Factors affecting regional shifts of U.S pork production

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Factors affecting regional shifts in pork production

Abstract: The U.S. pork industry in the recent past has transferred into fewer, larger and specialized operations. Inputs availability, developments of transportation systems, technological changes, government regulations and the consumer preferences have been driving changes in the pork industry. Spatial inequalities affect the competitiveness of one region relative to other regions. This paper is focused on how these forces affect the regional competitiveness of the pork industry and movement towards larger, specialized and geographically concentrated operations. 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 although raising hogs in larger operations is less costly, small-sized operations in some regions still need to produce hogs to meet the demand for consumption and export. 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 greater role in location of production and processing. Pork operations tend to locate near the populous areas to meet the consumer demand and to minimize the transportation cost. Pressures from current and future environment 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. The current trend of fewer and larger production units and location change in the pork industry will continue.

Introduction:

The U.S. pork industry is an important value-added sector in the agricultural economy. The 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). 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.

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 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.

Objectives and research questions:

1. To analyze recent regional shifts in the U.S. pork industry.

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

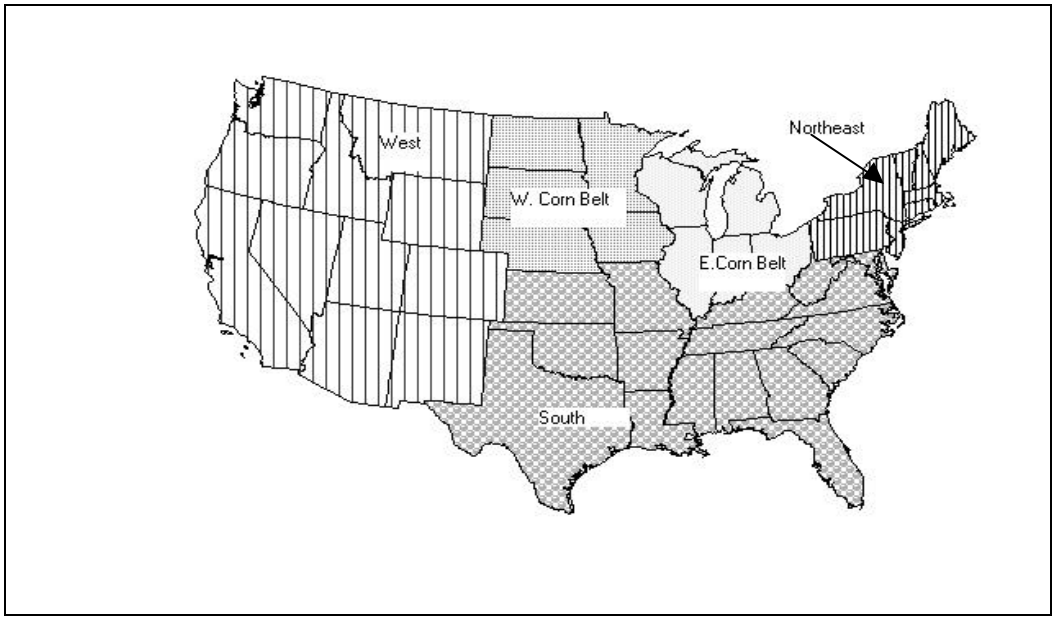
2. To predict the future locations of pork production and processing operations.

- What factors influence location of pork production and processing?
- What are the best locations and levels of production and processing based on the factors influencing supply and demand?

Trend of pork production in U.S.:

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 1: Demarcation of geographical regions[1]



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).

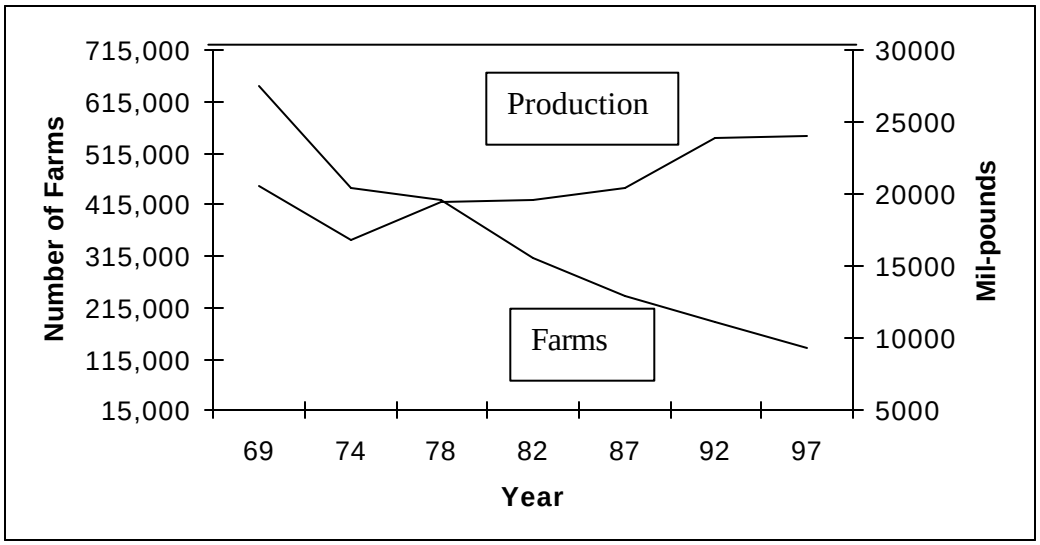
Historically, hogs have been raised on farms that produced corn and other crops. In the past three recent decades, farming has become more specialized. The size of production

1 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)

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. The share of hog slaughter rose from 34 percent in the top four firms in 1980 to 56 percent in 1998 (Carstensen, 2001).

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. The increasing trend of production and decreasing trend of the number of farms can be represented from the following figure.

Figure 2: Trends in pork production and number of pig farms in the U.S.



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

Increasing geographic concentration of production:

Concentration[2] in hog industry refers to the inequality in the pork production among different geographic regions, states, and counties. Recently, 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). There has been a major growth in pork production in the South, particularly in North Carolina over time. In some counties, pork production has increased dramatically. Out of the top 25 hog producing counties, 11 counties are from Iowa and eight counties are from North Carolina. This gives some insights that 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.

Factors affecting locations of production:

Factors that make a location desirable for hog production over other locations cause regional shifts and contribute to the geographic concentration of production. Feed costs and production restrictions for example 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.

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

1. **Technological changes**: 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 unit weight gain. 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 cost minimization are the primary factors in determining the location (Healy and Ilbery, 1990). Technological development in animal health and nutrition have made it possible to reduce the outbreak and spread of diseases even with very large number of hogs confined in one location.

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. 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. In some cases, 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 also demand for land use would increase in order to spread the manure generated by the hog industry.

4. Economic options: Agriculture may 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 may be the result of fewer economic alternatives for the farmers in the Southern region. The pork industry has contributed economic benefits in the forms of employment, farm income, and tax revenues.

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 the site specific, least mobile resource is one of the important determinants in the location of hog operations.

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).

7. Consumer demand: The role of consumer demand on structural change of the hog industry is debatable. 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 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.

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.

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.

Transshipment model to optimize the production and processing of pork:

Many components described above are combined to minimize the total cost of production, processing and distribution of pork. The costs of production including the environmental compliance costs are included enterprise budgeting (Appendix 7). The processing capacity in each region is the sum of the existing capacities of pork processing plants (Appendix 9). The maximum quantity of pork a region could produce is calculated on the basis of existing production (Adhikari, 2002). 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 (Appendix 3). 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. An interregional mathematical programming model is constructed for the analysis.

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'.

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,……,n; j=1,2,3,4……,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

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

Subject to

$$P_i - \sum_{i=1}^{n} Q_{ij} \geq 0 \quad (2)$$

$$Q_i + \sum_{i=1}^{n} Q_{ij} \leq P_i \quad (3)$$

$$X_i + \sum_{i=1}^{n} X_{ij} \geq D_i \quad (4)$$

$$P_i, Q_i, X_i, X_{ij} \geq 0 \quad (5)$$

Where,

Equation 1 is the objective function that we are minimizing.

Equation 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 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 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 5 implies no negative production, shipment and consumption.

The mathematical model described in equation 1 to 5, now can be solved to find the optimal solution by Lagrangean method[3]. 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

3 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.

- 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.
- 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.

Transshipment model set up:

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".

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, 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 Appendix 3. 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. Appendix 3 shows the number of hogs sold and the number hogs actually slaughtered.

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 (Appendix 9). 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. 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 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.

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. Product movement between regions creates a derived demand[4] for transport services. 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

4 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).

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, no quantity and time (faster delivery vs. slower delivery) discounts, are made to make the model simple. Although we recognize the non-linearity property of 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.

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.

Results and discussion

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.

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 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 10), 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. 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 1.

Table 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
VA & WV	Toga	123	123	312	558	558	0	-4.52
WA	Grant	11	11	28	50	50	0	-3.75

Production region	Reference point	Operation size and level of production				Upper limit	Slack	Highest Shadow Price $
		Small	Medium	Large	Total			
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.

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 2 indicates the pattern/direction of live hog flow from production regions (origins) to processing regions (destinations).

Table 2: Pattern of pig flow in the optimum solution (1,000 Head)

Processing region*	Source of pig (Production region/state)	Processing region	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 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

Region	Location of Processing	Total Processed	Processing Capacity	Slack	Shadow price* $/hog
ND	Minot	239.2	239	-0.2	-44.16
NE	Fremont	7150	7,150	0	-6.95
OH	Sandusky	962	962	0	-45.15
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 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 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 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 3 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 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.

Pork demand and shadow prices: Demand for pork was estimated for each market by Adhikari (2002). 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. 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 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

Table 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 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. 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[5] 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.

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.

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

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.

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, capacity constraints, and transportation costs. All these parameters were either estimated or compiled using the secondary data from various sources. 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.

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 increase in pork demand, expansion of pork production, expansions of pork processing capacities, and increase in regulatory compliance costs.

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. The 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.

Expansion of production: In recent past decades, the number of hog-raising farms has dropped sharply, 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. Let us further assume that production expansion will follow the historical trend and there will be growth in medium- to large-sized operations and small-sized operations would continue to disappear. 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.

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).

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. 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. 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).

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.

Table 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
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

Region	Size of Firm	Level in Solution*	Slack	Shadow Price $/pig	Region	Size of Firm	Level in Solution	Slack	Shadow Price $/pig
	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
	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

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) 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 Table 6.

Table 7: 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 base model (Year 1997) and the projected scenario (Year 2010) are listed in Appendix 13 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: 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 9: 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 9).

Table 10: 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.

Limitation of the study:

1. This study relied on the secondary data from different sources. 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.

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Appendices:

Appendix 1: Number of operations[6] 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

Appendix 2: 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

6 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.

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 3: 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	Columb ia
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
Total (U.S.)	104,302,165	93,871,948.1			

Appendix 4: 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			

Appendix 5: 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 6: 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 7A: 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 7B: 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 7C: 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 8: Environmental compliance costs by states and regions

State	EPA Region	Region (this study)	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
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 9: 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		

Notes: 1. Cost estimates in these locations are based on the regional average.
2. All the processing plants in individual states are combined as single plant location.
3. Details per unit processing costs calculations are discussed in Adhikari, 2002

Appendix 10: 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
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

State	Production level			Shadow	State	Production level			Shadow
		Level	Upper	Price		Size	Level	Upper	Price
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 11: 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 12: 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 13: Production levels in the base and projected model (1,000 hogs)

Region	Base Model	2010 Scenario	Change in Prod.	%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

Region	Base Model	2010 Scenario	Change in Prod.	%Change
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