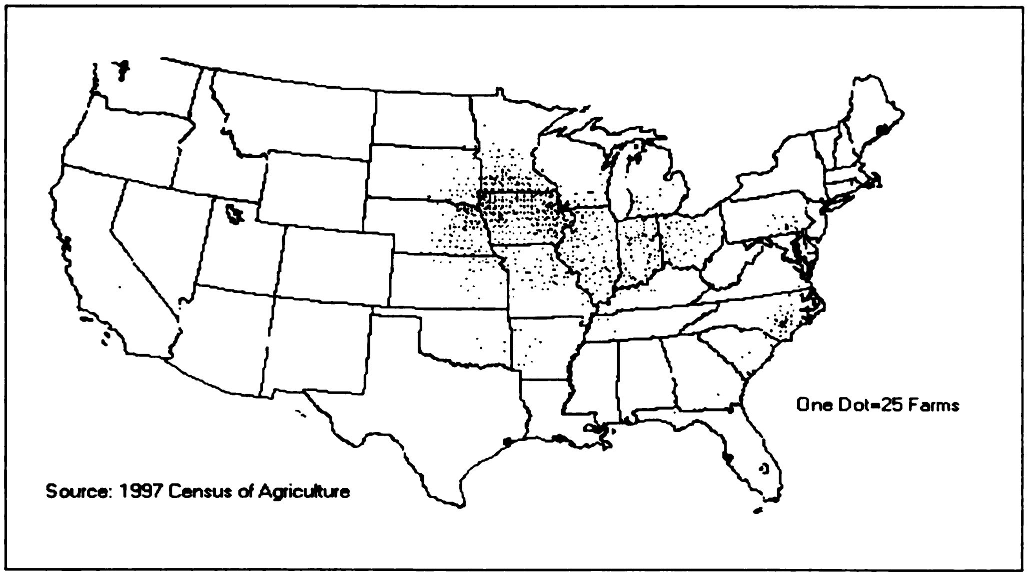
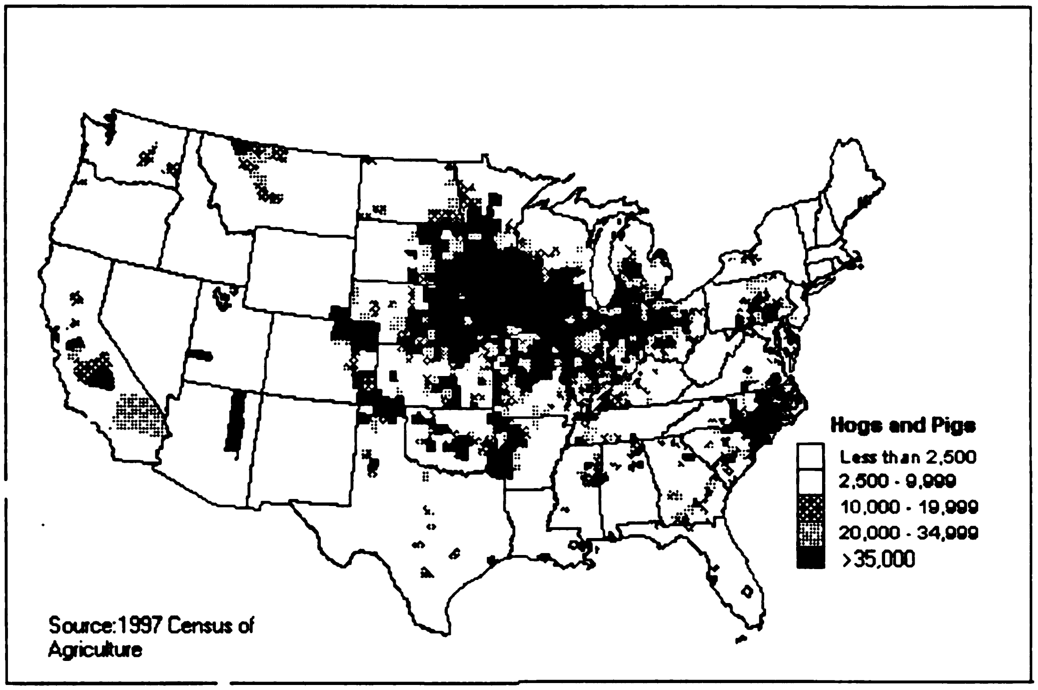


Figure 3.5: Hogs and pigs sold by counties in 1997



3.3 Factors affecting location of production

What factors make some locations desirable for hog production over other locations? Factors that influence the location decisions and regional shifts contribute to the geographic concentration of hog production. Production restrictions and feed costs are important factors for industry location. Competitiveness in state regulations for farms and agribusiness, taxes, labor costs and characteristics, and closeness to final markets are also the important factors (Gillespie, 1996). Some of the factors, which potentially influence the pork industry structure, are discussed below.

3.3.1 Technological change

There is considerable agreement among agricultural economists that the structural change is driven by technology and efforts by producers to gain economies of scale. New technologies and managerial techniques bring profit opportunities. The cost-saving motivations in production processes are important factors for development and adoption of new technologies. For example, new technologies in animal feeding have helped reduce the amount of corn required per hundredweight of pork produced. Transportation cost of corn out of the Midwest has become lower over the past few years because of volume discounts given to large producers (Good, 1994). Profit maximization and production and distribution cost minimization are the primary factors in determining the location (Healy and Ilbery, 1990). Technological break-through in animal health (good nutrition and medication), all-in/ all-out production, and multi-site production have made it possible to reduce the outbreak and spread of diseases even with very large number of hogs confined in one location. This can be taken as an example of technological changes contributing to industrialization of hog industry.

3.3.2 Corporate farming laws

Restrictive laws potentially push pork production away from particular areas toward others (Welsh, 1998). Nine states (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin) have anti-corporate farming laws (Hamilton, 1995 and Knoeber, 1997). The anti-corporate farming laws prohibit corporations from owning farmland or from conducting farm operations. The intention of such laws is to protect the family farms by excluding agribusiness and conglomerates from direct production and from controlling farm production (Krause, 1983).

The states of North Carolina, Arkansas, Utah, and Colorado have experienced substantial increases in pork production. Growths in production in these locations can be partially attributed to favorable corporate farming and environmental policies that allow large-scale farming using non-traditional business arrangements (Gillespie, 1996). Anti-corporate farming laws have restricted innovative corporate swine producers in the southeast from expanding their operations to major swine producing states in the Midwest (Knoeber, 1997).

3.3.3 Property values

Agricultural land values in proximity to hog operations may rise due to demand for manure application rights. If there is little or no hog production in the area initially, property values are reduced more by the addition of a hog operation (Hubbel and Welsh, 1998). Hubbel and Welsh suggested " property values may push hog production into counties where it already exists at substantial levels, because the marginal reduction in their property values will be less in these counties". The value of agricultural land is high in the eastern part of the country and the west coast. Parts of New Mexico, Arizona, Texas, Nevada, Wyoming, Montana, South Dakota and Nebraska have cheaper agricultural land. These areas may interest hog producers in moving their hog production in the future.

It may be possible that the introduction of hog production in an area of low economic activities would increase the property value because the industry generates new economic opportunities in the area and demand for land use would increase in order to spread the manure generated by the hog industry.

3.3.4 Economic options

Agriculture may be one industry that will provide increasing economic benefits to rural America through value-added agricultural practices. We can take the case of recent changes in the southern economy. Hog production in the southern region is increasing and it may be due to the lack of economically viable alternatives for farmers. Martin and Zering (1997) argued, "Pork production in the South was not an economically important commodity prior to the 1970s. The political climate surrounding traditional cash crops left many farmers uncertain as to whether there was a profitable future with these commodities. Given the small farm size and low yielding soils, individuals recognized the need to search for and develop alternative farm enterprises". Choice of pork production enterprises is the result of fewer economic alternatives for the farmers in the South. Pork production and processing enterprises have contributed economic benefits to the communities in the forms of employment, farm income, and tax revenues.

3.3.5 Environmental adsorptive capacity

Environmental characteristics such as soil type and climate of a specific region are important in making location decisions (Boehlje, 1995). As the number of hogs per unit land increases beyond a limit, the by-product may exceed the environmental adsorptive capacity or the carrying capacity. This leads to serious environmental problems such as high nutrient content in soil and water. The adsorptive capacity is site specific and it is the least mobile resource. Therefore, adsorptive capacity is an important determinant in the location of hog operations.

3.3.6 Public policies

Public policies influence technological progress. For example, the U.S. government's decision to privatize commercial production of nitrogen fertilizer during World War II enabled rapid expansion of the use of fertilizers. Policies such as the federal commodity price support program, Commodity Credit Corporation's storage program for feed grains, and improved transportation played important roles in affecting the spatial distribution of crop and livestock production (Abdalla et al., 1995). Change in public policy could provide a basis for the structural change indirectly through impacts on adoption of technology, producer risks, and geographic location (Reimund et al., 1981).

3.3.7 Consumer demand

The role of consumer demand on structural change of the hog industry is under debate. Some economists believe that the main push for the change has come from the demand side. Boehlje and Schrader (1998), and Barkema and Cook (1993) recently argued that consumer driven forces are primarily responsible for the changes in the U.S.

pork industry. New market channels of communication such as production contracts and vertical integration connect to consumers. Demand for good quality pork has been the driving force behind the structural change. Consumers demand meat products with more specific traits such as leanness, tenderness, flavor, convenience, and nutritional value. Meat packers convey the consumer demand information to producers through production and marketing contracts. Rhodes (1995) does not agree with these views and he argues that changes in the hog industry are driven by profit motives. Producers expand horizontally to control production costs and increase their returns. Location adjacent to final markets is an important factor for production location decisions. We can take the examples of North Carolina and Utah. North Caroline is well situated to furnish the Eastern Seaboard with pork and Utah is well positioned to fulfill the California markets and Asian export markets.

3.3.8 Contractual arrangements

A tightly vertically coordinated system facilitates signaling consumer preferences back to producers. Production contracts, for example, are effective in transferring consumer preferences. Such contractual arrangements also assure the supply of quality hogs to the pork processing plants. Contract production enables the large processors to continue growing rapidly. In contract production, the producer's capital is not tied up in building and equipment. The producer is able to direct his resources to building more farrowing units where more hogs can be produced. Because of the long history of contract production in the poultry industry, contracting is readily accepted in North Carolina. There are adequate people who maintain interest in becoming part of the production process as contract growers and finishers and financial institutions look favorably on providing capital for contract production (Goods, 1994 and Hurt, 1999). Hog production in non-traditional areas can become competitive with the traditional area because they can realize efficiency gains through improved managerial and production techniques and marketing contracts.

3.3.9 Agglomeration

In production economies, there are internal and external economies of scale. It is a well-known fact that economy of scale is one of the internal factors of expansion in production level. External economy of scale arises from "localization economies" (Roe et al., 2002). Agglomeration implies that performance of a pork operation improves by the easy access of industry infrastructures and services. When many related businesses are concentrated in one location, there becomes easy availability of inputs, technical and administrative services. Diffusion of production and marketing information is improved and the transaction costs are lowered due to the geographical concentration of firms (Krugman, 1991). Among the various factors affecting the regional competitiveness of the hog industry, consumer demand, environmental regulations and costs of production are the most dominant factors. Furthermore, most factors discussed above have direct or indirect effects on production costs. These three factors are discussed in detail in the following sections of this study.

Chapter 4

IV. Approximation of pork demand

4.1 Introduction

Demand and supply along with other forces shape the industry structure. Boehlje and Schrader (1998) and Martinez et al. (1997) argued that the consumer driven forces are responsible for the changes in the U.S. pork industry. Consumers want pork and pork products at reasonable prices. They adjust the quantity of pork demanded based on the market prices of pork and other substitutes. The mathematical model used in this study will adjust the number of pigs to be produced in different locations based on the quantity of pork demanded. Pork production (supply) and consumption (demand) are interrelated to clear the market. If the price falls, quantity demanded increases; if the price increases, quantity supplied increases. The conditional predictions are combined to generate a regional allocation in U.S. pork system.

Consumer demand for a commodity is an important component in analyzing and forecasting the effects of changes in prices of commodities and consumer income. This research is designed to study the consumer demand system of pork to achieve a better understanding of its effect on the location of pork production and processing. Grannis and Seidl (1998) argued that a change in consumer demand might be partially responsible for the change in the hog industry. From late 1970s, pork and beef lost market share to chicken partly due to the health concerns of consumers. Decrease in market shares of pork and beef is partly contributed to the reduction in production costs of chicken due to technology advances. Moschini and Meilke (1989) concluded that the movement toward white meats supports the idea that dietary concerns are partly responsible for the changes in the pattern of meat consumption. Today's consumers prefer meat products that are leaner, more consistent, and more convenient to prepare. In order to meet consumer needs, pork processors build alliances with hog breeders and producers to ensure breeding and production decisions that yield a superior quality of pork. Such alliances are more effective if the market participants are located closer to each other. Pork production and processing firms move to the locations where the demand for pork and pork products is larger.

The objectives of this chapter are to give a brief description of the theory and application of meat demand system analysis and to estimate the market demand of pork in the U.S. This chapter will use three different meat demand models that are published in different journals to estimate the pork demand. The log linear, the Rotterdam, and the almost ideal demand systems will be used on per capita pork consumption data. The model, which explains the per capita pork consumption better than the other models, will be picked for further analyses of the pork sector.

4.2 Theoretical background

Directly specified and utility-based demand models are two general approaches of demand analysis. Directly specified models have been used for many years and are built on the economic theory of consumer behavior relative to price and income. Utility-based models are built on the assumption that the consumer behaves rationally and chooses the consumption basket so as to maximize his/her utility subject to a budget constraint. According to Theil and Clements (1987), these demand models give an intuitive explanation of the parameters of the demand equations and can be used to test the empirical validity and theoretical restrictions of demand equations.

Economic theory tells us that consumer demand is a function of consumer income, tastes, and the price of goods. Phlips (1974), Theil (1975), Deaton and Muellbauer (1980), and Johnson et al. (1984) have documented the theory of consumer demand. The utility function is a measurement of consumer satisfaction obtained from the consumption of a bundle of commodities at a given time. The consumer as a rational decision-maker, chooses the commodity mix so as to maximize his/her total utility. The utility maximization problem can be written as

$$MaxU = f(q_1, q_2, q_3, \ldots\ldots, q_n) \qquad (1)$$

$$\text{Subject to } \sum_{i=1}^{n} p_i q_i \leq I \qquad (2)$$

where, 'U' is the consumer utility which is strictly increasing, strictly quasiconcave and twice differentiable, p_i and q_i are the price and quantity of the i^{th} commodity. 'I' represents the consumer total income and it is equal to the expenditure (no savings assumption). Equation (2) is called a consumer budget constraint and states that total expenditure on all commodities is not greater than total income. Expression 1 and 2 can be solved and rewritten as a Marshallian demand function (m_i)

$$q_i = m_i(I, p_i \ldots p_n) \qquad (3)$$

This Marshallian demand function indicates that the demand for a commodity (q_i) is a function of its own price (p_i), prices of other commodities (p_n) in the consumption bundle, and individual's income *(I)*. A utility function expressed as the function of quantity consumed, i.e., U=f(q) is called a direct utility function, whereas a function expressed in terms of prices of commodities and consumer income is called an indirect utility function. The indirect utility function can be expressed by the following equation

$$U = f[m_1(I, p_1 \dots p_n), \dots, m_n(I, p_1 \dots p_n)] \quad (4)$$

where $m_1, \dots, m_n$ are the set of Marshallian demand functions from equation (3) which can be written in a short form as

$$U = V(I, P) \quad (5)$$

where V is an indirect utility function. Application of Roy's identity to the indirect utility function gives rise the quantity demanded.

$$\frac{\partial V / \partial p_i}{\partial V / \partial I} = q_i \quad (6)$$

The indirect utility function is useful for determining what change in income is necessary to compensate for a given change in price and still keep the utility of consumer constant.

Similarly, a cost or expenditure function can also be used to derive consumer demand. This approach assumes that the consumer minimizes the cost of attaining a given utility 'U' at the price 'p'. This minimization problem can be written as

$$C(U, p_i) = \min_{q_i} p_i . q_i \quad (7)$$

$$\textit{subject to } U(q_1, q_2, \dots\dots, q_n) = U \quad (8)$$

where, $C(U, p_i)$ represents the cost of the optimal quantities of q_i at price p_i $(i = 1, 2 \dots n)$ and utility level U. Total expenditure (E) is represented by $\sum p_i q_i = E$, which is the least expensive way of reaching the highest possible utility level. The cost minimizing demand function tells us how the quantity consumed is affected by prices given the utility *(U)* held constant.

By taking partial derivatives of the given cost function with respect to prices, we can derive the Hicksian compensated demand function (h_i). The process is called the Shephard's lemma and it gives the quantity (*q*) demanded as below

$$\frac{\partial C(U,p_i)}{\partial P_i} = h_i(U,p_i) = q_i \qquad (9)$$

4.3 General restrictions and assumptions of demand systems

The system of demand equations from utility maximization or cost minimization has four basic general properties that take the form of mathematical restrictions. These properties are (1) adding up, (2) homogeneity (3) symmetry and (4) negativity[7].

1. Adding up: By this restriction, the sum of the budget shares is equal to `one' and implies that the total value of all the goods in the basket is equal to total expenditure.

2. Homogeneity: Homogeneity implies that the Marshallian demand functions are homogeneous to degree zero in prices and income. Quantity demanded remains unchanged if all the prices and income changes are by the same proportion. Hicksian demand are homogenous to degree zero in prices.

3. Symmetry: The cross price derivatives of the Hicksian demands are symmetric for all $i \neq j$ and this symmetry condition can be represented by

7 For a detailed discussion, refer to Theil (1975), Deaton and Muellbauer (1980) and Phlips (1983). The demand systems summarized here are based on these publications.

$$\frac{\partial^2 C(U,p)}{\partial p_i p_j} = \frac{\partial^2 C(U,p)}{\partial p_j p_i} \qquad (10)$$

where, C(U,p) is cost function and the Hicksian demands are obtained by taking derivatives of this function as described in equation (9). According to Young's theorem, if these two derivatives are continuous, they are identical and the order of differentiation doesn't matter. The symmetry property guarantees that consumers make rational and consistent choice.

4. Negativity: This negativity condition implies that an increase in price with utility held constant must cause demand for that good to fall or at least remain unchanged.

$$\frac{\partial^2 C(U,p)}{\partial p^2{}_i} \leq 0 \qquad (11)$$

Adding up and homogeneity conditions are consequences of the specification of budget constraint. Symmetry and negativity derive from the existence of consistent preferences. Phlips (1983) has explained that observed consumer behaviors often do not satisfy the theoretical restrictions because theory is a simplification of reality and statistical data generally contain some measurement errors. It is not possible to include all the items entering into the consumer's budget in demand system analysis because the number of parameters to be estimated becomes very large. For example: for a system of "n" items, we need to estimate n (n+1) parameters. By application aggregation and symmetry restrictions, the numbers of parameters to be estimated are reduced to ½ (n^2 +n)-1. Degrees of freedom and multicolinearity are important econometric problems of using large systems.

The consumption bundle is partitioned into subsets each including items that are substitutes or complements to each other than to items in other subsets. The concept of separability is useful in the two-stage budgeting procedure for the allocation of the consumer's expenses across the group of goods. First the consumer allocates his/her total expenditure to broad commodities groups such as food, housing, clothing, recreation etc. Then he/she optimally allocates spending in specific goods (e.g. pork) in a particular group (e.g. meat). Application of separability assumption makes demand analysis simpler.

4.3 Market demand

An individual consumer or household is the basic unit of demand analysis. The market demand for a consumer good is the sum of the consumers' demands. Economists generally use two approaches to estimate the market demand system. The first approach specifies functional forms to estimate the demand parameters. It incorporates the separability assumptions, which have the advantage of reducing the dimension of the estimation problem and imposing behavioral restrictions. With this assumption, the result of the demand theory for individuals can be evaluated in market level data (Johnson, et al., 1986). Brandow (1961) and Frisch (1959) pioneered a second approach that deals with the approximations of demand systems. This approach is common in the discipline of applied economics and used in policy and commodity market analyses.

4.4 Demand model specification

There are four basic approaches to the derivation of the theoretical demand system.

1. Linear Expenditure system (LES)

Klein and Rubin (1947-48) developed LES model. This approach maximizes utility function subject to the budget constraints. They expressed the expenditure on a good as a linear function of total expenditure and all prices. They imposed the adding up, the homogeneity and symmetry restrictions in the system. Stone (1954) applied the LES in Britain. This approach was popular until the 1970s and is still in use.

2. Indirect utility function approach

The indirect utility function approach is based on the algebraic specification of the indirect utility function. The optimum quantity demanded depends indirectly on the prices of goods being bought and the individual's income level so as to maximize the utility. Roy's theorem is used to obtain demand function from the corresponding indirect utility function (v). The theorem can be expressed as:

$$q_i = -\frac{\partial v / \partial p_i}{\partial v / \partial I} \qquad i= 1,\ldots,n \qquad (15)$$

3. Marshallian demand function approach

This approach is a direct approximation of the Marshallian demand functions. This is similar to Stone's (1954) logarithmic demand function with some variation. The first order approximation of the demand system is used instead of logarithms. The Rotterdam model is based on the Marshalian demand function. Rotterdam models are specified using prices and measure of real income. Logarithmic differentials of demand functions developed under this specification are expressed as

$$\Delta(\ln q_i) = \sum_{j=1}^{n} \gamma_{ij} \Delta(\ln P_j) + \beta_i \Delta \ln I \qquad (16)$$

where γ_{ij} is the cross price elasticity of the ith commodity with respect to the jth price and β_i is the income elasticity of the commodity 'i'. The real income 'I' can be replaced by Divisia volume index (DQ)[8] as suggested by Theil and Clements (Alston and Chalfant, 1993). Individual commodity demand functions are then weighted by their corresponding expenditure proportions w_i.

4. Cost function approach

This approach transforms the consumer's problem from maximizing utility with respect to prices and income to that of minimizing the cost of attaining a given level of utility with the same prices and income. Deaton and Muellbauer (1980a) used the cost function approach to derive the Almost Ideal Demand System (AIDS) model. The AIDS model can be represented in the budget share form.

$$w_i = \alpha_i + \sum_j r_{ij} \ln p_j + \beta_i \ln(E/p) \qquad (18)$$

where, w_i is the budget share of good i. E is the total expenditure and p represents the price index, and α_i, β_i and r_{ij} are their parameters associated with intercept, prices of

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8 $$DQ = \sum_{i}^{n} \bar{s}_i \Delta \ln q_i \qquad (17)$$

where, DQ = Divisia volume index, $\bar{s}_i$ = average market share of commodity i, and q = per capita consumption of commodity i. DQ is used to replace the income variable in the demand equation.

meats and expenditure respectively. The model that uses this price index is called "Linear Approximate AIDS (LA/AIDS)" model.

4.5 Demand system approximation and application

The AIDS and the Rotterdam model are two demand systems commonly used by applied economists. The AIDS model is popular due to its flexibility, compatibility with aggregation over consumers, and simplicity to estimate and interpret. Similarly, the Rotterdam model is becoming popular and is argued to be a good alternative model to the AIDS model (Alston and Chalfant, 1993). Both systems are consistent with the theory of consumer demand. Alston and Chalfant compared two econometric demand systems to explain quarterly U.S. meat demand (1967-1988). They concluded that the Rotterdam model was superior to the AIDS model based on the specification test. But, the authors have cautioned that their results should not be taken as evidence in general and other data sets could yield opposite conclusions.

4.5.1 Pork demand approximation

The Rotterdam and the AIDS specifications by Alston and Chalfant (1993) and log linear demand model by Hahn (1998)[9] are chosen to examine how close these models

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9 . Rotterdam Model $\bar{s}_i \Delta \ln q_i = \Gamma_i + \sum_{j=1}^{n} \theta_{ij} D_j + \sum_{j=1}^{n} \gamma_{ij} \Delta \ln P_j + \beta_i DQ$ (19)

AIDS Model: $\Delta s_i = \Gamma_i + \sum_{j=1}^{n} \theta_{ij} D_j + \sum_{j=1}^{n} \gamma_{ij} \Delta \ln P_j + \beta_i DQ$ (20)

Log-linear Model: $\ln q_i = \beta_0 + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \beta_i DQ$ (21)

Where Γ and β_0 are intercepts, D_j are seasonal dummies, P_j are prices of meats, Y_t is per capita income in time t. s_i =market share and q_i is quantity of meat demanded and DQ is Divisia Volume Index. Description of models is given above in theoretical background section.

can explain the U.S. pork demand. In order to calculate per capita pork consumption, parameters associated with prices of meats and income were estimated by using the meat demand models by Alston and Chalfant (1993) and Hahn (1998) with little modification.

This research is interested in predicting long-term pork demand rather than quarterly fluctuations. Quarterly dummy variables that capture seasonal effects in the original demand equation (equation 19) are removed. Estimating Divisia Volume Index (DQ)[10] for each state is tedious because prices of meats in each state are difficult to obtain, if not impossible. To overcome this problem, we assumed single DQ for all states to estimate per capita pork consumption. The equations 19-21 now can be written as,

$$\bar{s}_i \Delta \ln q_i = \Gamma_i + \sum_{j=1}^{n} \gamma_{ij} \Delta \ln P_j + \beta_i DQ \qquad \text{Rotterdam Model} \qquad (22)$$

$$\Delta s_i = \Gamma_i + \sum_{j=1}^{n} \gamma_{ij} \Delta \ln P_j + \beta_i DQ \qquad \text{AIDS Model} \qquad (23)$$

$$\ln q_i = \Gamma_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \beta_i DQ \qquad \text{Log linear model} \qquad (24)$$

where ,

Γ_i are intercepts, P_j are prices of meats (beef, pork, chicken and fish) , s_i =share of meat i on total meat expenditures, q_i are quantity of meats demanded. Each model consists of four simultaneous equations to estimate the per capita consumption demand (national level) of beef, pork, chicken and fish. Model 22 estimates product of moving average of consumption share and change in log of quantity of meat i demanded. Model 23

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10 $DQ = \sum_{i}^{n} \bar{s}_i \Delta \ln q_i$

estimates change in expenditure shares of meats and model 24 estimates log of per capita pork consumption. From the estimated left-hand sides of the equations, we can calculate the per capita demands for different meats. Due to the simultaneity problem, the quantity of four different meats demanded and their prices were included to estimate the parameters for the pork demand. This research is interested in pork demand only. Hereafter, only the pork demand parameters and estimation are discussed.

Three alternative demand estimation models given in equation 21 to 23 were used to estimate the per capita pork demand in U.S. in order to determine the best econometric model. Comparison of estimated demand by these models and observed demand are listed in Table 4.1 and Table 4.2.

Table 4.1 Goodness of fit of the models in predicting pork demand

Model	R-squared (%)	Root MSE	% Deviation [1]	Paired T-Test [2]
Rotterdam	94	0.007	1.75	NS
AIDS	25	0.007	0.90	NS
Log-linear	28	0.057	5.80	**

1. Average deviation from observed pork demands.
2. Comparison between the observed and estimated pork demands.

Ho: mean (Rotterdam - observed) = mean (diff) = 0,
Ho: mean (AIDS - observed) = mean (diff) = 0 and
Ho: mean (Rotterdam - AIDS) = mean (diff) = 0 are failed to reject.
Ho: mean (Rotterdam – loglinear) = mean (diff) = 0 is rejected.

Based on the goodness of fit, the Rotterdam model and the AIDS model are able to describe the per capita pork demand more precisely. Demands estimated by the log-linear model have higher deviations (forecasting error) from the observed values and null hypothesis that "mean difference between observed demands and estimated demands is zero" is rejected. The null hypothesis couldn't be rejected in the Rotterdam model and AIDS model.

Table 4.2 Comparison of per capita pork consumption estimates (pounds) different demand models (1970 to 1999)*

Year	Observed	Rotterdam	AIDS	Log-linear
1971	60.2	61.2	61.0	54.1
1972	54.3	56.5	53.9	48.4
1973	48.5	47.4	49.3	48.6
1974	52.4	52.6	52.0	52.3
1975	42.7	44.1	42.8	47.0
1976	45.1	45.0	44.5	51.6
1977	46.7	46.4	47.3	52.3
1978	46.5	47.3	46.6	50.5
1979	53.2	51.7	53.5	52.5
1980	56.8	56.5	57.6	53.1
1981	54.2	53.9	54.1	49.4
1982	48.6	48.7	48.3	47.7
1983	51.3	50.4	51.2	51.7
1984	51.0	52.2	51.8	52.3
1985	51.5	51.2	51.3	50.6
1986	48.6	48.6	49.0	50.1
1987	48.8	47.3	48.7	49.6
1988	52.1	51.7	52.8	53.1
1989	51.5	52.3	52.3	51.6
1990	49.4	48.5	48.8	48.1
1991	49.9	49.2	49.7	50.1
1992	52.6	52.6	52.8	52.3
1993	52.0	52.3	52.2	50.7
1994	52.7	52.6	52.6	51.1
1995	52.2	52.1	52.5	50.8
1996	48.9	48.6	48.9	49.1
1997	48.5	47.6	48.6	50.1
1998	52.3	54.1	52.8	53.9
1999	53.7	53.9	53.4	51.1

*Observed and estimated per capita pork consumption.

The R-squared value is larger in the Rotterdam model compared to the AIDS and the log-linear models. However, these R-squares can be misleading. Dependent variables (left-hand side in the empirical equations) are different in the AIDS and the

Rotterdam models therefore the explanatory variables are not describing the same thing. The log-linear model has a different set of dependent and explanatory variables. Based on the forecasting errors and paired T-Test, both the Rottterdam and the AIDS model are superior to the log-linear model.

Now, we face the challenge of deciding which of these two models (Rottterdam and AIDS models) to pick to estimate the pork demand. The AIDS model (equation 23) estimates the change in consumption share of pork in a given year and we need to derive the quantity of pork demand indirectly and the calculation is more complicated. Estimation of pork demand by the Rotterdam model (equation 22) is more direct. The predicted dependent variable, if divided by the average pork consumption share, results the change in the log of pork consumption. Estimation of pork consumption and the elasticity are more direct. Alston and Chalfant (1993) also concluded that the Rotterdam model was superior to the AIDS model based on the specification tests. Because of simplicity and the recommendation by Alston and Chalfant, the Rotterdam model was chosen for further analysis.

4.6 Empirical estimation of pork demand

Systems of simultaneous equations consisting of pork, beef, chicken and fish demands were used to estimate the per capita consumption of pork in the U.S. (Appendix 4.3). The three stage least-square procedure of econometric estimation was used to solve the simultaneous equations. The parameter estimates for the pork demand equation are listed in the following table (other meats were also included in the econometric model). Coefficients, associated with beef price (γ_{31}), chicken price (γ_{32}), pork price (γ_{33}), fish price (γ_{34}), and income (β_3) have expected signs.

Table 4.3 Parameter estimates for pork demand by Rotterdam model (1970 to 1999)

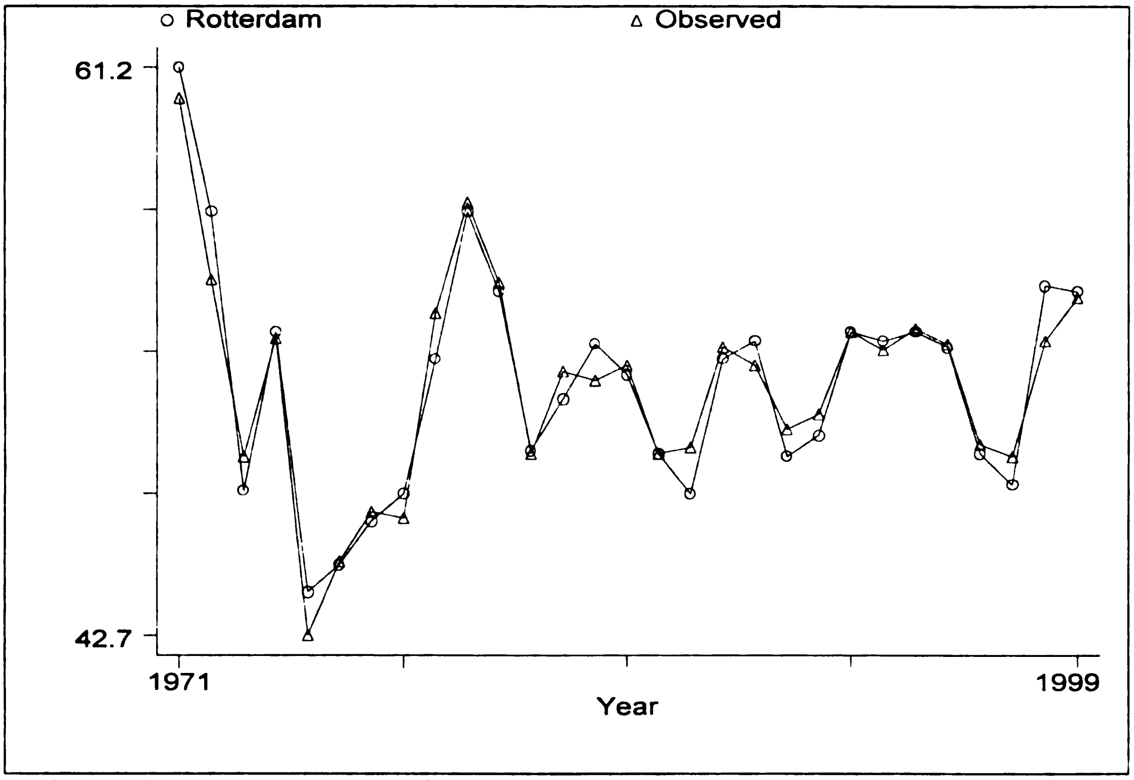
Parameter	Estimates	Error (Robust)	P Value
Γ_3	-0.0007	.0013	0.582
γ_{31}	0.1731	0.0173	0.000**
γ_{32}	0.0117	0.0077	0.131
γ_{33}	-0.1907	0.0195	0.000**
γ_{34}	0.0059	0.0109	0.584
β_3	0.4537	0.0514	0.000**

R^2=0.94 Chi-square= 500 P=000 RMSE= 0.007

Note: Parameters associated with beef and chicken demands are given in Appendix 4.3.

Beef is a substitute of pork and the quantity of pork demanded goes up with increased price of beef. Fish and chicken are also substitutes for pork and the regression coefficients, γ_{34} and γ_{32} are not statistically significant at the five percent probability level. The regression coefficient associated with pork price (γ_{33}) is negative and statistically significant as expected. The coefficient (β_3) related to the Divisia Volume Index, which is a proxy for personal income is statistically significant in explaining the per capita pork consumption. The regression procedure used to estimate the system of equations is given in Appendix 4.3. A graphical representation of estimated and observed per capita pork demand is given in Fig. 4.1 to compare the predictability of the model.

Figure 4.1: Estimated and observed per capita pork consumption (1972-1999)*



*Estimated by Rotterdam model, forecasting error=1.75%

Estimated and observed per capita pork consumption, for 29 years were compared to examine the strength of the Rotterdam model. Sixteen observed values were greater and 11 were smaller than the estimated values and two values were equal. The average difference between these two series was only 1.69 pounds. The average estimated demand was 50.92 pounds and the average of the observed demands was 50.90. On the basis of T-Test and F-Test, we fail to reject the hypothesis (H_O) that the means and variance are equal (Table 4.1). In other words, the hypothesis that "the mean differences between estimated and observed values are equal to zero" was failed to reject. Therefore, we may conclude that Rotterdam model as written in equation 22 is able to predict the per capita pork demand.

Consumption figures listed above in Table 4.4 and Table 4.5 represent the national average per capita consumption. We wanted to estimate per capita consumption for each state in the U.S. Demographic composition of the population e.g. age, sex and ethnicity also influence the consumption decisions. These variables were not included in the system of equation above. The predicted pork consumptions were augmented to reflect the difference in demographic characteristics by geographical regions. Differences in sex and age of individuals on the consumption pattern can be perceived from Table 4.4 below, which was obtained from the Continuing Survey of Food Intakes by Individuals by USDA (http://www.barc.usda.gov/bhnrc/foodsurvey/home.htm).

Table 4.4 Quantities of pork consumption by regions and selected age/sex groups*

Age group	Pork Consumption (gram/day/head)				
	Northeast	Midwest	West	South	USA Average
5 and under	4	5	3	5	4.25
Males (20+)	15	19	12	13	14.75
Males (60+)	14	22	16	14	16.5
Females (20+)	11	16	6	10	10.75
Females (60+)	10	13	8	10	10.25
Weighted Average	12.6	18.2	13.1	17.7	**15.8**
Population Share	19.6	23.5	22.0	34.9	100
Demand adj.factor	0.798	1.15	0.829	1.12	**1.0**

*Compiled from continuing survey of food intakes by individuals, USDA, 1994-96

Geographic regions with a higher percentage of children and females have a tendency of lower per capita pork consumption. Females, who are sixty and older consume a smaller amount of pork in comparison to their male counterparts. Similarly, the regional consumption pattern also is interesting to note. The Midwest is highest in average per capita pork consumption followed by the South. These factors are used to adjust the regional estimates of per capita pork demand. Based on the relative differences on pork consumption in 1994-96, adjustment factors are computed for each region.

$$Adjust.factor = \frac{regionalAverage(weighted)}{nationalAverage(weighted)}$$

Estimated per capita pork consumptions are then multiplied by the corresponding adjustment factors. The adjustment factor of 0.798 (i.e. 12.6 regional average divided by national average 15.8), for Northeast regions, for example, implies that other things remaining constant, per capita pork consumption in the Northeast is 20.3 percent lower than the national average. The adjusted total pork demands by different states are presented in Appendix 4.4.

Table 4.5 Estimated regional pork demands 1997

	Pork Demand (pounds)	
Region	Observed	Estimated
Eastern Corn Belt	2,365,334,718	2,669,658,196
Western Corn Belt	378,547,354	323,063,273
South	4,956,711,107	5,448,498,609
Northeast	2,525,595,208	1,982,982,793
West	2,853,627,723	2,324,559,260
Total U.S.A.	12,987,504,940	12,748,762,131

Note: Aggregated from Appendix 4.4

The Bureau of Economic Analysis grouped the states into four geographic regions namely Midwest, Northeast, South and West. The Midwest region is divided into the Eastern Corn Belt and Western Corn Belt regions to make the grouping consistent with following chapters of this dissertation. The estimated regional demand is listed in Table 4.5. The calculated demand is based on the adjustment factors (Table 4.4), population, and estimated per capita pork consumption (Table 4.2). Aggregated demand of pork in 1997 is highest in the South followed by the Eastern Corn Belt region. Demand estimates by states are listed in Appendix 4.4.

4.7 Pork export demand

According to the U.S. Foreign Agricultural Trade Database, annual increase in pork production in the U.S. is approximately two percent. With increasing production, total domestic consumption is also increasing at a slower pace. In contrary to domestic demand, export demand for pork has been increasing rapidly and the U.S. is now a net exporter of pork. The export market has become an increasingly important outlet for the U.S. pork industry in recent years and its importance will further increase in the future. According to the United States Meat Export Federation's estimates, exports have added about $6 /cwt to the price of that the American producers receive[11]. Table 4.6 shows the annual export of pork from the U.S. to some of the countries or geographic regions.

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11 www.usda.gov/oce/waob/outlook98/speeches/033/

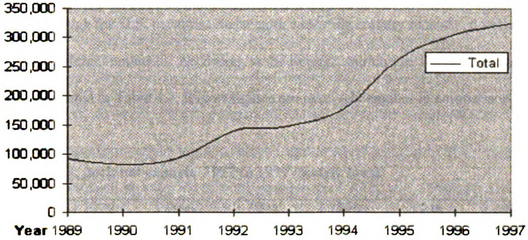
Table 4.6 Pork export to selected countries from 1989 to 1997 (metric ton)

Country	Annual pork exports (metric ton)								
	1989	1990	1991	1992	1993	1994	1995	1996	1997
Australia	77	155	206	215	71	16	19	80	1,378
Canada	4,404	7,273	8,113	9,023	11,008	16,321	17,528	29,677	41,804
China (Mainland)	177	206	517	120	30	49	196	741	2,747
China (Taiwan)	283	85	125	57	129	162	4,935	9,824	2,397
E. Europe	655	4,235	1,224	3,067	864	1,064	1,959	1,088	961
Japan	50,934	43,499	41,451	73,855	78,792	85,513	131,700	178,792	162,576
Latin America	30,943	22,427	36,484	46,342	35,448	58,392	31,264	29,909	39,342
Mexico	23,363	14,604	28,442	37,905	28,999	50,642	20,962	22,526	29,877
Netherlands	224	107	126	144	153	228	864	488	491
World	92.806	82,187	93,752	140,238	148,469	177,313	263,895	305,875	324,507

Source: Compiled from the U.S. Foreign Agricultural Trade Database.

Annual U.S. pork export has increased from 92,806 metric tons in 1989 to 324,507 metric tons in 1997, which is a 250 percent increase in eight years. Asia has been the most important market for U.S. pork. In 1997, Japan imported 514,000 metric tons of pork and 162,576 metric tons of the total import was from the U.S. The U.S. is an important pork exporting country to Japan. The growth in U.S. pork export can be visualized by the following figure:

Fig. 4.2 Annual U.S. pork export demand (1989-1997)



There is a huge potentiality for international market growth for pork. The Chinese market can become an important outlet for U.S. pork. The current living standard in China is almost equal to living standards in Taiwan 25 years ago. This fact suggests that when economic development in China reaches the level of Taiwan, the Chinese economy is projected to be greater than the combined economies of the U.S., Canada, the European Union, and Japan (Hayes and Clemens, 1997). It is projected that China's pork imports will grow to about nine million metric tons by the year 2007. Other important U.S. pork importing countries/regions are Mexico, Canada, Australia, European Union, and Latin America. The USDA projects that U.S. pork exports in the year 2005 will be approximately double the current level of 324,507 metric tons.

4.8 Pork import

Although the U.S. became a major pork exporting country recently, it still imports pork from different countries. According to the Foreign Agriculture Service, total pork imports are listed in Table 4.7. Import figures are relatively smaller in comparison to the exports.

Table 4.7 U.S. pork net exports, 1992 to 1997 (metric tons)

Year	1992	1993	1994	1995	1996	1997
Import	293	336	337	301	280	274
Export	140,238	148,469	177,313	263,895	305,875	324,507
Net Export	139,945	148,133	176,976	263,594	305,595	324,233

Source: FAS online (http://www.fas.usda.gov/dlp2/circular/1997/97-03/porkimpo.htm)

Net pork export can now be obtained from subtracting the annual import from the total export. Net export quantity will be treated as a demand from a separate region in the partial equilibrium model in Chapter Seven. A total net U.S. pork export in 1997 was 324,233 metric tons (713,312,600 pounds).

Chapter 5

V. Regional competitive position of pork industry

Expansion of an industry in different geographical areas arises because of cost advantages associated with production and marketing. In the pork industry, industrialization has contributed to productivity gains. Economic incentives, through lower production costs exist in many areas for improving the efficiency of the hog operations. The pork industry has additional economic benefits from further increases in coordination between the production and packing stages. An assured large, stable flow of uniform, high quality hogs to the packing plant can reduce pork production costs and satisfy consumer demand for high quality pork products (Martinez, 1999).

Economies of scale obtained by technological innovations have further contributed to the per-unit production cost reduction. The dramatic increase in hog production in the Southeast is contributed by the increase in contracting in hog production and the decline in tobacco industry. North Carolina farmers for example, quickly accepted contracting in hog production because of the state's familiarity with production contracts in poultry. Contracting operations stabilized farm income in the face of potential loss in tobacco revenue (Hurt, 1994).

5.1 Economics of production

Production costs include costs of cash expense items and costs related to capital investments (fixed costs). Variable costs, such as feed, labor, veterinary and medicine, fuel and the fixed costs such as farm overhead, taxes, insurance, and interest are accounted as cash expenses. Capital replacement cost is the amount that is set aside each year so that capital items can be replaced over time, in order to remain in business for the long term. Non-cash expenses such as unpaid family labor and opportunity costs of land are also accounted in production costs.

Total revenue from hog operations is calculated as the average price of a unit of pork (e.g. hundredweight) times the number of units sold. It is assumed that the individual hog firms are price takers under the perfectly competitive market. Under this assumption, the total revenue curve will be an upward sloping and straight line. Both the total cost function and total revenue function determine the profits from hog operations. Where the difference between total revenue and the total costs is maximum, is the optimum level of production. The production level where marginal cost is less than marginal revenue (unit price), the firms are giving up the profits. Similarly, if the marginal revenues are less than the marginal costs, firms are bearing unnecessary losses (Cramer and Jensen, 1997). Profitability of hog production operations is, therefore, affected by input costs, and the price of pork received.

Figure 5.1: Short-run equilibrium with three different firms

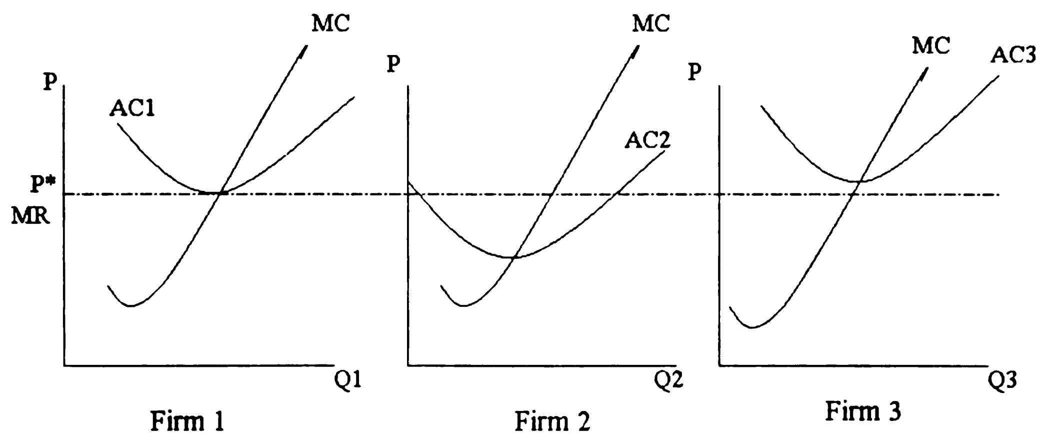


Figure 5.1 represents three hypothetical hog operations/firms. Combinations of price (P) and output (Q) that lie above the average total cost curve (firm 2) represent positive profits and the combinations that lie below represent negative profits (firm 3). The first firm is operating in zero economic profit condition where marginal cost (MC) is equal to the market price (P*) and average cost (AC). Firm 1 and firm 2 remain in the market where as firm 3 will exit the market in the long run if it still remains unprofitable at P*. However, in short run, the firm may be better off to remain in business if its average variable cost is lower than the market price (marginal revenue). It can cover some of its sunk/fixed costs by remaining in the production business.

5.2 Feed supplies and hog production

Historically, pork production and processing operations have been concentrated in the Corn Belt states, an area with surplus feed. Corn farms with pigs have been profitable relative to other types of farms (Hayenga et al, 1998). In the Corn Belt states, pig production has been a value-adding enterprise on available grain supplies and utilizing available labor. Recently, growth in production has occurred in areas outside the Corn Belt, especially in North Carolina, Kansas and Oklahoma (Hayenga et al., 1998). It is interesting to investigate why this change occurred. The possible reasons behind the pork production location shift out of the Corn Belt to the corn deficit states may be the following:

- Bulk grain-purchasing capacity: Larger firms have higher grain purchasing capacity and per unit grain transportation cost decreases substantially with increased volume.
- Technological changes in production system: Adoption of advanced production and management technologies helps to improve efficiency in production. Larger production units that can more easily adopt advanced technologies have higher production efficiency than their smaller counterparts.
- Environmental constraints: Lower costs of compliance in some locations relative to other locations and fewer environmental restrictions improve profitability.
- Mechanical advances: Presence of modern high-speed feed mills for example lower feed processing costs. Newer and larger operations are more likely to install modern mills, which are cost efficient. Instead of upgrading the old facilities, it may be convenient to start with new sets of operations.
- Climate and soils: Higher costs of construction and higher energy cost during the winter season in the Midwest region are disadvantages relative to other states. Lower cooling costs in the summer in the Midwest may partly offset the higher winter costs. Similarly, high humidity and high rainfall make manure management more complicated.

About 60 percent of the total variable cost of pork production is appropriated to feed. Corn is the single most important input in pork rations. Soybean meal is the second important feed component. Iowa, Minnesota, and South Dakota are the states where the corn prices are lowest among the major pork producing states. However, the lower feed cost doesn't guarantee the profitability of the pork operations since several other factors also contribute to the competitive advantage of one area over the others as described earlier.

Average prices of corn grain and soybean meal in some of the selected pork producing states are listed in Table 5.1. Prices are higher in corn deficit, new emerging hog producing states (e.g. North Carolina, Oklahoma, and Utah) relative to the traditional hog producing states (e.g. Iowa, Illinois, and Minnesota). Prices of feeder pigs and labor cost are relatively higher in traditional areas as compared to emerging areas as shown in Appendix 5.4. Higher feed costs in southern and western states are partially compensated by lower prices of feeder pigs and lower cost of hired labor.

One can reduce the total cost either by paying a lower price of an input or using less of it. Therefore, production areas with higher feed cost can still be competitive if they can increase the efficiency of feed. Feed efficiency is measured in terms of pounds of feed used for per pounds of gain in hog's body weight. Similarly, production costs are expected to rise with increased labor use. Labor efficiency, hour worked per hundredweight gain for hogs is generally improved by capital-intensive production technologies. Regional differences in pigs weaned per litter, litters per sow, and operation size are also important in production efficiency. These elements reduce the cost of feeder pig production.

Table 5.1 Average prices of inputs in different regions (1994-1998)

Regions	Mkt.hog $/cwt	Corn price $/bushels	Soybean meal price $/bushels	Wage rate $/hr	Feeder pigs $/cwt
E. Corn Belt	45.22	2.54	13.89	6.49	84.17
W. Corn Belt	44.90	2.45	13.89	6.45	88.02
South	43.27	2.79	16.43	5.85	73.25
Northeast	42.11	2.84	15.20	6.10	88.08
West	49.66	2.99	22.20	6.47	83.38

Source: Calculated from Appendix 5.4

Commodity prices listed in this table are calculated from the prices listed in Appendix 5.4. Market hogs are most expensive on weight basis in the West followed by the Corn Belt. The Corn Belt has access to cheaper corn and soybean meal, which are the important inputs for raising hogs. Lower labor cost in pork production in the Southern region is due to lower wage rates. In addition to the direct production costs, firms incur regulatory costs, which is an important consideration in modern hog business. Different aspects of environmental regulations and costs of compliance are discussed in detail in Chapter Six.

5.3 Pig feeding operations budgets (grow to finish)

As discussed earlier, there are different kinds of operations in pig production. Pork production systems are commonly divided into three stages. These stages are:

- Breeding sows operations (Breeding)
- Early-weaned pigs operations (Nursery) and
- Feeding-to-finish operations (Finishing)

All these three stages of production can be in a single site (different facilities) or in different sites. The feeder-to-finish production system is the most important since it incurs the major share of production costs and adds most of the gain. These operations produce 200-265 pound market hogs. These types of operations are easier to compare for their relative profitability in different locations. In general, feeder-to-finish operations have smaller net return per hundredweight gain. These operators buy feeder pigs, which results in higher operating costs. On the other hand, farrow-to-finish operations have higher overhead costs because these kinds of operations involve all three stages of production and require more buildings and equipment.

Cost of raising hogs varies by type of operation, size, and other location specific factors. One production unit cannot represent all other operations in entire region. A direct survey of production units could be very expensive and is beyond the scope of this dissertation. This research mostly uses the secondary data from USDA databases, costs and returns survey (FCRS), and various university sources. Some data are based on expert opinion and some are derived based on existing information, and assumptions.

5.3.1 Assumptions made in enterprise budgeting

The source of revenues for feeding to finishing operations is from the sale of market hogs. The weight of market hogs is assumed to be 250 pounds per pig. Not all the feeder pigs started in feeding operations survive until the marketing stage. A four-percent death loss (expert opinion) is used in adjusting operating costs and revenue. The average market weight per pig is assumed to be constant throughout the regions. The differences in revenue come from market prices in different regions. Price of market hogs doesn't vary within a region and size of operations since the producers are price takers[12]. The product sold and the inputs used are homogeneous.

5.4 Enterprise budgets: Feeder to finish operations

5.4.1 Formulation of pig diets

Composition of corn-based feed as presented in Table 5.4 is based on nutrient and energy requirements of hogs. For example, to constitute 2000 pounds of feed for growing hogs, we need to mix 1631 pounds of corn, 321 pounds of soybean meal and minerals and vitamins. Rations are formulated to meet the nutritional requirements of hogs. Instead of corn grain, some pork producers may use barley and sorghum as a substitute as mentioned above. However, barley constitutes about two percent of total feed grain and use of sorghum is also limited in the U.S. Therefore, corn is taken as a standard feed grain in this study. Composite feed is fed according to the age of hogs until they are marketed.

Hogs undergo several physiological changes between weaning and finishing (market weight). Daily feed intake increases steadily during this period. Physiological changes of pigs during the growth are important considerations for feeding requirements. Feed costs are derived on the basis of diets and average prices of corn and soybean meal. In order to achieve maximum feed efficiency, it is necessary to feed well-balanced diets. Different groups of pigs need different compositions and amounts of diets designed for specific purposes. Hog diets can be classified in the following four categories:

12 This assumption is for a simplification of the model. Size of operation may indeed impact price due to quantity premiums.

- Sow diets: Designed for bred gilts and sows using corn, barley, sorghum or wheat as the primary energy source) and the amount may vary by age and body weights. In general 4 to 5 lbs per day is recommended.
- Boar diets: The composition is similar to that of sow diets and the common feeding level is 5 lb to 6.5 lb per day. Younger boars require more feed than older boars because of their faster growth.
- Baby pig diets: Diets used for weaning pigs at the age of three weeks (45 pounds) or less. Nutritional requirements change quickly in this stage. Diets are based on age and body weights. Different kinds of antibiotics are also supplied in diets for these young pigs.
- Growing-finishing diets (45 to 250 pounds pigs): In this stage, diets play an important role in the quality of meat and weight gain. Consumers demand for lean meat has resulted in greater efforts by breeders and finishers to improve the quality of meat. High lean gain pigs gain a minimum of 0.75 pound of lean pork per day from approximately 45 to 240 lb of body weights. In order to obtain high lean gain, specially formulated diets with higher amino acids levels should be fed.

Several biophysical factors affect nutrient requirement for pigs. Such factors influence amount of feed and nutrient concentration[13]. Such factors are:

- Temperatures (weather)
- Genetic background and sex
- Health status of pigs
- Quality of feed (presence of toxin and molds, nutrient contents)
- Feed additives and growth promoters

Temperature and housing conditions play important roles in determining the nutrient needs for pigs. Pigs housed in open areas are exposed to greater fluctuation of temperatures than those housed in confinement facilities. Maintenance energy costs are higher in uncontrolled housing environments. Pigs of different genotypes and sex have different production efficiencies and thus the different nutrient requirements. Similarly, health status, pig feed quality, and growth promoters' influence feed efficiency. Higher feed efficiency of feeding operations lowers the total feed requirement per pig.

Table 5.2 Growing-finishing: feed usage by pig growth rate

Group (body weight in pounds)	Average daily gain (lb/day) from 45 to 250 lb		
	1.6	1.8	2.0
	Lb of feed per pig		
Grower 1 (45-80)	90	80	75
Grower 2 (80-130)	160	140	125
Finisher 1 (130-190)	205	180	165
Finisher 2 (190-250)	240	210	190
Total	695	610	555

Source: Swine nutrition guide Nebraska Cooperative Extension Service/USDA.

13 http://www.asci.ncsu.edu:80/Nutrition/NutritionGuide/introd~1/intro.htm

Table 5.2 presents the feed requirements during growing to finishing phase depending on the pigs' growth rate, as suggested by Nebraska Cooperative Extension service/USDA. If average daily gain is 1.6 pounds, then the total feed requirements will be 695 pounds per pig to reach the market weight of 250 pounds. Pigs need only 555 pounds of feed to reach the same weight if the daily average gain is two pounds but the ration will be more costly. Producers switch diets according to estimated pig weight. Monitoring growth helps ensure hogs are provided with the right diet to get optimum feed efficiency.

Table 5.3 Suggested diets for finishing swine using corn as the major grain source

Ingredients	Weaning to 140 lbs body wt.		140 to 250 lbs body wt.	
	Pounds/ton	%	Pounds/ton	%
Corn yellow	1454	73	1631	82
Soybean meal 44 %	492	25	321	16
Calcium carbonate	15	0.75	16	0.80
Dicalcium phosphate	29	1.45	22	1.10
Salt	7	0.35	7	0.35
Trace mineral-vitamin mix	3	0.15	3	0.15
Totals	2000	100	2000	100

Compiled from Pork Industry Handbook, Michigan State University Extension, # E-1130

Yellow corn is the primary energy source for pig diets. Sorghum or barley can be used as substitutes for corn to some extent depending on their relative prices and availability. Appendix 5.2 shows the top-ten barley and sorghum along with corn producing states. Barley producing states such as North Dakota, Montana, Idaho, and sorghum producing states such as Kansas, Texas, and Nebraska can use barley or sorghum in pig diets to some extent. However, barley and sorghum-based diets are not as efficient as corn-based diets because barley and sorghum contain less energy and high fiber as compared to corn. Even though, these three grains are substitutes for each other, barley and sorghum are not widely used in pig nutrition in the U.S. Therefore, it is assumed in this study that all the diets are corn based.

Feeder pigs

It is assumed that all the finishing operations buy feeder pigs. Costs involved prior to the growing phase are not included in the budgets. These costs are factored into the price of feeder pigs. Price of feeder pigs in different regions including a few major pork-producing states are presented in Appendix 5.4. Cost of feeder pigs is the second most important variable cost after feed costs.

Labor costs

Labor cost is another important consideration in the hog/pork business. Labor availability and wage rates differ by geographical locations. Difference in hired labor costs comes from the amount of labor employed by the feeding operations and average annual hourly wages of field and livestock labor in different states. Average annual per hour wage rates of field and livestock labor in major hog producing states are given in Appendix 5.4. The proportion of hired labor and unpaid labor (family labor and management) per hundred hogs are assumed to be different by the size of operations. Small-sized operations rely more on family labor whereas large-sized operations employ a higher proportion of hired labor in total number of labor hours. Fringe benefits especially the health insurance to the employee in Eastern Corn Belt and Northeast production regions are generally higher than the other production regions.

Overhead costs

Opportunity costs of unpaid labor, capital recovery of machinery and equipment, opportunity cost of land, taxes and insurance, and general farm overhead come under overhead costs. Differences in overhead costs are greatly influenced by the economic opportunities of family labor, land values, government policies on income and property taxes.

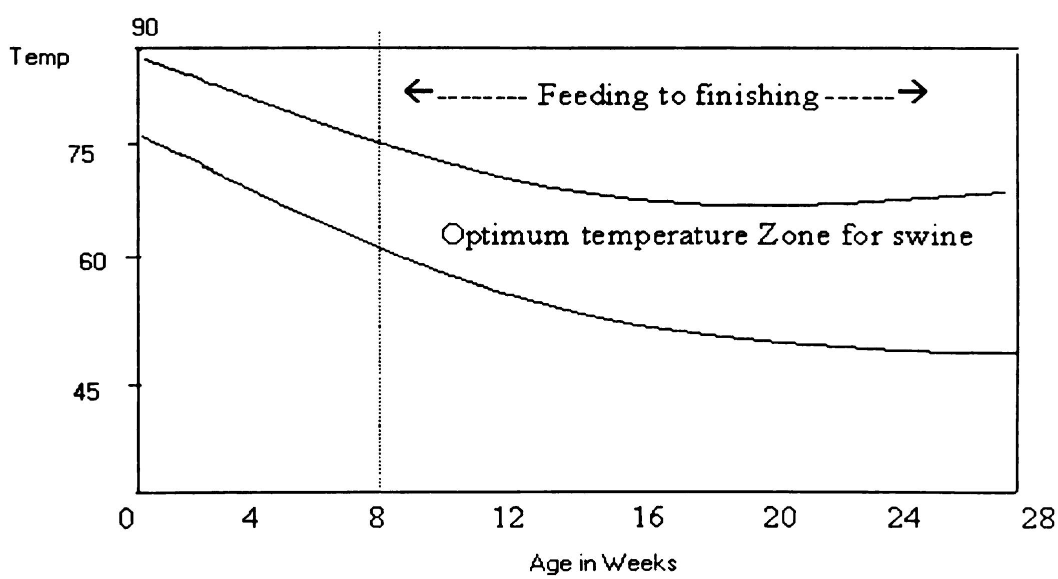
Utility costs

Climatic conditions in the production locations contribute in regional differences in cost on facility construction and temperature control. Figure 5.2 illustrates the importance of temperature control for proper growth of hogs. Different sizes pigs (ages) require different air temperature ranges, for better performance. Smaller pigs up to 40 pounds require higher temperatures than the larger pigs. Larger pigs have an optimum feed efficiency when temperatures are between 50-70 degrees F (ASAE standards, 1997). The optimum temperature zone has narrower range for younger pigs. Older pigs can resist a wider range of temperatures.

In addition to temperature control, proper ventilation, relative humidity, and sanitation are important considerations for efficiency in pork production. Figure 5.3 shows the requirement of ventilation in various outside temperatures to control heat and humidity in the pork feeding facilities (adopted from Jones, 1996).

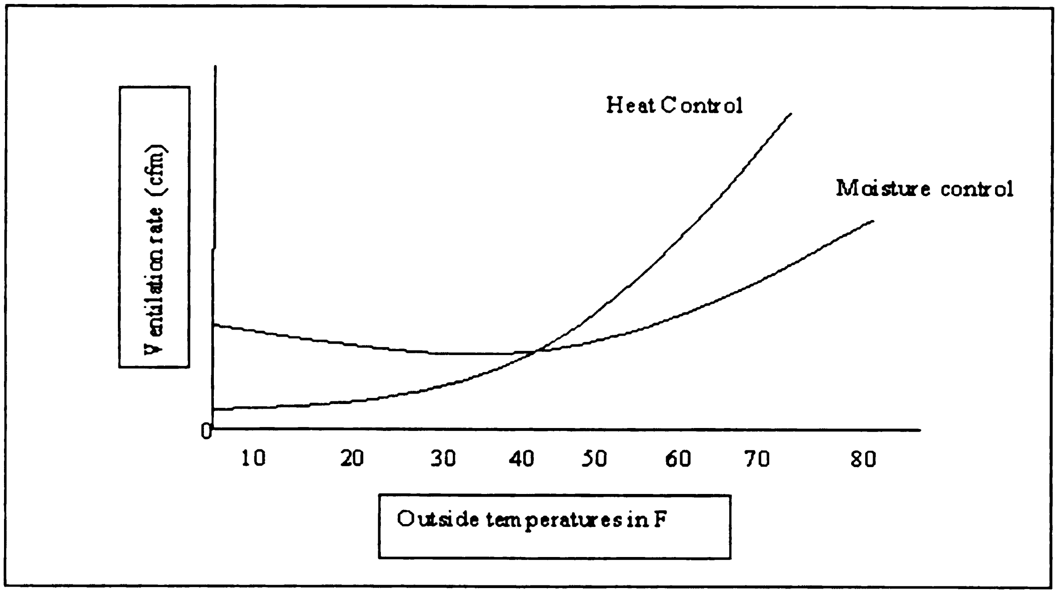
Costs for fuel and electricity, and buildings and equipment are related to environmental control in pork feeding operations. However, the costs of heating and insulation in colder locations mostly offset the cost of cooling and ventilation in warmer locations (expert opinion). Regional differences in cost associated with the temperature, humidity, and ventilation are indirectly captured by the utility costs that are listed in enterprise budgets (Appendix 5.6A to 5.6C).

Figure 5.2 Approximate optimum temperature zones for pigs



Source: ASAE Standards, 1997.

Figure 5.3 Ventilation curves for pig feeding operation.



Source: Cooperative Extension Service, Purdue University, 1996.

5.4.2 Enterprise budgets by regions and size of operations

Costs of raising hogs in different production regions were compiled. The budgets are presented in 100 hog basis. This makes it easier to compare costs and revenues across regions and size of operations. Three different scenarios by size of operations are considered for cost comparison. The medium size of operations is considered as the base scenario. An adjustment in variable costs and overhead costs are made to represent the budgets for small and large-sized finishing operations in all regions and budgets are modified to capture the economy of scale. The state level inventory data were obtained from a USDA database.

Table 5.4 Hogs inventories by size of operations in selected states in 1997

State	Small (<1000 Head)	Medium (1000-4999)	Large (>5000 Head)
	%	%	%
AR	11	46	43
GA	23	33	44
IL	33	42	25
IN	31	42	27
IA	30.5	43.5	26
KS	25	23	52
KY	33	38	29
MI	27	43	30
MN	30	40	30
MO	22	24	54
NE	41	33	26
NC	2	26	72
OH	51	37	12
OK	6	12	82
PA	27	46	27
SD	40.5	25.5	34
WI	56	38	6
Other States	22	22	56
US	25	35	40

Source: USDA (http://www.nass.usda.gov:81/ipedb/).

The numbers in Table 5.4 show that most of the pork production operations in the U.S. have more than 5,000 hogs and fall into the category of large. All the hog operations are categorized as small, medium or large, based on the number of hogs in inventory. It is interesting to note the regional differences in size of operations. Southern states such as North Carolina, Arkansas, Georgia, and Oklahoma have a higher percentage of hog inventories in larger operations. Midwestern states such as Iowa, Indiana, Wisconsin, Nebraska, and Michigan have more hogs in small to medium sized operations. Costs of raising hogs in these three categories are calculated separately by the enterprise budgeting approach. Table 5.5a to 5.5e summarize the 1998 enterprise budgets representing feeding operations in different regions and size of feeding operations. A sample of detailed enterprise budgets by locations is given in Appendix 5.6.

Table 5.5a Feeder to finish system: cost and return per 100 hogs, E. Corn Belt*

Items	Small		Medium		Large	
	Quantity	$ Amt	Quantity	$ Amt	Quantity	$ Amt
Market hogs (cwt)	240	10,851	240	10,851	240	10,851
Corn (BU.)	938	2,252	885	2,252	885	2,252
Soybean meal (cwt)	134	1,856	126	1,751	126	1,751
Other feed cost		296		279		279
Feed cost		4,397		4,282		4,282
Hired labor (hr)	29	187	36	231	61	398
Unpaid labor (hr)	86	780	53	667	21	255
Total labor (hr)	115	967	89	898	82	653
Compliance cost**		31		81		105
Veterinary med.		106		78		57
Total variable cost (VC)		10,487		8,988		8108
Overhead cost (OC)		3,067		2,378		1,966
Total cost (TC)		13,505		11,366		10,074
Rev. less TC		-2,653		-513		778
Rev. less VC		414		1,864		2,743

*Values may vary by each state in the region

** Costs listed in Table 6.6 as calculated by averaging the costs listed in Appendix 6.3.

Table 5.5b Feeder to finish system: cost and return per 100 hogs, W. Corn belt*

Items	Small		Medium		Large	
	Quantity	$ Amt	Quantity	$ Amt	Quantity	$ Amt
Market hogs (cwt)	240	11,003	240	11,003	240	11,003
Corn (BU.)	938	2,194	885	2,194	885	2,194
Soybean meal (cwt)	134	1856	126	1,751	126	1,751
Other feed cost		296		279		279
Feed cost		4,376		4,224		4,224
Hired labor (hr)	21	137	28	181	50	323
Unpaid labor (hr)	64	715	42	527	17	208
Total labor (hr)	85	852	70	708	67	531
Compliance cost**		31		81		105
Veterinary cost		133		98		71
Total variable cost (VC)		10,652		9,127		8,168
Overhead cost (OC)		3,101		2,108		1,790
Total cost (TC)		13,752		11,235		9,958
Rev. less TC		-2,750		-232		1,095
Rev. less VC		351		1,876		2,835

*Values may vary by each state in the region

** Compliance costs listed in Table 6.6 as calculated by averaging the costs listed in Appendix 6.3.

Table 5.5c Feeder to finish system: cost and return per 100 hogs, South*

Items	Small		Medium		Large	
	Quantity	$ Amt	Quantity	$ Amt	Quantity	$ Amt
Market hogs (cwt)	240	10,385	240	10,385	240	10,385
Corn (BU.)	938	2,653	885	2,503	885	2,503
Soybean meal (cwt)	134	2,195	126	2,071	126	2,071
Other feed cost		295		279		279
Feed cost		5,144		4,852		4,852
Hired labor (hr)	19	111	26	155	46	267
Unpaid labor (hr)	57	468	40	326	15	126
Total labor (hr)	76	579	66	481	61	393
Compliance cost**		31		119		108
Veterinary cost		115		85		62
Total variable cost (VC)		10,592		9,136		8,266
Overhead cost (OC)		2,288		1,586		1,384
Total cost (TC)		12,880		10,722		9,651
Rev. less TC		-2,495		-337		734
Rev. less VC		-207		1,248		2,118

*Values may vary by each state in the region

**Compliance costs listed in Table 6.6 as calculated by averaging the costs listed in Appendix 6.3.

Table 5.5d Feeder to finish system: cost and return per 100 hogs, Northeast*

Items	Small		Medium		Large	
	Quantity	$ Amt	Quantity	$ Amt	Quantity	$ Amt
Market hogs (cwt)	240	10,040	240	10,040	240	10,040
Corn (BU.)	938	2,665	885	2,514	885	2,514
Soybean meal (cwt)	134	2,031	126	1,916	126	1916
Other feed costs		296		279		279
Feed cost		4,992		4,709		4,709
Hired labor (hr)	34	207	46	283	78	478
Unpaid labor (hr)	102	1323	70	803	27	301
Total labor (hr)	136	1530	116	1086	105	779
Compliance cost**		39		195		113
Veterinary cost		80		59		43
Total variable cost		11,218		9,685		8,686
Overhead cost (OC)		3,288		2,992		2,992
Total cost (TC)		14,506		12,677		11,678
Rev. less TC		-4,466		-2,637		-1,638
Rev.less OC		-1,178		354		1,354

*Values may vary by each state in the region.

** Compliance costs listed in Table 6.6 as calculated by averaging the costs listed in Appendix 6.3.

Table 5.5e Feeder to finish production system: cost and return per 100 hogs, west*

Items	Small		Medium		Large	
	Quantity	$ Amt	Quantity	$ Amt	Quantity	$ Amt
Market hogs (cwt)	240	11,208	240	11,208	240	11,208
Corn (BU.)	938	2,807	885	2,648	885	2,648
Soybean meal (cwt)	134	2,831	126	2671	126	2,671
Other feed costs		296		279		279
Feed cost		5,934		5,598		5,598
Hired labor (hr)	18	112	25	158	42	108
Unpaid labor (hr)	52	827	37	620	13	376
Total labor (hr)	70	939	62	741	55	484
Compliance cost**		31		81		105
Veterinary med.		145		57		107
Total variable cost (VC)		12,509		10,784		9,802
Overhead cost (OC)		3,291		2,105		1,740
Total cost (TC)		15,801		12,889		11,542
Rev. less TC		-4,592		-1,681		-333
Rev.less VC		-1,301		741		1,406

*Values may vary by each state in the region.
** Compliance costs listed in Table 6.6 as calculated by averaging the costs listed in Appendix 6.3.

Amount of feed is assumed to be the same across the regions. However, amount varies among the sizes of feeding operations. Smaller operations (fewer than 1000 pigs) are less efficient in feed than the medium (1000-4,999 pigs) and large (more than 5,000 pigs) operations. Overall, six percent more feed cost is considered in smaller operations. Quantity and costs of corn and soybean meals are included in tables. Other feed costs include the cost of minerals and vitamins that are mixed in the pig's diets.

The quantity of hired labor hours varies by regions and size of operations. The number and hours of labor employed are dependent on the type of technology used in pork feeding operations, wage rates, and labor availability. Total labor hours consist of hired labor and family labor. The labor costs and corresponding labor hours are based on the USDA's commodity costs and return survey, 1998[14]. Dollar amounts on hired labor were divided by average wage rate in the region to obtain labor hour per hog. Similarly, opportunity costs of labor were used to calculate hours of family (unpaid) labor used in the production process.

Hisham El-Osta (1996) estimated the average opportunity costs (Table 5.6) of farm labor for different regions using weighted least squares regression. Although these estimations are for the 1988 fiscal year, we may assume that these costs have increased or decreased proportionately in 1998 and can be used as information to compare the relative opportunity cost of labor in different regions.

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14 Producers were surveyed about production practices and costs in 1998. Hog costs and return accounts were prepared using a guideline by the American Agricultural Economics Association (AAEA) task force on cost and return estimation.

Table 5.6 Estimated opportunity cost of unpaid family labor

Region	Opportunity Cost ($)
South	8.24
West	15.74
Northeast	11.53
Midwest	12.49

Source: USDA, Technical Bulletin Number 1848, pp.19

Traditional (old) technology requires more labor as compared to modern automated systems of feeding. Labor costs in larger and smaller sized operations are adjusted from medium (base) sized operations. It is assumed that larger operations require 73 percent of labor hours as compared to mid-sized operations. Similarly, smaller operations are less efficient and require 36 percent more labor than the mid-sized operations. These adjustments are based on a publication from the Purdue Cooperative Extension Service.

Table 5.7 Cost of production comparisons by pork production system ($/Cwt)*

Costs	1200 sow (Large size)	600 sow (Mid size)	300 sow (Small size)
Total Feed	18.56 (100)	18.56 (100)	19.80 (106.68)
Total Labor	2.06 (72.54)	2.84 (100)	3.86 (135.92)
Total Direct	22.07 (100)	22.07 (100)	23.37 (105.89)
Total	34.25 (95.88)	35.72 (100)	38.63 (108.15)

Source: Compiled from "Positioning Your Pork Operation for the 21st Century"
*Numbers in parentheses are relative costs in percentage by sizes

Cost structure in three different sizes of operations is for the farrow-to-finish operation systems. These relative costs are extrapolated to adjust the cost differential of different sizes of feeder-to-finish production systems. The cost differential lies mainly in feed costs due to differences in feed efficiencies, labor efficiencies, and in indirect costs such as building and equipment. The cost differences are not due to the unit prices of inputs but are due to the differences in their efficiencies. Overhead cost varies by locations and size of operation. Six percent of additional overhead cost per pig is assumed in smaller operations on the basis of Table 5.7.

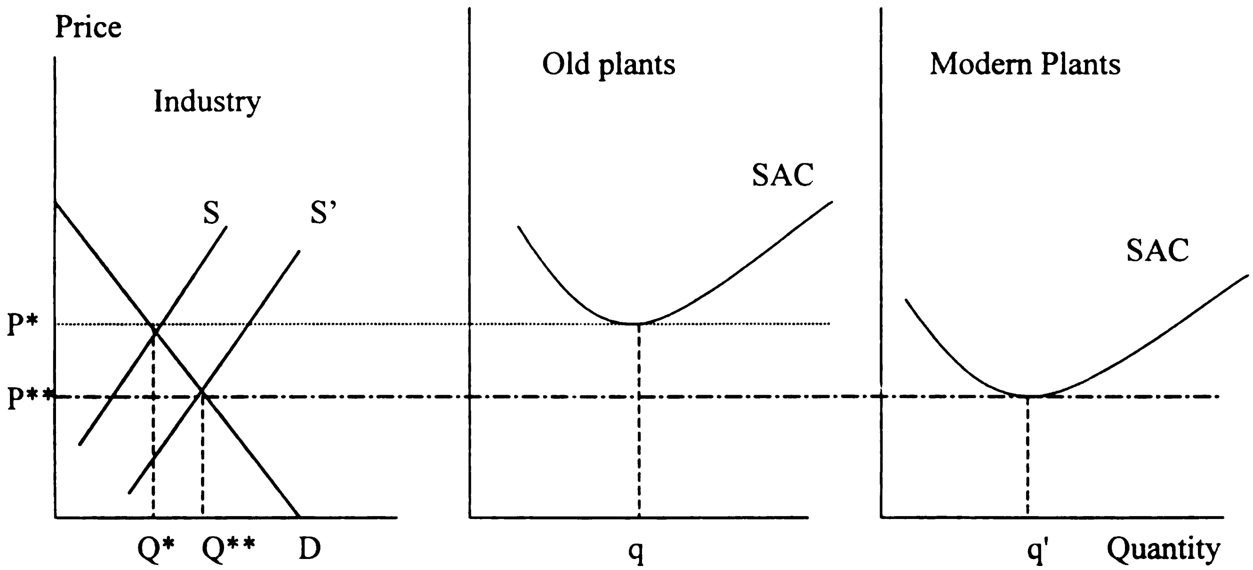
Pork feeding operations of all sizes operate at a loss if we account all the cash expenses and opportunity costs given the prices of all inputs and output. However, producers get positive earnings if we consider only the variable costs. The Eastern Corn Belt regions producers reap the highest operating profit ($1,861 per 100 hogs) followed by the Western Corn Belt region and the West region ($1,661).

The results of production systems analyses as outlined above suggest that smaller producers have limited ability to compete with larger producers on a cost of production basis. The key to keeping hog business competitive is higher production efficiency. Feed, labor, and building and equipment efficiencies are potential means of cutting production costs. Smaller producers who do not attain strong efficiencies in production are at a disadvantage relative to larger producers. Prices of inputs and output in one location do not differ by size. All the firms are assumed as price takers and the individual firm does not have market power to control the price of inputs and outputs.

5.5 Pork processing industry in regional competition

The pork processing industry is one of the determinants of the regional competitiveness of the pork industry. Modern restructuring of pork processing facilities has given the pork processing industry the ability to process large quantities of high-quality pork products at competitive prices. The pork processing industry today is characterized by a decreasing number of companies, the most profitable of which operate very large, relatively new, capital-intensive processing and packing facilities (Martinez, 1999). Packing costs decrease by size of the plants, but the procurement and transportation costs rise. Improvement of vertical coordination offsets high procurement costs (Cassell and West, 1967).

Figure 5.4: Old vs. modern processing plants



(Cost structure of and modern pork processing plants)

In Fig 5.3, old plants are operating in higher short run average costs (SAC) whereas modern plants have lower average costs. Modern processing plants, due to lower average costs, can remain competitive under the lower equilibrium market (industry) price (P**). The lower average cost shifts out the industry supply curve, forcing older plants out of business. Competitiveness of such facilities is critically dependent on high volumes of raw product, because unit costs are driven lower as more hogs are slaughtered (up to a certain range). In the current state-of-the-art packing facilities, economies of size begin to be realized when four million hogs are processed per year (ERS, 1996).

5.6 Locations of pork processing plants

The meat industry is one of the largest manufacturing industries in rural America. Meat processing plants provide a substantial impact in rural economy. It is a source of economic growth and many communities welcome meatpacking industries for their impact on the local economy. On the flip side, meatpacking industries can pose environmental threats and, hence, local, regional or state government limit their growth by imposing various regulations. These two factors along with other many factors contribute to shaping the industry structure. Pig slaughter and the pork processing industry in the U.S. is becoming more concentrated and the number of plants is declining. The number of pork processing firms reporting to the USDA in 1980 was 446 and this number in 1995 declined to 209 (Hayenga, 1997). The few large pork-processing companies are dominant in their market shares. Table 5.8 illustrates the recent market share of five dominant companies in the pork processing sector.

Table 5.8 Plant capacities of the five largest slaughter firms in 1997

Rank	Company	Approx. Daily capacity (1,000 head)	Capacity share (%)
1	Smithfield	80.3	19
2	IBP	72.6	17
3	ConAgra	39.4	9
4	Cargill	37.8	9
5	Hormel	34.7	8
	All other	160.6	38

Source: Hayenga et al, 1998.

The largest five companies slaughtered 62 percent of total hogs in 1997. Smithfield and IBP only captured 36 percent of the market share. Spatial distribution of pork processing facilities is listed in the Table 5.9. All the hogs slaughtered by one company may not be located in one geographic area. The table lists pork companies, their locations, and the daily capacities in terms of number of hogs slaughtered. The average capacity of processing plants by geographic regions is summarized in Table 5.10.

Table 5.9 Estimated daily slaughter capacities in different pork processing plants.

			1997	1998	1999	2000	(Head)
Company	Plant	State	Capacity	Capacity	Capacity	Capacity	Average
Smithfield	Tar Heel	NC	24,000	32,000	28,800	32,000	29,200
	Smithfield	VA	9,500	9,500	9,500	9,500	9,500
	Gwaltney	VA	8,800	8,800	8,800	8,800	8,800
	Sioux Falls	SD	15000	15000	15000	15000	15,000
	Sioux City	IA	15000	15000	15000	15000	15,000
IBP	Waterloo	IA	17,000	17,000	18,000	18,000	17,500
	Logansport	IN	15,000	15,000	13,400	13,400	14,200
	Storm Lake	IA	13,400	13,400	13,400	13,400	13,400
	Col.Junction	IA	13,000	13,000	6,500	10,500	10,750
	Madison	NE	7,500	7,500	7,500	7,500	7,500
	Perry	IA	6700	6700	6700	6700	6,700
Swift	Worthington	MN	15,700	15,700	15,700	15,700	15,700
	Marshalltown	IA	15,700	15,700	15,700	15,700	15,700
	Louisville	KY	8,000	8,000	8,000	8,000	8,000
Excel	Beardstown	IL	16,000	16,000	16,000	16,000	16,000
	Ottumwa	IA	10,000	10,000	14500	14500	12,250
	Marshall	MO	11,800	11,800	8200	8200	10,000
Hormel	Austin	MN	16,000	16,000	16,000	16,000	16,000
	Fremont	NE	11,700	11,700	8500	8500	10,100
	Rochelle	IL	7,000	7,000	7100	7100	7,050
Farmland	Crete	NE	8,300	8,300	8,300	8,300	8,300
	Denison	IA	7,500	7,500	7,500	7,500	7,500
	Monmouth	IL	7,000	7,000	7,000	7,000	7,000
	Dubuque	IA	11,000	11,000	11,000	11,000	11,000
Seaboard	Guymon	OK	8000	8000	15000	15000	11,500
Indiana Pack	Delphi	IN	13000	13000	11000	11000	12,000
Sara Lee	West Point	MS	6500	6500	6500	6500	6,500
	Newburn	TN	1500	800	2500	2500	1,825
Lundy's	Clinton	NC	8000	8000	8000	8000	8,000
Iowa Packing	Des Moines	IA	6000	6000	6000	6000	6,000
	Chicago	IL	1200	1200	2000	2000	1,600

			1997	1998	1999	2000	(Head)
Company	Plant	State	Capacity	Capacity	Capacity	Capacity	Average
Hartfield	Hartfield	PA	7000	7000	7000	7000	7,000
Prem.Std.	Milan	MO	5000	5000	7000	7000	6,000
Clougherty	Vernon	CA	6000	6000	6000	6000	6,000
J.H.Routh	Sandusky	OH	3700	3700	3700	3700	3,700
Greenwood	Greenwood	SC	3000	3000	3000	3000	3,000
Sioux-Preme	Sioux Center	IA	2650	2650	2650	2650	2,650
Johnsonville	Watertown	WI	1800	1800	1800	1000	1,600
	Mommence	IL			500	1500	1,000
Pork packers	Downs	KS	1600	1600	1600	1600	1,600
Bob Evans Farms	Bidwell	OH					
	Xenia	OH					
	Hillsdale	MI					
	Galva	IL	1500	1500	1500	1500	1,500
Yosemite Meat	Modesto	CA	1200	1200	1200	1200	1,200
Cloverdale Foods	Minot	ND	920	920	920	920	920
Leidy's	Souderton	PA	800	800	800	800	800
Owens Sausage	Richardson	TX	800	800	800	800	800
Odom's	Little Rock	AR	750	750	750	750	750
Abbeyland Foods	Curtiss, WI	WI	700	700	700	700	700
Independent Meat	Twin Falls	ID	650	650	650	650	650
Brown packing	Little Rock	AR	600	600	600	600	600
Fineberg packing	Memphis	TN	500	500	500	500	500
Lowell Packing	Fitzgerald	GA			350	350	350
Masami Meat Co.	Klamath Falls	OR	300	300	300	300	300
Simeus Foods	Forest City	NC				300	300
Carleton Packing	Carleton	OR	250	250	250	250	250
Metzger Packing	Paducah	KY	250	250	250	250	250
All companies	Total		374,770	382,070	379,920	387,620	381,095

Source: Compiled from the National Pork Producer Council (NPPC).

Table 5.10 Regional distribution of pork processing capacity

Region	Capacity (head/day)	Capacity share (percent)
Northeast	7,800	2.04
Eastern Corn Belt	83.850	24.57
Western Corn Belt	174,470	45.67
South	97,475	25.52
West	8,400	2.2

About 46 percent of the pork processing capacity lies in the Western Corn Belt States (Iowa, Minnesota, Nebraska, South Dakota and North Dakota) only. Another 25 percent of hogs are processed in the Eastern Corn Belt and about 30 percent of hogs processing capacity are out of the Corn Belt (South, Northeast and West). From the above tables we may conclude that Smithfield and IBP are the most dominant companies and the Corn Belt states are still the important states in pork production and processing. The state of North Carolina (Southern production region) is also one of the dominant players in the pork processing industry.

5.6.1 Pork processing cost

According to a survey of managers of the six largest firms and two firms with new plants conducted by Hayenga in 1997, average estimates of fixed plant and equipment costs were $6 per head for single-shift plants and $3 for double-shift plants. Average variable costs were $22 and $20 per head for single-shift and double-shift plants respectively. Labor cost is making up approximately 50 percent of total variable costs in slaughter and processing. Therefore, total-processing costs in different locations are greatly affected by wages paid to the slaughterers and butchers. Regional differences in processing costs are calculated based on the wage rates of the workers employed in animal slaughtering and processing facilities, and information obtained from the survey by Hayenga (1997). The processing costs on a regional basis are given in Table 5.11 and the pork processing costs by states are listed in Table 7.2 and Appendix 5.3.

Table 5.11 Regional pork processing costs, 1997

Region	Processing cost $/Head	Processing cost $/cwt*
Northeast	25.88	10.49
Eastern Corn Belt	24.50	9.93
Western Corn Belt	25.50	9.83
South	25.26	10.34
West	26.50	10.74

*Compiled from ERS/USDA monthly hog slaughter data 1974 –1997.

In this chapter, we compiled regional differences in pork production and processing costs. We gathered and discussed information that is relevant in pork industry. Information we gathered was not complete and we made several assumptions in our calculations. Production and processing costs and capacity constraints discussed here in this chapter will be used in the transshipment model in Chapter Seven.

Chapter 6

VI. Environmental regulations and regional competition in the hog industry

The Census of Agriculture (1997) indicates that the number of hog operations in the U.S. has decreased by half in the last 10 years, but the total inventory has remained roughly unchanged as the remaining operations have become larger and smaller operations have gone out of business. Due to the increased concentration of the industry, environmental concerns related to hog production are rising in the U.S.

The hog industry in the U.S. faces the same regulatory pressure as other major hog producing countries in Europe. However, unlike most of the European countries, the U.S. hog industry enjoys the benefit of the availability of abundant land. Utilizing the abundant land resource, hog producers in the U.S. can build newer and larger operations that can better absorb manure and waste products. In this chapter, an environmental stringency index is developed which can be useful in determining the relative regulatory hardship among the various hog producing states.

6.1 Hog production and manure management

Manure obtained from animal feeding operations is a good source of plant nutrients. If used properly, manure can substitute for the commercial fertilizers that are used for crop production. Nitrogen and phosphorus are primary plant nutrients that are abundant in hog manure. Both these nutrients, however, can be harmful for water quality if manure gets into the groundwater and/or surface water systems. Nitrogen is highly soluble which can contaminate water through surface runoff, drainage and leaching whereas phosphorus is less mobile and, only moderately soluble with water.

Integration of crop and livestock production is a crucial element of manure management since the integrated enterprises use manure as a fertilizer in crop production. Inability to utilize all the manure nutrients produced in the farm creates environmental problems. It is not possible to incorporate all the manure generated from animal feeding operations in limited croplands. Increased animal production even with proper waste handling, raises environmental problems by increasing the size of potential waste storage spills and raising the level of excess manure application (Innes, 2000). Once the contamination has occurred, it is hard to remove the contaminants from the water. Imposition of nutrient standards is costly and difficult to monitor, therefore manure management is regulated through the required management practices and techniques in the wastage collection, storage and field application (Metcalfe, 2000).

Because of ongoing structural changes (increased concentration) in animal production, manure nutrient loading is on the rise (McBride, 1997). Increased concern about the environmental effect of livestock waste is attributable to recent increases in the concentration of livestock production (Pagano and Abdalla, 1995). According to ERS (2000), in 1997, about 15 percent of very small farms and 72 percent of large operations had inadequate capacity to utilize all the nitrogen produced from their operations and these operations create greater risk of high nitrogen content in soil and ground water. Almost all state governments impose restrictions on manure applications to some extent. Nitrogen and phosphorus standards are the most common nutrient restrictions. According to the Animal Confinement Policy National Task Force Survey (1998), the states of Florida, Kansas, Michigan, Oklahoma, Pennsylvania, Texas, Vermont, Washington and Wisconsin are concerned with phosphorus standards. Similarly, nitrogen standards are imposed in Arkansas, Iowa, Illinois, Florida, Georgia, Kansas, Kentucky, North Carolina, New Mexico, Missouri, Oklahoma, Pennsylvania, Rhode Island, Texas, Utah, Vermont, and Wisconsin.

6.2 Regulations and hog industry relocation

The U.S. livestock industries face regulatory pressures from local, state and federal government/agencies. Many U.S. states have their own set of regulations in addition to federal regulations that shape the livestock industry. Environmental regulations can vary among counties and even between townships within a state. Compliance with environmental regulations may increase the cost of pork production and hence decrease the net profits. It has been estimated that in the U.S. and the European Union countries, the hog producers bear the extra burden of $0.40 to $3.20 per hog in compliance costs, and that is up to eight percent of total hog production costs (Sullivan et al., 2000).

Hog operations can reduce the total production costs by controlling compliance costs. In order to achieve this goal, firms either need to change the existing production practices to the practices that are environmentally friendly or move their operations to the geographic locations that are less stringent and more friendly (locations where the environmental regulations are less severe or are more likely met or locations where compliance is easy to meet because of climate). There is a general belief that strict environmental regulations drive industries out of some states into others. Some people argue that to attract waste generating firms, some states adjust their regulation downward to the mandated lower level, the federal regulation. Studies have shown that environmental regulations are relatively unimportant compared to the other factors in a firm's location decision (Metcalfe, 2001). Traditional factors such as the level of manufacturing activities and energy costs are more important than the environmental regulations on the location decision. However, environmental policy variables have larger effects on location decisions than wages or taxes (Stafford, 2000). Unlike the manufacturing sector, this may not be the case for the livestock industries and the environmental factors may influence the industry locations.

6.3 Confined animal feeding operations and state regulations

Different local and state policies and other relevant laws and ordinances for animal confinement operations influence the location of animal production. Hurt and Zering (1993) reported that the regulatory factor was one of the important factors that could explain the growth in swine industry in North Carolina. Favorable regulatory factors allowed expansion of the hog industry in North Carolina earlier, but this is not the case now. Environmental restrictions are getting tougher due to the excessive growth of the hog industry in the state of North Carolina, which can be applicable to other states also. There are too many regulations and ordinances, and there is a lack of systematic analysis to reach definite conclusions. Furthermore, these regulations are not static and are subjected to modification or removal over time. The listing of such regulations together with their relative roles in animal feeding operations and deriving a stringency index would be an important task to fill this gap in the literature.

Listings of the various regulations imposed by federal, state and local governments for different states are presented in Table 6.2. A short description of the regulations is given in Table 6.1. The particular legislations either not imposed (score 0) in the state or imposed in the state (score 1) or extensively imposed (score 2) are categorized. Some regulations, such as requirement mediation outside the court and zoning exemptions are helpful to animal feeding operations. Such regulations are assigned negative scores toward the calculation of a stringency index. The stringency index derived here is based on the database published by "Animal Confinement Policy National Task Force". The national Center for Agricultural Law Research and Information and the Task Force are still working on this database for verification.

Table 6.1 Descriptions of federal and state stringency

Stringency	*Description*	*Code*
CAFO controversial	Confined animal feeding operations are usually controversial.	1=yes, 0=no
Corporation	Corporations are prohibited in owning farmlands or engaging in confined livestock operations in the state.	1=yes, 0=no
Supply restriction	Restrictions on packers owning or contracting livestock supplies.	1=yes, 0=no
Waste and manure management	Require appropriate design and construction of the waste-collection and storage systems. Require management plan for approval. Field application plan of manure nutrients.	2=yes, 0=no
Geological testing	Physiological or geological tests required e.g. floodplain restrictions, soil borings, and compaction.	1=yes, 0=no

Stringency	*Description*	*Code*
Moratoria	Restrictions on size of operations and production in local area or the state.	1=yes, 0=no
Setbacks	Minimum distance requirements for feeding operations and manure/waste storage from property lines and water sources.	1=yes, 0=no
Public hearing	Needs public hearing in CAFO establishment before the state approval.	2=yes, 0=no
Nutrient standards	Restrictions on amounts of manure applications, timing of land application, set backs for application, and irrigation.	2=yes, 0=no
Odor standards	Restrictions on number of objectionable days per year.	2=yes, 0=no
Flies and insect	Requires controlling flies and other insects related to CAFO.	2=yes, 0=no
Mediation	State require/provide mediation or arbitration other than court system.	-1=yes, 0=no
Exemption from Zoning	State government exempt confined livestock operation and manure application from zoning authority.	-1=yes, 0=no
Fees	State government during approval process assesses fees.	1=yes, 0=no
Training requirement	State government imposes education or training requirements for manure management.	1=yes, 0=no
Population density	States with relatively higher population densities are potentially more stringent to hog industry (1-4 index)	4=very dense 1=not dense

Approval requirements for facility and waste management system plans are common in most of the states. Animal feeding operations are required to prepare nutrient management plans and they are required to comply with the standards based on the nitrogen content of manure that is applied to the soil. Some states, e.g. Michigan and Kansas impose the phosphorus nutrient standard. The phosphorus standard can be more stringent because the application of manure requires more land since plants need less phosphorus than nitrogen.

Table 6.2. a: Stringency on livestock feeding operations, 1998

State	CAFO Controv.	Prohibit Corpo.	Restriction on supply	Increased Conflict	Setback	Public Hearing	Staff Visits	Nutrient Standard	Odor Standard
Alabama	1	0	0	1	0	0	0	0	0
Arizona	1	0	0	0	0	0	1	2	2
Arkansas	1	0	0	1	1	2	1	2	0
California	1	0	0	1	0	0	0	2	2
Colorado	1	0	0	1	1	0	0	1	0
Connecticut	1	0	0	1	1	2	1	0	0
Florida	0	0	0	0	1	0	0	2	2
Georgia	1	0	0	1	1	2	1	2	0
Idaho	1	0	0	0	0	2	1	0	0
Illinois	1	0	0	1	1	2	1	2	2
Indiana	1	0	0	1	1	0	1	2	0
Iowa	1	1	1	0	1	2	1	2	0
Kansas	1	1	0	1	1	2	1	2	2
Kentucky	1	0	0	1	1	2	0	2	2
Maine	1	0	0	1	0	0	1	0	0
Maryland	0	0	0	1	1	2	1	2	2
Michigan	1	0	0	1	0	0	0	2	0
Minnesota	1	1	0	1	0	2	0	2	0
Mississippi	1	0	0	1	1	0	1	2	2
Missouri	1	0	0	1	1	2	0	2	0
Montana	1	0	0	1	0	0	1	2	0
Nebraska	1	1	1	1	1	2	1	2	0

State	CAFO Controv.	Prohibit Corpo.	Restriction on supply	Increased Conflict	Setback	Public Hearing	Staff Visits	Nutrient Standard	Odor Standard
Nevada	1	0	0	1	0	0	0	0	2
New Jersey	0	0	0	1	0	0	0	0	0
New Mexico	0	0	0	1	0	2	0	2	0
New York	1	0	0	1	0	0	0	0	0
N. Carolina	1	0	0	1	1	2	0	2	0
N. Dakota	1	1	-	1	0	0	0	0	2
Ohio	1	0	0	1	1	2	1	2	0
Oklahoma	1	0	0	1	1	2	1	2	2
Oregon	1	0	0	1	1	0	0	2	0
Pennsylvania	1	0	0	1	1	0	0	2	0
Rhode Island	0	0	0	1	1	2	1	2	0
S. Carolina	1	0	0	1	1	2	1	2	2
S. Dakota	1	1	1	1	1	2	1	2	0
Tennessee	1	0	0	1	1	2	0	2	0
Texas	1	0	0	1	1	2	0	2	0
Utah	1	0	0	1	0	2	1	2	0
Vermont	1	0	0	1	1	2	0	2	0
Virginia	1	0	0	1	0	2	0	2	0
Washington	1	0	0	1	0	0	0	0	0
Wisconsin	1	1	0	1	0	2	0	2	2
Wyoming	1	0	0	0	1	2	0	2	0

Table 6.2. b: Stringency on livestock feeding operations, 1998

State	Flies & Insects	Mediation	Zoning Exempt	Moratoria	Geo-test	Manure Management		Approval Fees	Popul. Density Index	Training	Stringency Index
						Structure	Plan				
Alabama	0	-1	0	0	0	0	0	0	1	-	2
Arizona	2	0	0	0	0	0	0	0	1	0	9
Arkansas	0	0	-1	1	1	2	1	1	1	1	15
California	2	-1	0	0	0	2	1	0	2	0	12
Colorado	0	0	0	1	0	0	0	0	1	0	6
Connecticut	2	0	0	0	0	0	1	1	4	-	14
Florida	2	0	-1	0	1	2	1	1	2	0	13
Georgia	0	0	0	1	1	2	1	1	2	0	16
Idaho	0	0	0	1	1	2	1	0	1	0	10
Illinois	0	0	-1	0	1	2	1	1	2	1	17
Indiana	0	0	0	0	1	2	1	1	2	0	13
Iowa	0	-1	-1	0	1	2	1	1	1	1	14
Kansas	0	0	-1	0	1	0	1	1	1	1	15
Kentucky	0	0	0	1	1	2	1	1	1	0	16
Maine	2	0	0	0	0	0	0	0	1	0	6
Maryland	2	0	0	1	1	2	1	1	3	0	20
Michigan	0	0	-	0	0	0	0	0	2	0	6
Minnesota	0	0	0	1	1	2	1	0	1	0	13
Mississippi	0	0	0	1	1	2	1	0	1	0	13
Missouri	0	0	0	-	1	2	1	1	1	1	14
Montana	0	0	0	0	1	2	1	1	1	0	11

State	Flies & Insects	Mediation	Zoning Exempt	Moratoria	Geo-test	Manure Management		Approval Fees	Popul. Density Index	Training	Stringency Index
Nebraska	0	-1	0	1	1	2	1	1	1	0	16
Nevada	0	-1	0	0	0	2	1	1	1	0	8
New Jersey	0	-	-	0	0	0	0	0	4	0	5
N. Mexico	0	-	0	-	0	2	1	1	1	0	10
New York	0	0	0	0	0	2	0	0	3	0	7
N. Carolina	2	-1	0	1	1	2	1	1	2	1	16
N. Dakota	2	-1	0	1	1	2	1	0	1	-	12
Ohio	2	-1	-1	0	1	2	1	1	3	0	16
Oklahoma	2	-1	0	1	1	2	1	1	1	1	19
Oregon	0	0	0	0	1	2	1	1	1	0	11
Pennsylvania	0	0	0	0	0	2	1	0	3	0	11
R. Island	0	0	0	0	0	0	0	0	4	0	11
S. Carolina	2	0	-1	0	1	2	1	1	2	1	18
S. Dakota	0	0	0	0	1	2	1	1	1	1	17
Tennessee	0	0	0	0	1	2	1	1	2	1	15
Texas	2	-1	0	0	1	2	1	1	1	1	15
Utah	0	0	0	0	0	2	1	1	1	0	12
Vermont	2	0	-1	0	1	2	1	0	1	0	13
Virginia	0	-1	-	0	0	2	1	1	2	1	12
Washington	0	-	0	0	1	2	1	0	1	0	7
Wisconsin	0	-1	0	0	0	2	1	0	1	0	12
Wyoming	2	-1	0	0	1	2	1	0	1	-	12

Methods and timings of field applications are also important aspects of nutrient management. Application of manure when the soil is saturated with water or the ground is frozen can be detrimental to surface water and groundwater. The rate of manure application in soil depends on several factors such as the soil absorption capacity and requirements of plant nutrients especially nitrogen, phosphorus and potash. Rain and melting snow can cause organic nitrogen to wash into streams if manure has been applied to unprotected cropland. Excess phosphorus, attached to soil particles, can be carried into streams by soil erosion. It has been recommended that liquid manure should not be spread within 30 feet and solid manure within 15 feet of a watercourse. Population density can be the important factor for environmental stringency. It is likely that highly populated states are more concerned about the hog industry growth and put more stringent regulation in future.

Tabulation of regulatory information in the above table allows for a state-by-state comparison of the relative stringency level and ranks the states according to the stringency index. Numbers assigned to regulations imposed are summed to create the over all stringency indexes for the states. After constructing the index, states are grouped into four groups to identify states of high stringency to low stringency and to assign estimated environmental compliance costs as suggested by the U.S. Environmental Protection Agency (U.S. EPA). Fig. 6.1 and Table 6.3 illustrate the environmental stringency indices in the U.S.

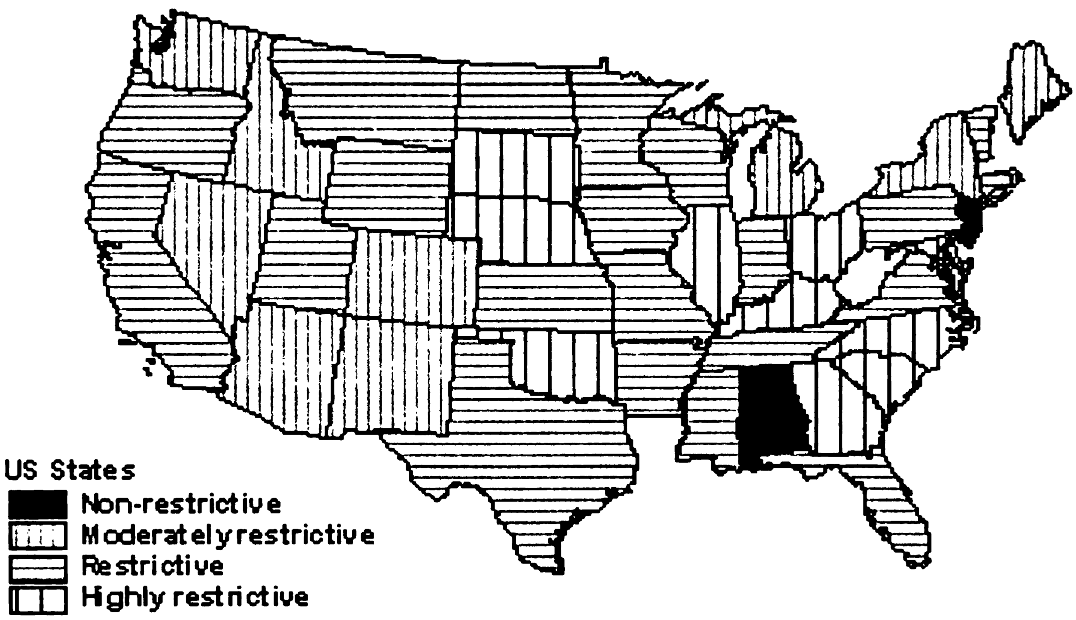
Table 6.3 Environmental stringency grouping

Stringency	States
Highly Restrictive (Index >15)	Illinois, Kentucky, Maryland, Nebraska, North Carolina, Ohio, Oklahoma, South Carolina, and South Dakota.
Restrictive (Index 11-15)	Arkansas, California, Connecticut, Florida, Indiana, Iowa, Kansas Minnesota, Missouri, Mississippi, Montana, North Dakota, Oregon, Pennsylvania, Rhode Island, Tennessee, Texas, Utah, Virginia, Vermont, Wisconsin, and Wyoming.
Moderately Restrictive (Index 6-10)	Arizona, Colorado, Idaho, Maine, Michigan, Nevada, New York, New Mexico, and Washington
Little or Nonrestrictive (Index <6)	Alabama and New Jersey

This stringency classification is derived from the index developed in Table 6.2. The index is very subjective, but it expresses the opinion of several experts. The classification of states in different stringency groups is, therefore, not perfect. The states of North Dakota and Nebraska, for instance, are classified as highly restrictive for confined animal feeding operations. But it is less likely that these states will not expand pork production. Similarly, the states of New York and New Jersey fall under a less restrictive category and the pork production in these states is less likely to expand. Assigning the compliance cost to individual states based on the stringency index derived in Table 6.2 is tedious, if not impossible.

The U.S. EPA has proposed regulations to reduce the water pollution from large livestock operations. It is expected that the revision on the existing Clean Water Act will reduce water pollution from agriculture, one of the leading sources of pollution. Under the Clean Water Act, Concentrated Animal Feeding Operations (CAFOs) are considered as point sources of pollution. In response to concerns about the contamination of rivers, lakes, streams and other water sources from manure and other animal wastes, the U.S. EPA and the USDA developed the Unified National Strategy for animal feeding operations as part of the Clean Water Action Plan. Under this plan various alternative options have been proposed to control point source pollution from CAFOs.

Figure 6.1: Environmental stringency grouping



The state of West Virginia, New Hampshire and Louisiana are not indexed for the stringency due to the unavailability of data during this research. Dark colored states in Fig. 6.1. (AL, and NJ) are little or non-restrictive. Similarly, the states of Arizona, Colorado, Idaho, Maine, Michigan, Nevada, New York, New Mexico and Washington are moderately restrictive production regions. The stringency grouping based on the index developed in Table 6.2 is subjective. However, this classification gives some idea on how friendly various states are to the hog producers. It is not possible to calculate the dollar amount as a compliance cost by states from this index. It is possible that less restrictive production areas may be more costly than more restrictive areas in waste management and compliance because of differences in topography, soil and climatic factors.

6.4 Description of technology options for manure management

In order to estimate the costs associated with environmental regulations, it is important to analyze the available technology options for waste management. The United States Environmental Protection Agency has suggested seven different technology options depending on the vegetation, topography, soil types, hydrology, climatic conditions and concentration of confined animal feeding operations.

Option 1: Nitrogen-based manure application: Nutrient management planning, land application limited to nitrogen based agronomic application, lagoon depth markers, periodic inspections, mortality handling, record keeping, soil sampling once every three years, 100-foot setback from surface water.

Option 2: Same as Option 1, but restricts the rate of manure application to the phosphorus based rate. CAFOs that require phosphorus based land application incur additional costs because they need to apply additional commercial fertilizer to fulfill nitrogen requirements for crops and more land is required to spread the manure.

Option 3: Option 2 plus groundwater requirements. If beneath the production area, there is a direct hydrologic connection to surface water, then that will require groundwater monitoring and controls (e.g. installing monitoring wells, ground water sampling twice a year, installing impermeable pads in manure storage areas).

Option 4: Option 3 plus requirements of sampling of surface waters adjacent to production area and the area to which manure is applied.

Option 5: Option 2 plus zero discharge requirements from the production area that doesn't allow for an overflow

Option 6: Option 2 plus large operations require installing anaerobic digestion and gas combustion to treat the manure.

Option 7: Option 2 plus prohibition of manure application to frozen, snow-covered or saturated ground.

The U.S. EPA cost methodology report for swine and poultry sectors has estimated the costs of installation, operation, and maintenance of several techniques and practices that are required for regulatory options. The USDA's representative farm approach has been adopted to estimate regulatory compliance cost. The U.S. EPA has estimated the costs to address those who need to implement an operation, technique, or practice in order to meet proposed requirements. Frequency factors, based on regulatory requirements, geographic location, type and size of operations, and status of the industry are calculated. For example, the surface water monitoring frequency factor of 27.9 for large operations in the Midwest indicates that 27.9 % of operations already have installed surface water monitoring systems or they are required to install in the near future and 72.1% of operations do not need to invest into the system. The U.S. EPA has considered all these facts to calculate regulatory costs for the swine industry. However, the details of the methodology of calculation is undisclosed. The frequency factors that were considered in compliance cost calculation by the U.S. EPA are given in Table 6.4.

Table 6.4 Management techniques required by swine operations by region[15.]

Management technique	Frequency factors[16] (%)			
	MW/medium	MW/Large	MA/Medium	MA/Large
Groundwater well installation	72.54	72.54	76.09	76.09
Surface water monitoring	4.60	27.90	5.70	17.90
Soil augur	0.00	94.00	0.00	94.00
Manure sampler	0.00	71.90	0.00	71.90
Manure spreader scale calibration	0.00	71.90	0.00	71.90
Initial nutrient management plan	10.70	46.90	24.90	69.40
Recurring nutrient management plan	10.70	46.90	24.90	69.40
Soil testing	90.00	94.00	90.00	94.00
Groundwater links to surface water	1.10	23.10	7.00	12.30
Testing manure	2.10	38.30	6.10	29.90
Recordkeeping	71.00	98.90	93.10	99.90
Calibration of manure spreader	0.00	99.00	0.00	99.00
Groundwater maintenance monitoring	72.54	72.54	76.09	76.09
Mortality composting	72.54	72.54	76.09	76.09
Lagoon liners maintenance	72.54	72.54	76.09	76.09
Lagoon depth marker	0.00	99.00	0.00	99.00
Storm water diversion	72.54	72.54	76.09	76.09
Stream buffer maintenance	0.00	99.00	0.00	99.00
Visual inspection	0.00	25.00	0.00	25.00
Feeding strategies	14.9	67.70	17.80	72.70
Solid liquid separator	7.70	0.00	2.30	1.50

Source: Compiled from 2001-U.S.EPA data.

15. The U.S. EPA has classified geographic regions as: Mid-Atlantic (MA) region: MD, ME, NC, NH, NJ, NY, PA, RI, TN, VT, WV, VA, CT, DE, KY, MA. Midwest (MW) region: IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI. Central region: MT, WY, ID, CO, UT, NV, AZ, NM, TX, OK. Pacific region: CA, WA, OR, AK, HI. Southern region: AL, AR, FL, GA, LA, MS, SC

16 Frequency factors: Percentage of industry that already implements particular operations, techniques, or practices required by the proposed environmental compliance rules.

The U.S. EPA has estimated environmental compliance costs for 514 medium and large feeder-to-finish operations representing 33,390 feeder-to finish operations in the U.S. Table 6.5 summarizes the costs by technology options and size of operation. The data and method used to derive this table is discussed in Appendix 6.1. Different technology options require different facility structures and equipment and hence incur various levels of compliance costs. Costs can differ even under the same options due to the variation in location, topography, soil type, land availability, and size of operation.

Table 6.5 Technology options for CAFOs and compliance costs*

Option	Compliance costs ($/ hog)			
	Mid-Atlantic		Midwest	
	Medium	Large	Medium	Large
Option 1	0.47	0.31	0.16	0.46
Option 2	1.45	0.37	0.42	0.16
Option 3	2.42	1.36	0.77	1.14
Option 4	2.44	1.25	0.85	1.46
Option 5	1.90	1.08	1.16	1.16
Option 6	-	2.12	-	1.17
Option 7	1.59	0.74	0.64	0.52
Average	1.95	1.13	0.81	1.05

*Compiled from 2001-U.S.EPA data with additional assumptions

Compliance costs for medium-sized operations in Option 6 is not applicable because this option is designed only for large operations that require installation of anaerobic digestion and gas combustion systems. Option 2 is more stringent than Option 1 and option 3 is more stringent than the Option 2. In most of the cases, compliance costs are consistent with the technology options or the level of stringency. However, this condition may not hold in all cases. Option 2 in the Midwest region has smaller compliance costs than Option 1, although Option 2 has additional restrictions over Option 1. It should be kept in mind the fact that hog operations required to comply with Option 1 and Option 2 are not necessarily required to be in the similar situations (e.g. soil type, topography, land availability). Similar structures within a few miles distance may have different costs due to the geological factors.

The U.S. EPA data analyzed above does not include an estimation of compliance costs for small-sized hog operations. The U.S. EPA assumes smaller units do not need to invest significant amounts in manure management to comply with environmental regulations. However, this dissertation research assumes that the small hog operation is also required to invest in manure management. Since the environmental impacts of small hog operations are comparatively small, let us assume that a small operation's compliance cost is equivalent to the average costs in Option 1 in Table 6.5. Furthermore, cost calculations are done only for the Mid-Atlantic (MA) and the Midwest (MW) regions. According to the U.S. EPA cost structure in the South, Pacific and Central regions would be equivalent to the costs in the Midwest region. With these assumptions, we can assign environmental compliance costs to all states and regions.

Table 6.6 Compliance costs by production region*

Region	Compliance cost $/hog		
	Small	Medium	Large
Northeast	0.39	1.95	1.13
E. Corn belt	0.31	0.81	1.05
W. Corn belt	0.31	0.81	1.05
South	0.34	1.19	1.08
West	0.31	0.81	1.05

* Cost by states are listed in Appendix 6.3

The regional compliance costs in Table 6.6 were calculated by averaging the costs by states as listed in Appendix 6.3. and these costs are linked to the feeder-to-finish production system enterprise budgets in Chapter Five, Table 5.5 and Appendix 5.6.

Chapter 7

VII. Optimization of production and processing of pork

Many of the components described in the previous chapters are combined to minimize the total cost of production, processing and distribution of pork in the U.S. to meet demand. An interregional mathematical programming model is constructed. The costs of production including the compliance costs of pigs are determined from enterprise budgets developed in Chapter Five of this dissertation. Slaughtering and packing costs are also compiled in Chapter Five. Transportation costs between the production regions and the consumption regions are calculated based on the travel distance and information obtained from trucking companies. The regression model in Chapter Four has estimated consumption demand. Regional consumption estimates are obtained by multiplying estimated per capita pork consumption and the population in the region. Export demand is determined exogenously and the data were obtained from the USDA. Export demand is treated as a separate consumption region in the mathematical model.

The processing capacity in each region is the sum of the existing capacities of pork processing plants. The maximum quantity of pork a region could produce is calculated on the basis of existing production. Some states and regions have the potential for increasing their pork production level. However, government regulations (high compliance cost or moratoria) will not allow a region to increase its pork production beyond a certain limit.

Analysis of interregional competition in pork production is developed on the principle of comparative advantage that deals with only one commodity, unlike the regional comparative advantage that deals with several commodities (Mighell and Black, 1951). Interregional competition analysis determines the competitive position of various regions that produce the same commodity.

7.1 Mathematical programming: economic environment

The comparative advantage can arise from various factors. The lower cost of feeding hogs in each region is due to the availability of lower costs of feed, higher feed efficiency, economy of scale, lower environmental compliance costs, and several other factors favorable for pork production in one region over another region. Similarly, lower processing costs and/or higher consumption demands can be advantageous to some regions over other regions.

Takayama and Judge (1971) used interregional linear activity analysis, a production and allocation model to address the regional competitive advantages. The transshipment linear programming method used in this study is based on the model used by Takayama and Judge. The mathematical model, which minimizes the total costs of producing, slaughtering, packing and transporting pork, has the following characteristics: There are 'n' regions of production, processing and consumption. Hogs are primary (intermediate) products and pork is a final product. Each region has a unit production cost for raising hogs and these costs are known. The primary product passes through a processing plant (slaughtered and packed) to convert to a final product (pork). The rate which hogs are transformed to pork cuts is known and fixed for all regions. Each region has a unit processing cost for processing pigs into pork and these processing costs are known. A non-negative, known quantity of pork is demanded in each region.

Hogs and pork are mobile commodities whereas production facilities and processing plants are immobile. Processing costs are in constant proportion for all output levels and these costs may vary from one region to another. Distance separates all the possible pairs of production, processing and consumption regions. The shipment costs per unit of pigs and pork from each region are known. The supply of the final commodity (pork) is equal to or greater than the total demand. All the pigs and pork are homogeneous products and therefore, pork processors and consumers are indifferent to the source of their supplies. Market prices of all the inputs and outputs are fixed in time 't'.

7.2 Mathematical model

In order to specify the transshipment model in mathematical form, the following notations are used,

i,j are regions and $i=1,2,3,4,\ldots,n$; $j=1,2,3,4\ldots,n$

F_i = cost of feeding hogs (including environmental cost) in region i ($/cwt)

B_{ij} = cost of transporting slaughter hogs from region i to j

S_i = cost of slaughtering/processing pigs in region i

C_{ij} = cost of transporting processed pork from region i to j

P_i = number of finished pigs fed in production region i

Q_{ij} = number of pigs transported from production region i to processing region j

X_{ij} = amount of pork transported from processing region i to market j

D_i = consumption demand of pork in market i

Given the setting described above, the multi-regional allocation model now can be written in mathematical form as,

Minimize

$$\sum_{i=1}^{n} F_i P_i + \sum_{i=1}^{n} \sum_{j=1}^{n} B_{ij} Q_{ij} + \sum_{i=1}^{n} S_i X_i + \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} X_{ij} \qquad (7.1)$$

Subject to

$$P_i - \sum_{i=1}^{n} Q_{ij} \geq 0 \qquad (7.2)$$

$$Q_i + \sum_{i=1}^{n} Q_{ij} \leq P_i \qquad (7.3)$$

$$X_i + \sum_{i=1}^{n} X_{ij} \geq D_i \qquad (7.4)$$

$$P_i, Q_i, X_i, X_{ij} \geq 0 \qquad (7.5)$$

Where,

Equation 7.1 is the objective function that we are minimizing.

Equation 7.2 indicates the maximum number of pigs a region can market (in the base model, number of pigs marketed in 1997 are assumed to be the upper limit of the capacity and we permit changing this limit in the scenario analyses).

Equation 7.3 is the number of finished pigs region i ships to itself and ships to other regions is less than or equal to the number of pigs produced in that region.

Equation 7.4 denotes consumption demand for pork in region i is less than or equal to the pork produced in region i plus the in shipments of pork from region j.

Equation 7.5 implies no negative production, shipment and consumption.

Assumptions:

Optimization: The objective function is minimized.

Homogeneity: All slaughter hogs and all the packed pork are homogeneous.

Proportionality: Unit costs of inputs are constant and do not depend upon volume.

Determinism: All the coefficients in objective functions are known constants.

Additivity: No interaction effects between activities.

Continuity: Activities and resources can also be in fractions.

Finiteness: There is a finite number of activities and constraints.

The assumption of additivity and proportionality together define linearity in the activities. The linearity property of production function leads to constant returns to scale.

The mathematical model described in equation 7.1 to 7.5, now can be solved to find the optimal solution by Lagrangean method[17]. The Kuhn-Tucker conditions must hold for the optimum solution. The conditions state that in order to obtain efficient activities, regional market prices must be such that:

- Profits are zero on all production, processing and marketing activities
- Market prices of live hogs and pork are positive only if regional availability is equal to zero (If a region is producing more than the actual demand then the price of the surplus is equal to zero and it has no economic value).
- Rents on pork processing plants are positive only if the capacities in each case are fully utilized.

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17 For a detailed problem specification, necessary and sufficient conditions for optimality, see Chapter 1-6 in Partial and Temporal Price and Allocation Models by Takayama and Judge, 1971.

- If there is a flow of a product (live hogs or pork) from region i to region j, then the difference in market price of these products in these regions is equal to the unit transportation cost.

7.3 Transshipment model set up

7.3.1 Production regions

Hog feeding operations are distributed in all states in the U.S., although such operations are highly concentrated in a few states as described in Chapter Three of this dissertation. Most of the U.S. states in this analysis are considered as separate production regions except where a few smaller states are combined and considered to be one production region. Production sites where the most hogs are concentrated in each state are the points of origin from where hogs are transported to the slaughter/processing plants. Hereafter, if a production region is named with the state name it refers to the "supply center" as indicated in Table 7.1.

Although a production region is competitive in terms of production costs, it cannot grow its production infinitely beyond the carrying capacity of its natural resources. Based on personal interviews with industry experts[18], in the states of North Carolina, South Carolina, Virginia, South Dakota, Nebraska, Missouri, and Delaware this is "very unlikely" from the current level. Michigan and Colorado fall under the category of "not likely to expand pork production". The New England States (Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, and New Jersey) have lower potentialities to grow due to higher population densities. Growth in pork production is more likely to occur in the remainder of the states. The number of hogs marketed in 1997 by production regions and the possibility of expansion of production are listed in Table 7.1. The number of hogs marketed can be misleading because hogs are sometimes sold more than once. According to the industry experts, average number of hogs slaughtered is 90 percent of the number of hogs marketed. There are some instances when hogs are sold twice. According to the pork industry experts, approximately 10 percent hogs are sold twice. In order to avoid the double counting, the number of hogs slaughtered is calculated as the 90 percent of the number hogs marketed. Therefore, the production capacity of a region is assumed to be the number of hogs slaughtered.

Production regions are categorized from one through four on the basis of expansion potential (1=almost impossible to expand, 2=not likely to expand, 3= less likely to expand and 4=likely to expand). According to the industry experts, the states of Missouri, North Carolina and South Carolina fall under category 'one' since the expansion of the hog industry is very difficult in these states. Scarcities of land for manure application, moratorium from federal and state governments, and already concentrated hog businesses are some of the factors that limit the expansion. Table 7.1 shows the number of hogs sold and the number hogs actually slaughtered.

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18. Dr. Laura M. Cheney, Department of Agricultural Economics, Michigan State University, personal interview, August 2001.

Table 7.1 Production regions and number of hogs marketed in 1997

State	Hogs Marketed	Hogs Slaughtered	Growth Potential	Production Concentration	Supply Center
AL	378,545	340,690.5	4	Eastern Valley	Jackson
AZ	394,924	355,431.6	4	North	Navajo
AR	1,126,268	101,3641	4	South West	De Queen
CA	364,129	327,716.1	4	South Central	Bakersfield
CO	1,492,986	134,3687	2	Morgan	Morgan
FL	114,986	103,487.4	4	Central	Gainesville
GA	1,100,078	990,070.2	4	South Central	Albany
ID	75,778	68,200.2	4	North West	Lewiston
IL	8,028,400	7,225,560	4	North West	Henry
IN	6,670,396	6,003,356	4	Central	Anderson
IA	23,475,424	21,127,882	4	Central	Des Moines
KS	3,269,308	2,942,377	4	South West	Stevens
KY	1,135,250	1,021,725	4	Midwest	Davies
LA	64,030	57,627	4	Central	Alexandria
MD, DE, NJ	204,545	184,090.5	4	Eastern	Baltimore
MI	1,732,164	1,558,948	2	South West	Kalamazoo
MN	8,990,979	8,091,881	4	South Central	Martin
MS	456,040	410,436	4	Central	Columbia
MO	6,365,955	5,729,360	1	North Central	Chariton
MT	263,909	237,518.1	4	North Central	Sweet Grass
NE	6,245,220	5,620,698	3	North East	Columbus
NV	19,889	17,900.1	4	Western	Sparks
NM	9,875	8,887.5	4	Central	Albuquerque
NY	131,275	118,147.5	3	West	Genesee
NC	16,373,417	14,736,075	1	South Coastal	Bladen
ND	325,051	292,545.9	4	South East	Ransom
OH	3,292,762	2,963,486	4	West Central	Mercer
OK	3,274,897	2,947,407	4	Panhandle	Guymon
OR	70,439	63,395.1	4	North West	Yamhill
PA	1,541,633	1,387,470	4	South East	Lebanon
SC	538,219	484,397.1	1	South Central	Orangeburg
SD	2,324,800	2,092,320	4	South East	Sioux fall
TN	670,236	603,212.4	4	West	Fayette
TX	921,404	829,263.6	4	North H. Plains	Fort Worth
UT	280,720	252,648	4	South East	Orangeville
VA	590,142	531,127.8	1	Central	Toga
WA	55,652	50,086.8	4	East Central	Grant
WV	29,587	26,628.3	4	Western	Charleston
WI	1,576,287	14,18658	4	South West	Grant
WY	250,887	225,798.3	4	South East	Cheyenne
New England	46,895	42,205.5	3	North East	Laconia
AK & HI	28,784	25,905.6			
Total (U.S.)	104,302,165	93,871,948.1			

7.3.2 Processing regions

All the pork-processing plants that were operational in 1997 are considered to be processing regions. If a single state has two or more processing facilities, they are combined to represent one processing region. The existing capacities of the plants are assumed to be the maximum capacities of processing (Table 7.2).

Table 7.2 Annual maximum hog slaughtering capacity in different regions (1997)

Region	Capacity	Processing cost	Location of plants**
Arkansas	351,000	26.07	Little Rock
California	1,872,000	25.65	Vernon
Iowa	30,667,000	25.54	Waterloo
Idaho	169,000	25.25	Twin Falls
Illinois	8,502,000	25.08	Beards Town
Indiana	7,280,000	25.91	Logansport
Kansas	416000	25.62	Downs
Kentucky	2,145,000	25.33	Louisville
Minnesota	8,242,000	26.17	Austin
Missouri	4,368,000	24.38	Marshall
Mississippi	1,690,000	23.74	West Point
N. Carolina	8,320,000	24.54	Tar Heel
N. Dakota	239,200	24.96	Minot
Nebraska	7,150,000	25.5	Fremont*
Ohio	962,000	28.13	Sandusky
Oklahoma	2,080,000	25.26	Guymon*
Oregon	143,000	26.5	Klamath Falls
Pennsylvania	2,028,000	26.59	Hartfield
S. Carolina	780,000	24.91	Green Wood
S. Dakota	3,900,000	25.5	Sioux Falls*
Tennessee	520,000	25.13	New Burn
Texas	208,000	25.1	Richardson
Virginia	4,758,000	25.86	Smithfield
Wisconsin	650,000	27.21	Water Town
Total (U.S.)	97,440,200		

*Cost estimates in these locations are based on the regional average.
**All the processing plants in individual states are combined as single plant location.
***Details per unit processing costs calculations are discussed in Chapter Six.

It is not likely that all the processing plants will operate everyday during the year. For simplicity we can assume that a processing plant's maximum annual capacity cannot exceed 260 multiples (i.e. 52 weeks of five working days) of existing daily capacity. The value of by-products such as organs, bones, skin and hair that are obtained from processing should be taken into account in order to calculate the cost of pork production. This issue is discussed in section 8.3 and processing costs are discussed more in Chapter Five.

7.3.3 Pork consumption regions (markets)

Table 7.3 Regional demarcation and quantity of pork demanded (1,000 lbs)

State	Demand point (Node)	Demand	State	Demand point (Node)	Demand
AL	Montgomery, AL	230,323	NE	Lincoln, NE	91,721
AR	Little Rock, AR	179,849	NV	Las Vegas, NV	46,352
AZ	Phoenix, AZ	134,560	NJ	Trenton, NJ	306,703
CA	Fresno, CA	1,272,857	NM	Santa Fe, NM	68,070
CO	Denver, CO	153,737	NY	New York, NY	690,892
CT	Hartford, CT	124,465	NC	Raleigh, NC	396,037
DC	Washing. DC	39,186	ND	Bismarck, ND	35,085
DE	Dover, DE	28,189	OH	Columbus, OH	613,772
FL	Orlando, FL	782,799	OK	Oklah. City, OK	176,690
GA	Atlanta, GA	399,099	OR	Portland, OR	128,134
ID	Boise, ID	47,830	PA	Philadelphia, PA	457,565
IL	Chicago, IL	657,510	RI	Providence, RI	37,584
IN	Indianapolis, IN	321,454	SC	Columbia, SC	202,056
IA	Des Moines, IA	156,250	SD	Pierre, SD	40,007
KS	Kansas City, KS	139,482	TN	Nashville, TN	286,735
KY	Lexington, KY	208,333	TX	Fort Worth, TX	1,031,877
LA	Alexandria, LA	231,981	UT	Salt L. City, UT	81,600
ME	Augusta, ME	47,418	VA	Richmond, VA	22,416
MD	Annapolis, MD	271,513	VT	Montpelier, VT	358,943
MA	Boston, MA	232,877	WA	Olympia, WA	221,407
MI	Detroit, MI	535,656	WI	Milwaukee, WI	96,793
MN	St. Paul, MN	256,606	WV	Charleston, WV	284,661
MS	Columbus, MS	145,639	WY	Cheney, WY	18,965
MO	Columbia, MO	288,264	Export, HI, AK		784,355
MT	Billings, MT	34,716	Total		12,746,500
NH	Concord, NH	63,062			

Demand for pork consumption has been estimated in Chapter Four. For mathematical programming purposes, the contiguous U.S. is divided into the 50 consumption regions (Table 7.3). Mostly the state capitals or the major metropolitan cities are assumed to be consumption centers. Processed pork is distributed to the consumption regions at wholesale levels. Retail distributions to the local outlets are not included in the model.

7.3.4 Transportation cost

Transportation cost is one of the important components in an interregional competition model. Transportation costs influence the magnitude of flow of the commodity. The gains from the regional flow of commodity can accrue only if there is some means to transport goods from one geographical region to another region at a cost that is less than the difference in market prices between the two regions. The product movement between regions creates a derived demand[19] for transport services.

It would be desirable to use actual point-to-point transportation rates, but lack of data hinders this approach. The model assumes a single pickup or delivery point for each supply and demand region. The trucking rates are the increasing function of mileage, but the relationship may not be perfectly linear. The shipping of pigs/pork incurs loading and unloading costs, which is not related to distance between the origin and destination. Several assumptions, such as that the trucks are in full load, there are no quantity discounts, and there are no time discounts (faster delivery vs. slower delivery), are made to make the model simple. Although we recognize the non-linearity property of

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19 Demand schedules for inputs that are used to produce final products. The term-derived demand is applicable to wholesale or farm-level demand functions. Derived demand incurs marketing, processing and transportation costs (Tomek and Robinson).

transportation costs, we assumed a flat rate of transportation cost, i.e. five cents/cwt per mile. This rate is consistent with the census bureau data and with expert opinions.

Highway distance between point of origin and destination was estimated using the network analysis procedure of the geographic information system (GIS). Mostly the state capitals or the major metropolitan cities are assumed to be consumption centers. Costs of pork distribution from consumption centers (wholesale) to the supermarkets in local cities and towns are not accounted for in this analysis. The analysis would be too complicated if we were to consider all the cities and towns in the distribution network.

7.4 Transshipment model tableau

A simple two-region programming tableau, which is consistent with the equations 7.1 through 7.5, is given in Table 7.4. The tableau shows the flow of a commodity through production, processing and marketing activities. Production activities in regions A and B are given in the first four columns. Columns 5 through 8 are transportation activities in which pigs are transported to processing plants in region A and B. The technical coefficients (C_j) and transfer coefficients are given in the body of the tableau. B_i represents the regional restrictions on production capacities, processing plants capacities, and regional demands that need to be met. The coefficient 0.61 indicates the conversion factor for converting live hogs to the pork cuts for wholesale. In other words, out of 100 pounds of live pigs, we recover only 61 pounds of pork (based on expert opinion). The remaining 39 percent of weight goes to by-products (hide, lard, hotdogs, etc.) and wastes. The coefficient of 0.1 is the conversion factor from 1,000 cwt to million pounds.

Table 7. 4 A simple transshipment-programming tableau

			Prod	Prod	Prod	Prod	Ship A	Ship A	Ship B	Ship B	Process	Process	Ship	Ship	Ship	Ship
			Small	Large	Small	Large	To	To	To	To	A Plant	B Plant	A Plant	A Plant	B Plant	B Plant
Activities in	Region =>		A	A	B	B	A Plant	B Plant	A Plant	B Plant			To M1	To M2	To M1	To M2
Solution			1000 H	1000 H	1000 H	1000 H	1000 H	1000 H	1000 H	1000 H	1000 cwt	1000 cwt	1000 cwt	1000 cwt	1000 cwt	1000 cwt
		Cj	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
	Sign	Bi														
A Small,1000 Hogs	<=	R1	1													
A Large,1000 Hogs	<=	R2		1												
B Small, 1000 Hogs	<=	R3			1											
B Large, 1000 Hogs	<=	R4				1										
A pool 1000 hogs	<=	0	-1	-1			1	1								
B pool 1000 Hogs	<=	0			-1	-1			1	1						
A in plant	<=	0					-1		-1		0.4					
B in plant	<=	0								-1		0.4				
A plant cap,1000 H	<=	R9									0.4					
B plant cap,1000 H	<=	R10										0.4				
A out,1000 cwt	<=	0									-0.61		1	1		
B out,1000 cwt	<=	0										-0.61			1	1
Demand M1, mil pounds	>=	R13											0.1		0.1	
Demand M2, mil pounds	>=	R14												0.1		0.1

Regions " A" and "B", Production operation size "small" and "large", C_j =cost of activity j. M1 and M2 are markets, C1 to C14 are costs incurred for the production, transportation and processing activities.

A simple two-region transshipment model was extended to find optimal production, processing and flow of pigs and pork in the U.S. The extended model consisted of 41 production regions, 24 processing regions, and 50 consumption regions (markets). The states of Hawaii and Alaska were not included in this analysis. The states of Maryland, Delaware and New Jersey were combined and assigned as the Maryland (Baltimore) production region. Similarly, smaller states (ME, NH, VT, MA, RI, and CT) in the Northeast region were combined and assigned as the New Hampshire (Laconia) production region. In 1997, only 24 states had pork-processing facilities. If a single state had more than one pork-processing facility in different locations then they were combined to make one processing region. All the U.S. states except Hawaii and Alaska were used as pork markets. Demand for export was treated as a separate production region. The linear programming algorithms procedure from the General Algebraic Modeling System (GAMS) was used to program and solve the model. The detailed GAMS programming model is listed in Appendix 7.1

Chapter 8

VIII. Results and discussion

The specific objective of the regional allocation model was to find a set of optimal levels of regional production, processing, and flow of live pigs and processed pork at a minimum cost under the given economic environment. The linear programming model developed to find the optimum solution is shown in Appendix 7.1. In the beginning of the analysis, the 'single price' of the pork in all markets (the national average) was assumed to estimate the demand of pork (Chapter Four). In the optimal solution of the transshipment model, the shadow prices of pork were different in various markets. These shadow prices were used to re-estimate the regional pork demands. Re-estimated demands (quantity) were entered into the programming tableau. This procedure was repeated until the model returned stable results (when the sum of the absolute differences between market prices and the shadow prices converged). The results showed that the total cost of supplying pork (at the wholesale level) to meet the market 1997 pork demand was $15,429.34 million.

8.1 Optimum production level by region

The number of pigs marketed (production capacity) in the year 1997 and the optimum level of pigs (in small-, medium- and large-sized operations) that the production regions should produce in order to minimize the total cost is listed in Table 8.1. It is interesting to note that the state of Florida and the New England states have zero production levels in the optimum solution. The reason behind it is simple: other production regions can produce and ship pigs at lower costs instead of producing pork in these regions. Large-sized operations in most of the production regions should produce at current levels to meet the market demand. Small- and mid-sized operations are not competitive in some states/regions. Higher cost of production in small-sized operations makes them less competitive compared to the large-sized operations. The production regions, which have zero production at the optimum level, have the highest shadow price (zero instead of a negative number). The shadow price of –103.24 in the state of California (Appendix 8.1), for instance, indicates that if one can manage to market one more finished pig from a large-sized operation in California, the total cost (the objective value) would decrease by $103.24. Additional production of hogs in the production region where there is already a surplus (slack) production, does not contribute in cost minimization and therefore have a "zero' shadow price. In other words, a shadow price may be described as the value of resources in a particular production region, i.e. the amount to be compensated to the producers (Appendix 8.1).

The shadow price of production ranges from $ –122.15 per hog (Nevada, large-sized operation) to $0.00 (FL and New England). The states of Nevada, California, Oregon, New York, Missouri and South Dakota have higher negative shadow prices. Raising hogs in these regions reduces the total cost (the objective function) more quickly than in the production regions with lower negative shadow prices. If other conditions remained the same, these states should be considered if pork production were to be expanded. The current production level of hogs in these states is limited and it is costly to transport pork from the Corn Belt states to fulfill the demands. The total welfare of the country would improve by producing more hogs in these areas instead of transporting pork. The total number of slaughter hogs sold (capacity) in various regions and level of production in solution by various sizes of operations is presented in Table 8.1 and Appendix 8.1.

Table 8.1 Regional allocation of production by size of operations (1,000 of pigs)

Production region	Reference point	Operation size and level of production				Upper limit	Slack	Highest Shadow Price $
		Small	Medium	Large	Total			
AL	Jackson	20	75	191	286	341	55	0
AR	De Queen	0	435	436	871	1,014	143	0
AZ	Navajo	78	78	199	355	355	0	-1.45
CA	Bakersfield	72	72	184	328	328	0	-59.90
CO	Morgan	0	0	446	446	1,344	898	0
FL	Gainesville	0	0	0	0	103	103	0
GA	Albany	0	0	436	436	990	554	0
IA	Des Moines	6,444	9,191	5,493	21,128	21,128	0	-3.89
ID	Lewiston	0	15	38	53	68	15	0
IL	Henry	2,384	3,035	24	5,444	5,444	0	-22.86
IN	Anderson	1,861	2,521	1,621	6,003	6,003	0	-2.61
KS	Stevens	0	0	79	79	2,942	2,863	0
KY	Davies	337	388	296	1,022	1,022	0	-20.33
LA	Alexandria	0	13	32	45	58	13	0
MD	Baltimore	41	41	103	184	184	0	-13.56
MI	Kalamazoo	0	670	468	1,138	1,559	421	0
MN	Martin	2,428	3,237	2,428	8,092	8,092	0	-9.69
MO	Chariton	1,260	1,375	3,094	5,729	5,729	0	-27.82
MS	Columbia	0	90	230	320	410	90	0
MT	Sweet Grass	0	0	19	19	237.6	219	0
NC	Bladen	0	2,651	10,610	13,261	14,736	1,475	0
ND	Ransom	11	64	164	239	293	54	0
NE	Columbus	2,304	1,855	1,461	5,621	5,621	0	-18.42
N. England	Laconia	0	0	0	0	42	42	0
NM	Albuquerque	0	2	5	7	9	2	0
NV	Sparks	4	4	10	18	18	0	-79.14
NY	Genesee	26	26	66	118	118	0	-14.28
OH	Mercer	772	1,096	356	2,224	2,963	739	0
OK	Guymon	0	0	2,417	2,417	2,947	530	0
OR	Yamhill	14	14	36	63	63	0	0
PA	Lebanon	375	638	375	1,387	1,387	0	-9.91
SC	Orangeburg	0	107	271	378	484	106	0
SD	Sioux Fall	847	534	711	2,092	2,092	0	-23.9
TN	Fayette	133	133	338	603	603	0	-23.95
TX	Fort Worth	0	0	208	208	829	621	0
UT	Orangeville	0	56	141	197	253	56	0

Production region	Reference point	Operation size and level of production				Upper limit	Slack	Highest Shadow Price $
		Small	Medium	Large	Total			
VA & WV	Toga	123	123	312	558	558	0	-4.52
WA	Grant	11	11	28	50	50	0	-3.75
WI	Grant	0	539	847	1,386	2,180	794	0
WY	Cheyenne	0	0	126	126	226	100	0

Note: Upper limit is the right hand side of the constraint in mathematical programming. Slack level of production implies unused production capacity. Reference point is the location where production is concentrated in that particular production region and distances for transportation were measured from this point.

8.2 Optimum level of pork processing by region

Pork processing plants obtain finished pigs from the production regions. Live pigs are transported from the surrounding production regions to the processing plants as an intermediate product. As discussed earlier, processing plants have capacity constraints. It may not be possible to process all the pigs raised in the processing region due to capacity constraints of plants. Similarly, some processing plants do not have a sufficient supply of live hogs and they need to haul pigs from other regions. Table 8.2 indicates the pattern/direction of live hog flow from production regions (origins) to processing regions (destinations).

Table 8.2 Pattern of pig flow in the optimum solution

Processing region (000 Head)*	Source of pig (Production region/state)	Processing region (000 Head)	Source of pig (Production region/state)
AR (351)	AR	ND (239)	ND
CA (1,351)	AZ, CA, CO, NV, NM, UT	NE (7,150)	NE, IA
IA (19,380)	IA	OH (962)	OH
ID (169)	ID, MT, WY	OK (2,080)	OK
IL (6,805)	IL, MO	OR (143)	OR, ID, WA
IN (7,280)	IN, MI, OH	PA (2,028)	MD, NY, NC, PA
KS (416)	KS, OK	SC (780)	NC, SC
KY (2,145)	KY, IN	SD (3,198)	MN, SD
MN (7,941)	IA, MN, WI	TN (520)	AR
MO (4,368)	MO	TX (208)	TX
MS (1,690)	AL, GA, LA, MS, TN	VA (4,758)	NC, VA
NC (8,320)	NC	WI (650)	WI

*Numbers in parentheses indicate the total number of pigs shipped from the production region(s) to the processing region.

The states of California, Mississippi and Pennsylvania are major live hog deficit states and they bring live hogs from various other states (production regions) to keep their pork processing plant running at full capacities. The states of Iowa and North Carolina are major pork-producing states and they supply live hogs to various processing regions.

Table 8.3 Locations and optimal levels of processing (1,000 of hogs)

Region	Location of Processing	Total Processed	Processing Capacity	Slack	Shadow price* $/hog
AR	Little Rock	351	351	0	-88.47
CA	Vernon	1350.961	1,872	521.039	0
IA	Waterloo	19379.51	30,667	11287.49	0
ID	Twin Falls	169	169	0	-62.76
IL	Beards Town	6804.919	8,502	1697.081	0
IN	Logansport	7280	7,280	0	-33.61
KS	Downs	416	416	0	-43.1
KY	Louisville	2145	2,145	0	-40.15
MN	Austin	7940.573	8,242	301.427	0
MO	Marshall	4368	4,368	0	-15.62
MS	West Point	1690	1,690	0	-60.07
NC	Tar Heel	8320	8,320	0	-57.06
ND	Minot	239.2	239	-0.2	-44.16
NE	Fremont	7150	7,150	0	-6.95
OH	Sandusky	962	962	0	-45.15

Region	Location of Processing	Total Processed	Processing Capacity	Slack	Shadow price* $/hog
OK	Guymon	2080	2,080	0	-90.61
Org	Klamath Falls	143	143	0	-36.42
PA	Hartfield	2028	2,028	0	-43.88
SC	Green Wood	780	780	0	-90.94
SD	Sioux Falls	3198.313	3,900	701.687	0
TN	New Burn	520	520	0	-41.01
TX	Richardson	208	208	0	-115.79
VA	Smithfield	4758	4,758	0	-54.98
WI	Water Town	650	650	0	-38.93
	USA	82,931	97,440	14508.53	

*Shadow price indicates that additional processing capacity in that particular region would reduce the objective value by the listed amount.

Current pork-processing capacities (upper bound) of different regions and the optimum level of processing required to meet the consumer demand are listed in Table 8.3 and Appendix 8.3. It is interesting to note that most of the processing plants are operating at full capacities. Processing capacity in many processing regions is a limiting factor, at least in the short run, to expand the pork industry. Processing plants in Vernon (CA), Beards Town (IL), Waterloo (IA), Austin (MN), and Sioux Falls (SD) could process more hogs from the current optimum level if there were more demand for pork for consumption in U.S or for export. The processing plants that have slack processing capacities have "zero" marginal values/shadow prices. Therefore, increasing the processing capacities in these surplus capacity regions under the given conditions does not contribute to reduction of the total cost in the system. Regions with the larger negative shadow prices (e.g. Texas) are the ones where the processing capacities should be expanded first. In the long run, processing industries adjust their location (immobile processing plants become mobile) and the processing plants can be shifted to different regions, if it is more profitable to do so. The states of Texas, Oklahoma, South Carolina, Arkansas, and Missouri will be the top five processing regions for expansion of processing capacities in the future if the demand of pork grows.

Table 8.4 Shipment of pork from processing regions to the markets

Market*	Processing	Market	Processing	Market	Processing
AL	IL, MS	LA	AR, NE	OH	IN
AR	AR, TN	MA	OH, PA	OK	NE
AZ	OK	MD	NC	OR	ND, OR, SD
CA	CA, MN	ME	PA	PA	NC
CO	SD	MI	IA	RI	VA
CT	NE	MN	MN	SC	NC
FL	IL, KY, NC, SC	MS	MS	SD	SD
DC	NC, VA	MO	MO	TN	IL
DE	NC	MT	SD	TX	KS, MO, NE, OK, TX
GA	IL	NC	NC	WA	SD
IA	IA	ND	ND	WI	WI, IA
ID	ID, NE	NE	NE	WY	NE
IL	IA	NH	PA	WV	KY
IN	IN	NM	OK	UT	NE
KS	IA, MO	NJ	VA	VT	PA
KY	IN, KY	NV	CA	VA	VA
		NY	IA, PA, VA	Export	IA

*Wholesale markets (destination) obtain processed pork from the processing regions (origin) to fulfill retail market.

Processing plants supply pork to the wholesale markets. The optimal solution in Table 8.4 indicates the flow (direction) of pork from processing regions to the markets. Quantities of pork shipped from the processing regions to the markets are listed in Appendix 8.2 that would minimize the total cost under the given set of constraints. Pork processed in Iowa, North Carolina, Nebraska, and Pennsylvania covers most of the markets. Looking at the Table 8.4, a question can be raised: why Arkansas is shipping out pork to Louisiana and shipping in some pork from Tennessee. It sounds a little confusing, but it should be kept in mind that the processing plants and the markets may not be in the same location in the same state. The distance between processing plants and market and transportation costs along with other constraints determined the direction of pork shipments.

8.3 Pork demand and shadow prices

In Chapter Four, the demand for pork was estimated for each market. Data on meat consumption and prices by each region (states) were not available. Therefore, the national average of per capita of pork consumption was estimated by a system of equations using the national average quantities of meats and their prices. Their regional demand for pork was then adjusted on the basis of demographic characteristics and their pork consumption behavior (details in Chapter Four). The shadow prices in different markets obtained from a cost minimization procedure were used to re-estimate the pork demand. This procedure was repeated several times. Total pork demands and the shadow prices by markets (states) in the optimal solution are listed in the Table 8.5.

In terms of total quantity of pork demand, the top ten markets are CA, TX, FL, IL, NY, OH, MI, PA, NC, and GA. The shadow price of pork ranged from \$1.20 (IA) to \$1.96 (WA) per pound at the wholesale level (shadow price for export is \$1.14/pound but it is due to the fact that transportation costs involved in export are not included in the analysis). Markets in WA, OR, ME, and ID in the Western region, and the New England states in the Northeast region have relatively higher shadow prices. This information indicates that it is expensive to supply pork to these markets in the current pork industry settings. This result may be useful to the pork industry leaders. Expansion of pork production and processing capacities in these areas, where the shadow prices of demands are higher would reduce the total costs and would ultimately improve the total social welfare.

Table 8.5 Market demand (Mil. Pounds) and shadow prices

Market*	Optimum Demand	Shadow Price	Market	Optimum Demand	Shadow Price
AL	210.737	1.61	ND	34.825	1.36
AR	127.238	1.50	OH	593.82	1.43
AZ	158.373	1.74	OK	168.922	1.47
CA	1111.101	1.77	ORG	107.027	1.94
CO	146.351	1.48	PA	414.848	1.64
FL	675.829	1.81	SC	183.879	1.63
GA	367.231	1.59	SD	40.874	1.28
IA	164.884	1.20	TN	274.452	1.47
ID	40.878	1.85	TX	955.36	1.57
IL	668.297	1.30	UT	72.916	1.69
IN	319.826	1.35	VA	338.532	1.51
KS	141.662	1.30	WA	184.067	1.96
KY	201.115	1.44	WI	291.42	1.28
LA	208.074	1.67	WY	18.064	1.48
MD	250.406	1.58	NH	54.553	1.80
MI	519.044	1.43	CT	111.288	1.69
MN	265.663	1.25	DC	36.323	1.57
MS	137.293	1.51	DE	26.035	1.58
MO	294.321	1.28	MA	202.95	1.78
MT	32.884	1.50	ME	40.459	1.86
NE	94.422	1.26	NJ	276.588	1.66
NV	40.195	1.79	RI	32.786	1.77
NM	63.892	1.53	VT	19.482	1.79
NY	618.077	1.68	WV	90.805	1.53
NC	371.967	1.52	EX	847.015	1.14

*Export includes demand from the states of Hawaii and Alaska.

The average price of pork in this model at the wholesale level is $1.22/lb and the total pork marketed is 12,647 million pounds. Pigs are slaughtered and processed into pork cuts by standard ways at the packing plants, to sell in the wholesale market. Wholesale cuts are further processed for retail sale. During these processes, in addition to meat (pork), a number of by-products are obtained which have economic value. The value of the by-products must be taken into account while calculating pork price spreads.

An USDA report[20] indicates that the average value of by-products account for $0.05 per pound of pork at the wholesale level. With this piece of information, we can adjust the wholesale price. The prices of by-products were subtracted from the total processing costs so that the imputed pork price would take into account the by-products. According to industry experts, after adjusting for by-products, the average retail price of pork would be about a 75 –100 percent mark-up from wholesale prices. If we assume the given mark-ups, then the estimated retail price of pork would be $2.13 to $2.44 per pound.

8.4 Industry implications

The analysis of the pork sector discussed in this study would be useful to the U.S. pork industry participants. The analysis contains useful information about the competitiveness of the various regions/states in pork production and processing. Some of the existing pork production operations (particularly the smaller-sized operations) are not efficient and therefore, will exit the industry. Small-sized production facilities are vulnerable and the trend of fewer and larger hog operations will continue.

The cost minimization model used in this study indicates that the states of Florida and New Hampshire (representing the New England States) should not raise pigs at all. However, in reality this statement may not be practical. This can be taken as an indication that pork production in these areas is less likely to expand under the economic environment outlined in the model description in Chapter Seven. Higher Production costs and distant processing facilities make the pork production expensive in these regions.

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20 http://www.ers.usda.gov/briefing/foodpricespreads/meatpricespreads/pork.xls

Higher negative shadow prices (marginal costs) in the states of NV, CA, OR, NY, MO and SD (for example) are an indication that the pork industry would be better off to expand production in these regions. Demands of pork relative to supplies are higher in the states with higher negative shadow prices. Human settlement and feed availability are probably the most important factors for pork industry structure. Feed cost is a major cost component in production and it is expensive to transport pork if the distance between production regions and markets is too far. Expansion of pork production and processing capacities in the areas (CA, TX, FL, IL, NY, OH, MI, PA, NC and GA), where the shadow prices of pork demands are higher (negative) would reduce the total costs. However, production and processing costs are also important consideration to decide the pork production locations. The states of Florida and Georgia have slack live hog production on the supply side and higher shadow prices on the demand side. The processing facility is the one of the limiting factors here. Establishment of processing facilities in these states would save the transportation cost. In the current (year 1997) pork industry setting, the costs of supplying pork in the Western and Northeast regions are higher. If the pork industry expands its production and processing facilities in these regions, the first mover is likely to reap good incentives.

This study made several assumptions in pork demand analyses, cost of production and processing analyses, and linear programming modeling. The linear programming model requires the assumption that the parameters and constant values in the model are known with certainty. The model requires specifically defined values to represent pork demand, production costs, environmental compliance costs, processing costs, technical coefficients described in Table 7.4 (programming tableau), capacity constraints, and transportation costs. All these parameters were estimated or compiled using the secondary data obtained from different sources (Appendix 1). Due to the uncertainty of future events and quality of the data used, there is a potentiality of significant deviations between the parameters used in this analysis and the real parameters. Therefore, analysis of a likely future scenario would be useful.

8.5 Scenarios analysis

It is important to conduct sensitivity analyses in order to determine the robustness of the results of the mathematical programming modeling. One may ask a question: what would happen if one or more assumptions were relaxed or changed? Sensitivity analyses would be useful to visualize the impact of likely scenarios in the pork industry. The impacts of a few likely scenarios on the base model (model described above) are analyzed below. The scenario differs from the base model by these following factors:

1. Increase in pork demand
2. Expansion of pork production
3. Expansion of pork processing capacities
4. Increase in regulatory compliance cost

8.5.1 Increase in pork demand

Per capita pork consumption in the U.S. does not show any trend by time. Increase in population size is the most important factor in the quantity of pork demand. The U.S. Census Bureau has projected population by states based on assumptions about future births, deaths, international migration, and domestic migration. Population projections are available for the year 2005, 2015 and 2025. The U.S. population by states for 2010 was linearly extrapolated between 2005 and 2015. The projected U.S.

population would grow by 12 % from the 1997 population. If the per capita pork consumption in 2010 remained at current levels then the total pork demands by state would change by the proportionate change in population. If this assumption holds, there would be a higher growth of pork demand in the Western states (e.g. Nevada, Colorado, Washington, and Utah) and growth would be slower in the Corn Belt states and the currently highly populated areas (Table 8.6).

As discussed earlier (Chapter Four), U.S. pork export increased by 250 percent from 1989 to 1997. Asia is considered to be an important export market for the U.S. pork industry. Canada, Australia, European Union, and Latin America are other important markets for U.S. pork export. It is expected in the near future that the export demand of pork will grow dramatically. If the trend continues, an USDA projection shows that total pork export in the next decade will be approximately double the 1997 level of pork export. In this scenario, total pork export would be 1,426 million pounds in 2005. Let us assume that this level of export will hold in the year 2010 too.

8.5.2 Expansion of production

In recent past decades, the number of hog-raising farms has dropped sharply (Table 3.1), however the total number of farms keeping more than 1,000 pigs has increased. Smaller farms are continuously leaving the hog business. It is expected that this trend will continue in the future and the hog industry will be further geographically concentrated. According to an industry expert (personal interview), pork-producing states are classified into four groups. The classification is given in Table 7.1. Assume that pork production will expand first in class four production regions "likely to expand". When the production expands it would follow the historical trend and there would be growth in medium- to large-sized operations and small-sized operations would continue to disappear. Let us further assume the number of pigs raised by medium- to large-sized operations would double and small-sized operations would remain the same in the pork production regions that are identified as "likely to expand" regions.

8.5.3 Expansion of processing capacity in the West

Pork processing capacity seems to be a limiting factor in most of the regions. In the current industry structure, there are few processing facilities in the western region of the U.S. From the base model, we observed that pork in the Western states was relatively expensive (high shadow price). Results show higher negative shadow prices in the states of Nevada, California, and Oregon. Higher shadow price comes partly from the higher transportation costs which could be reduced if there were more processing facilities in the region. If the trend of location shift continues, it is likely that the production and processing of pork will expand toward the West. In the year 2010, let us assume pork-processing capacity in the West would double from the current level (1997).

8.5.4 Increase in compliance costs

The compliance cost and industry location is a much-discussed topic in pork industry related literature. Industry experts and scholars believe that regional variations in environmental regulations influence migration of hog/pork operations to the locations where the regulations are less severe. In Chapter Six, environmental compliance costs by production regions and size of operations were estimated (Table 6.6). These estimated costs were incorporated into the total cost of production. The estimated environmental costs did not have a large share in total costs (roughly one percent of total costs). Metcalfe (2000), in a study, also concluded that environmental costs have minor impacts on the price of pork. In his study, increases in environmental compliance costs by 25 percent to 200 percent lead to a 0.26 percent to 2.05 percent decrease in pork export. It implies that compliance costs do not affect the competitiveness of the hog industry. However, governmental regulations are uncertain and difficult to predict. We know from the environmental stringency grouping in Table 6.3 that some U.S. states are more stringent than others. Let us assume that compliance cost will increase sharply (say double from the year 1997 level) in "Highly Restrictive" and "Restrictive" states (KY, NE, OH, IL, NC, SD, OK, SC, MD, CA, ND, UT, VA, WI, WY, FL, IN, MN, VT, CT, IA, MO, MS, AR, KS, TN, TX) and that it is not changed in other less stringent states (NY, WA, NV, AZ, ID, NM, MT, OR, PA, RI, AL, NJ, CO, ME, MI).

8.5.5 Results of the scenario analysis

Results of the base model showed that the states of Florida and New Hampshire (New England) have no production in the optimum solution. The new projected scenario (Year 2010) also now has the states of Washington, Colorado and Louisiana out of the production regions. Most of the small-sized operations (e.g. AL, FL, GA, IN)

Table 8.6 Optimum level of pork production in year 2010 (1,000 of pigs)

Region	Size of Firm	Level in Solution*	Slack	Shadow Price $/pig	Region	Size of Firm	Level in Solution	Slack	Shadow Price $/pig
AL	Small	0	149.904	0	MT	Large	266.02	0	-1.65
	Medium	0	149.904	0	N.Eng.	Small	1.956	0	-36.415
	Large	381.573	0	-2.35		Medium	1.956	0	-61.725
AR	Small	0	78.195	0		Large	4.977	0	-74.415
	Medium	0	156.389	0	NV	Small	64.36	0	-58.3
	Large	398.077	0	-4.375		Medium	128.72	0	-87.57
AZ	Small	0	111.5	0		Large	327.652	0	-101.31
	Medium	932.549	0	-10.01	NM	Small	0	294.721	0
	Large	871.731	0	-23.75		Medium	0	7662.758	0
CA	Small	72.097	0	-38.745		Large	2703.22	18516.73	0
	Medium	144.194	0	-67.815	NY	Small	575.892	935.486	0
	Large	367.042	0	-81.355		Medium	1096.49	0	-18.9

Region	Size of Firm	Level in Solution*	Slack	Shadow Price $/pig	Region	Size of Firm	Level in Solution	Slack	Shadow Price $/pig
CO	Small	0	295.611	0		Large	355.618	0	-29.3
	Medium	0	295.611	0	NC	Small	2304.486	0	-24.505
	Large	0	752.465	0		Medium	1854.831	0	-46.275
FL	Small	0	22.767	0		Large	1461.381	0	-56.625
	Medium	45.535	0	-5.615	ND	Small	3.938	0	-58.88
	Large	115.906	0	-16.015		Medium	7.877	0	-84.63
GA	Small	0	227.716	0		Large	20.048	0	-97.58
	Medium	653.447	0	-0.02	OH	Small	0	176.845	0
	Large	871.261	0	-12.51		Medium	0	707.378	0
IA	Small	2384.435	0	-21.885		Large	4833.749	0	-9.78
	Medium	6069.47	0	-47.185	OK	Small	0	13.947	0
	Large	48.78	0	-59.885		Medium	27.895	0	-17.555
ID	Small	0	15.004	0		Large	71.003	0	-27.925
	Medium	0	30.008	0	OR	Small	0	374.617	0
	Large	76.385	0	-5.365		Medium	0	1276.472	0
IL	Small	1861.041	0	-11.46		Large	429	320.234	0
	Medium	5042.819	0	-31.93	PA	Small	106.567	0	-6.365
	Large	3241.813	0	-44.45		Medium	213.134	0	-25.245
IN	Small	0	6444.004	0		Large	542.525	0	-35.595
	Medium	12096.8	6284.459	0	SC	Small	847.39	0	-19.625
	Large	10986.5	0	-12.52		Medium	533.542	0	-40.915
KS	Small	0	735.594	0		Large	711.389	0	-52.545
	Medium	1353.494	0	-1.475	SD	Small	132.707	0	-33.015
	Large	3060.072	0	-14.185		Medium	265.414	0	-58.135
KY	Small	0	337.17	0		Large	675.598	0	-70.805
	Medium	776.511	0	-20.59	TN	Small	0	182.438	0
	Large	592.601	0	-30.94		Medium	364.876	0	-4.31
LA	Small	0	12.678	0		Large	928.775	0	-14.91
	Medium	0	25.357	0	TX	Small	0	55.582	0
	Large	0	64.543	0		Medium	0	111.164	0
MD	Small	40.5	0	-38.58	TX	Large	208	74.965	0
	Medium	81	0	-60.32	UT	Small	0	122.706	0
	Large	206.181	0	-70.7		Medium	122.706	0	-2.025
MI	Small	0	420.916	0		Large	312.344	0	-15.525
	Medium	670.348	0	-8.435	VA	Small	11.019	0	-51.6
	Large	467.684	0	-21.175		Medium	22.037	0	-72.76
MN	Small	2427.565	0	-19.68		Large	56.097	0	-84.42
	Medium	6473.506	0	-40.06	WA	Small	0	794.449	0
	Large	4855.129	0	-52.6		Medium	0	1078.18	0
MS	Small	0	1260.459	0		Large	0	1693.039	0
	Medium	0	2750.092	0	WI	Small	49.676	0	-15.605
	Large	1781.35	4406.359	0		Medium	99.351	0	-35.805
MO	Small	90.296	0	-40.965		Large	252.895	0	-48.255

Region	Size of Firm	Level in Solution*	Slack	Shadow Price $/pig	Region	Size of Firm	Level in Solution	Slack	Shadow Price $/pig
	Medium	180.592	0	-60.305	WY	Small	0	9.285	0
	Large	459.688	0	-72.785		Medium	0	18.571	0
MT	Small	0	52.254	0		Large	47.27	0	-7.73
MT	Medium	0	104.508	0	NE		7150		

*Level in solution in thousand of pigs

of the mid-sized operations (AL, AR, ID, MS, MT, OH, OR, TX and WY) and will not be competitive in pork production by the year 2010. The shadow price of production ranged from $ –122.15 per hog (Nevada, large-sized operation) to $0.00 (FL, CO, MT, and WY) in the base model. This range narrowed in the projected scenario ($-101.31 to $0.00). Details of the size of the firm and underlying shadow prices of production are listed in Appendix 8.4 (results of scenario analysis).

Table 8.8 Pattern of hog flow in year 2010 (predicted)

Processing region	Source of hog (Production region)	Processing region	Source of hog (Production region)
AR	AR	ND	ND
CA	AZ, CA, NV, UT	NE	NE
IA	IA	OH	OH, MI
ID	UT	OK	OK
IL	IL, MO	OR	OR, ID, WA
IN	IN, MI	PA	NY, PA
KS	OK	SC	NC, SC
KY	KY, IN	SD	MN, SD
MN	MN, WI	TN	AR
MO	MO	TX	TX
MS	AL, MS, TN	VA	NC, VA, MD
NC	NC	WI	WI

In the projected scenario, the pattern of pig flow is similar to the base model. There are few variations in the pattern. For example, the state of Nebraska shipped in live hogs in the base model but in the projected scenario, NE obtained live hogs from itself. Similarly, unlike in the base model, the Pennsylvania processing region did not in-ship pigs from Maryland, North Carolina and New Hampshire.

The production level in solution of the the base model (Year 1997) and the projected scenario (Year 2010) are listed in Appendix 8.4 to identify the winners and losers. The results show that some of the states gain in pork production share and others lose from the current optimum level. The state of FL, N.England, NM, KS, and NV will be top winner in terms of percentage change. Similarly, the states of WA, LA, OK, MO, and ND will be the top loser in percentage change in production. Increase in the numbers of hogs slaughtered in 2010 will be substantially higher in the state of IN, MN, IL, and KS. States of IA, NC, MO, and OK will be in the column of loser by the year 2010. The result indicates that although the trend of shifting location will be continuous but pork production will still be concentrated in the Corn Belt states.

Table 8.9 Locations and levels of processing in the year 2010 (1,000 of Hogs)

Region	Level	Slack	Shadow Price $/hog	Region	Level	Slack	Shadow Price $/hog
AR	351	0	-114.16	NC	8320	0	-28.43
CA	5616	0	-31.14	ND	297.883	180.517	0.00
IA	19368.29	11298.71	0.00	OH	962	0	-86.23
ID	507	0	-70.64	OK	2080	0	-79.07
IL	8502	0	-39.76	OR	429	0	-103.61
IN	7280	0	-74.31	PA	2028	0	-76.46
KS	416	0	-44.19	SC	780	0	-95.40
KY	2145	0	-80.85	SD	7800	0	-4.42
MN	7029.919	1212.081	0.00	TN	520	0	-66.70
MS	1690	0	-107.48	TX	208	0	-130.98
MO	4368	0	-18.40	VA	4758	0	-26.35
NE	7150	0	-4.96	WI	650	0	-33.06

Table 8.10 Pattern of pork flow in optimum solution (Year 2010)

Market	Processing (origin)	Market	Processing (origin)	Market	Processing (origin)
AL	MS, MO	LA	SD	OH	IN
AR	AR, IL	MA	OH, PA	OK	SD
AZ	OK	MD	NC, VA	OR	ND, OR, SD
CA	CA, MN	ME	PA	PA	NC
CO	SD	MI	IA	RI	PA
CT	NE	MN	IA, MN	SC	NC, SC
FL	KY, MN	MS	MS	SD	SD
DC	NC	MO	MO	TN	IL
DE	NC	MT	SD	TX	IA, KS, MO, NE, OK, SD, TX
GA	IL	NC	NC	WA	SD
IA	IA	ND	ND	WI	IA
ID	ID, NE	NE	NE	WY	NE
IL	IA	NH	PA	WV	IN, KY
IN	IA, IN	NM	OK	UT	NE
KS	IA	NJ	IA	VT	PA
KY	IN	NV	CA	VA	VA
				Export	IA

The processing capacity in the 2010 scenario is mostly used up. In the base model, the slack capacity was 15 million head, whereas in the projected scenario the processing plants except in CA, IA, and SD were completely used up. If the pork industry required slaughtering about five million more pigs/year, the model would have been infeasible. Since all of the processing facilities in the base model were kept operational in the new scenario, the pattern of pork flow was almost identical in terms of direction of flow (Table 8.10).

Table 8.11 Demands (Mil. Pounds) and shadow prices (per/lb) in year 2010

Market	Level (Mil lbs)	Shadow Price $/lb	Market	Level (Mil lbs)	Shadow Price $/lb
AL	226.11	1.72	ND	36.28	1.46
AR	137.11	1.64	OH	586.52	1.55
AZ	186.50	1.85	OK	179.28	1.58
CA	1283.68	1.84	OR	122.55	2.03
CO	169.61	1.58	PA	412.33	1.76
FL	776.17	1.93	SC	196.80	1.75
GA	417.24	1.71	SD	44.53	1.38
IA	163.63	1.32	TN	303.01	1.58
ID	52.76	1.82	TX	1093.77	1.68
IL	668.07	1.42	UT	87.04	1.79
IN	329.98	1.47	VA	369.14	1.63
KS	148.47	1.40	WA	213.61	2.05
KY	206.29	1.56	WI	299.63	1.40
LA	218.77	1.76	WY	21.98	1.59
MD	268.69	1.70	NH	42.35	1.92
MI	501.82	1.55	CT	112.72	1.79
MN	284.12	1.32	DC	26.75	1.69
MS	144.12	1.63	DE	38.75	1.70
MO	306.85	1.39	MA	207.08	1.90
MT	37.66	1.59	ME	41.71	1.98
NE	97.79	1.37	NJ	287.29	1.78
NV	71.49	1.86	RI	33.49	1.89
NM	77.43	1.63	VT	20.84	1.91
NY	612.18	1.80	WV	89.25	1.64
NC	411.67	1.64	EX	1556.64	1.26

*Export (EX) includes demand from the states of Hawaii and Alaska.

The state of CA, FL, TX, IL, NY, OH, MI, GA, NC, and PA are still the top 10 markets in terms of quantity of pork demanded. The range of shadow price per pound of pork in the 2010 scenario was $1.06 (IA) to $1.81. The average wholesale pork price went down from $1.22/lb to $1.19/lb.

Chapter 9

IX. Summary and conclusion

The pork industry structure in the U.S. is in rapid transition due to the technology-induced industrialization process. Technological advances have resulted in cost efficiency by reducing the average cost of production. However, all the market participants cannot capture benefits by cost efficiency. Large-scale hog production that utilizes new technologies have a competitive advantage over smaller and traditional operations to capture their market shares. Larger and newer operations have better arrangements with feed mills, packers, and other contractors to reduce the production costs. This phenomenon encourages a shift to larger and specialized operations. Pork operations in the U.S. are not only getting larger, but, are also moving to non-traditional pork producing areas such as Oklahoma, Arkansas and Utah. This structural change affects positively or negatively on the farm communities, the environment, and consumers.

The primary objective of this study was to analyze the trends in the U.S. pork production industry and to review the factors that contributed to structural changes of the industry. Results of this analysis are useful to policy makers and the pork industry leadership to introduce to the existing pork industry and to anticipate further changes in the future.

Structural adjustment in the pork industry is driven by technological changes. The cost-saving motive in production, processing and distribution of pork is the leading factor for the development and adoption of new technologies. Public policies and regulations, property values, alternative economic options, geological characteristics, consumer demand, contractual arrangement, and agglomeration have been described in the literature as the factors responsible for location change in the hog industry. Among these factors, consumer demand for pork, environmental regulations, and cost of production were analyzed in detail in this study.

The almost ideal demand system (AIDS) and the "Rotterdam" models are common in demand analyses. Based on the recommendation by Alston and Chalfant (1993), and a better fit on U.S. meat data, the Rotterdam model was chosen to estimate per capita meat demand in the U.S. Regional pork demands were then adjusted by the demographic compositions and consumption behavior. Per capita pork consumption was highest in the Midwest, followed by the South, and the lowest pork consumption was in the Northeast region of the U.S.

An enterprise budgeting approach was adopted to calculate the production cost in feeder-to-finishing operations. Costs were calculated individually for various production regions (E. Corn Belt, W. Corn Belt, South, Northeast and South) and type of operations (small-, medium- and large-sized). Regional production costs were then adjusted by states for variations in input prices (e.g. corn price, soybean price, wage rates etc.). Environmental compliance costs were also incorporated into the enterprise budgets. The result of cost analysis suggests that smaller operations have limited ability to compete with larger production facilities. Larger operations have higher efficiencies in feed, buildings and equipment and labor. As is with the number of farms raising hogs, the number of pork processing facilities has declined. The number of pork processing firms were 446 in 1980 and the number declined to 209 in 1995. There are a few dominant meatpacking plants (Smithfield, IBP, ConAgra, Cargil and Hormel) that process more than 60 percent of total pork supplied in the U.S. markets. The competitive advantage of one production region over other regions arises from the various factors such as lower feed costs, higher feed efficiency, friendly environmental and other regulations, and accessibility of markets.

A mathematical programming method (transshipment linear programming), as suggested by Takayama and Judge (1971) was used to analyze the interregional production, processing and distribution of pork in the U.S. to minimize the total cost in the system. Forty production regions, three types of production units (small, medium and large), 24 processing regions and 50 markets were used in the LP model. The results revealed that existing pork production operations in the Florida, and New England production regions are not competitive due to higher production costs and distant processing facilities. The states of NV, CA, OR, NY, MO and SD have higher negative shadow prices in the mathematical programming solution. It is an indication that these production areas should be considered for expansion of pork production in order to minimize the total cost in the system. The results also revealed that the pork industry tends to locate near the populous areas due to easy market access and to reduce the transportation costs. But, the opposite forces- threat from current and future environment regulations, scarcity of agricultural land for manure management and the government moratoria tend to keep the hog operations away from major cities and towns. These opposite forces along with other factors determine the locations of pork production. A likely future scenario analysis suggested that the Western region would experience higher growth in pork production compared to other regions by the year 2010. The trend of smaller production units leaving the industry will continue and the pork industry will be more consolidated in fewer and larger operations.

Limitation of the study:

1. This study relied on the secondary data from different sources (Appendix 1). Some of the key data were obtained from expert opinions. Results of the study are greatly affected by the quality of the data. Some of the data were not available due to disclosure reasons.
2. In the mathematical programming section, only the price of the pork was allowed to change in the iterative procedure to adjust the market demand. Prices of other meats were kept unchanged. The substitution effect was ignored.
3. Regional demarcation of production, processing and markets were broad (state level). The model estimated the state level aggregate supply and demand . Expanding the model up to townships and city level would generate better results, but such expansion would be costly in terms of time and money.
4. Export demands were treated exogenously and analysis of the export market would better predict the pork industry in future.
5. This model doesn't cover many aspects (factors such as quality of meat, land values etc.) due to the unavailability of data. There is the potentiality of introducing errors.

Suggested future research:

1. The cost minimization model presented in this study allocated the optimal level of pork production to each production regions. Most of the production regions are individual states. The optimal level of production of hogs in Michigan, for instance, was 1,138,000 pigs per year. Although production is scattered throughout the state, it is more concentrated in the Kalamazoo area. It would be interesting to discover the best locations in Michigan that would meet all the constraints. Application of the geographical information system (GIS) would be highly desirable at this point. Factors such as geological characteristics (soil type, soil fertility, topography and hydrology), locations of cities and town, rivers, lakes, parks and roads along with federal, state and local regulations and standards (e.g. setbacks) could be considered in the analysis. Such analyses would be useful for all production regions (states) to identify exact locations of hog production.
2. Processing capacity is one of the major bottlenecks in the pork industry expansion in the U.S. It is expected that there would be higher population growth in the western part of the country. Future expansion of the pork industry would be in the Western region due to the higher pork demand and availability of agricultural lands. It would be useful to do feasibility studies of establishing one or more meat packing plants in the West (e.g. Washington, Idaho and Utah).

Appendices

Appendix 1: Source of data

Data	Source
Price of corn	USDA-NASS Agricultural prices, Annual Summary
Price of hogs	USDA-NASS Agricultural prices, Annual Summary
Hog inventories	US Census of Agriculture
No. of farms by states	US Census of Agriculture
Population	US Bureau of the Census
Meat prices	USDA-NASS Red Meat Yearbook
Pork consumption by region	USDA Continuing Survey of Food Intakes by Individuals
Per capita income	Income Statistics Branch, US Bureau of the Census
Wage rates	Bureau of Labor Statistics
Opportunity costs of labor	USDA, Technical Bulletin number 1848
Hog nutrition	Pork Industry Handbook, Michigan State University
Pork export and import	US Foreign Agricultural Trade Database
Compliance costs	US Environmental Protection Agency (EPA)
Pig slaughter capacity	National Pork Producer Council (NPPC)
Shipping costs	US Census Bureau, 1997 Economic Census

Appendix 3

Appendix 3. 1 America's top 25 hog producing counties, 1997

1997 Rank	1992 Rank	County	State	Inventory, 97
1	1	Duplin	NC	2,034,349
2	2	Sampson	NC	1,775,702
3	797	Texas	OK	907,046
4	3	Sioux	IA	762,294
5	28	Bladen	NC	758,701
6	736	Sullivan	MO	Not Available
7	36	Wayne	NC	529,439
8	16	Martin	MN	489,024
9	5	Plymouth	IA	460,965
10	32	Hamilton	IA	448,312
11	8	Washington	IA	436,353
12	4	Delaware	IA	401,729
13	114	Mercer	MO	Not Available
14	34	Hardin	IA	395,359
15	11	Greene	NC	391,672
16	9	Carroll	IA	372,598
17	182	Wright	IA	358,616
18	25	Sac	IA	350,473
19	6	Lancaster	PA	349,774
20	77	Robeson	NC	327,559
21	43	Blueearth	MN	325,829
22	22	Lyon	IA	325,619
23	23	Kossuth	IA	323,029
24	100	Lenoir	NC	315,588
25	133	Pitt	NC	303,393

Appendix 4

Appendix 4.1 U.S. per capita meat consumption and prices of meats 1970-99

Year	Prices of Meats*				CPI Food	Per Capita Consumption			
	Beef	Chicken	Pork	Fish		Beef	Pork	Chicken	Fish
1970	0.79	0.35	1.06	0.35	0.39	84.4	55.4	40.1	11.7
1971	0.82	0.36	0.96	0.39	0.40	83.7	60.2	40.1	11.5
1972	0.90	0.36	1.11	0.42	0.42	85.1	54.3	41.5	12.5
1973	1.08	0.52	1.48	0.48	0.48	80.4	48.5	39.7	12.7
1974	1.11	0.49	1.47	0.56	0.55	85.5	52.4	39.6	12.1
1975	1.12	0.55	1.80	0.60	0.60	88	42.7	38.8	12.1
1976	1.09	0.52	1.82	0.67	0.62	94.1	45.1	41.9	12.9
1977	1.09	0.52	1.72	0.75	0.66	91.5	46.7	42.7	12.6
1978	1.33	0.57	1.95	0.82	0.72	87.1	46.5	44.8	13.4
1979	1.69	0.59	1.98	0.89	0.80	77.9	53.2	47.6	13
1980	1.78	0.63	1.91	0.98	0.87	76.4	56.8	47.3	12.4
1981	1.80	0.65	2.09	1.06	0.94	77.2	54.2	48.7	12.6
1982	1.82	0.64	2.36	1.10	0.97	76.9	48.6	48.9	12.4
1983	1.80	0.65	2.34	1.11	0.99	78.5	51.3	49.1	13.3
1984	1.82	0.73	2.31	1.15	1.03	78.3	51	50.8	14.1
1985	1.78	0.70	2.31	1.20	1.06	79	51.5	52.4	15
1986	1.79	0.77	2.50	1.31	1.09	78.7	48.6	53.5	15.4
1987	1.93	0.76	2.71	1.45	1.14	73.7	48.8	56.6	16.1
1988	2.03	0.84	2.62	1.53	1.18	72.5	52.1	56.7	15.1
1989	2.16	0.92	2.64	1.60	1.25	68.9	51.5	58.3	15.6
1990	2.34	0.91	3.03	1.64	1.32	67.6	49.4	60.7	15
1991	2.40	0.88	3.13	1.66	1.36	66.6	49.9	63.1	14.8
1992	2.40	0.89	2.98	1.69	1.38	66.3	52.6	66.8	14.7
1993	2.49	0.93	3.07	1.75	1.41	64.9	52	69.5	14.9
1994	2.47	0.94	3.12	1.83	1.44	66.9	52.7	70.4	15.1
1995	2.45	0.95	3.15	1.92	1.48	67.3	52.2	69.8	14.9
1996	2.44	1.02	3.46	1.93	1.53	68	48.9	70.8	14.7
1997	2.48	1.06	3.64	1.98	1.57	66.7	48.5	71.8	14.5
1998	2.55	1.04	3.27	2.12	1.61	67.9	52.3	72.4	14.8
1999	2.58	1.06	3.32	2.07	1.64	68.9	53.7	77.3	15.2

*Nominal prices

Appendix 4.2 Meat Expenditure Shares 1970-1994

Year	Meat Expenditure Share				Divisia volume index
	Beef	Pork	Chicken	Fish	
1970	0.4641	0.4091	0.0983	0.0285	.
1971	0.4747	0.3969	0.0979	0.0305	0.0291
1972	0.4881	0.3838	0.0947	0.0334	-0.0263
1973	0.4692	0.3868	0.1110	0.0330	-0.0748
1974	0.4800	0.3890	0.0971	0.0339	0.0573
1975	0.4840	0.3764	0.1039	0.0357	-0.0665
1976	0.4760	0.3828	0.1007	0.0404	0.0632
1977	0.4700	0.3808	0.1048	0.0444	0.0010
1978	0.4759	0.3730	0.1061	0.0450	-0.0171
1979	0.4762	0.3807	0.1009	0.0421	0.0025
1980	0.4750	0.3783	0.1045	0.0422	0.0130
1981	0.4676	0.3812	0.1063	0.0449	-0.0091
1982	0.4683	0.3824	0.1039	0.0454	-0.0437
1983	0.4589	0.3898	0.1033	0.0480	0.0341
1984	0.4545	0.3753	0.1187	0.0515	0.0033
1985	0.4475	0.3788	0.1164	0.0573	0.0147
1986	0.4349	0.3750	0.1279	0.0623	-0.0194
1987	0.4171	0.3878	0.1264	0.0686	-0.0163
1988	0.4152	0.3853	0.1342	0.0653	0.0144
1989	0.4097	0.3739	0.1475	0.0688	-0.0193
1990	0.4079	0.3866	0.1420	0.0635	-0.0204
1991	0.4034	0.3939	0.1408	0.0619	0.0025
1992	0.3976	0.3922	0.1479	0.0623	0.0267
1993	0.3920	0.3882	0.1564	0.0633	-0.0060
1994	0.3896	0.3888	0.1564	0.0652	0.0199
1995	0.3882	0.3872	0.1572	0.0674	-0.0036
1996	0.3805	0.3879	0.1664	0.0652	-0.0199
1997	0.3702	0.3947	0.1709	0.0642	-0.0090
1998	0.3841	0.3793	0.1670	0.0696	0.0387
1999	0.3787	0.3798	0.1745	0.0670	0.0286

Note: Calculated values are based on the data in Appendix 4.1

Appendix 4.3 Regression analysis of per capita pork demand

*Demand system estimation (Rotterdam Model)

Simultaneous equations estimation using reg3 command
Homogeneity restriction (imposed by eqn 1,2,3)
Symmetry restriction (imposed by eqn 4,5,6)
Adding up restriction (when we recover fish eqn, this restriction in maintained)
constraint define 1
[SBdlnPQ]dlnbeefp+[SBdlnPQ]dlnchkp+[SBdlnPQ]dlnpkp+[SBdlnPQ]dlnfshp=0
constraint define 2
[SBdlnBQ]dlnbeefp+[SBdlnBQ]dlnchkp+[SBdlnBQ]dlnpkp+[SBdlnBQ]dlnfshp=0
constraint define 3
[SBdlnCQ]dlnbeefp+[SBdlnCQ]dlnchkp+[SBdlnCQ]dlnpkp+[SBdlnCQ]dlnfshp=0
constraint define 4 [SBdlnPQ]dlnbeefp =[SBdlnBQ]dlnpkp
constraint define 5 [SBdlnPQ]dlnchkp = [SBdlnCQ]dlnpkp
constraint define 6 [SBdlnBQ]dlnchkp = [SBdlnCQ]dlnbeefp
Three stage regression method
reg3 (SBdlnPQ dlnbeefp dlnchkp dlnpkp dlnfshp DQ)(SBdlnBQ dlnbeefpdlnchkp dlnpkp dlnfshp DQ)(SBdlnCQ dlnbeefp dlnchkp dlnpkp dlnfshp DQ),constraint (1-6)

Equation	Obs	Parms	RMSE	"R-sq"	Chi2	P
SBdlnPQ	29	5	.0067	0.938	457.566	0.000
SBdlnBQ	29	5	.0073	0.809	139.703	0.000
SBdlnCQ	29	5	.0027	0.354	14.5327	0.005

	Coef.	Std. Err.	z	P>|z|
SBdlnPQ				
dlnbeefp	.1730	.0173	9.981	0.000
dlnchkp	.0116	.0077	1.512	0.131
dlnpkp	-.1906	.0194	-9.804	0.000
dlnfshp	.0059	.0108	0.547	0.584
DQ	.4536	.0514	8.809	0.000
cons |	-.0007	.0012	-0.550	0.582
SBdlnBQ				
dlnbeefp	-.1938	.0209	-9.247	0.000
dlnchkp	.0170	.0083	2.036	0.042
dlnpkp	.1730	.0173	9.981	0.000
dlnfshp	.0036	.0107	0.342	0.733
DQ	.5004	.0510	9.812	0.000
cons	-.0028	.0013	-2.137	0.033

SBdlnCQ				
dlnbeefp	.0171	.0083	2.036	0.042
dlnchkp	-.0179	.0074	-2.403	0.016
dlnpkp	.0117	.0077	1.512	0.131
dlnfshp	-.0108	.0073	-1.474	0.140
DQ	.0453	.0217	2.084	0.037
cons	.0031	.0005	5.987	0.000

Endogenous variables: SBdlnPQ SBdlnBQ SBdlnCQ
Exogenous variables: dlnbeefp dlnchkp dlnpkp dlnfshp DQ

Three stage regression method (AIDS model)

reg3 (dporksh dlnbeefp dlnchkp dlnpkp dlnfshp DQ)(dbeefsh dlnbeefp dlnchkp dlnpkp dlnfshp DQ)(dchicsh dlnbeefp dlnchkp dlnpkp dlnfshp DQ),constraint (1-6)

Constraints:

(1) [dporksh]dlnbeefp + [dporksh]dlnchkp + [dporksh]dlnpkp + [dporksh]dlnfshp = 0.0
(2) [dbeefsh]dlnbeefp + [dbeefsh]dlnchkp + [dbeefsh]dlnpkp + [dbeefsh]dlnfsh p = 0.0
(3) [dchicsh]dlnbeefp + [dchicsh]dlnchkp + [dchicsh]dlnpkp + [dchicsh]dlnfsh p = 0.0
(4) [dporksh]dlnbeefp - [dbeefsh]dlnpkp = 0.0
(5) [dporksh]dlnchkp - [dchicsh]dlnpkp = 0.0
(6) [dbeefsh]dlnchkp - [dchicsh]dlnbeefp = 0.0

Equation	Obs	Parms	RMSE	"R-sq"	Chi2	P
dporksh	29	5	.0067	0.25	20.08	0.00
dbeefsh	29	5	.0073	0.16	19.70	0.00
dchicsh	29	5	.0028	0.82	142.34	0.00

	Coef.	Std. Err.	z	P>|z]
dporksh				
dlnbeefp	-.0010	.0173	-0.059	0.953
dlnchkp	-.0331	.0080	-4.105	0.000
dlnpkp	.0499	.0194	2.568	0.010
dlnfshp	-.0157	.0106	-1.481	0.139
DQ	.07582	.0510	1.484	0.138
cons	-.0007	.0012	-0.554	0.579

dbeefsh				
dlnbeefp	.0549	.0212	2.580	0.010
dlnchkp	-.0347	.0087	-3.962	0.000
dlnpkp	-.0010	.0173	-0.059	0.953
dlnfshp	-.0191	.0107	-1.789	0.074
DQ	.0447	.0510	0.876	0.381
cons	-.0026	.0013	-1.989	0.047
dchicsh				
dlnbeefp	-.0347	.0087	-3.962	0.000
dlnchkp	.08139	.00786	10.350	0.000
dlnpkp	-.0331	.0080	-4.105	0.000
dlnfshp	-.0135	.0074	-1.809	0.070
DQ	-.0656	.0225	-2.910	0.004
cons |	.0030	.0005	5.595	0.000

Endogenous variables: dporksh dbeefsh dchicsh
Exogenous variables: dlnbeefp dlnchkp dlnpkp dlnfshp DQ

Demand system estimation (Log-linear model)
Three-stage least squares regression
Constraints:
(1) [lnporkq]dlnbeefp + [lnporkq]dlnchkp + [lnporkq]dlnpkp + [lnporkq]dlnfshp = 0.0
(2) [lnbeefq]dlnbeefp + [lnbeefq]dlnchkp + [lnbeefq]dlnpkp + [lnbeefq]dlnfshp = 0.0
(3) [lnchicq]dlnbeefp + [lnchicq]dlnchkp + [lnchicq]dlnpkp + [lnchicq]dlnfshp = 0.0
(4) [lnporkq]dlnbeefp - [lnbeefq]dlnpkp = 0.0
(5) [lnporkq]dlnchkp - [lnchicq]dlnpkp = 0.0
(6) [lnbeefq]dlnchkp - [lnchicq]dlnbeefp = 0.0

Equation	Obs	Parms	RMSE	"R-sq"	Chi2	P
lnporkq	29	5	.0573	0.285	10.382	0.03
lnbeefq	29	5	.1024	0.089	4.210	0.37
lnchicq	29	5	.2040	0.099	3.546	0.47

	Coef.	Std. Err.	z	P>|z|
lnporkq				
dlnbeefp	.1196	.1506	0.795	0.427
dlnchkp	.1694	.1794	0.944	0.345
dlnpkp	-.3836	.2104	-1.822	0.068
dlnfshp	.0943	.2429	0.388	0.698
DQ	.3956	.6126	0.646	0.518
cons	3.9256	.0130	300.42	0.000

	Coef.	Std. Err.	z	P>|z|
lnbeefq				
dlnbeefp	-.0537	.2297	-0.234	0.815
dlnchkp	-.3754	.2858	-1.313	0.189
dlnpkp	.11969	.1506	0.795	0.427
dlnfshp	.30948	.2537	1.220	0.223
DQ	-.3751	.7672	-0.489	0.625
cons	4.3178	.0195	220.893	0.000
lnchicq				
dlnbeefp	-.3754	.285	-1.313	0.189
dlnchkp	.7973	.5612	1.421	0.155
dlnpkp	.1694	.1794	0.944	0.345
dlnfshp	-.5912	.3997	-1.479	0.139
DQ	2.434	1.4335	1.698	0.090
cons	3.996	.0375	106.581	0.000

Endogenous variables: lnporkq lnbeefq lnchicq
Exogenous variables: dlnbeefp dlnchkp dlnpkp dlnfshp DQ

Appendix 4.4 Approximated pork demand (pounds) by states, 1997

State	Region*	Demand/cap (Estimated)	Adj. Factor	Demand/cap (Adjusted)	Population1 '97	Demand '97
Alabama	S	47.6	1.12	53.312	4,320,281	230,322,821
Alaska	W	47.6	0.83	39.508	608,846	24,054,288
Arizona	W	47.6	0.83	39.508	4,552,207	179,848,594
Arkansas	S	47.6	1.12	53.312	2,524,007	134,559,861
California	W	47.6	0.83	39.508	32,217,708	1,272,857,208
Colorado	W	47.6	0.83	39.508	3,891,293	153,737,204
Connecticut	NE	47.6	0.8	38.08	3,268,514	124,465,013
DC	S	47.6	1.12	53.312	735,024	39,185,599
Delaware	S	47.6	1.12	53.312	528,752	28,188,827
Florida	S	47.6	1.12	53.312	14,683,350	782,798,755
Georgia	S	47.6	1.12	53.312	7,486,094	399,098,643
Hawaii	W	47.6	0.83	39.508	1,189,322	46,987,734
Idaho	W	47.6	0.83	39.508	1,210,638	47,829,886
Illinois	ECB	47.6	1.15	54.74	12,011,509	657,510,003
Indiana	ECB	47.6	1.15	54.74	5,872,370	321,453,534
Iowa	WCB	47.6	1.15	54.74	2,854,396	156,249,637
Kansas	S	47.6	1.12	53.312	2,616,339	139,482,265
Kentucky	S	47.6	1.12	53.312	3,907,816	208,333,487
Louisiana	S	47.6	1.12	53.312	4,351,390	231,981,304
Maine	NE	47.6	0.8	38.08	1,245,215	47,417,787
Maryland	S	47.6	1.12	53.312	5,092,914	271,513,431
Massachusetts	NE	47.6	0.8	38.08	6,115,476	232,877,326
Michigan	ECB	47.6	1.15	54.74	9,785,450	535,655,533
Minnesota	ECB	47.6	1.15	54.74	4,687,726	256,606,121
Mississippi	S	47.6	1.12	53.312	2,731,826	145,639,108
Missouri	S	47.6	1.12	53.312	5,407,113	288,264,008
Montana	W	47.6	0.83	39.508	878,706	34,715,917
N. Hampshire	NE	47.6	0.8	38.08	1,656,042	63,062,079
Nebraska	WCB	47.6	1.15	54.74	1,675,581	91,721,304
Nevada	W	47.6	0.83	39.508	1,173,239	46,352,326
New Jersey	NE	47.6	0.8	38.08	8,054,178	306,703,098
New Mexico	W	47.6	0.83	39.508	1,722,939	68,069,874
New York	NE	47.6	0.8	38.08	18,143,184	690,892,447
North Carolina	S	47.6	1.12	53.312	7,428,672	396,037,362
North Dakota	WCB	47.6	1.15	54.74	640,945	35,085,329
Ohio	ECB	47.6	1.15	54.74	11,212,498	613,772,141
Oklahoma	S	47.6	1.12	53.312	3,314,259	176,689,776
Oregon	W	47.6	0.83	39.508	3,243,254	128,134,479
Pennsylvania	NE	47.6	0.8	38.08	12,015,888	457,565,015

Rhode Island	NE	47.6	0.8	38.08	986,966	37.583,665
South Carolina	S	47.6	1.12	53.312	3,790,066	202,055,999
South Dakota	WCB	47.6	1.15	54.74	730,855	40,007,003
Tennessee	S	47.6	1.12	53.312	5,378,433	286,735,020
Texas	S	47.6	1.12	53.312	19,355,427	1,031,876,524
Utah	W	47.6	0.83	39.508	2,065,397	81,599,705
Vermont	NE	47.6	0.8	38.08	588,665	22,416,363
Virginia	S	47.6	1.12	53.312	6,732,878	358,943,192
Washington	W	47.6	0.83	39.508	5,604,105	221,406,980
West Virginia	S	47.6	1.12	53.312	1,815,588	96,792,627
Wisconsin	ECB	47.6	1.15	54.74	5,200,235	284,660,864
Wyoming	W	47.6	0.83	39.508	480,031	18,965,065
Total (U.S.)		47.6	1	47.6	267,783,607	12,746,499,693

*S=South, W=West, NE=North East, ECB=Eastern Corn Belt, WCB=Western Corn Belt

Appendix 4.5 U.S. agricultural exports: Live animals and meats, 1997

State	Export share %	Pork export (MT)	State	Export share %	Pork export (MT)
Alabama	0.47	1,519	Nevada	0.01	45
Arizona	0.90	2,911	New Jersey	0.04	134
Arkansas	0.08	266	New Mexico	0.29	933
California	3.18	10,312	New York	0.32	1,029
Colorado	5.09	16,532	N. Carolina	2.43	7,891
Florida	0.78	2,544	N. Dakota	0.40	1,289
Georgia	0.86	2,797	Ohio	0.66	2,128
Idaho	1.44	4,680	Oklahoma	0.37	1,192
Illinois	4.40	14,284	Oregon	0.08	248
Indiana	1.25	4,067	Pennsylvania	2.86	9,275
Iowa	9.96	32,323	S. Carolina	0.14	449
Kansas	12.86	41,741	S. Dakota	2.31	7,501
Kentucky	3.98	12,912	Tennessee	0.47	1,526
Louisiana	0.02	61	Texas	13.10	42,515
Michigan	1.95	6,325	Utah	1.02	3,297
Minnesota	4.18	13,559	Virginia	1.62	5,272
Mississippi	0.48	1,571	Washington	1.91	6,188
Missouri	1.33	4,304	Wisconsin	3.09	10,026
Montana	0.31	1,001	Wyoming	0.25	806
Nebraska	15.12	49,052	Total	100.00	324,507

Source: Compiled from http://www.ers.usda.gov/data/FATUS/DATA/16010.xls

Appendix 5

Appendix 5.1 Hog and pigs production and marketing

	Production	Marketing	Value of prod.	Average Price	Value	Total pigs
	(1,000 lbs)	(1,000 lbs)	($1,000)	($/CWT)	($/head)	Dec. 1, 1997
AL	83,458	87,705	40,606	49	80	190,000
AK	871	564	498	57	150	2,100
AZ	87,296	91,500	41,156	47	88	145,000
AR	254,014	260,945	143,175	56	79	860,000
CA	82,156	84,365	44,508	54	110	210,000
CO	347,895	345,910	198,448	57	88	790,000
CT	1,851	1,786	870	47	110	4,500
DE	13,719	13,525	6,331	46	79	30,000
FL	24,839	26,641	11,410	46	85	55,000
GA	230,861	254,877	113,699	49	81	520,000
HI	6,340	6,105	5,091	80	130	29,000
ID	17,292	17,557	8,622	50	82	30,000
IL	1,819,944	1,860,100	928,630	51	83	4,700,000
IN	1,533,336	1,545,464	775,270	51	84	3,950,000
IA	5,419,830	5,439,021	2,801,426	52	85	14,600,000
KS	735,468	757,466	393,043	53	73	1,530,000
KY	255,202	263,026	135,731	53	74	570,000
LA	13,967	14,835	6,536	47	88	32,000
ME	3,572	2,542	1,679	47	88	6,000
MD	31,450	30,850	14,880	47	81	85,000
MA	4,250	3,403	1,998	47	88	18,500
MI	396,899	401,325	207,562	52	89	1,030,000
MN	2,080,925	2,083,120	1,112,009	53	85	5,700,000
MS	102,882	105,660	51,599	50	86	220,000
MO	1,411,364	1,474,928	712,923	51	69	3,550,000
MT	62,465	61,145	33,310	53	85	180,000
NE	1,424,897	1,446,955	784,814	55	90	3,500,000
NV	4,454	4,608	2,375	53	110	7,500
NH	991	700	466	47	97	4,402
NJ	2,715	3,016	898	33	97	23,000
NM	2,213	2,288	955	43	88	6,000
NY	30,086	30,415	13,505	45	81	79,000
NC	3,827,575	3,793,557	2,071,550	54	72	9,600,000
ND	73,515	75,311	33,971	46	85	200,000
OH	769,772	762,900	403,338	52	79	1,700,000
OK	746,751	758,761	374,487	50	88	1,650,000
OR	16,440	16,320	9,354	57	88	35,000
PA	363,231	357,181	183,513	51	85	1,100,000
RI	1,204	1,162	566	47	85	2,800
SC	124,390	124,700	62,387	50	75	305,000
SD	544,203	538,633	293,001	54	84	1,400,000

TN	143,047	155,287	72,219	50	75	340,000
TX	224,131	213,480	106,047	47	83	580,000
UT	84,510	65,040	49,676	59	88	295,000
VT	1,469	1,272	690	47	110	2,900
VA	141,783	136,730	73,020	52	75	400,000
WA	14,454	12,894	7,365	51	97	39,000
WV	7,402	6,855	3,533	48	85	16,000
WI	354,113	365,210	188,631	53	84	740,000
WY	53,728	58,128	24,474	46	97	95,000
U.S.	23,979,220	24,165,768	12,551,845	52	82	60,799,171

Source: http://usda.mannlib.cornell.edu/usda/reports/general/sb/b9590599.txt

Appendix 5.2 Production of barley, sorghum and corn grain in selected states, 1997

State	Barley	Corn	State	Sorghum	Corn
	(,000 Bu)	(,000 Bu)		(,000 Bu)	(, 000 Bu)
N. Dakota	101,250	58,410	Kansas	273,000	371,800
Montana	63,600	1,890	Texas	185,850	241,500
Idaho	60,040	6,665	Nebraska	61,500	1,135,200
Washington	37,240	18,050	Missouri	40,920	299,000
Minnesota	27,540	851,400	Oklahoma	24,500	23,460
Colorado	10,080	143,080	Illinois	14,105	1,425,450
California	9,900	45,050	S. Dakota	11,360	326,400
Wyoming	9,200	7,020	Arkansas	11,100	23,125
Oregon	8,280	5,265	N. Mexico	10,340	14,875
Utah	8,170	2,940	Louisiana	7,546	48,789
USA	374,478	9,206,832		653,106	9,206,832

Source: Compiled from USDA/NASS database. http://www.nass.usda.gov: 81/ipedb/

Appendix 5. 3 Comparison of wage rates and processing costs by selected states

State	Hourly Wage ($)	Adj. Factor	Average Variable cost	Adjusted cost Processing per head	Fixed cost Per head	Processing Per head	Region
Alabama	6.01	0.67	21	17.52	4.5	22.02	South
Arizona	9.47	1.05	21	21.57	4.5	26.07	West
Arkansas	7.53	0.84	21	19.30	4.5	23.80	South
California	9.11	1.01	21	21.15	4.5	25.65	West
Colorado	8.54	0.95	21	20.48	4.5	24.98	West
Connecticut	12.54	1.40	21	25.15	4.5	29.65	Northeast
Florida	6.59	0.73	21	18.20	4.5	22.70	South
Georgia	8.79	0.98	21	20.77	4.5	25.27	South
Idaho	8.77	0.98	21	20.75	4.5	25.25	West
Illinois	8.63	0.96	21	20.58	4.5	25.08	E.Corn Belt
Indiana	9.34	1.04	21	21.41	4.5	25.91	E.Corn Belt
Iowa	9.02	1.00	21	21.04	4.5	25.54	W.Corn Belt
Kansas	9.09	1.01	21	21.12	4.5	25.62	W.Corn Belt
Kentucky	8.84	0.98	21	20.83	4.5	25.33	South
Louisiana	6.79	0.76	21	18.43	4.5	22.93	South
Maine	8.83	0.98	21	20.82	4.5	25.32	Northeast
Maryland	8.26	0.92	21	20.15	4.5	24.65	South
Massachusetts	10.33	1.15	21	22.57	4.5	27.07	Northeast
Michigan	9.2	1.02	21	21.25	4.5	25.75	E. Corn Belt
Minnesota	9.56	1.06	21	21.67	4.5	26.17	E. Corn Belt
Mississippi	7.48	0.83	21	19.24	4.5	23.74	South
Missouri	8.03	0.89	21	19.88	4.5	24.38	South
Montana	9.51	1.06	21	21.61	4.5	26.11	West
New Jersey	11.55	1.29	21	24.00	4.5	28.50	Northeast
New Mexico	8.73	0.97	21	20.70	4.5	25.20	West
New York	10.87	1.21	21	23.20	4.5	27.70	Northeast
North Carolina	8.16	0.91	21	20.04	4.5	24.54	South
North Dakota	8.52	0.95	21	20.46	4.5	24.96	W. Corn Belt
Ohio	11.24	1.25	21	23.63	4.5	28.13	E. Corn Belt
Oregon	9.84	1.10	21	22.00	4.5	26.50	West
Pennsylvania	9.92	1.10	21	22.09	4.5	26.59	Northeast
South Carolina	8.48	0.94	21	20.41	4.5	24.91	South
Tennessee	8.67	0.96	21	20.63	4.5	25.13	South
Texas	8.64	0.96	21	20.60	4.5	25.10	South
Virginia	9.29	1.03	21	21.36	4.5	25.86	South
Washington	9.68	1.08	21	21.81	4.5	26.31	West
West Virginia	7.14	0.79	21	18.84	4.5	23.34	South
Wisconsin	10.45	1.16	21	22.71	4.5	27.21	E.Corn Belt
U.S. Average	8.99	1.00	21	21.00	4.5	25.50	

Note: Compiled from Bureau of Labor Statistics (1998)

Appendix 5.4 Average prices of inputs and market hogs in selected States, (1998)

State	Mkt. hogs $/cwt	Corn price $/bushel	Soybean meal $/bushel	Wage $/hr	Feeder pigs $/cwt	Region
Illinois	44.88	2.60	14.00	6.74	86.08	E. Corn Belt
Indiana	44.93	2.59	14.00	6.81	89.18	E. Corn Belt
Michigan	45.75	2.48	13.63	6.58	83.48	E. Corn Belt
Ohio	46.40	2.57	14.00	6.39	78.98	E. Corn Belt
Minnesota	47.63	2.36	13.63	7.03	91.17	E. Corn Belt
Wisconsin	44.13	2.48	13.63	5.92	83.13	E. Corn Belt
Maine	42.00	NA	15.53	NA	88.08*	North East
N. Jersey	39.93	2.82	15.53	6.86	88.08*	North East
Pennsylvania	44.03	2.96	15.53	5.93	88.08*	North East
N. York	40.55	2.88	15.53	6.37	88.08**	North East
Arkansas	44.00	2.57	15.60	5.76	73.25*	South
Florida	40.53	2.86	17.47	6.59	73.2*5	South
Georgia	44.15	2.92	17.47	6.11	68.08	South
Kentucky	45.65	2.68	14.03	5.68	72.43	South
Louisiana	40.50	2.75	15.60	5.64	73.25*	South
Maryland	42.15	2.88	15.53	6.27	73.25*	South
Missouri	44.75	2.61	14.00	5.92	74.48	South
Mississippi	45.88	2.66	15.60	5.39	73.25*	South
N. Carolina	47.08	2.87	16.20	5.85	79.63	South
Oklahoma	43.88	2.83	16.43	5.98	73.25*	South
S. Carolina	43.45	2.87	17.47	5.48	73.25*	South
Tennessee	43.78	2.66	16.20	5.88	71.67	South
Texas	40.98	2.78	16.43	5.56	73.25*	South
Virginia	46.50	2.76	16.20	6.02	73.25*	South
W. Virginia	40.03	2.90	16.20	5.62	73.23*	South
Iowa	47.63	2.47	14.00	6.54	89.58	W. Corn Belt
Kansas	44.78	2.60	16.20	6.84	83.23	W. Corn Belt
North Dakota	40.85	2.32	14.03	6.76	73.25*	W. Corn Belt
Nebraska	48.10	2.52	14.03	6.39	90.80	W. Corn Belt
S. Dakota	47.20	2.30	14.03	5.66	88.02	W. Corn Belt
Arizona	45.00	2.99*	20.17	6.00	83.38**	West
California	48.28	3.23	20.17	6.57	83.38**	West
Colorado	48.48	2.66	20.17	6.08	83.38**	West
Idaho	43.88	3.22	21.30	6.32	83.38**	West
Montana	45.43	2.68	20.17	5.61	83.38**	West
N. Mexico	43.93	2.76	20.17	5.90	83.38**	West
Oregon	50.15	3.15	22.20	6.50	83.38**	West
Utah	44.90	3.25	20.17	5.99	83.38**	West
Washington	45.48	2.99	22.20	7.08	83.38**	West
Wyoming	44.58	2.79	20.17	5.32	83.38**	West

* Calculated on the basis of regional average ** Based on national average

Appendix 5.5 Suggested high nutrient density diets for growing swine using corn as the major grain source (100 pigs).

	Week=>	1	2	3	4	5	6	7	8	9	10
Ingredients	(lb)										
Corn yellow	1454	175.571	205.341	232.822	258.776	283.801	306.045	326.755	345.164	362.805	378.146
Soybean meal 44%	492	59.409	69.483	78.782	87.564	81.541	87.932	93.883	99.172	104.241	108.648
Calcium Carbonate	15	1.811	2.118	2.402	2.670	2.999	3.234	3.453	3.648	3.834	3.996
Dicalcium Phosphate	29	3.502	4.096	4.644	5.161	4.686	5.054	5.396	5.700	5.991	6.244
Salt	7	0.845	0.989	1.121	1.246	1.312	1.415	1.511	1.596	1.677	1.748
Mineral (mix)	3	0.362	0.424	0.480	0.534	0.562	0.606	0.647	0.684	0.719	0.749
Totals	2000	241.500	282.450	320.250	355.950	374.903	404.287	431.645	455.963	479.267	499.532
Daily gain,lb		115	129	141	151	159	166	172	176	179	1810
Feed:gain		2.100	2.190	2.271	2.357	2.358	2.435	2.510	2.591	2.677	2.760
	Week=>	11	12	13	14	15	16	17	18	Average	Total
Corn yellow	1454									Feeders	
Wheat middling	492	422.242	435.463	447.031	457.773	466.036	473.473	480.083	484.215	351.275	44260.652
Soybean meal 48%	15	83.102	85.704	87.981	90.095	91.721	93.185	94.486	95.299	100.054	12606.744
Dicalcium Phosphate	29	4.142	4.272	4.385	4.491	4.572	4.645	4.710	4.750	3.621	456.195
Salt	7	5.695	5.874	6.030	6.175	6.286	6.387	6.476	6.531	6.052	762.605
Mineral (mix)	3	1.812	1.869	1.919	1.965	2.000	2.032	2.060	2.078	1.622	204.368
Totals	2000	0.777	0.801	0.822	0.842	0.857	0.871	0.883	0.891	0.795	100.188
Daily gain,lb		517.771	533.983	548.168	561.341	571.473	580.592	588.698	593.765	463.419	58390.752
Feed:gain		182	183	183	182	181	179	177	174	167.222	
		2.845	2.918	2.995	3.084	3.157	3.244	3.326	3.412	2.735	

Appendix 5.6A Feeder pig-to-finish production costs and return per 100 hogs (large scale operations)

	E. Corn Belt			W. Corn Belt			South			Northeast			West		
	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar
Market Hogs (cwt)	240.00	45.22	10851.60	240.00	45.85	11003.14	240.00	43.27	10384.88	240.00	41.83	10040.00	240.00	46.70	11208.50
Variable Costs															
Corn (bu)	885.21	2.54	2251.98	885.21	2.48	2193.85	885.21	2.83	2503.03	885.21	2.84	2513.71	885.21	2.99	2648.45
Soybean meal 44% (cwt)	126.07	13.89	1750.94	126.07	13.89	1750.94	126.07	16.43	2070.66	126.07	15.2	1916.23	126.07	21.18	2670.53
Calcium Carbonate (lb)	456.20	0.05	22.81	456.20	0.05	22.81	456.20	0.05	22.81	456.20	0.05	22.81	456.20	0.05	22.81
Dicalcium Phosphate (lb)	762.61	0.19	144.90	762.61	0.19	144.90	762.61	0.19	144.90	762.61	0.19	144.90	762.61	0.19	144.90
Salt (lb)	204.37	0.30	61.31	204.37	0.30	61.31	204.37	0.30	61.31	204.37	0.30	61.31	204.37	0.30	61.31
Vit & trace mineral mix (lb)	100.19	0.50	50.09	100.19	0.50	50.09	100.19	0.50	50.09	100.19	0.50	50.09	100.19	0.50	50.09
Total Feed Costs (100 pigs)			4282.03			4223.90			4852.80			4709.04			5598.08
Purchased feeders (Hd)	100.00	27.65	2764.82	100.00	28.92	2891.59	100.00	24.06	2406.37	100.00	28.93	2893.26	100.00	27.39	2739.01
Veterinary and medicine		0.57	56.94		0.71	71.18		0.62	61.92		0.43	42.71		0.78	77.77
Bedding and litter		0.02	2.14		0.03	2.85		0.01	1.42		0.01	1.42		0.02	1.55
Marketing		0.72	71.89		0.74	74.02		1.57	156.59		0.70	69.75		1.94	193.74
Hired labor	61.40	6.49	398.26	50.09	6.45	322.92	45.73	5.85	267.44	78.38	6.10	477.98	41.57	6.40	265.95
Custom services		0.46	45.83		0.62	62.40		0.70	70.20		0.29	29.25		4.01	400.69
Fuel, lube, and electricity		1.14	114.08		1.42	142.35		1.02	102.38		0.86	85.80		1.41	141.44
Repairs		0.91	90.68		0.84	83.85		0.79	78.98		0.98	97.50		0.97	97.12
Compliance costs (regulatory)		1.05	105.00		1.05	105.00		1.08	107.67		1.13	113.00		1.05	105.00
Interest on operating capital		1.76	176.48		1.87	187.20		1.60	159.90		1.66	165.75		1.82	181.60
Total, variable costs (100 pigs)			8108.12			8167.98			8266.39			8686.19			9801.96
Opportunity cost of unpaid labor	20.47	12.49	255.64	16.70	12.49	208.55	15.24	8.24	125.60	26.13	11.53	301.25	13.86	15.74	218.08
Capital recovery		14.54	1453.73		13.40	1339.65		11.09	1108.58		15.68	1567.80		13.75	1374.70
Opportunity cost of land		0.06	5.85		0.08	7.80		0.09	8.78		0.04	3.90		0.08	7.57
Taxes and insurance		0.87	86.78		0.78	78.00		0.72	72.15		0.96	95.55		0.44	44.04
General farm overhead		1.64	163.80		1.56	156.00		0.69	69.23		1.72	171.60		0.96	95.88
Total, allocated overhead			1965.79			1790.00			1384.32		29.92	2991.85			1740.27
Total Cost			10,073.91			9,957.98			9,650.71			11678.04			11542.23

Appendix 5.6B Feeder pig-to-finish production costs and return per 100 hogs (medium scale operations)

	Eastern Corn Belt			Western Corn Belt			South			Northeast			West		
	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar
Market Hogs (cwt)	240.00	45.22	10851.60	240.00	45.85	11003.14	240.00	43.27	10384.88	240.00	41.83	10040.00	240.00	46.70	11208.50
Variable Costs															
Corn (bu)	885.21	2.54	2251.98	885.21	2.48	2193.85	885.21	2.83	2503.03	885.21	2.84	2513.71	885.21	2.99	2648.45
Soybean meal 44% (cwt)	126.07	13.89	1750.94	126.07	13.89	1750.94	126.07	16.43	2070.66	126.07	15.2	1916.23	126.07	21.18	2670.53
Calcium Carbonate (lb)	456.20	0.05	22.81	456.20	0.05	22.81	456.20	0.05	22.81	456.20	0.05	22.81	456.20	0.05	22.81
Dicalcium Phosphate (lb)	762.61	0.19	144.90	762.61	0.19	144.90	762.61	0.19	144.90	762.61	0.19	144.90	762.61	0.19	144.90
Salt (lb)	204.37	0.30	61.31	204.37	0.30	61.31	204.37	0.30	61.31	204.37	0.30	61.31	204.37	0.30	61.31
Vit & trace mineral mix (lb)	100.19	0.50	50.09	100.19	0.50	50.09	100.19	0.50	50.09	100.19	0.50	50.09	100.19	0.50	50.09
Total Feed Costs (100 pigs)			4282.03			4223.90			4852.80			4709.04			5598.08
Purchased feeders (Hd)	100.00	37.87	3787.43	100.00	39.61	3961.08	100.00	32.96	3296.40	100.00	39.63	3963.38	100.00	37.52	3752.07
Veterinary and medicine		0.78	78.00		0.98	97.50		0.85	84.83		0.59	58.50		1.07	106.53
Bedding and litter		0.03	2.93		0.04	3.90		0.02	1.95		0.02	1.95		0.02	2.13
Marketing		0.98	98.48		1.01	101.40		2.15	214.50		0.96	95.55		2.65	265.40
Hired labor	35.62	6.49	231.06	28.12	6.45	181.30	26.44	5.85	154.64	46.43	6.10	283.14	24.70	6.40	158.04
Custom services		0.46	45.83		0.62	62.40		0.70	70.20		0.29	29.25		4.01	400.69
Fuel, lube, and electricity		1.14	114.08		1.42	142.35		1.02	102.38		0.86	85.80		1.41	141.44
Repairs		0.91	90.68		0.84	83.85		0.79	78.98		0.98	97.50		0.97	97.12
Compliance costs (regulatory)		0.81	81.00		0.81	81.00		1.19	119.00		1.95	195.00		0.81	81.00
Interest on operating capital		1.76	176.48		1.87	187.20		1.60	159.90		1.66	165.75		1.82	181.60
Total, variable costs (100 pigs)			8987.96			9126.88			9136.56			9685.86			10784.10
Opportunity cost of unpaid labor	53.44	12.49	667.42	42.19	12.49	526.90	39.66	8.24	326.80	69.65	11.53	803.04	37.05	15.74	583.17
Capital recovery of machinery and equipment		14.54	1453.73		13.40	1339.65		11.09	1108.58		15.68	1567.80		13.75	1374.70
Opportunity cost of land (rental rate)		0.06	5.85		0.08	7.80		0.09	8.78		0.04	3.90		0.08	7.57
Taxes and insurance		0.87	86.78		0.78	78.00		0.72	72.15		0.96	95.55		0.44	44.04
General farm overhead		1.64	163.80		1.56	156.00		0.69	69.23		1.72	171.60		0.96	95.88
Total, allocated overhead (100 pigs)			2377.57			2108.35			1585.52		29.92	2991.85			2105.36
Total Cost			11,365.53			11,235.23			10,722.08			12677.71			12889.46

Appendix 5.6C Feeder pig-to-finish production costs and return per 100 hogs (small scale operations)

	Eastern Corn Belt			Western Corn Belt			South			Northeast			West		
	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar	Quantity	$/unit	Dollar
Market Hogs (cwt)	240.00	45.22	10851.60	240.00	45.85	11003.14	240.00	43.27	10384.88	240.00	41.83	10040.00	240.00	46.70	11208.50
Variable Costs															
Corn (bu)	938.33	2.54	2251.98	938.33	2.48	2193.85	938.33	2.83	2653.21	938.33	2.84	2664.53	938.33	2.99	2807.35
Soybean meal 44% (cwt)	133.63	13.89	1855.99	133.63	13.89	1855.99	133.63	16.43	2194.90	133.63	15.2	2031.20	133.63	21.18	2830.76
Calcium Carbonate (lb)	483.57	0.05	24.18	483.57	0.05	24.18	483.57	0.05	24.18	483.57	0.05	24.18	483.57	0.05	24.18
Dicalcium Phosphate (lb)	808.36	0.19	153.59	808.36	0.19	153.59	808.36	0.19	153.59	808.36	0.19	153.59	808.36	0.19	153.59
Salt (lb)	204.37	0.30	61.31	216.63	0.30	64.99	216.63	0.30	64.99	216.63	0.30	64.99	216.63	0.30	64.99
Vit & trace mineral mix (lb)	100.19	0.50	50.09	106.20	0.50	53.10	106.20	0.50	53.10	106.20	0.50	53.10	106.20	0.50	53.10
Total Feed Costs (100 pigs)			4397.15			4345.70			5143.97			4991.59			5933.97
Purchased feeders (Hd)	100.00	51.51	5150.90	100.00	53.87	5387.07	100.00	44.83	4483.10	100.00	53.90	5390.19	100.00	51.03	5102.82
Veterinary and medicine		1.06	106.08		1.33	132.60		1.15	115.36		0.80	79.56		1.45	144.88
Bedding and litter		0.04	3.98		0.05	5.30		0.03	2.65		0.03	2.65		0.03	2.89
Marketing		1.34	133.93		1.38	137.90		2.92	291.72		1.30	129.95		3.61	360.94
Hired labor	28.85	6.49	187.14	21.20	6.45	136.65	18.94	5.85	110.79	33.98	6.10	207.18	17.52	6.40	112.08
Custom services		0.46	45.83		0.62	62.40		0.70	70.20		0.29	29.25		4.01	400.69
Fuel, lube, and electricity		1.14	114.08		1.42	142.35		1.02	102.38		0.86	85.80		1.41	141.44
Repairs		0.91	90.68		0.84	83.85		0.79	78.98		0.98	97.50		0.97	97.12
Compliance cost (rugulatory)		0.31	31.00		0.31	31.00		0.34	33.67		0.39	39.00		0.31	31.00
Interest on operating capital		1.76	176.48		1.87	187.20		1.60	159.90		1.66	165.75		1.82	181.60
Total, variable costs (100 pigs)			10437.22			10652.03			10592.71			11218.42			12509.44
Opportunity cost of unpaid labor	86.56	12.49	1081.10	63.59	12.49	794.27	56.83	8.24	468.26	101.93	11.53	1175.20	52.55	15.74	827.18
Capital recovery of machinery and equipment		14.54	1540.95		14.20	1420.03		11.75	1175.09		16.62	1661.87		13.75	1374.70
Opportunity cost of land (rental rate)		0.06	6.20		0.08	8.27		0.09	9.30		0.04	4.13		0.08	8.02
Taxes and insurance		0.87	91.98		0.83	82.68		0.76	76.48		1.01	101.28		0.47	46.68
General farm overhead		1.64	173.63		1.65	165.36		0.73	73.38		1.82	181.90		1.02	101.64
Total, allocated overhead (100 pigs)			3067.49		29.25	3100.86		21.58	2287.74		31.02	3288.31		31.05	3291.35
Total Cost			13,504.71			13,752.88			12,880.45			14506.73			15800.78

Appendix 6

Appendix 6.1 Data and procedure for compliance cost estimation

The data for this analysis were obtained from an EPA publication entitled "Cost Methodology Report for Swine and Poultry Sector". The data include regulatory compliance costs for different sized feeder to finish operations. Costs are categorized as fixed costs, capital costs, and operation and management costs. Three-year recurring costs and five-year recurring costs for manure management facilities maintenance are suggested. In addition to cost, information on locations (Mid-Atlantic and Midwest region), size of operation (Medium and Large), technology options, number of facilities are also given in this data.

This research intended to find the compliance cost under the various technology options in various geographic regions and sizes of operations. The U.S. EPA data were used as a base for this analysis. Few assumptions were made before analyzing these costs. The effective life of the manure management facility was expected to be ten years. Manure management technology keeps changing and hog operations in ten years' time are likely to change significantly in size and even in existence. Capital costs and fixed costs were incurred in the first year and operating costs every year in equal amounts. Three-year recurring costs were incurred in year-1, year-3, year-6 and year-9. Similarly, five-year recurring costs were incurred in year-1 and year-5. All these costs were put together and discounted (10 %) to calculate the present values of costs. Annualized costs per operation in different locations, technologies and sizes were derived. The annualized discounted costs were calculated by the formula:

$$P = A \frac{(1+i)^n - 1}{i(1+i)^n}$$

where,

P=Sequence of level of cost in present value

A=Costs in each period

n=Number of year

i= interest rate (discount rate)

After calculation of annualized compliance cost per operation, weighted average costs for different options, regions, and sizes were calculated.

$$\text{Average cost} = \frac{\text{Annualized cost per operation} * \text{No. of operations}}{\text{Total number of operations in the group}}$$

$$\text{Cost per hog} = \frac{\text{Cost per operation}}{\text{Inventory} * \text{Turnover}}$$

Number of hogs per operation and number of turnovers are critical assumptions. The U.S. EPA assumed number of turnovers per year per operation as 2.8. The U.S. EPA has given the range of inventory in size groups. Based on the given range, 3,000 hogs for medium size and 4,000 hogs for large size of operations were assumed to calculate the compliance cost per hog.

Appendix 6.2 Regulatory compliance costs for swine (grow to finish, 1997)

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
1	1	Mid-Atlantic	288	Large	643	738	181
2	1	Mid-Atlantic	154	Large	883	975	189
3	2	Mid-Atlantic	173	Large	677	2,124	202
4	2	Mid-Atlantic	92	Large	968	4,444	241
5	3	Mid-Atlantic	28	Large	24,796	738	2,252
6	3	Mid-Atlantic	41	Large	24,830	2,124	2,273
7	3	Mid-Atlantic	15	Large	55,373	975	3,724
8	3	Mid-Atlantic	22	Large	55,459	4,444	3,776
9	3	Mid-Atlantic	88	Large	643	738	181
10	3	Mid-Atlantic	131	Large	677	2,124	202
11	3	Mid-Atlantic	47	Large	883	975	189
12	3	Mid-Atlantic	70	Large	968	4,444	241
13	4	Mid-Atlantic	28	Large	24,796	1,130	7,385
14	4	Mid-Atlantic	41	Large	24,830	2,516	7,406
15	4	Mid-Atlantic	15	Large	55,373	1,367	8,857
16	4	Mid-Atlantic	22	Large	55,459	4,836	8,909
17	4	Mid-Atlantic	88	Large	643	1,130	5,314
18	4	Mid-Atlantic	131	Large	677	2,516	5,335
19	4	Mid-Atlantic	47	Large	883	1,367	5,322
20	4	Mid-Atlantic	70	Large	968	4,836	5,374
21	5	Mid-Atlantic	115	Large	119,903	738	2,566
22	5	Mid-Atlantic	173	Large	119,937	2,124	2,587
23	5	Mid-Atlantic	62	Large	290,930	975	5,990
24	5	Mid-Atlantic	92	Large	291,015	4,444	6,042
25	5	Mid-Atlantic	115	Large	757,409	738	24,775
26	5	Mid-Atlantic	173	Large	757,443	2,124	24,796
27	5	Mid-Atlantic	62	Large	1,894,502	975	61,729
28	5	Mid-Atlantic	92	Large	1,894,588	4,444	61,781
29	6	Mid-Atlantic	173	Large	98,039	27,124	-17,555
30	6	Mid-Atlantic	92	Large	173,966	29,444	-42,722
31	7	Mid-Atlantic	115	Large	643	738	181
32	7	Mid-Atlantic	173	Large	677	2,124	202
33		Mid-Atlantic	92	Large	968	4,444	241
34	7	Mid-Atlantic	62	Large	883	975	189
36	1	Mid-Atlantic	247	Medium	1.281	685	401
37	1	Mid-Atlantic	44	Medium	1,449	746	440
38	1	Mid-Atlantic	122	Medium	1,626	818	487
39	2	Mid-Atlantic	148	Medium	2,204	1,607	968
40	2	Mid-Atlantic	26	Medium	2,907	2,202	1,336
41	2	Mid-Atlantic	73	Medium	3,719	2,909	1,772
42	3	Mid-Atlantic	24	Medium	9,951	685	1,724
43	3	Mid-Atlantic	35	Medium	10,874	1,607	2,291
44	3	Mid-Atlantic	4	Medium	13,570	746	1,931
45	3	Mid-Atlantic	6	Medium	15,028	2,202	2,826

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
46	3	Mid-Atlantic	12	Medium	17,737	818	2,170
47	3	Mid-Atlantic	18	Medium	19,830	2,909	3,455
48	3	Mid-Atlantic	75	Medium	1,281	685	401
49	3	Mid-Atlantic	113	Medium	2,204	1,607	968
50	3	Mid-Atlantic	13	Medium	1,449	746	440
51	3	Mid-Atlantic	20	Medium	2,907	2,202	1,336
52	3	Mid-Atlantic	37	Medium	1,626	818	487
53	3	Mid-Atlantic	56	Medium	3,719	2,909	1,772
54	4	Mid-Atlantic	24	Medium	9,951	1,077	7,620
55	4	Mid-Atlantic	35	Medium	10,874	1,999	8,187
56	4	Mid-Atlantic	4	Medium	13,570	1,138	7,826
57	4	Mid-Atlantic	6	Medium	15,028	2,594	8,722
58	4	Mid-Atlantic	12	Medium	17,737	1,210	8,066
59	4	Mid-Atlantic	18	Medium	19,830	3,301	9,351
60	4	Mid-Atlantic	75	Medium	1,281	1,077	6,296
61	4	Mid-Atlantic	113	Medium	2,204	1,999	6,863
62	4	Mid-Atlantic	13	Medium	1,449	1,138	6,336
63	4	Mid-Atlantic	20	Medium	2,907	2,594	7,231
64	4	Mid-Atlantic	37	Medium	1,626	1,210	6,382
65	4	Mid-Atlantic	56	Medium	3,719	3,301	7,668
66	5	Mid-Atlantic	99	Medium	37,659	685	1,128
67	5	Mid-Atlantic	148	Medium	38,581	1,607	1,695
68	5	Mid-Atlantic	18	Medium	55,676	746	1,525
69	5	Mid-Atlantic	26	Medium	57,134	2,202	2,420
70	5	Mid-Atlantic	49	Medium	77,062	818	1,996
71	5	Mid-Atlantic	73	Medium	79,155	2,909	3,281
72	5	Mid-Atlantic	99	Medium	206,336	685	7,065
73	5	Mid-Atlantic	148	Medium	207,259	1,607	7,632
74	5	Mid-Atlantic	18	Medium	325,321	746	10,966
75	5	Mid-Atlantic	26	Medium	326,779	2,202	11,861
76	5	Mid-Atlantic	49	Medium	466,674	818	15,600
77	5	Mid-Atlantic	73	Medium	468,767	2,909	16,885
78	7	Mid-Atlantic	99	Medium	1,281	685	401
79	7	Mid-Atlantic	148	Medium	2,204	1,607	968
80	7	Mid-Atlantic	18	Medium	1,449	746	440
81	7	Mid-Atlantic	26	Medium	2,907	2,202	1,336
82	7	Mid-Atlantic	49	Medium	1,626	818	487
83	7	Mid-Atlantic	73	Medium	3,719	2,909	1,772
84	1	Mid-Atlantic	89	Large	11,666	648	398
85	1	Mid-Atlantic	180	Large	19,006	760	545
86	2	Mid-Atlantic	53	Large	86,744	1,041	16,038
87	2	Mid-Atlantic	108	Large	208,015	1,219	39,504
88	3	Mid-Atlantic	9	Large	29,165	648	2,140
89	3	Mid-Atlantic	13	Large	104,243	1,041	17,780
90	3	Mid-Atlantic	17	Large	57,498	760	3,288
91	3	Mid-Atlantic	26	Large	246,507	1,219	42,247

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
92	3	Mid-Atlantic	27	Large	11,666	648	398
93	3	Mid-Atlantic	41	Large	86,744	1,041	16,038
94	3	Mid-Atlantic	55	Large	19,006	760	545
95	3	Mid-Atlantic	82	Large	208,015	1,219	39,504
96	4	Mid-Atlantic	9	Large	29,165	1,040	7,273
97	4	Mid-Atlantic	13	Large	104,243	1,433	22,912
98	4	Mid-Atlantic	17	Large	57,498	1,152	8,421
99	4	Mid-Atlantic	26	Large	246,507	1,611	47,380
100	4	Mid-Atlantic	27	Large	11,666	1,040	5,531
101	4	Mid-Atlantic	41	Large	86,744	1,433	21,170
102	4	Mid-Atlantic	55	Large	19,006	1,152	5,678
103	4	Mid-Atlantic	82	Large	208,015	1,611	44,637
104	5	Mid-Atlantic	36	Large	86,735	648	37,096
105	5	Mid-Atlantic	53	Large	86,744	1,041	15,818
106	5	Mid-Atlantic	72	Large	208,003	760	37,346
107	5	Mid-Atlantic	108	Large	208,015	1,219	39,143
108	5	Mid-Atlantic	36	Large	658,057	648	26,184
109	5	Mid-Atlantic	53	Large	658,067	1,041	33,898
110	5	Mid-Atlantic	72	Large	1,645,966	760	64,952
111	5	Mid-Atlantic	108	Large	1,645,978	1,219	88,643
112	6	Mid-Atlantic	53	Large	184,106	26,041	-12,464
113	6	Mid-Atlantic	108	Large	381,013	26,219	-29,927
114	7	Mid-Atlantic	36	Large	15,218	648	11,387
115	7	Mid-Atlantic	53	Large	90,296	1,041	27,027
116	7	Mid-Atlantic	72	Large	24,844	760	18,609
117	7	Mid-Atlantic	108	Large	213,853	1,219	57,568
118	1	Mid-Atlantic	30	Medium	7,735	639	502
119	1	Mid-Atlantic	5	Medium	41,311	639	1,327
120	1	Mid-Atlantic	24	Medium	10,311	709	594
121	2	Mid-Atlantic	18	Medium	28,955	1,026	5,056
122	2	Mid-Atlantic	3	Medium	41,698	1,026	7,518
123	2	Mid-Atlantic	14	Medium	57,112	1,319	10,619
124	3	Mid-Atlantic	3	Medium	14,425	639	1,727
125	3	Mid-Atlantic	4	Medium	35,645	1,026	6,282
126	3	Mid-Atlantic	0	Medium	50,425	639	2,669
127	3	Mid-Atlantic	1	Medium	50,812	1,026	8,859
128	3	Mid-Atlantic	2	Medium	22,212	709	2,069
129	3	Mid-Atlantic	3	Medium	69,013	1,319	12,094
130	3	Mid-Atlantic	9	Medium	7,735	639	502
131	3	Mid-Atlantic	14	Medium	28,955	1,026	5,056
132	3	Mid-Atlantic	2	Medium	41,311	639	1,327
133	3	Mid-Atlantic	2	Medium	41,698	1,026	7,518
134	3	Mid-Atlantic	7	Medium	10,311	709	594
135	3	Mid-Atlantic	11	Medium	57,112	1,319	10,619
136	4	Mid-Atlantic	3	Medium	14,425	1,031	7,623
137	4	Mid-Atlantic	4	Medium	35,645	1,418	12,178

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
138	4	Mid-Atlantic	0	Medium	50,425	1,031	8,564
139	4	Mid-Atlantic	1	Medium	50,812	1,418	14,755
140	4	Mid-Atlantic	2	Medium	22,212	1,101	7,965
141	4	Mid-Atlantic	3	Medium	69,013	1,711	17,990
142	4	Mid-Atlantic	9	Medium	7,735	1,031	6,397
143	4	Mid-Atlantic	14	Medium	28,955	1,418	10,952
144	4	Mid-Atlantic	2	Medium	41,311	1,031	7,223
145	4	Mid-Atlantic	2	Medium	41,698	1,418	13,413
146	4	Mid-Atlantic	7	Medium	10,311	1,101	6,490
147	4	Mid-Atlantic	11	Medium	57,112	1,711	16,515
148	5	Mid-Atlantic	12	Medium	28,569	639	10,456
149	5	Mid-Atlantic	18	Medium	28,955	1,026	4,926
150	5	Mid-Atlantic	2	Medium	41,311	639	1,174
151	5	Mid-Atlantic	3	Medium	41,698	1,026	7,365
152	5	Mid-Atlantic	10	Medium	56,501	709	23,148
153	5	Mid-Atlantic	14	Medium	57,112	1,319	10,443
154	5	Mid-Atlantic	12	Medium	179,313	639	7,404
155	5	Mid-Atlantic	18	Medium	179,700	1,026	9,337
156	5	Mid-Atlantic	2	Medium	282,632	639	11,625
157	5	Mid-Atlantic	3	Medium	283,019	1,026	15,225
158	5	Mid-Atlantic	10	Medium	405,442	709	16,287
159	5	Mid-Atlantic	14	Medium	406,052	1,319	21,401
160	7	Mid-Atlantic	12	Medium	10,958	639	7,014
161	7	Mid-Atlantic	18	Medium	32,178	1,026	11,569
162	7	Mid-Atlantic	2	Medium	45,091	639	8,964
163	7	Mid-Atlantic	3	Medium	45,478	1,026	15,155
164	7	Mid-Atlantic	10	Medium	14,676	709	9,415
165	7	Mid-Atlantic	14	Medium	61,477	1,319	19,440
166	1	Mid-Atlantic	81	Large	119,757	580	29,432
167	1	Mid-Atlantic	94	Large	290,778	580	73,215
168	2	Mid-Atlantic	49	Large	119,757	580	6,146
169	2	Mid-Atlantic	56	Large	290,778	580	14,948
170	3	Mid-Atlantic	8	Large	143,910	580	31,503
171	3	Mid-Atlantic	12	Large	143,910	580	8,217
172	3	Mid-Atlantic	9	Large	345,269	580	76,750
173	3	Mid-Atlantic	13	Large	345,269	580	18,483
174	3	Mid-Atlantic	25	Large	119,757	580	29,432
175	3	Mid-Atlantic	37	Large	119,757	580	6,146
176	3	Mid-Atlantic	29	Large	290,778	580	73,215
177	3	Mid-Atlantic	43	Large	290,778	580	14,948
178	4	Mid-Atlantic	8	Large	143,910	972	36,636
179	4	Mid-Atlantic	12	Large	143,910	972	13,350
180	4	Mid-Atlantic	9	Large	345,269	972	81,882
181	4	Mid-Atlantic	13	Large	345,269	972	23,615
182	4	Mid-Atlantic	25	Large	119,757	972	34,564
183	4	Mid-Atlantic	37	Large	119,757	972	11,279

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
184	4	Mid-Atlantic	29	Large	290,778	972	78,348
185	4	Mid-Atlantic	43	Large	290,778	972	20,081
186	5	Mid-Atlantic	32	Large	119,757	580	29,432
187	5	Mid-Atlantic	49	Large	119,757	580	6,146
188	5	Mid-Atlantic	38	Large	290,778	580	73,215
189	5	Mid-Atlantic	56	Large	290,778	580	14,948
190	5	Mid-Atlantic	32	Large	657,987	580	24,772
191	5	Mid-Atlantic	49	Large	657,987	580	24,772
192	5	Mid-Atlantic	38	Large	1,645,936	580	61,722
193	5	Mid-Atlantic	56	Large	1,645,936	580	61,722
194	6	Mid-Atlantic	49	Large	217,119	25,580	-11,611
195	6	Mid-Atlantic	56	Large	463,776	25,580	-28,015
196	7	Mid-Atlantic	32	Large	119,757	580	29,432
197	7	Mid-Atlantic	49	Large	119,757	580	6,146
198	7	Mid-Atlantic	38	Large	290,778	580	73,215
199	7	Mid-Atlantic	56	Large	290,778	580	14,948
200	1	Mid-Atlantic	51	Medium	37,029	580	8,304
201	1	Mid-Atlantic	9	Medium	54,985	580	12,882
202	1	Mid-Atlantic	29	Medium	76,299	580	18,320
203	2	Mid-Atlantic	31	Medium	37,029	580	1,995
204	2	Mid-Atlantic	5	Medium	54,985	580	2,916
205	2	Mid-Atlantic	17	Medium	76,299	580	4,011
206	3	Mid-Atlantic	5	Medium	45,698	580	9,628
207	3	Mid-Atlantic	7	Medium	45,698	580	3,318
208	3	Mid-Atlantic	1	Medium	67,106	580	14,372
209	3	Mid-Atlantic	1	Medium	67,106	580	4,407
210	3	Mid-Atlantic	3	Medium	92,409	580	20,003
211	3	Mid-Atlantic	4	Medium	92,409	580	5,694
212	3	Mid-Atlantic	16	Medium	37,029	580	8,304
213	3	Mid-Atlantic	23	Medium	37,029	580	1,995
214	3	Mid-Atlantic	3	Medium	54,985	580	12,882
215	3	Mid-Atlantic	4	Medium	54,985	580	2,916
216	3	Mid-Atlantic	9	Medium	76,299	580	18,320
217	3	Mid-Atlantic	13	Medium	76,299	580	4,011
218	4	Mid-Atlantic	5	Medium	45,698	972	15,523
219	4	Mid-Atlantic	7	Medium	45,698	972	9,214
220	4	Mid-Atlantic	1	Medium	67,106	972	20,268
221	4	Mid-Atlantic	1	Medium	67,106	972	10,302
222	4	Mid-Atlantic	3	Medium	92,409	972	25,899
223	4	Mid-Atlantic	4	Medium	92,409	972	11,589
224	4	Mid-Atlantic	16	Medium	37,029	972	14,200
225	4	Mid-Atlantic	23	Medium	37,029	972	7,890
226	4	Mid-Atlantic	3	Medium	54,985	972	18,777
227	4	Mid-Atlantic	4	Medium	54,985	972	8,812
228	4	Mid-Atlantic	9	Medium	76,299	972	24,216
229	4	Mid-Atlantic	13	Medium	76,299	972	9,906

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
230	5	Mid-Atlantic	20	Medium	37,029	580	8,304
231	5	Mid-Atlantic	31	Medium	37,029	580	1,995
232	5	Mid-Atlantic	4	Medium	54,985	580	12,882
233	5	Mid-Atlantic	5	Medium	54,985	580	2,916
234	5	Mid-Atlantic	12	Medium	76,299	580	18,320
235	5	Mid-Atlantic	17	Medium	76,299	580	4,011
236	5	Mid-Atlantic	20	Medium	178,806	580	6,960
237	5	Mid-Atlantic	31	Medium	178,806	580	6,960
238	5	Mid-Atlantic	4	Medium	282,143	580	10,824
239	5	Mid-Atlantic	5	Medium	282,143	580	10,824
240	5	Mid-Atlantic	12	Medium	404,903	580	15,414
241	5	Mid-Atlantic	17	Medium	404,903	580	15,414
242	7	Mid-Atlantic	20	Medium	37,029	580	8,304
243	7	Mid-Atlantic	31	Medium	37,029	580	1,995
244	7	Mid-Atlantic	4	Medium	54,985	580	12,882
245	7	Mid-Atlantic	5	Medium	54,985	580	2,916
246	7	Mid-Atlantic	12	Medium	76,299	580	18,320
247	7	Mid-Atlantic	17	Medium	76,299	580	4,011
248	1	Mid-West	356	Large	634	740	180
249	1	Mid-West	78	Large	920	1,050	188
250	2	Mid-West	214	Large	655	2,238	193
251	2	Mid-West	47	Large	982	5,447	227
252	3	Mid-West	39	Large	27,458	740	2,515
253	3	Mid-West	59	Large	27,479	2,238	2,528
254	3	Mid-West	9	Large	70,800	1,050	4,600
255	3	Mid-West	13	Large	70,862	5,447	4,638
256	3	Mid-West	103	Large	634	740	180
257	3	Mid-West	155	Large	655	2,238	193
258	3	Mid-West	23	Large	920	1,050	188
259	3	Mid-West	34	Large	982	5,447	227
260	4	Mid-West	39	Large	27,458	1,132	7,023
261	4	Mid-West	59	Large	27,479	2,630	7,036
262	4	Mid-West	9	Large	70,800	1,442	9,108
263	4	Mid-West	13	Large	70,862	5,839	9,146
264	4	Mid-West	103	Large	634	1,132	4,688
265	4	Mid-West	155	Large	655	2,630	4,701
266	4	Mid-West	23	Large	920	1,442	4,696
267	4	Mid-West	34	Large	982	5,839	4,734
268	5	Mid-West	142	Large	115,511	740	2,478
269	5	Mid-West	214	Large	115,532	2,238	2,491
270	5	Mid-West	31	Large	327,306	1,050	6,716
271	5	Mid-West	47	Large	327,368	5,447	6,754
272	5	Mid-West	142	Large	728,228	740	23,826
273	5	Mid-West	214	Large	728,249	2,238	23,839
274	5	Mid-West	31	Large	2,136,432	1,050	69,589
275	5	Mid-West	47	Large	2,136,494	5,447	69,627

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
276	6	Mid-West	214	Large	155,261	27,238	-15,110
277	6	Mid-West	47	Large	362,771	30,447	-43,296
278	7	Mid-West	142	Large	634	740	180
279	7	Mid-West	214	Large	655	2,238	193
280	7	Mid-West	31	Large	920	1,050	188
281	7	Mid-West	47	Large	982	5,447	227
283	1	Mid-West	1432	Medium	1,222	651	571
284	1	Mid-West	256	Medium	1,360	692	595
285	1	Mid-West	314	Medium	1,520	748	625
286	2	Mid-West	859	Medium	1,780	1,314	914
287	2	Mid-West	154	Medium	2,243	1,740	1,137
288	2	Mid-West	188	Medium	2,839	2,313	1,435
289	3	Mid-West	157	Medium	10,721	651	2,069
290	3	Mid-West	236	Medium	11,279	1,314	2,412
291	3	Mid-West	28	Medium	14,587	692	2,273
292	3	Mid-West	42	Medium	15,470	1,740	2,815
293	3	Mid-West	34	Medium	19,612	748	2,539
294	3	Mid-West	52	Medium	20,930	2,313	3,348
295	3	Mid-West	416	Medium	1,222	651	571
296	3	Mid-West	623	Medium	1,780	1,314	914
297	3	Mid-West	74	Medium	1,360	692	595
298	3	Mid-West	111	Medium	2,243	1,740	1,137
299	3	Mid-West	91	Medium	1,520	748	625
300	3	Mid-West	137	Medium	2,839	2,313	1,435
301	4	Mid-West	157	Medium	10,721	1,043	5,408
302	4	Mid-West	236	Medium	11,279	1,706	5,751
303	4	Mid-West	28	Medium	14,587	1,084	5,611
304	4	Mid-West	42	Medium	15,470	2,132	6,153
305	4	Mid-West	34	Medium	19,612	1,140	5,877
306	4	Mid-West	52	Medium	20,930	2,705	6,687
307	4	Mid-West	416	Medium	1,222	1,043	3,910
308	4	Mid-West	623	Medium	1,780	1,706	4,253
309	4	Mid-West	74	Medium	1,360	1,084	3,933
310	4	Mid-West	111	Medium	2,243	2,132	4,475
311	4	Mid-West	91	Medium	1,520	1,140	3,964
312	4	Mid-West	137	Medium	2,839	2,705	4,774
313	5	Mid-West	573	Medium	35,584	651	1,258
314	5	Mid-West	859	Medium	36,142	1,314	1,601
315	5	Mid-West	102	Medium	52,421	692	1,616
316	5	Mid-West	154	Medium	53,303	1,740	2,158
317	5	Mid-West	126	Medium	75,036	748	2,096
318	5	Mid-West	188	Medium	76,355	2,313	2,905
319	5	Mid-West	573	Medium	192,862	651	6,799
320	5	Mid-West	859	Medium	193,421	1,314	7,142
321	5	Mid-West	102	Medium	304,152	692	10,435
322	5	Mid-West	154	Medium	305,035	1,740	10,977

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
323	5	Mid-West	126	Medium	453,791	748	15,324
324	5	Mid-West	188	Medium	455,110	2,313	16,133
325	7	Mid-West	573	Medium	1,222	651	571
326	7	Mid-West	859	Medium	1,780	1,314	914
327	7	Mid-West	102	Medium	1,360	692	595
328	7	Mid-West	154	Medium	2,243	1,740	1,137
329	7	Mid-West	126	Medium	1,520	748	625
330	7	Mid-West	188	Medium	2,839	2,313	1,435
331	1	Mid-West	110	Large	11,452	699	394
332	1	Mid-West	92	Large	20,421	892	573
333	2	Mid-West	66	Large	83,631	1,379	13,896
334	2	Mid-West	55	Large	233,808	1,689	39,975
335	3	Mid-West	12	Large	30,914	699	2,364
336	3	Mid-West	18	Large	103,093	1,379	15,866
337	3	Mid-West	10	Large	69,666	892	3,963
338	3	Mid-West	15	Large	283,053	1,689	43,365
339	3	Mid-West	32	Large	11,452	699	394
340	3	Mid-West	48	Large	83,631	1,379	13,896
341	3	Mid-West	27	Large	20,421	892	573
342	3	Mid-West	40	Large	233,808	1,689	39,975
343	4	Mid-West	12	Large	30,914	1,091	6,872
344	4	Mid-West	18	Large	103,093	1,771	20,374
345	4	Mid-West	10	Large	69,666	1,284	8,471
346	4	Mid-West	15	Large	283,053	2,081	47,873
347	4	Mid-West	32	Large	11,452	1,091	4,902
348	4	Mid-West	48	Large	83,631	1,771	18,404
349	4	Mid-West	27	Large	20,421	1,284	5,081
350	4	Mid-West	40	Large	233,808	2,081	44,483
351	5	Mid-West	44	Large	83,621	699	6,641
352	5	Mid-West	66	Large	83,631	1,379	13,680
353	5	Mid-West	37	Large	233,797	892	24,071
354	5	Mid-West	55	Large	233,808	1,689	39,587
355	5	Mid-West	44	Large	632,705	699	24,558
356	5	Mid-West	66	Large	632,715	1,379	25,875
357	5	Mid-West	37	Large	1,856,159	892	72,043
358	5	Mid-West	55	Large	1,856,170	1,689	78,040
359	6	Mid-West	66	Large	238,237	26,379	-10,717
360	6	Mid-West	55	Large	595,597	26,689	-30,331
361	7	Mid-West	44	Large	14,937	699	11,178
362	7	Mid-West	66	Large	87,116	1,379	24,680
363	7	Mid-West	37	Large	26,702	892	20,006
364	7	Mid-West	55	Large	240,089	1,689	59,408
365	1	Mid-West	171	Medium	7,586	653	698
366	1	Mid-West	30	Medium	8,755	651	720
367	1	Mid-West	62	Medium	10,199	734	790
368	2	Mid-West	103	Medium	7,971	1,110	1,842

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
369	2	Mid-West	18	Medium	39,438	1,110	6,639
370	2	Mid-West	37	Medium	55,744	1,459	9,597
371	3	Mid-West	19	Medium	14,947	653	2,091
372	3	Mid-West	28	Medium	15,332	1,110	3,234
373	3	Mid-West	3	Medium	18,735	651	2,238
374	3	Mid-West	5	Medium	49,418	1,110	8,157
375	3	Mid-West	7	Medium	23,581	734	2,471
376	3	Mid-West	10	Medium	69,126	1,459	11,277
377	3	Mid-West	50	Medium	7,586	653	698
378	3	Mid-West	74	Medium	7,971	1,110	1,842
379	3	Mid-West	9	Medium	8,755	651	720
380	3	Mid-West	13	Medium	39,438	1,110	6,639
381	3	Mid-West	18	Medium	10,199	734	790
382	3	Mid-West	27	Medium	55,744	1,459	9,597
383	4	Mid-West	19	Medium	14,947	1,045	5,429
384	4	Mid-West	28	Medium	15,332	1,502	6,572
385	4	Mid-West	3	Medium	18,735	1,043	5,576
386	4	Mid-West	5	Medium	49,418	1,502	11,495
387	4	Mid-West	7	Medium	23,581	1,126	5,809
388	4	Mid-West	10	Medium	69,126	1,851	14,615
389	4	Mid-West	50	Medium	7,586	1,045	4,037
390	4	Mid-West	74	Medium	7,971	1,502	5,180
391	4	Mid-West	9	Medium	8,755	1,043	4,059
392	4	Mid-West	13	Medium	39,438	1,502	9,978
393	4	Mid-West	18	Medium	10,199	1,126	4,129
394	4	Mid-West	27	Medium	55,744	1,851	12,935
395	5	Mid-West	68	Medium	27,131	653	1,091
396	5	Mid-West	103	Medium	27,516	1,110	2,234
397	5	Mid-West	12	Medium	39,051	651	15,442
398	5	Mid-West	18	Medium	39,438	1,110	6,490
399	5	Mid-West	25	Medium	55,134	734	17,748
400	5	Mid-West	37	Medium	55,744	1,459	9,422
401	5	Mid-West	68	Medium	184,409	653	6,926
402	5	Mid-West	103	Medium	168,034	1,110	7,414
403	5	Mid-West	12	Medium	264,302	651	10,864
404	5	Mid-West	18	Medium	264,688	1,110	11,597
405	5	Mid-West	25	Medium	394,335	734	15,580
406	5	Mid-West	37	Medium	394,945	1,459	16,944
407	7	Mid-West	68	Medium	10,740	653	7,072
408	7	Mid-West	103	Medium	11,125	1,110	8,215
409	7	Mid-West	12	Medium	12,441	651	8,169
410	7	Mid-West	18	Medium	43,124	1,110	14,088
411	7	Mid-West	25	Medium	14,513	734	9,508
412	7	Mid-West	37	Medium	60,058	1,459	18,314
413	1	Mid-West	101	Large	115,367	580	28,308
414	1	Mid-West	48	Large	327,157	580	82,531

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
415	2	Mid-West	61	Large	115,367	580	5,920
416	2	Mid-West	29	Large	327,157	580	16,821
417	3	Mid-West	11	Large	142,191	580	30,643
418	3	Mid-West	17	Large	142,191	580	8,255
419	3	Mid-West	5	Large	397,037	580	86,942
420	3	Mid-West	8	Large	397,037	580	21,232
421	3	Mid-West	29	Large	115,367	580	28,308
422	3	Mid-West	44	Large	115,367	580	5,920
423	3	Mid-West	14	Large	327,157	580	82,531
424	3	Mid-West	21	Large	327,157	580	16,821
425	4	Mid-West	11	Large	142,191	972	35,151
426	4	Mid-West	17	Large	142,191	972	12,763
427	4	Mid-West	5	Large	397,037	972	91,450
428	4	Mid-West	8	Large	397,037	972	25,740
429	4	Mid-West	29	Large	115,367	972	32,816
430	4	Mid-West	44	Large	115,367	972	10,428
431	4	Mid-West	14	Large	327,157	972	87,039
432	4	Mid-West	21	Large	327,157	972	21,329
433	5	Mid-West	40	Large	115,367	580	28,308
434	5	Mid-West	61	Large	115,367	580	5,920
435	5	Mid-West	19	Large	327,157	580	82,531
436	5	Mid-West	29	Large	327,157	580	16,821
437	5	Mid-West	40	Large	632,635	580	23,824
438	5	Mid-West	61	Large	632,635	580	23,824
439	5	Mid-West	19	Large	1,856,136	580	69,585
440	5	Mid-West	29	Large	1,856,136	580	69,585
441	6	Mid-West	61	Large	269,973	25,580	-9,383
442	6	Mid-West	29	Large	688,946	25,580	-26,702
443	7	Mid-West	40	Large	115,367	580	28,308
444	7	Mid-West	61	Large	115,367	580	5,920
445	7	Mid-West	19	Large	327,157	580	82,531
446	7	Mid-West	29	Large	327,157	580	16,821
447	1	Mid-West	294	Medium	34,999	580	7,986
448	1	Mid-West	53	Medium	51,801	580	12,268
449	1	Mid-West	74	Medium	74,370	580	18,027
450	2	Mid-West	176	Medium	34,999	580	2,089
451	2	Mid-West	32	Medium	51,801	580	2,951
452	2	Mid-West	44	Medium	74,370	580	4,110
453	3	Mid-West	32	Medium	44,498	580	9,484
454	3	Mid-West	48	Medium	44,498	580	3,587
455	3	Mid-West	6	Medium	65,028	580	13,946
456	3	Mid-West	9	Medium	65,028	580	4,629
457	3	Mid-West	8	Medium	92,462	580	19,940
458	3	Mid-West	12	Medium	92,462	580	6,023
459	3	Mid-West	85	Medium	34,999	580	7,986
460	3	Mid-West	128	Medium	34,999	580	2,089

ID	Option	Region	# Facilities	Size of oper.	Capital cost	Fixed cost	Oper. cost
461	3	Mid-West	15	Medium	51,801	580	12,268
462	3	Mid-West	23	Medium	51,801	580	2,951
463	3	Mid-West	21	Medium	74,370	580	18,027
464	3	Mid-West	32	Medium	74,370	580	4,110
465	4	Mid-West	32	Medium	44,498	972	12,822
466	4	Mid-West	48	Medium	44,498	972	6,925
467	4	Mid-West	6	Medium	65,028	972	17,285
468	4	Mid-West	9	Medium	65,028	972	7,968
469	4	Mid-West	8	Medium	92,462	972	23,278
470	4	Mid-West	12	Medium	92,462	972	9,362
471	4	Mid-West	85	Medium	34,999	972	11,324
472	4	Mid-West	128	Medium	34,999	972	5,428
473	4	Mid-West	15	Medium	51,801	972	15,607
474	4	Mid-West	23	Medium	51,801	972	6,290
475	4	Mid-West	21	Medium	74,370	972	21,365
476	4	Mid-West	32	Medium	74,370	972	7,449
477	5	Mid-West	118	Medium	34,999	580	7,986
478	5	Mid-West	176	Medium	34,999	580	2,089
479	5	Mid-West	21	Medium	51,801	580	12,268
480	5	Mid-West	32	Medium	51,801	580	2,951
481	5	Mid-West	30	Medium	74,370	580	18,027
482	5	Mid-West	44	Medium	74,370	580	4,110
483	5	Mid-West	118	Medium	167,137	580	6,723
484	5	Mid-West	176	Medium	167,137	580	6,723
485	5	Mid-West	21	Medium	263,811	580	10,337
486	5	Mid-West	32	Medium	263,811	580	10,337
487	5	Mid-West	30	Medium	393,794	580	15,197
488	5	Mid-West	44	Medium	393,794	580	15,197
489	7	Mid-West	118	Medium	34,999	580	7,986
490	7	Mid-West	176	Medium	34,999	580	2,089
491	7	Mid-West	21	Medium	51,801	580	12,268
492	7	Mid-West	32	Medium	51,801	580	2,951
493	7	Mid-West	30	Medium	74,370	580	18,027
494	7	Mid-West	44	Medium	74,370	580	4,110

Appendix 6.2 Continued for additional variables

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
1	255	0	3748.5306	374.85
2	511	0	5428.2369	542.82
3	1,750	0	12018.314	1201.83
4	4,252	0	26119.019	2611.9
5	255	2,703	48621.43	4862.14
6	1,750	2,703	56891.213	5689.12
7	511	2,703	90533.347	9053.33
8	4,252	2,703	111225.13	11122.51
9	255	2,703	10470.492	1047.05
10	1,750	2,703	18740.275	1874.03
11	511	2,703	12150.198	1215.02
12	4,252	2,703	32840.98	3284.1
13	255	2,703	83707.499	8370.75
14	1,750	2,703	91977.282	9197.73
15	511	2,703	125619.42	12561.94
16	4,252	2,703	146311.2	14631.12
17	255	2,703	45556.561	4555.66
18	1,750	2,703	53826.344	5382.63
19	511	2,703	47236.267	4723.63
20	4,252	2,703	67927.05	6792.7
21	255	0	139128.8	13912.88
22	1,750	0	147398.59	14739.86
23	511	0	334684.33	33468.43
24	4,252	0	355375.12	35537.51
25	255	0	926745.96	92674.6
26	1,750	0	935015.75	93501.57
27	511	0	2314997.6	231499.76
28	4,252	0	2335689.3	233568.93
29	1,750	5,000	26794.588	2679.46
30	4,252	5,000	-53836.661	-5383.67
31	255	0	3748.5306	374.85
32	1,750	0	12018.314	1201.83
33	4,252	0	26119.019	2611.9
34	511	0	5428.2369	542.82
36	227	0	5694.884	569.49
37	292	0	6479.1313	647.91
38	368	0	7386.8061	738.68
39	1,198	0	15728.984	1572.9
40	1,825	0	22327.561	2232.76
41	2,570	0	30136.2	3013.62

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
42	227	2,854	30404.548	3040.45
43	1,198	2,854	40438.648	4043.86
44	292	2,854	35775.311	3577.53
45	1,825	2,854	51616.982	5161.7
46	368	2,854	41970.719	4197.07
47	2,570	2,854	64720.112	6472.01
48	227	2,854	12792.36	1279.24
49	1,198	2,854	22826.459	2282.65
50	292	2,854	13576.607	1357.66
51	1,825	2,854	29425.036	2942.5
52	368	2,854	14484.282	1448.43
53	2,570	2,854	37233.675	3723.37
54	227	2,854	70647.752	7064.78
55	1,198	2,854	80681.852	8068.19
56	292	2,854	76011.757	7601.18
57	1,825	2,854	91860.186	9186.02
58	368	2,854	82213.923	8221.39
59	2,570	2,854	104963.32	10496.33
60	227	2,854	53028.805	5302.88
61	1,198	2,854	63062.905	6306.29
62	292	2,854	53819.811	5381.98
63	1,825	2,854	69661.482	6966.15
64	368	2,854	54720.727	5472.07
65	2,570	2,854	77476.88	7747.69
66	227	0	46986.694	4698.67
67	1,198	0	57019.794	5701.98
68	292	0	68039.672	6803.97
69	1,825	0	83881.343	8388.13
70	368	0	93022.173	9302.22
71	2,570	0	115771.57	11577.16
72	227	0	255792.02	25579.2
73	1,198	0	265826.12	26582.61
74	292	0	401496.62	40149.66
75	1,825	0	417338.29	41733.83
76	368	0	574583.93	57458.39
77	2,570	0	597333.33	59733.33
78	227	0	5694.884	569.49
79	1,198	0	15728.984	1572.9
80	292	0	6479.1313	647.91
81	1,825	0	22327.561	2232.76
82	368	0	7386.8061	738.68

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
83	2,570	0	30136.2	3013.62
84	159	207,255	531130.01	53113
85	279	498,323	1263957	126395.7
86	582	0	198797.57	19879.76
87	775	0	479719.79	47971.98
88	159	209,958	567125.19	56712.52
89	582	2,703	234792.75	23479.28
90	279	501,026	1327711	132771.1
91	775	2,703	543473.75	54347.38
92	159	209,958	537851.97	53785.2
93	582	2,703	205519.53	20551.95
94	279	501,026	1270679	127067.9
95	775	2,703	486441.75	48644.17
96	159	209,958	602211.26	60221.13
97	582	2,703	269872.06	26987.21
98	279	501,026	1362797.1	136279.71
99	775	2,703	578559.82	57855.98
100	159	209,958	572938.04	57293.8
101	582	2,703	240598.84	24059.88
102	279	501,026	1305765.1	130576.51
103	775	2,703	521527.82	52152.78
104	159	0	338829.16	33882.92
105	582	0	197310.59	19731.06
106	279	0	462437.34	46243.73
107	775	0	477279.78	47727.98
108	159	0	836396.69	83639.67
109	582	0	890836.74	89083.67
110	279	0	2086989.9	208698.99
111	775	0	2249814.5	224981.45
112	582	5,000	140948.14	14094.81
113	775	5,000	220866.26	22086.63
114	159	207,255	608956.92	60895.69
115	582	0	276624.48	27662.45
116	279	498,323	1391890.1	139189.01
117	775	0	607652.79	60765.28
118	180	41,347	115398.53	11539.85
119	180	0	51726.858	5172.69
120	253	100,722	266650.74	26665.07
121	586	0	66783.92	6678.39
122	586	0	96167.636	9616.76
123	896	0	134225.29	13422.53

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
124	180	44,201	137465.81	13746.58
125	586	2,854	88857.958	8885.8
126	180	2,854	77008.944	7700.89
127	586	2,854	121442.96	12144.3
128	253	103,576	295618.78	29561.88
129	896	2,854	163193.33	16319.33
130	180	44,201	122496.01	12249.6
131	586	2,854	73881.395	7388.14
132	180	2,854	58824.334	5882.43
133	586	2,854	103265.11	10326.51
134	253	103,576	273748.22	27374.82
135	896	2,854	141322.77	14132.28
136	180	44,201	177709.02	17770.9
137	586	2,854	129101.16	12910.12
138	180	2,854	117245.39	11724.54
139	586	2,854	161686.17	16168.62
140	253	103,576	335861.98	33586.2
141	896	2,854	203436.53	20343.65
142	180	44,201	162732.45	16273.25
143	586	2,854	114124.6	11412.46
144	180	2,854	99067.538	9906.75
145	586	2,854	143501.56	14350.16
146	253	103,576	313991.42	31399.14
147	896	2,854	181565.97	18156.6
148	180	0	100687.99	10068.8
149	586	0	65905.247	6590.52
150	180	0	50692.727	5069.27
151	586	0	95133.506	9513.35
152	253	0	214803.06	21480.31
153	896	0	133035.71	13303.57
154	180	0	230803.45	23080.34
155	586	0	246464.3	24646.43
156	180	0	362652.29	36265.23
157	586	0	389580.43	38958.04
158	253	0	517370.39	51737.04
159	896	0	556041.09	55604.11
160	180	41,347	162636.3	16263.63
161	586	0	114028.44	11402.84
162	180	0	107125.52	10712.55
163	586	0	151566.3	15156.63
164	253	100,722	330637.09	33063.71

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
165	896	0	198211.64	19821.16
166	0	0	319268.59	31926.86
167	0	0	786219.93	78621.99
168	0	0	161877.96	16187.8
169	0	0	392391.89	39239.19
170	0	2,703	364141.49	36414.15
171	0	2,703	206750.86	20675.09
172	0	2,703	871326.04	87132.6
173	0	2,703	477498	47749.8
174	0	2,703	325990.55	32599.05
175	0	2,703	168599.92	16859.99
176	0	2,703	792941.89	79294.19
177	0	2,703	399113.85	39911.38
178	0	2,703	399227.56	39922.76
179	0	2,703	241836.93	24183.69
180	0	2,703	906405.35	90640.53
181	0	2,703	512577.31	51257.73
182	0	2,703	361069.86	36106.99
183	0	2,703	203685.99	20368.6
184	0	2,703	828027.96	82802.8
185	0	2,703	434199.92	43419.99
186	0	0	319268.59	31926.86
187	0	0	161877.96	16187.8
188	0	0	786219.93	78621.99
189	0	0	392391.89	39239.19
190	0	0	826001.54	82600.15
191	0	0	826001.54	82600.15
192	0	0	2063696.5	206369.65
193	0	0	2063696.5	206369.65
194	0	5,000	176654.23	17665.42
195	0	5,000	312436.21	31243.62
196	0	0	319268.59	31926.86
197	0	0	161877.96	16187.8
198	0	0	786219.93	78621.99
199	0	0	392391.89	39239.19
200	0	0	93735.934	9373.59
201	0	0	142634.74	14263.47
202	0	0	200704.32	20070.43
203	0	0	51093.253	5109.33
204	0	0	75274.313	7527.43
205	0	0	103989.44	10398.94

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
206	0	2,854	118451.36	11845.14
207	0	2,854	75801.917	7580.19
208	0	2,854	171924.17	17192.42
209	0	2,854	104570.49	10457.05
210	0	2,854	235287.23	23528.72
211	0	2,854	138572.36	13857.24
212	0	2,854	100833.41	10083.34
213	0	2,854	58190.728	5819.07
214	0	2,854	149732.22	14973.22
215	0	2,854	82371.789	8237.18
216	0	2,854	207801.79	20780.18
217	0	2,854	111086.92	11108.69
218	0	2,854	158687.8	15868.78
219	0	2,854	116045.12	11604.51
220	0	2,854	212167.37	21216.74
221	0	2,854	144806.94	14480.69
222	0	2,854	275530.43	27553.04
223	0	2,854	178808.8	17880.88
224	0	2,854	141076.61	14107.66
225	0	2,854	98427.173	9842.72
226	0	2,854	189968.67	18996.87
227	0	2,854	122614.99	12261.5
228	0	2,854	248045	24804.5
229	0	2,854	151323.37	15132.34
230	0	0	93735.934	9373.59
231	0	0	51093.253	5109.33
232	0	0	142634.74	14263.47
233	0	0	75274.313	7527.43
234	0	0	200704.32	20070.43
235	0	0	103989.44	10398.94
236	0	0	226428.81	22642.88
237	0	0	226428.81	22642.88
238	0	0	355882.67	35588.27
239	0	0	355882.67	35588.27
240	0	0	509666.59	50966.66
241	0	0	509666.59	50966.66
242	0	0	93735.934	9373.59
243	0	0	51093.253	5109.33
244	0	0	142634.74	14263.47
245	0	0	75274.313	7527.43
246	0	0	200704.32	20070.43

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
247	0	0	103989.44	10398.94
248	252	0	3721.311	372.13
249	576	0	5825.1232	582.51
250	1,818	0	12354.589	1235.46
251	5,172	0	31169.297	3116.93
252	252	2,370	52221.471	5222.15
253	1,818	2,370	60854.748	6085.47
254	576	2,370	111419.78	11141.98
255	5,172	2,370	136757.19	13675.72
256	252	2,370	9615.1502	961.52
257	1,818	2,370	18248.428	1824.84
258	576	2,370	11718.962	1171.9
259	5,172	2,370	37063.136	3706.31
260	252	2,370	83083.15	8308.32
261	1,818	2,370	91716.428	9171.64
262	576	2,370	142281.45	14228.15
263	5,172	2,370	167618.87	16761.89
264	252	2,370	40476.83	4047.68
265	1,818	2,370	49110.107	4911.01
266	576	2,370	42580.642	4258.06
267	5,172	2,370	67918.056	6791.81
268	252	0	134130.55	13413.05
269	1,818	0	142763.83	14276.38
270	576	0	376334.03	37633.4
271	5,172	0	401671.45	40167.14
272	252	0	891139.19	89113.92
273	1,818	0	899772.47	89977.25
274	576	0	2610420.1	261042.01
275	5,172	0	2635757.6	263575.75
276	1,818	5,000	100961.51	10096.15
277	5,172	5,000	136219.56	13621.96
278	252	0	3721.311	372.13
279	1,818	0	12354.589	1235.46
280	576	0	5825.1232	582.51
281	5,172	0	31169.297	3116.93
283	191	0	6589.3913	658.94
284	234	0	7123.5425	712.35
285	292	0	7802.5507	780.26
286	884	0	13238.125	1323.81
287	1,329	0	17631.036	1763.1
288	1,928	0	23501.85	2350.18

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
289	191	3,048	33793.334	3379.33
290	884	3,048	40442.067	4044.21
291	234	3,048	39272.109	3927.21
292	1,329	3,048	49779.603	4977.96
293	292	3,048	46411.247	4641.12
294	1,928	3,048	62102.787	6210.28
295	191	3,048	14169.316	1416.93
296	884	3,048	20818.05	2081.8
297	234	3,048	14703.467	1470.35
298	1,329	3,048	25210.961	2521.1
299	292	3,048	15382.476	1538.25
300	1,928	3,048	31081.775	3108.18
301	191	3,048	56753.714	5675.37
302	884	3,048	63402.448	6340.24
303	234	3,048	62225.731	6222.57
304	1,329	3,048	72733.225	7273.32
305	292	3,048	69364.869	6936.49
306	1,928	3,048	85063.168	8506.32
307	191	3,048	37129.697	3712.97
308	884	3,048	43778.43	4377.84
309	234	3,048	37657.089	3765.71
310	1,329	3,048	48164.583	4816.46
311	292	3,048	38342.856	3834.29
312	1,928	3,048	54042.155	5404.22
313	191	0	45594.841	4559.48
314	884	0	52243.574	5224.36
315	234	0	65085.506	6508.55
316	1,329	0	75592	7559.2
317	292	0	91261.075	9126.11
318	1,928	0	106953.61	10695.36
319	191	0	240324.59	24032.46
320	884	0	246974.33	24697.43
321	234	0	376424.34	37642.43
322	1,329	0	386931.83	38693.18
323	292	0	559424.44	55942.44
324	1,928	0	575116.98	57511.7
325	191	0	6589.3913	658.94
326	884	0	13238.125	1323.81
327	234	0	7123.5425	712.35
328	1,329	0	17631.036	1763.1
329	292	0	7802.5507	780.26

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
330	1,928	0	23501.85	2350.18
331	209	85,939	229469.38	22946.94
332	410	342,942	879871.53	87987.15
333	920	0	183061.3	18306.13
334	1,244	0	511270.62	51127.06
335	209	88,309	268140.5	26814.05
336	920	2,370	221732.41	22173.24
337	410	345,312	957923.46	95792.35
338	1,244	2,370	589322.55	58932.26
339	209	88,309	235363.22	23536.32
340	920	2,370	188955.14	18895.51
341	410	345,312	885765.36	88576.54
342	1,244	2,370	517164.46	51716.45
343	209	88,309	299002.18	29900.22
344	920	2,370	252594.09	25259.41
345	410	345,312	988785.13	98878.51
346	1,244	2,370	620184.23	62018.42
347	209	88,309	266224.9	26622.49
348	920	2,370	219816.82	21981.68
349	410	345,312	916627.04	91662.7
350	1,244	2,370	548026.14	54802.61
351	209	0	130144.43	13014.44
352	920	0	181601.35	18160.13
353	410	0	399225.07	39922.51
354	1,244	0	508648.12	50864.81
355	209	0	800329.86	80032.99
356	920	0	813111.65	81311.16
357	410	0	2345831	234583.1
358	1,244	0	2390914.9	239091.49
359	920	5,000	208741.71	20874.17
360	1,244	5,000	435293.95	43529.4
361	209	85,939	305843.69	30584.37
362	920	0	259435.61	25943.56
363	410	342,942	1017500.6	101750.06
364	1,244	0	648899.73	64889.97
365	194	0	13827.248	1382.72
366	191	50,244	140078.88	14007.89
367	278	15,133	55153.505	5515.35
368	671	0	24541.8	2454.18
369	671	0	88431.837	8843.18
370	1,035	0	126713.24	12671.32

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
371	194	3,048	38183.493	3818.35
372	671	3,048	48891.286	4889.13
373	191	53,292	167899	16789.9
374	671	3,048	116251.96	11625.2
375	278	18,181	87477.349	8747.73
376	1,035	3,048	159030.33	15903.03
377	194	3,048	21407.173	2140.72
378	671	3,048	32121.724	3212.17
379	191	53,292	147658.8	14765.88
380	671	3,048	96011.762	9601.18
381	278	18,181	62733.43	6273.34
382	1,035	3,048	134293.17	13429.32
383	194	3,048	61137.114	6113.71
384	671	3,048	71844.907	7184.49
385	191	53,292	190852.62	19085.26
386	671	3,048	139205.58	13920.56
387	278	18,181	110430.97	11043.1
388	1,035	3,048	181983.95	18198.39
389	194	3,048	44367.553	4436.76
390	671	3,048	55075.346	5507.53
391	191	53,292	170619.18	17061.92
392	671	3,048	118972.14	11897.21
393	278	18,181	85693.81	8569.38
394	1,035	3,048	157246.79	15724.68
395	194	0	36028.544	3602.85
396	671	0	46736.337	4673.63
397	191	0	144931.83	14493.18
398	671	0	87424.742	8742.47
399	278	0	177074.5	17707.45
400	1,035	0	125530.41	12553.04
401	194	0	232745.45	23274.54
402	671	0	222266.08	22226.61
403	191	0	339240.02	33924
404	671	0	347193.08	34719.31
405	278	0	501621.94	50162.19
406	1,035	0	515572.79	51557.28
407	194	0	60063.266	6006.33
408	671	0	70771.058	7077.11
409	191	50,244	194112.85	19411.28
410	671	0	142465.81	14246.58
411	278	15,133	118392.67	11839.27

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
412	1,035	0	189945.65	18994.57
413	0	0	307281.45	30728.14
414	0	0	885565.99	88556.6
415	0	0	155960.42	15596.04
416	0	0	441430.54	44143.05
417	0	2,370	355781.61	35578.16
418	0	2,370	204460.58	20446.06
419	0	2,370	991153.89	99115.39
420	0	2,370	547018.43	54701.84
421	0	2,370	313175.29	31317.53
422	0	2,370	161854.26	16185.43
423	0	2,370	891459.83	89145.98
424	0	2,370	447324.38	44732.44
425	0	2,370	386643.29	38664.33
426	0	2,370	235322.26	23532.23
427	0	2,370	1022015.6	102201.56
428	0	2,370	577880.11	57788.01
429	0	2,370	344036.96	34403.7
430	0	2,370	192715.94	19271.59
431	0	2,370	922321.51	92232.15
432	0	2,370	478186.06	47818.61
433	0	0	307281.45	30728.14
434	0	0	155960.42	15596.04
435	0	0	885565.99	88556.6
436	0	0	441430.54	44143.05
437	0	0	794241.98	79424.2
438	0	0	794241.98	79424.2
439	0	0	2327042.7	232704.27
440	0	0	2327042.7	232704.27
441	0	5,000	244567.34	24456.73
442	0	5,000	546480.81	54648.08
443	0	0	307281.45	30728.14
444	0	0	155960.42	15596.04
445	0	0	885565.99	88556.6
446	0	0	441430.54	44143.05
447	0	0	89556.564	8955.66
448	0	0	135300.7	13530.07
449	0	0	196794.92	19679.49
450	0	0	49698.601	4969.86
451	0	0	72326.879	7232.69
452	0	0	102729.59	10272.96

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
453	0	3,048	116760.51	11676.05
454	0	3,048	76902.543	7690.25
455	0	3,048	167449.27	16744.93
456	0	3,048	104475.45	10447.54
457	0	3,048	235396.86	23539.69
458	0	3,048	141331.53	14133.15
459	0	3,048	97136.489	9713.65
460	0	3,048	57278.526	5727.85
461	0	3,048	142880.63	14288.06
462	0	3,048	79906.804	7990.68
463	0	3,048	204374.85	20437.48
464	0	3,048	110309.51	11030.95
465	0	3,048	139714.13	13971.41
466	0	3,048	99856.165	9985.62
467	0	3,048	190409.65	19040.97
468	0	3,048	127435.83	12743.58
469	0	3,048	258350.48	25835.05
470	0	3,048	164291.91	16429.19
471	0	3,048	120090.11	12009.01
472	0	3,048	80238.906	8023.89
473	0	3,048	165841.01	16584.1
474	0	3,048	102867.18	10286.72
475	0	3,048	227328.47	22732.85
476	0	3,048	133269.89	13326.99
477	0	0	89556.564	8955.66
478	0	0	49698.601	4969.86
479	0	0	135300.7	13530.07
480	0	0	72326.879	7232.69
481	0	0	196794.92	19679.49
482	0	0	102729.59	10272.96
483	0	0	213157.92	21315.79
484	0	0	213157.92	21315.79
485	0	0	334259.03	33425.9
486	0	0	334259.03	33425.9
487	0	0	497090.88	49709.09
488	0		497090.88	49709.09
489	0	0	89556.564	8955.66
490	0	0	49698.601	4969.86
491	0	0	135300.7	13530.07
492	0	0	72326.879	7232.69
493	0	0	196794.92	19679.49

ID	1997 3 yr recurrent	1997 5 yr recurrent	Present value	Average annual Cost/operation
494	0	0	102729.59	10272.96

*Source: United States Environmental protection Agency, 2001
(**http://www.epa.gov/ost/guide/cafo/pdf/PPCostReport.pdf**)

Definitions of the variables listed in the above table
ID= Identification Number
Option=Technology option adopted in these operations
Region=Geographical location
# of facilities= Number of facilities in the category
Capital= Capital investments for waste management
Operart= Operation and management cost
3 year recurrent=Cost reoccurring in every 3 years
5 year recurrent= Cost reoccurring in every 5 years

Compliance cost data analysis

There are some outliers in the data. Remove outlier by hadimvo method in STATA programming.

hadimvo costphog,gen (odd)

Beginning number of observations:	489
Initially accepted:	2
Expand to (n+k+1)/2:	245
Expand, p = .05:	458
Outliers remaining:	31

The results say that observation 459 to 491 are outliers (odd) and therefore are dropped. We are interested in compliance costs per hog by size of operation, production region and the underlying technology options

Size 1=medium-sized operation
Size 2=large-sized operation
Region 1= Mid-Atlantic
Region 2= Mid-West
Technology options: technology 1 to technology 7 (Described in Chapter 6, section 6.4))

Appendix 6.3 Environmental compliance cost per pig by location, size of operation and technology options (descriptive statistics)

Region	Size	Option	Cost (Mean)	Range
1	1	1	0.31	0.002-0.58
1	1	2	0.37	0.36-1.23
1	1	3	1.36	0.10-5.39
1	1	4	1.25	0.08-6.38
1	1	5	1.08	0.01-5.89
1	1	6	2.12	0.72-6.47
1	1	7	0.74	0.18-2.62
2	1	1	0.46	0.01-1.34
2	1	2	0.16	0.01-0.37
2	1	3	1.15	0.03-4.04
2	1	4	1.46	1.36-6.24
2	1	5	1.16	0.01-5.00
2	1	6	1.18	0.16-2.63
2	1	7	0.52	0.10-1.66
1	2	1	0.47	0.05-1.31
1	2	2	1.45	0.03-4.41
1	2	3	2.41	0.02-5.85
1	2	4	2.43	0.49-6.90
1	2	5	1.90	(0.77)-7.04
1	2	6	-	-
1	2	7	1.59	0.10-4.09
2	2	1	0.16	0.003-0.88
2	2	2	0.42	.0023-1.65
2	2	3	0.77	0.009-4.07
2	2	4	0.85	0.02-2.85
2	2	5	1.16	0.009-5.86
2	2	6	-	-
2	2	7	0.63	0.014-3.17

Size 1=medium-sized operation, Size 2=large-sized operation
Region 1= Mid-Atlantic, Region 2= Mid-West
Technology options: technology 1 to technology 7

Appendix 6.4 Environmental compliance costs by states and regions

State	EPA Region	Region (this study)	Compliance costs per hog		
			Small	Medium	Large
AL	South	South	0.31	0.81	1.05
AR	South	South	0.31	0.81	1.05
AZ	Central	West	0.31	0.81	1.05
CA	Pacific	West	0.31	0.81	1.05
CO	Central	West	0.31	0.81	1.05
CT	Mid-Atlantic	Northeast	0.39	1.95	1.13
FL	South	South	0.31	0.81	1.05
GA	South	South	0.31	0.81	1.05
IA	Midwest	W. Corn Belt	0.31	0.81	1.05
ID	Central	West	0.31	0.81	1.05
IL	Midwest	E. Corn Belt	0.31	0.81	1.05
KS	Midwest	W. Corn Belt	0.31	0.81	1.05
KY	Mid-Atlantic	South	0.39	1.95	1.13
LA	South	South	0.31	0.81	1.05
MA	Mid-Atlantic	Northeast	0.39	1.95	1.13
MD	Mid-Atlantic	South	0.39	1.95	1.13
ME	Mid-Atlantic	Northeast	0.39	1.95	1.13
MI	Midwest	E. Corn Belt	0.31	0.81	1.05
MN	Midwest	E. Corn Belt	0.31	0.81	1.05
MO	Midwest	South	0.31	0.81	1.05
MS	South	South	0.31	0.81	1.05
MT	Central	West	0.31	0.81	1.05
NC	Mid-Atlantic	South	0.39	1.95	1.13
ND	Midwest	W. Corn Belt	0.31	0.81	1.05
NE	Midwest	W. Corn Belt	0.31	0.81	1.05
NJ	Mid-Atlantic	Northeast	0.39	1.95	1.13
NJ	Mid-Atlantic	Northeast	0.39	1.95	1.13
NM	Central	West	0.31	0.81	1.05
NV	Central	West	0.31	0.81	1.05
NY	Mid-Atlantic	Northeast	0.39	1.95	1.13
OH	Midwest	E. Corn Belt	0.31	0.81	1.05
OK	Central	South	0.31	0.81	1.05
OR	Pacific	West	0.31	0.81	1.05
PA	Mid-Atlantic	Northeast	0.39	1.95	1.13
SC	South	South	0.31	0.81	1.05
SD	Midwest	W. Corn Belt	0.31	0.81	1.05
TN	Mid-Atlantic	South	0.39	1.95	1.13
TX	Central	South	0.31	0.81	1.05
UT	Central	W. Corn Belt	0.31	0.81	1.05

State	EPA Region	Region (this study)	Compliance costs per hog		
			Small	Medium	Large
VA	Mid-Atlantic	South	0.39	1.95	1.13
WA	Pacific	West	0.31	0.81	1.05
WI	Midwest	E. Corn Belt	0.31	0.81	1.05
WV	Mid-Atlantic	South	0.39	1.95	1.13
WY	Central	West	0.31	0.81	1.05

Appendix 7

Appendix 7.1 Shipping cost as a function of volume and distance

Truck Transportation	Dollar (million)	Tons (1000 Tons)	Average mile per shipment	$/cwt/mile
Less than 50 lb	189,451	9,546	111	8.13
50 to 99 lb	102,809	9,264	127	3.97
100 to 499 lb	499,753	70,727	173	1.86
500 to 749lb	182,787	36,230	204	1.12
750 to 999 lb	135.940	30,553	206	0.98
1000 to 9,999 lb	1,368,634	544,479	205	0.56
10,000 to 49,999 lb	2,121,594	3,957,795	167	0.15
50,000 to 99,999 lb	296,824	2,162,393	74	0.08
100,000 lb or more	83,741	879,688	86	0.05
Less than 50 miles	1,729,620	5,212,913	25	0.60
50 to 99 miles	500,926	866,735	50	0.53
100 to 249 miles	835.764	770,562	125	0.39
250 to 499 miles	709,017	415,852	250	0.31
500 to 749 miles or more	431,281	191,915	375	0.27
750 to 999 miles	259,706	103,369	500	0.23
1000 to 1499 miles	239,934	79,277	750	0.18
1500 to 1999 miles	149,645	37,500	1,000	0.18
2000 miles or more	125,637	22,552	1,400	0.18
Average Shipment cost:				
Live animals	6,173	5,922	272	0.17
Meat	153,843	71,952	136	0.71

Source: Transportation commodity flow survey, U.S. Census Bureau, 1997 Economic Census.

Appendix 7.2 Minimizing total cost of production, processing and transportation

```
OPTION LIMCOL = 0, LIMROW = 0;
SET PDREGION  Pooled production regions
  /  AL,AR,AZ,CA,CO,FL,GA,IA,ID,IL,IN,KS,KY,LA.MD,MI,MN.MS,MO,MT,NE,NV,NM,NY,
  NC,ND,OH,OK,ORG,PA,SC,SD,TN,TX,UT,VA,WA,WI,WY,NH   /;
SET TYPE Production types within regions
  /   SMALL, MEDIUM, LARGE   /;
SET PCREGION Processing regions
  /   AR,CA,IA,ID,IL,IN,KS,KY,MN.MO.MS,NC,ND,NE,OH,OK,ORg,PA,SC,SD,TN, TX,VA,WI /;
SET MARKET Markets
  /  AL,AR,AZ,CA,CO,CT,DC,DE,FL,GA,IA,ID,IL,IN,KS,KY,LA,MA,MD,ME,MI,
   MN,MO,MS,MT,NC,ND,NE,NH,NJ,NM.NV,NY,OH,OK,ORg,PA,RI,SC,SD,TN,
   TX.UT,VA,VT,WA,WI,WV,WY, EX/  ;
  SET MKT (MARKET)
  /AL,AR,AZ,CA,CO,CT,DC,DE,FL,GA,IA,ID,IL,IN,KS,KY.LA,MA,MD,ME,MI,
   MN,MO,MS,MT,NC,ND,NE,NH,NJ,NM,NV,NY,OH,OK,ORg,PA,RI,SC,SD,TN,
   TX,UT,VA,VT,WA,WI.WV,WY/;
   MKT (MARKET)=YES;
   MKT  ('EX')=NO;
TABLE DIST1 (PDREGION,PCREGION) IN MILES FROM PRODUCTION TO PROCESSING
REGION
TABLE DIST2(PCREGION,MARKET) IN MILES FROM PROCESSING TO MARKET
TABLE PRODCOST(PDREGION,TYPE) Production cost $1000 per 1000 head
```

	SMALL	MEDIUM	LARGE
AL	128.77	105.22	96.48
AR	126.43	104.38	93.78
AZ	158.06	128.66	114.92
CA	160.49	130.92	117.14
CO	154.99	125.76	112.01
FL	131.87	109.46	98.82
GA	132.39	111.04	99.37
IA	138.94	113.14	100.20
ID	161.83	132.19	118.43
IL	134.74	113.77	101.01
IN	134.68	113.70	100.94
KS	143.18	117.10	104.15
KY	125.34	103.36	92.77

LA	128.17	107.09	95.44
MD	129.37	107.13	96.51
MI	133.04	112.20	99.46
MN	132.14	111.26	98.48
MO	124.78	103.88	92.22
MS	127.18	105.10	94.53
MT	155.03	125.83	112.11
NC	130.07	107.80	97.21
ND	137.63	111.88	98.93
NE	139.41	113.60	100.67
NH	147.66	127.65	118.26
NM	158.01	128.89	115.42
NV	155.87	126.60	112.86
NY	148.02	129.12	118.72
OH	134.29	113.41	100.68
OK	130.04	107.77	97.16
Org	176.79	146.03	132.39
PA	148.52	129.64	119.29
SC	131.76	110.47	98.84
SD	137.18	111.56	98.65
TN	128.11	105.95	95.35
TX	129.54	108.38	96.74
UT	160.49	130.96	117.22
VA	129.16	108.00	96.34
WA	161.11	131.47	117.66
WI	132.72	112.02	99.33
WY	155.97	126.73	113.03 ;

TABLE PRODCAP(PDREGION,TYPE) Production capacity (1000 head)

	SMALL	MEDIUM	LARGE
AL	74.952	74.952	190.787
AZ	78.195	78.195	199.039
AR	111.5	466.275	435.866
CA	72.097	72.097	183.521
CO	295.611	295.611	752.465
FL	22.767	22.767	57.953
GA	227.716	326.723	435.631
ID	15.004	15.004	38.192

IL	2384.435	3034.735	24.39
IN	1861.041	2521.409	1620.906
IA	6444.004	9190.628	5493.249
KS	735.594	676.747	1530.036
KY	337.17	388.256	296.301
LA	12.678	12.678	32.271
MD	40.5	40.5	103.091
MI	420.916	670.348	467.684
MN	2427.565	3236.753	2427.565
MS	90.296	90.296	229.844
MO	1260.459	1375.046	3093.854
MT	52.254	52.254	133.01
NE	2304.486	1854.831	1461.381
NV	3.938	3.938	10.024
NM	1.956	1.956	4.977
NY	25.993	25.993	66.163
NC	294.721	3831.379	10609.974
ND	64.36	64.36	163.826
OH	1511.378	1096.49	355.618
OK	176.845	353.689	2416.874
Org	13.947	13.947	35.501
PA	374.617	638.236	374.617
SC	106.567	106.567	271.263
SD	847.39	533.542	711.389
TN	132.707	132.707	337.799
TX	182.438	182.438	464.387
UT	55.582	55.582	141.483
VA	122.706	122.706	312.344
WA	11.019	11.019	28.049
WI	794.449	539.09	846.519
WY	49.676	49.676	126.447
NH	9.285	9.285	23.635;

```
PARAMETER PROCCOST(PCREGION) Processing cost $1000 per 1000 HOGS
*value of by-products ($7.625 per hog)is subtracted from the processing cost
/   AR      18.445
    CA      18.025
    IA      17.915
    ID      17.625
    IL      17.455
    IN      18.285
    KS      17.995
    KY      17.705
    MN      18.545
    MO      16.755
    MS      16.115
    NC      16.915
    ND      17.335
    NE      17.875
    OH      20.505
    OK      17.635
    Org     18.875
    PA      18.965
    SC      17.285
    SD      17.875
    TN      17.505
    TX      17.475
    VA      18.235
    WI      19.585 /  ;
PARAMETER PROCCAP(PCREGION) Processing capacity (1000 head)
/   AR      351
    CA      1872
    IA      30667
    ID      169
    IL      8502
    IN      7280
    KS      416
    KY      2145
    MN      8242
    MO      4368
```

MS	1690
NC	8320
ND	239.2
NE	7150
OH	962
OK	2080
OR	143
PA	2028
SC	780
SD	3900
TN	520
TX	208
VA	4758
WI	650 / ;

PARAMETER DEMAND(MARKET) Market demand (million lbs)

/AL	230.32
AZ	179.85
AR	134.56
CA	1272.86
CO	153.74
CT	124.47
DE	28.19
DC	39.19
FL	782.80
GA	399.10
ID	47.83
IL	657.51
IN	321.45
IA	156.25
KS	139.48
KY	208.33
LA	231.98
ME	47.42
MD	271.51
MA	232.88
MI	535.66

```
     MN         256.61
     MS         145.64
     MO         288.26
     MT         34.72
     NE         91.72
     NV         46.35
     NH          63.06
     NJ         306.70
     NM         68.07
     NY         690.89
     NC         396.04
     ND         35.09
     OH         613.77
     OK         176.69
     ORG        128.13
     PA         457.57
     RI         37.58
     SC         202.06
     SD         40.01
     TN         286.74
     TX         1031.88
     UT         81.60
     VT         22.42
     VA         358.94
     WA         221.41
     WV         96.79
     WI         284.66
     WY         18.97
     EX         784.35   / ;
SCALAR TRATE1   TRANSPORTATION RATE PER 1000 LIVE HOGS PER MILE IN  $1000
/ 0.125/ ;
SCALAR TRATE2 TRANSPORTAION RATE PER 1000 CWT PORK IN $1000
/ 0.05/ ;
SCALAR CF1 Conversion factor live wt to processed pork (61 percent)
  /   0.61  / ;
SCALAR CF2 Conversion factor CWT to head (1 hog= 250 pounds)
  /  2.5  / ;
```

```
SCALAR CF3 conversion factor million pounds to 1000 cwt
 / 0.1 /;
VARIABLES
  LIVEPROD (PDREGION, TYPE) Total production of hogs by type and region (1000 head)
  LIVESHIP (PDREGION, PCREGION) shipment of live hogs (1000 head)
  TOTALPROC (PCREGION) Hog slaughtered (1000 hogs)
  PORKSHIP (PCREGION, MARKET) shipment of pork (1000 cwt processed pork)
  TOTCOST   total cost in 1000 of dollars ;
POSITIVE VARIABLES
        LIVEPROD,
        LIVESHIP,
        TOTALPROC,
        PORKSHIP ;
PARAMETER TC1 (PDREGION, PCREGION) Cost of transporting 1000 hogs from production region to
processing region (1000's of $);
TC1 (PDREGION, PCREGION) = (TRATE1*DIST1 (PDREGION, PCREGION));
PARAMETER TC2 (PCREGION,MARKET) Cost of transporting 1000 CWT pork from processing region
to market (1000 of $);
TC2 (PCREGION, MARKET) = (TRATE2*DIST2 (PCREGION, MARKET));
EQUATIONS
        PRODUCTCAP (PDREGION, TYPE) production capacity cannot be exceeded
        POOL (PDREGION) total hogs available for shipment for each production region
        PROCESSCAP (PCREGION) processing capacity cannot be exceeded
        CONVERT (PCREGION) convert head to cwt
        PROCESS (PCREGION) convert live hogs to pork
        MEETDEM (MARKET) market demand must be met
        OBJECTIVE objective function;
PRODUCTCAP (PDREGION, TYPE).. LIVEPROD (PDREGION,TYPE) =L=
PRODCAP(PDREGION,TYPE);
POOL(PDREGION).. SUM (TYPE,LIVEPROD(PDREGION,TYPE)) =G=
SUM(PCREGION,LIVESHIP(PDREGION,PCREGION));
CONVERT (PCREGION).. SUM (PDREGION, LIVESHIP(PDREGION,PCREGION))
=G=TOTALPROC(PCREGION);
PROCESSCAP(PCREGION).. TOTALPROC (PCREGION) =L= PROCCAP (PCREGION);
PROCESS (PCREGION).. CF1*CF2* TOTALPROC (PCREGION) =G= SUM (MARKET, PORKSHIP
(PCREGION, MARKET));
```

```
MEETDEM (MARKET).. CF3*SUM (PCREGION, PORKSHIP (PCREGION, MARKET)) =G=
DEMAND (MARKET);
OBJECTIVE..
SUM((PDREGION,TYPE),LIVEPROD(PDREGION,TYPE)*PRODCOST(PDREGION,TYPE))
        +
SUM((PDREGION,PCREGION),LIVESHIP(PDREGION,PCREGION)*TC1(PDREGION,PCREGION))
        + SUM(PCREGION,TOTALPROC(PCREGION)*PROCCOST(PCREGION))
        +
SUM((PCREGION,MARKET),PORKSHIP(PCREGION,MARKET)*TC2(PCREGION,MARKET))
        =E= TOTCOST;
MODEL TRANSHIP
  /   ALL   /;
SOLVE TRANSHIP USING LP MINIMIZING TOTCOST;
DISPLAY
 TC1, TC2, LIVEPROD.L, LIVESHIP.L, TOTALPROC.L, PORKSHIP.L, TOTCOST.L;
SCALAR C2 flexibility of demand for pork relative to pork price
 /   -0.7804   / ;
SCALAR C1 shift parameter for demand (included all factors except pork price)
/ 0.996  / ;
PARAMETER PRICE (MARKET) calculated iterated price;
PRICE (MARKET) = 2.31;
*/Retail price of pork in 1997 was $2.31.  The model starts with this price in the first iteration. In the
second iteration it will take the shadow price of each market as market price and re-estimates quantity
demanded. The process iterates 20 times/*
SET N /1*20/;
SCALAR dif /1/;
PARAMETER balance  (N, *);
LOOP (N$(dif > 0.001),
DEMAND (MARKET) = C1*DEMAND (MARKET)*(((1.75*MEETDEM.M (MARKET)/1000) / PRICE
(MARKET))**C2);
PRICE (MARKET) = 1.75*MEETDEM.M (MARKET)/1000;
*75% markup assumed
SOLVE TRANSHIP USING LP MINIMIZING TOTCOST;
  dif = sum(MARKET,ABS(PRICE(MARKET) - MEETDEM.M(MARKET)));
  balance (N,"DIFF PR") = dif; ) ;
DISPLAY balance, PRICE, DEMAND,
 LIVEPROD.L, LIVESHIP.L, TOTALPROC.L, PORKSHIP.L, TOTCOST.L;
```

Demand estimation iteration

From Chapter Four, pork demand is estimated by the equation

$$\bar{s}_i \Delta \ln q_i = \Gamma_i + \sum_{j=1}^{n} \gamma_{ij} \Delta \ln P_j + \beta_i DQ$$

In 1997, moving average of pork share = 0.2443, change in prices of beef, chicken and fish are 0, –0.02 and 0 respectively, DQ= -0.0013. Parameters for the variables are listed in Table 4.3

$\Delta \ln Q_t = C_1 + C_2 \Delta \ln P_t$ .... (a)

Where $\Delta \ln Q_t = Change$ in per capita pork consumption in time t

C_1 = Other component of demand equation, related to cross price and income

C_2 = Coefficient related to pork price

$\Delta \ln P$ = Change in pork price

Simplification of equation (a) with little algebra:

$$\ln Q_t - \ln Q_{t-1} = C_1 + C_2(\ln P_t - \ln P_{t-1})$$

$$\ln Q_t / \ln Q_{t-1} = C_1 + C_2(\ln P_t / \ln P_{t-1})$$

$$(Q_t / Q_{t-1}) = e(C_1) * e\{C_2(\ln P_t / \ln P_{t-1})\}$$

$$(Q_t / Q_{t-1}) = e * (C_1) * \{(P_t / P_{t-1})\}^{C_2}$$

$$Q_t = 0.996 * \{(P_t / P_{t-1})\}^{-0.78} * Q_{t-1}$$

Appendix 8

Appendix 8.1 Production levels and shadow prices in optimal solution (1,000 hogs)

State	Production level			Shadow	State	Production level			Shadow
		Level	Upper	Price		Size	Level	Upper	Price
AL	Small	20.328	74.952	0	NE	Small	2304.486	2304.486	-18.424
AL	Medium	74.952	74.952	-23.55	NE	Medium	1854.831	1854.831	-44.234
AL	Large	190.787	190.787	-32.29	NE	Large	1461.381	1461.381	-57.164
AR	Small	0	111.5	0	NV	Small	3.938	3.938	-79.14
AR	Medium	435.134	466.275	0	NV	Medium	3.938	3.938	-108.41
AR	Large	435.866	435.866	-10.6	NV	Large	10.024	10.024	-122.15
AZ	Small	78.195	78.195	-1.45	NM	Small	0	1.956	0
AZ	Medium	78.195	78.195	-30.85	NM	Medium	1.956	1.956	-7.37
AZ	Large	199.039	199.039	-44.59	NM	Large	4.977	4.977	-20.84
CA	Small	72.097	72.097	-59.895	NY	Small	25.993	25.993	-14.28
CA	Medium	72.097	72.097	-89.465	NY	Medium	25.993	25.993	-33.18
CA	Large	183.521	183.521	-103.245	NY	Large	66.163	66.163	-43.58
CO	Small	0	295.611	0	NC	Small	0	294.721	0
CO	Medium	0	295.611	0	NC	Medium	2650.73	3831.379	0
CO	Large	445.919	752.465	0	NC	Large	10609.97	10609.97	-10.59
FL	Small	0	22.767	0	ND	Small	11.014	64.36	0
FL	Medium	0	22.767	0	ND	Medium	64.36	64.36	-25.75
FL	Large	0	57.953	0	ND	Large	163.826	163.826	-38.7
GA	Small	0	227.716	0	OH	Small	771.777	1511.378	0
GA	Medium	0	326.723	0	OH	Medium	1096.49	1096.49	-20.88
GA	Large	435.631	435.631	-4.9	OH	Large	355.618	355.618	-33.61
IA	Small	6444.004	6444.004	-3.894	OK	Small	0	176.845	0
IA	Medium	9190.628	9190.628	-29.694	OK	Medium	0	353.689	0
IA	Large	5493.249	5493.249	-42.634	OK	Large	2416.874	2416.874	-1.115
ID	Small	0	15.004	0	OR	Small	13.947	-8.07	0
ID	Medium	15.004	15.004	-3.67	OR	Medium	13.947	-38.83	0
ID	Large	38.192	38.192	-17.43	OR	Large	35.501	-52.47	0
IL	Small	2384.435	2384.435	-22.859	PA	Small	374.617	374.617	-9.905
IL	Medium	3034.735	3034.735	-43.829	PA	Medium	638.236	638.236	-28.785
IL	Large	24.39	24.39	-56.589	PA	Large	374.617	374.617	-39.135
IN	Small	1861.041	1861.041	-2.61	SC	Small	0	106.567	0
IN	Medium	2521.409	2521.409	-23.59	SC	Medium	106.567	106.567	-11.705
IN	Large	1620.906	1620.906	-36.35	SC	Large	271.263	271.263	-23.335
KS	Small	0	735.594	0	SD	Small	847.39	847.39	-23.029
KS	Medium	0	676.747	0	SD	Medium	533.542	533.542	-48.649
KS	Large	79.126	1530.036	0	SD	Large	711.389	711.389	-61.559
KY	Small	337.17	337.17	-20.325	TN	Small	132.707	132.707	-1.785
KY	Medium	388.256	388.256	-42.305	TN	Medium	132.707	132.707	-23.945
KY	Large	296.301	296.301	-52.895	TN	Large	337.799	337.799	-34.545

State	Production level			Shadow	State	Production level			Shadow
		Level	Upper	Price		Size	Level	Upper	Price
LA	Small	0	12.678	0	TX	Small	0	182.438	0
LA	Medium	12.678	12.678	-1.055	TX	Medium	0	182.438	0
LA	Large	32.271	32.271	-12.705	TX	Large	208	464.387	0
MD	Small	40.5	40.5	-13.555	UT	Small	0	55.582	0
MD	Medium	40.5	40.5	-35.795	UT	Medium	55.582	55.582	-23.675
MD	Large	103.091	103.091	-46.415	UT	Large	141.483	141.483	-37.415
MI	Small	0	420.916	0	VA	Small	122.706	122.706	-4.515
MI	Medium	670.348	670.348	-16.09	VA	Medium	122.706	122.706	-25.675
MI	Large	467.684	467.684	-28.83	VA	Large	312.344	312.344	-37.335
MN	Small	2427.565	2427.565	-9.694	WA	Small	11.019	11.019	-3.75
MN	Medium	3236.753	3236.753	-30.574	WA	Medium	11.019	11.019	-33.39
MN	Large	2427.565	2427.565	-43.354	WA	Large	28.049	28.049	-47.2
MS	Small	0	90.296	0	WI	Small	0	794.449	0
MS	Medium	90.296	90.296	-20.42	WI	Medium	539.09	539.09	-12.439
MS	Large	229.844	229.844	-30.99	WI	Large	846.519	846.519	-25.129
MO	Small	1260.459	1260.459	-27.819	WY	Small	0	49.676	0
MO	Medium	1375.046	1375.046	-48.719	WY	Medium	0	49.676	0
MO	Large	3093.854	3093.854	-60.379	WY	Large	126.447	126.447	-1.58
MT	Small	0	52.254	0	NH	Small	0	9.285	0
MT	Medium	0	52.254	0	NH	Medium	0	9.285	0
MT	Large	18.875	133.01	0	NH	Large	0	23.635	0

Appendix 8.2 Pork processing locations and destinations (pork flow in solution)

Processing Region	Markets (Mil pounds)						
	AL	AR	AZ	CA	CO	FL	
AR		479.383					
CA				1658.264			
IL	903.049					3057.622	
KY						2317.468	
MN				10216.24			
MS	1204.318						
NC						193.701	
OK			1583.729				
SC						1189.5	
SD					1463.506		
TN		793					
	GA	IA	ID	IL	IN	KS	
IA		1648.837		6682.970		1279.548	
ID			257.725				
IL	3672.312						
IN					3198.258		
MO						137.070	
NE			151.058				
	KY	LA	MD	MI	MN	MS	
AR		67.495					
IA				5144.74	275.679		
IN	1965.540						
KY	45.607						
MN					2656.628		
MS						1372.932	
NE		1992.937					
NC			2130.786				
VA			349.682				
	MO	MT	NE	NV	NM	NY	
CA				401.951			
IA						4358.851	
MO	2943.205						
NE			944.223				
OK					638.915		
PA						1385.314	
SD		328.841					
VA						436.608	
	NC	ND	OH	OK	OR	PA	
IN			5938.202				
NE				1689.215			
NC	3719.667					4148.480	
ND		348.250			16.53		

OR					218.075		
SD					835.666		
	SC	**SD**	**TN**	**TX**	**UT**	**VA**	
IL			2744.518				
KS				634.4			
MO				3580.924			
NE				4071.724	729.158		
NC	1838.792						
OK				949.356			
SD		408.743					
TX				317.2			
VA						3385.323	
	WA	**WI**	**WY**	**NH**	**CT**	**DC**	
IA		1899.642					
NE			180.642		1112.877		
NC						22.951	
PA				545.529			
SD	1840.671						
WI		991.25					
	DE	**MA**	**ME**	**NJ**	**RI**	**VT**	**WV**
NC	260.35				327.861		
OH		1467.05					
PA		562.446	404.586			194.825	
VA				2765.875			
KY							908.050

Appendix 8.3 Pig flow from production locations to processing (1,000 hogs)

Production Region	Processing region					
	AR	**CA**	**IA**	**ID**	**IL**	**IN**
AR	351					
AZ		355.429				
CA		327.715				
IA			13429.36			
ID				23.678		
IL					5443.56	
IN						4880.083
MI						1138.032
MO					1361.359	
MT				18.875		
NV		17.90				
NM		6.933				
OH						1261.885
UT		197.065				
WY				126.447		

	KS	KY	MN	MS	MO	NE
AL				286.067		
GA				435.631		
IA			219.072			1529.302
IN		1123.273				
KS	79.126					
KY		1021.727				
LA				44.949		
MN			6985.891			
MS				320.14		
MO					4368	
NE						5620.698
OK	336.874					
TN				603.213		
WI			735.609			
	NC	**ND**	**OH**	**OK**	**OR**	**PA**
ID					29.518	
MD						184.091
NY						118.149
NC	8320					314.655
ND		239.2				
OH			962			
OK				2080		
OR					63.395	
PA						1387.47
WA					50.087	
	SC	**SD**	**TN**	**TX**	**VA**	**WI**
AR			520			
MN		1071.992				
NC	402.17				4200.244	
SC	377.83					
SD		2092.321				
TX				208		
VA					557.756	
WI						650

Appendix 8.4 Production levels in the base and projected model (1,000 hogs)

Production Region	1997 Base Model	2010 Scenario (Sensitivity)	Change in Production level	Change (%)
FL	0	161	161	Inf
N. England	0	9	9	Inf
NM	7	2703	2696	38517
KS	79	4414	4335	5487
NV	18	521	503	2793
NY	118	2028	1910	1619
MT	19	266	247	1300
OR	63	429	366	581
MS	320	1781	1461	457
SC	378	2092	1714	454
AZ	355	1804	1449	408
IN	6003	23083	17080	285
GA	436	1525	1089	250
UT	197	435	238	121
OH	2224	4834	2610	117
TN	603	1294	691	115
IL	5444	10146	4702	86
MD	184	328	144	78
CA	328	583	255	78
MN	8092	13756	5664	70
ID	53	76	23	44
KY	1022	1369	347	34
AL	286	382	96	33
NE	5621	7150	1529	27
MI	1138	1138	0	0
TX	208	208	0	0
PA	1387	862	-525	-38
SD	2092	1074	-1018	-49
AR	871	398	-473	-54
NC	13261	5621	-7640	-58
IA	21128	8503	-12625	-60
WY	126	47	-79	-62
WI	1386	402	-984	-71
VA & WV	558	89	-469	-84
ND	239	32	-207	-87
MO	5729	731	-4998	-87
OK	2417	99	-2318	-96
CO	446	0	-446	-100
LA	45	0	-45	-100
WA	50	0	-50	-100

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