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The location of the North American cattle-feeding industry: a nonspatial modeling approach

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by

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ABSTRACT

Pronounced differences in regional characteristics provide specific advantages to regional North American fed-beef industries. Possible future changes in the availability of land and grass for beef-cow maintenance, regional crop production, and transportation costs provide motivation for developing a better understanding of regional interactions in the U.S. fed-beef industry. In addition, the industry has become more North American in scope, depending on trade relationships between the United States, Canada, and Mexico that make up the supply and demand for the major commodities that drive the fed-beef industry. Because of beef-cow inventory reductions in the United States, feeder-cattle trade with Canada and Mexico has become as important to the U.S. cattle-feeding sector as trade between regions within the United States.

The purpose of this study is to develop a model to analyze the location of North American cattle feeding based on regional supply and demand of feedgrains, feeder cattle, and fed cattle. A nonlinear multiregional multicommodity model is solved. The model can be used to evaluate exogenous shocks imposed on the 1990-based system of equations. The model is used to evaluate the impact of three exogenous shocks on the structure of the North American cattle-feeding industry.

CHAPTER I. INTRODUCTION

Cattle feeding in the United States essentially consists of feeding grain to feeder cattle. The location of the cattle-feeding industry, therefore, depends on the regional prices of these inputs as well as the regional prices for slaughter-ready cattle. In the past, the industry has moved in response to changes in regional prices, first originating in the Central Plains and then moving to the Texas Panhandle. Several anticipated developments could cause the center of the cattle-feeding industry to move again in the future. These developments include proposed legislation to increase grazing fees on federal land, changes in the relative transportation costs of grain and cattle (beef), and the proposed opening of the U.S. border with Mexico. The purpose of this thesis is to evaluate how each of these events would alter the regional location of the North American cattle-feeding industry. This is achieved by constructing an eleven-region, nonspatial equilibrium model of the feeder cattle, feedgrain, and fed cattle markets of North America, and then by shocking this model to reflect each of the possible scenarios.

The thesis reviews literature on spatial equilibrium models in Chapter II. Chapter III provides an overview of the fed-beef industry, discussing the cow-calf, feedlot, and beef-packing sectors. The assumptions and data used in developing the model are presented in Chapter IV. The theoretical model utilized by Van der Sluis (1988) is described in Chapter V. This theoretical model is a general nonlinear multiregional multicommodity nonspatial equilibrium model, which incorporates supply and demand curves by using a nonlinear complementary algorithm. Chapter VI applies the model and data to the cattle-feeding sector of the fed-beef industry in North America, followed by descriptions and results of the scenarios in Chapter VII. Finally, the major findings of the thesis are summarized in Chapter VIII.

CHAPTER II. LITERATURE REVIEW

Samuelson (1952) first demonstrated that competitive equilibrium solutions could be reached by maximizing net social payoff, defined as the sum of consumer surplus and producer surplus in each region minus transportation cost. Samuelson's problem was solved using linear programming.

Takayama and Judge (1964) demonstrated that Samuelson's problem can be converted to a quadratic programming problem. The competitive spatial equilibrium model could be solved by maximizing a quadratic objective function subject to a set of linear constraints, given linear demand and supply functions and transportation costs.

Schrader and King (1962) further applied a linear-programming method to solve a point-trading spatial equilibrium model in order to determine the regional location of the beef cattle-feeding industry. The problem maximizes the value of the final product minus the cost of transportation. Supplies of feeder cattle, feed concentrates, and roughage are predetermined and prices for these inputs do not enter the problem directly. These factors are used to develop a production function for the production of carcass beef. Byrkett et al.(1976) later found that "it was not necessary to model roughage as a factor affecting the optimal location of cattle feeding."

The same topic continued to draw attention into the early 1980s when Clary et al.(1984) developed a regional, multiproduct, least-cost trans-shipment model to evaluate the optimal location of the U.S. cattle-feeding fed-beef industry. The linear program was based on 1980 economic and industry conditions. Objectives of the study were to estimate least-cost locations and optimal levels of production, determine least-cost shipment routes, and evaluate impacts of changes in costs and supplies of the factors involved. The results demonstrated that advantages were realized by cattle-feeding operations located near feedgrain and feeder-cattle supplies.

Moschini and Meilke (1987) analyzed spatial price differences in the North American livestock sector. The three regions evaluated were Eastern Canada, Western Canada, and the United States, while Toronto, Calgary, and Omaha were used as the respective location points for transfer costs and price differentials. The price differential equations were estimated as a function of trade volume. Using the estimated price differentials, a short-run, three-region normative spatial equilibrium model was developed. The model parameters are based on 1984 data and the model is used to simulate the short-run effects on prices, demand, and trade flows, of exogenous shocks affecting supply, transportation costs, and demand.

The structure of Moschini and Meilke's model (1987) is based on the principle of the "law of one price." This means that the price difference between any two trading regions differs precisely by the transfer cost, and the sign of the price difference depends on the direction of trade. In addition, the price difference between two non-trading regions differs by less than the transfer cost. The transfer cost is determined by transportation costs, subsidies, tariffs, and currency exchange rate. The model assumes "homogenous goods, perfect information, timeless and frictionless adjustment, and competitive behavior of the trading countries."

Similar to Moschini's model, Van der Sluis (1988) utilized a nonlinear multicountry multicommodity nonspatial equilibrium model to evaluate the impacts of beef irradiation on feedgrain and beef trade between the United States, Australia, Argentina, and Japan. The model uses own-price and cross-price elasticities, and equilibrium conditions are specified directly and solved by using a nonlinear complementary algorithm. This approach is used to model the North American fed-beef industry and is described in detail in Chapter V.

CHAPTER III. OVERVIEW OF THE FED-BEEF INDUSTRY

Cow-Calf and Feedlot Operations

Due in large part to the agricultural crisis from 1982 to 1987, the number of U.S. operations with cattle declined over 21 percent from 1980 to 1990, and during the same time the U.S. beef-cow inventory decreased by over 15 percent. This was the largest decline in the number of operations ever experienced during herd liquidation. All U.S. regions experienced a decline in the number of cattle operations, with the Central Plains and the Lake States having the largest declines, 25 percent and 27 percent, respectively. The Northwest and Southwest regions had the smallest decrease, about 12 percent each. While the Lake States beef-cow inventory weathered the biggest decline of 18 percent, the Southwest was the only region to have an increase in the beef-cow inventory over the past decade.

The U.S. cattle-feeding sector, of course, felt the impact of herd liquidation. While the United States saw an overall decline in cattle feeding of about 5 percent, the regional story is more revealing. The data illustrate a definite shift of cattle feeding between regions. The Central Plains is the only U.S. region that had a decline of cattle and calves on feed from 1980 to 1985, followed by an increase from 1985 to 1990. This increase in cattle-feeding activity occurred while the opposite trend was taking place in neighboring regions.

Regional cattle-feeding shifts were significantly affected by the agricultural crisis in the early-to-mid 1980s. Many agricultural producers, especially smaller operators, exited the business as financial burdens forced them into bankruptcy. The combination of government support programs, drought, high interest rates, and sharp drops in land values caused mixed crop-livestock enterprises in the Central Plains to reduce livestock feeding and instead to sell cash grain. This created a more desirable economic environment to the neighboring regions with large commercial feedlots feeding customer-owned cattle.

In the late 1980s lower feedgrain prices, higher slaughter-cattle prices, and additional slaughter capacity attributed to the increased number of cattle on feed in the Central Plains. In addition, tax law changes in 1986 sharply reduced incentives for outside business interests to feed cattle with the commercial feedyards in the Southern Plains. However, the remaining feedyards were larger and more efficient than those existing before the early 1980s. By factoring in the advantages of economies of size, proximity to a large feedgrain supply, and underutilized beef-packer capacity, Central Plains cattle feeders made long-term decisions to increase the scale of their operations (Nalivka 1991).

Beef-Packing Sector

A smaller cattle inventory also meant fewer cattle available for slaughter. Consequently, the beef-packing industry also entered a period of rapid consolidation. In 1980, the four largest beef-packing firms accounted for 39 percent of the annual slaughter capacity in the United States. By 1991, the four-firm concentration ratio had grown to 75 percent (Sterling Marketing). Iowa Beef Processors is the only company that remained in the top four throughout the 1980s and it has held the number-one position every year.

There have also been significant changes in the composition of the cattle herd. All sectors of the fed-beef industry have promoted heavier cattle, with the average live-slaughter weight increasing by 6 percent from 1980 to 1990. Packers find it more efficient to slaughter and fabricate larger carcasses. Cattle feeders continue to pay a premium for larger-frame feeder calves. Because higher prices are received for larger-frame feeder calves, cow-calf operators push for bigger breeding stock. At the same time, purebred-cattle operations receive higher prices for large-frame seed stock and the show ring has placed the grand champion ribbon on the larger-frame cattle.

Canadian and Mexican Cattle Industry

Canada and Mexico have become increasingly important to the U.S. cattle feeding sector as domestic feeder-cattle supplies have decreased. In 1990, 1.26 million (USDA 1991) and 450,000 (Ross 1991) head of feeder cattle and calves were imported from Mexico and Canada, respectively. Recently, the U.S. herd has begun to expand (USDA 1991), but this slow growth will still leave U.S. cattle feeders demanding more feeder cattle in order to utilize capacity at the feedlot. The late 1980s and 1990 fed-beef market conditions have promoted increased imports of feeder and slaughter cattle from Canada and Mexico. As the fed-beef industry enters the 1990s and further trade agreements are developed with Canada and Mexico, it is important to analyze cattle feeding not as a U.S. market, but as a much larger North American market.

The Canadian and Mexican cattle industries have been affected by many of the same factors affecting the U.S. industry over the past decade. Consequently, similar changes relative to downsizing of the industry have occurred.

The Canadian beef-cow inventory has remained about constant in 1980 and 1990, however, liquidation of 318,000 beef cows during the decade reached its low in 1986 at 3,180,000. The level of cattle slaughter in Canada also changed over the past decade. The 4 percent increase in Canada's cattle slaughter from 1980 to 1985 was primarily due to a liquidation of the beef and dairy cow herds, driven by many of the same factors affecting the U.S. industry. The 14 percent decrease from 1985 to 1990, however, was not solely a result of the liquidation. More Canadian slaughter cattle were being exported to the United States as premium choice steer prices in the U.S. justified feeding beyond Canadian grades (Ross 1991).

Although not apparent in the inventory numbers from 1980 to 1990, the Mexican beef-cow herd declined over 7 percent from 1988 to 1990. At the end of the decade, the total cattle inventory in Mexico had declined almost 4 percent, which increased total slaughter numbers. However, the beef-cow herd realized nearly 12 percent growth from 1980 to 1990 (USDA 1991).

CHAPTER IV. ASSUMPTIONS AND DATA

Introduction

The following data are considered to be the best representations of the respective markets. All of the data used here have been collected and aggregated to match the following regional breakdown of North America.

1. Northwest (NW)	Washington, Oregon, and Idaho
2. Southwest (SW)	California, Arizona, Utah, and Nevada
3. Northern Plains (NP)	Montana, Wyoming, North Dakota, and South Dakota
4. Central Plains (CP)	Colorado, Nebraska, Iowa, Kansas, and Missouri
5. Southern Plains (SP)	New Mexico, Texas, Oklahoma, Arkansas, and Louisiana
6. Southeast (SE)	Alabama, Mississippi, Florida, Georgia, Kentucky, Tennessee, North Carolina, and South Carolina
7. Lake States (LS)	Minnesota, Wisconsin, Michigan, Illinois, Indiana, and Ohio
8. Northeast (NE)	Connecticut, Delaware, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Virginia, Vermont, and West Virginia
9. Western Canada (WC)	British Columbia, Alberta, Saskatchewan, and Manitoba
10. Eastern Canada (EC)	Ontario, Quebec, and Maritimes
11. Mexico (MX)	Mexico

Feedgrain Production, Consumption, and Prices

Table 1 summarizes the feedgrain data used in the Chapter VI model. Tables A, B, C, and D in the Appendix present the data collected to produce Table 1.

Table 1. Regional feedgrain data, 1990

Region	Production[a]	Consumption by Livestock[a]	Composite Price[b]	Feedgrain Value[c]
1. NW	9,634	3,673	109.61	219
2. SW	3,319	7,651	121.49	243
3. NP	22,872	3,472	86.73	173
4. CP	90,532	39,033	90.80	182
5. SP	17,809	16,551	100.30	201
6. SE	13,725	17,331	101.07	203
7. LS	100,887	26,421	91.16	182
8. NE	7,951	8,562	100.29	201
9. WC	10,400	5,700	77.48	155
10. EC	7,640	8,360	108.50	217
11. MX	3,700	6,500	128.00	256
Total	288,469	143,254		

Sources: Agricultural Prices 1991; Annual Crop Summary 1991; Wailes and Vercimak 1989; Riley 1991; Farm Model 1991.

[a]thousand metric tons

[b]U.S. dollars per metric ton

[c]U.S. dollars of feedgrain to feed each feeder to slaughter weight (2 mt).

Feedgrain production

There are four major grains priced into feedlot rations in the United States: corn, barley, sorghum, and wheat. Production for the 1989 marketing year (Fall 1989 through Summer 1990) of these grains comprises the regional estimates of feedgrain production in the United States for calendar year 1990, as reported in the USDA Annual Crop Summary (1991). The total production of the four grains is defined as the production of feedgrain for the U.S. regions, while barley and corn are used for Canada and sorghum for Mexico.

Corn is the preferred feedgrain in the United States, however, all four grains can be used in the rations. All U.S. regions use corn as the major feedgrain except the Northwest, which primarily feeds barley. In 1990, wheat was fed in all U.S. regions except the Lake States, Northeast, and Southeast. Relative to other grains, sorghum is not a major feedgrain in the United States, but the Southern Plains uses a high percentage of sorghum when it is priced competitively, and Mexico imports sorghum from the Southern Plains.

Sorghum is the chief feedgrain in Mexico and is used as the proxy for the feedgrain market in Mexico because government intervention keeps corn prices above world levels and priced out of the livestock feeding rations. Mexico is a sorghum-deficit region requiring imports from the United States to satisfy its feed use.

As the Canadian cattle-feeding industry has shifted to the west where corn is not grown, barley has become the primary feedgrain. However, some corn is grown and fed in Eastern Canada. Consequently, barley and corn production, consumption, and price are used to represent the feedgrain market in both Canadian regions, as reported by Agriculture Canada (Farm Model 1991).

Feedgrain consumption

Wailes and Vercimak (1989) estimated U.S. grain consumption by livestock at the state level for 1990. These projections were estimated by multiplying livestock numbers by annual grain consumption of each class of livestock based on estimated rations for each state. The state numbers are aggregated into the regions outlined in this study to represent livestock feedgrain consumption.

The Farm Model used by Agriculture Canada, Ottawa, estimates the quantity of barley and corn used for feed, and the USDA reports the quantity of sorghum used for feed in Mexico. These sources are used for the feedgrain consumption in the Canadian and Mexican regions.

Feedgrain prices

The method of calculating regional feedgrain prices uses the percentage each grain comprises of the total feedgrain component of the estimated regional feedlot ration (Appendix Table E). For example, corn may constitute 80 percent of the ration and barley may account for 20 percent. The percentages are multiplied by the regional corn and barley price and added to equal the weighted composite feedgrain price.

U.S. corn, sorghum, barley, and wheat prices were collected from USDA's Agricultural Prices (1991). Agriculture Canada reports prices for barley and corn at Thunder Bay and the Prairies, which represent Eastern Canada and Western Canada, respectively. Canadian dollars are converted to U.S. dollars using the 1990 currency exchange rate of 1.1668 Canadian dollars per U.S. dollar (Sampson 1991). Because

Mexico imports most of its sorghum from the Southern Plains, the sorghum price in Mexico is estimated by adding a 5 percent duty and estimated transportation cost to the Southern Plains sorghum price (Riley 1991).

Feeder-Cattle Production and Prices

Table 2 summarizes the production, use, and price data for feeder-cattle markets used in the Chapter VI model. Tables F and G in the Appendix present the data used to generate the data in Table 2.

Table 2. Regional feeder-cattle data, 1990

Region	Production[a]	Use[a]	Price[b]	Value[c]
1. NW	1,161	1,030	90.33	542
2. SW	1,634	1,295	88.87	533
3. NP	3,556	947	94.13	565
4. CP	5,535	13,464	94.23	566
5. SP	6,259	5,951	91.67	550
6. SE	4,354	336	88.20	529
7. LS	2,301	2,786	95.68	574
8. NE	1,252	338	92.68	556
9. WC	2,676	1,739	88.35	530
10. EC	841	619	85.39	512
11. MX	6,530	5,269	77.30	463
Total	36,099	33,774		

Sources: Cattle 1991; Cattle on Feed 1991; Livestock Market Review 1990; Livestock Report March 1991; Bailey 1991; Brink 1991.

[a]thousand head

[b]U.S. dollars per hundred weight

[c]U.S. dollars per head (600 pounds)

Feeder-cattle production

Regional feeder-cattle production numbers were estimated to represent two factors: the number of calves available for feedlot and/or stocker operations and the place in which the calves were born. Estimation of regionally available feeder-cattle production in the United States begins with the calf crop as reported by the USDA, however, not all of these calves will be available to feedlots or stocker operators. Therefore, subtracted from the calf-crop number are beef and dairy heifer replacements, bulls heavier than 500 pounds, and commercial calf slaughter. This results in the number of calves that will be available for feeding to a fed-slaughter weight.

Statistics Canada (1991) reports the number of calves in Canada less than one year old on January 1, 1990, and this number is used as the available feeder cattle for 1990. This number reflects available feeder cattle less slaughter calves because it is a point-in-time number. In addition, replacement heifers are reported as a separate number; therefore, most of the calves on January 1 will be available for feedlot placement.

The National Livestock Federation of Mexico reports a calf-crop number for 1990. This number needs adjustment because all these calves will not be available as feeders. Mexico does not report a replacement heifer number so this number was estimated to get a number of surplus feeder cattle that represents reported feeder-cattle exports to the United States in 1990 (USDA May 1991).

Feeder-cattle prices

Feeder-cattle prices for the U.S. regions are generated using state prices reported by Cattle Fax (1991). The Cattle Fax state prices are a weighted average of the feeder-cattle markets within the state. For this research, a simple average of the state-reported 500- and 600-pound feeder steer prices is used to represent the regional feeder-cattle price. Cattle Fax prices are not reported for states within the Lake States or Northeast regions, therefore, the Lake States price was collected from the USDA Market News office in Springfield, Illinois, and the Northeast price was estimated using neighboring regions, prices and estimated transportation costs.

Canadian feeder-cattle prices are reported by Agriculture Canada. Toronto and Edmonton prices for 500- to 600-pound feeder steers are used as the feeder-cattle prices for Eastern and Western Canada, respectively. These prices are reported in Canadian dollars and are converted to U.S. dollars.

The feeder-cattle price in Mexico is based on the feeder-cattle price paid in the Southern Plains. The Mexican price is estimated by subtracting a $5.50 per hundred weight quality discount (Davis 1991), 5 percent per head tariff (USDA May 1991), and $5 per hundred weight transportation, from the Southern Plains feeder-cattle price.

Feeder-Cattle Utilization and Fed-Cattle Production

Over the five-year time frame used in the model, fed-cattle production and feeder-cattle use by feedlots and stocker operators closely parallel each other and for data collection purposes are considered equal. The number of USDA-reported fed-cattle marketings from feedlots is used as the feeder-cattle utilization number and the production of fed cattle. Fed marketings are only reported for the 13 major cattle-feeding states, therefore, fed marketings must be estimated for the nonreporting states.[1]

Reported fed-cattle marketings are not available in Mexico, thus, the number of cattle slaughtered is the closest approximation of the domestic use of feeder cattle in Mexico. The number of cattle slaughtered is also the number used as the approximation of the production of fed cattle. This assumption is relevant because slaughter-cattle trade between United States and Mexico in 1990 was inconsequential. This does not, however, restrict the use of the model if slaughter cattle are traded across the U.S./Mexican border in the future.

Agriculture Canada reports the number of marketings of steers and heifers by province. This number is reported as cattle are received at the beef-packing plants, consequently, fed cattle that originated from Canadian feedlots but were exported to the United States would not be accounted for in the marketing number. Since use of feeder cattle and production of fed cattle should be estimated prior to U.S./Canadaian trade, exports are added and imports are subtracted from the marketings by province.

Table 3 displays the fed-cattle production, utilization, price, and the market where the fed-cattle price was reported. Tables G and H in the Appendix present the

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[1]Estimation of fed marketings for the nonreporting states is accomplished by taking the ratio of the 13-state fed marketings to cattle and calves on feed January 1, 1990, of the same 13 states. The ratio is then multiplied by the number of cattle on feed for the nonreporting states, generating an estimate of fed marketings for nonreporting states (Gustafson 1991). The sum of the actual fed marketings reported for 13 states and the estimated fed marketings of the nonreporting states is the total fed marketings for the respective regions.

data used to generate the data in Table 3.

Table 3. Regional fed-cattle data, 1990

Region	Prod[a]	Use[a]	Price[b]	Value[c]	Market
1. NW	1,030	1,130	77.88	934	WA-OR Direct
2. SW	1,295	1,378	77.23	927	CA-NV Direct
3. NP	947	430	76.57	919	MT Direct
4. CP	13,464	14,989	78.75	945	NEB/KS Direct
5. SP	5,951	4,851	78.70	944	TX Panhandle
6. SE	336	295	75.85	910	Montgomery
7. LS	2,786	2,413	78.04	936	IL Direct
8. NE	338	505	77.79	933	Lancaster
9. WC	1,739	1,448	69.55	835	Edmonton
10. EC	619	570	76.18	914	Toronto
11. MX	5,269	5,269	64.58	775	Mexico City
Total	33,774	33,278			

Sources: Cattle on Feed 1991; Livestock Slaughter 1990 Summary; Livestock Market Review 1990; Bailey 1991; USDA Market News Offices.
[a]thousand head
[b]U.S. dollars per hundred weight
[c]U.S. dollars per head (1200 pounds)

Fed-Cattle Utilization and Prices

Fed-cattle utilization is simply the number of steers and heifers slaughtered in each region. Statistics from federally inspected (F.I.) steer and heifer slaughter are used for developing regional fed-cattle utilization numbers for the U.S. regions. The USDA regions have been slightly adjusted to better represent regional characteristics of the cattle-feeding industry. The characteristics of the cattle-feeding industry in Colorado are most similar to the states outlined in the Central Plains. The characteristics of the cattle-feeding industry in Utah are most similar to the states outlined in the Southwest. Colorado and Utah have been taken from the Northern Plains and added to the Central Plains and the Southwest, respectively. Colorado was estimated to slaughter 2,004,000 steers and heifers in 1990 (Post 1991). This number was subtracted from the Northern Plains and added to the Central Plains. It has been assumed that 400,000 steers and heifers were slaughtered in Utah in 1990 (Sterling Marketing). Again, this number is subtracted from the 1990 F.I. slaughter in the Northern Plains and added to the Southwest.

Canada's 1990 fed-cattle use is estimated from the sum of federally inspected steer and heifer slaughter in each province as reported by Agriculture Canada. Slaughter statistics for Mexico are reported by the Foreign Agriculture Service (USDA 1991). Mexico's cow and calf slaughter is subtracted from the total slaughter to generate the 1990 steer and heifer slaughter number.

Fed-cattle prices

Fed-cattle prices were collected from markets in each region that trade a high volume of slaughter cattle. U.S. prices are reported by the USDA Market News offices within each region and were collected for choice steers weighing 1,100 to 1,300 pounds. Canadian fed-steer prices were collected for steers graded as A1, 2, over 1,050 pounds for Edmonton and Toronto markets (Livestock Market Review 1990).

The National Livestock Federation of Mexico reports a monthly average grass-fed live steer wholesale price since most cattle are grass-fed in Mexico. The monthly quotes were averaged to get a 1990 price for slaughter steers. The number was reported in pesos and has been converted to U.S. dollars per hundred weight by using the 1990 currency exchange rate of 2812.6 Pesos per U.S. dollar (Sampson 1991).

Transfer Costs

Transfer costs are represented by the actual price difference of each commodity between regions. This is a transfer cost instead of a transportation cost because other variables such as tariffs, quality differences, currency exchange rates, commodity deterioration or shrinkage, and other market forces are incorporated into the price differential. Because the actual price differences incorporate these additional costs, the transportation cost and price difference are not always equal; however, both are similar in most cases.[2] Consequently, price differentials have been used in the model as a transfer cost for 1990 because it better represents the individual characteristics between regions.

Elasticities

Tables 4a and 4b present the elasticities used in the model. Own-and cross-price elasticities are used to express equilibrium conditions for the model. The feedgrain demand elasticities and the fed cattle own-price demand elasticity are

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[2]Estimated transportation costs were developed to compare to the actual price differences. Clary et al. (1984) estimated linear regression equations for truck and single-car rail grain transportation rates as a function of distance. In addition, average cattle-hauling rates for 1990 were collected from transportation companies. The 1990 annual average rate for hauling cattle was about $1.70 per loaded mile, with an average load of cattle weighing 49,000 pounds. These two source were used to compare estimated transportation rates to actual price differences. In most cases the actual price difference is very similar to the estimated transportation cost.

Table 4a. Supply elasticities

	Quantity	Feeder Cattle	Feedgrain	Fed Cattle
1. NW	Feeder Cattle	0.61	0	0
	Feedgrain	0	0.38	0
	Fed Cattle	-1.01	-0.44	1.70
2. SW	Feeder Cattle	0.61	0	0
	Feedgrain	0	0.38	0
	Fed Cattle	-1.01	-0.44	1.70
3. NP	Feeder Cattle	0.84	0	0
	Feedgrain	0	0.58	0
	Fed Cattle	-1.39	-0.70	2.34
4. CP	Feeder Cattle	0.54[a]	0	0
	Feedgrain	0	0.40[a]	0
	Fed Cattle	-0.88[a]	-0.29[c]	1.17[c]
5. SP	Feeder Cattle	0.42	0	0
	Feedgrain	0	0.22	0
	Fed Cattle	-0.69	-0.22	1.17
6. SE	Feeder Cattle	0.57	0	0
	Feedgrain	0	0.84	0
	Fed Cattle	-0.94	-0.39	1.60
7. LS	Feeder Cattle	0.27	0	0
	Feedgrain	0	0.48	0
	Fed Cattle	-0.44	-0.04	0.75
8. NE	Feeder Cattle	0.34	0	0
	Feedgrain	0	0.99	0
	Fed Cattle	-0.57	-0.13	0.96
9. WC	Feeder Cattle	0.84	0	0
	Feedgrain	0	0.58	0
	Fed Cattle	-1.39	-0.70	2.34
10. EC	Feeder Cattle	0.34	0	0
	Feedgrain	0	0.99	0
	Fed Cattle	-0.57	-0.13	0.96
11. MX	Feeder Cattle	0.61	0	0
	Feedgrain	0	0.38	0
	Fed Cattle	-1.01	-0.44	1.70

Sources: [a]Meyers et al. (1991), [b]Womack (1991), [c]calculated using homogeneity and proportionality restrictions

Table 4b. Demand elasticities

	Quantity	Feeder Cattle	Feedgrain	Fed Cattle
1. NW	Feeder Cattle	-1.01	-0.44	1.70
	Feedgrain	-0.15	-0.37	0.25
	Fed Cattle	0	0	-0.80
2. SW	Feeder Cattle	-1.01	-0.44	1.70
	Feedgrain	-0.15	-0.37	0.25
	Fed Cattle	0	0	-0.80
3. NP	Feeder Cattle	-1.39	-0.70	2.34
	Feedgrain	-0.15	-0.37	0.25
	Fed Cattle	0	0	-0.80
4. CP	Feeder Cattle	-0.88[a]	-0.35[c]	1.49[c]
	Feedgrain	-0.15[b]	-0.37[a]	0.25[b]
	Fed Cattle	0	0	-0.80[a]
5. SP	Feeder Cattle	-0.69	-0.22	1.17
	Feedgrain	-0.15	-0.37	0.25
	Fed Cattle	0	0	-0.80
6. SE	Feeder Cattle	-0.94	-0.39	1.60
	Feedgrain	-0.15	-0.37	0.25
	Fed Cattle	0	0	-0.80
7. LS	Feeder Cattle	-0.44	-0.04	0.75
	Feedgrain	-0.15	-0.37	0.25
	Fed Cattle	0	0	-0.80
8. NE	Feeder Cattle	-0.57	-0.13	0.96
	Feedgrain	-0.15	-0.37	0.25
	Fed Cattle	0	0	-0.80
9. WC	Feeder Cattle	-1.39	-0.70	2.34
	Feedgrain	-0.15	-0.37	0.25
	Fed Cattle	0	0	-0.80
10. EC	Feeder Cattle	-0.57	-0.13	0.96
	Feedgrain	-0.15	-0.37	0.25
	Fed Cattle	0	0	-0.80
11. MX	Feeder Cattle	-1.01	-0.44	1.70
	Feedgrain	-0.15	-0.37	0.25
	Fed Cattle	0	0	-0.80

Sources: [a]Meyers et al. (1991), [b]Womack (1991), [c]calculated using homogeneity and proportionality restrictions considered constant over all regions. Meyers' (1991) supply elasticities are regionally adjusted using three conditions: Shumway's (1988) regional elasticities, homogeneous of degree zero, and Moschini's (1991) proportionality condition. These conditions are explained in detail in Chapter VI after the theoretical model has been described.

CHAPTER V. THEORETICAL MODEL

The following theoretical model is used to directly specify equilibrium conditions for a multicommodity, multiregional, nonlinear, nonspatial equilibrium model. The notation for the following model and development of the GINO model come from Van der Sluis (1988). Supply and demand in each region for each commodity are specified as a function of prices and own-price and cross-price elasticities. Inverse supply and demand are solved for by taking the log of the supply and demand systems for each region and then solving for the log price. There are three sets of equilibrium conditions.

1. Price linkage: inverse supply equals inverse demand for each commodity in each region.
2. Quantity linkage: total supply equals total demand for each commodity.
3. Transfer Linkage: price in a deficit region is less than or equal to price in a surplus region plus the transfer cost.

The unknowns are production and utilization of each commodity in each region. After production and utilization are solved for, the equilibrium quantity, price, and surplus or deficit can be calculated.

The model must consist of at least the same number of equations as there are unknowns. For example, there are 66 unknowns in the Chapter VI model, therefore, the number of equations equals one quantity linkage equation for each commodity (3) plus (33) price linkages plus (30) transfer linkages. The optimal solution is found by having N(N-1)/2 conditional transfer linkages (Moschini 1987) to provide all potential transfer routes to the model so that the algorithm can chose N-1 optimal transfer linkages which then become binding. The program will only utilize N-1 transfer linkages for each commodity when solving the model.

The following equations and symbol definitions explain the structure of the model. Consider m regions trading n commodities where the supply curve is defined as

$$S_{ij} = \gamma_{ij} \prod_{k=1}^{n} P_{ik}^{\delta ijk} \qquad \text{for} \quad i=1,\ldots,m; \quad (1)$$
$$j=1,\ldots,n;$$
$$k=1,\ldots,n;$$

where S_{ij} is the quantity supplied of commodity j in region i;

P_{ik} is the price of commodity k in region i;

γ_{ij} is a supply shifter for commodity j in region i;

δ_{ijk} is a supply price elasticity; price of commodity k on supply for commodity j in region i.

The supply system of equations for region i is written in logarithmic form and then solved for price. This results in the inverse supply system of equations for region i. Written in matrix notation

$$[\ln P_{ik}] = [\delta_{ijk}]^{-1} * [\ln S_{ij} - \ln \gamma_{ij}] \quad (2)$$
$$(n*1) \qquad (n*n) \qquad (n*1)$$

The inverse supply curve for a single commodity is

$$P_{ij} = a_{ij} \prod_{k=1}^{n} S_{ik}^{dijk} \qquad \text{for} \quad i=1,...,m; \; j=1,...,n; \; k=1,...,n; \quad (3)$$

where $a_{ij} = \prod_{k=1}^{n} \gamma_{ik}^{-dijk}$;

d_{ijk} is the jk^{th} element of the inverse of the matrix of own- and cross-price supply elasticities.

The demand curve is defined as

$$D_{ij} = \alpha_{ij} \prod_{k=1}^{n} P_{ik}^{\beta ijk} \qquad \text{for} \quad i=1,...,m; \; j=1,...,n; \; k=1,...,n; \quad (4)$$

where D_{ij} is the quantity demanded of commodity j in region i;

α_{ij} is a demand shifter for commodity j in region i;

P_{ik} is the price of commodity k in region i;

β_{ijk} is a demand price elasticity; price of commodity k on demand for commodity j in region i.

The demand system of equations for region i is written in logarithmic form and then solved for price. This results in the inverse demand system of equations. Written in matrix notation

$$\underset{(n*1)}{[\ln P_{ik}]} = \underset{(n*n)}{[\beta_{ijk}]^{-1}} * \underset{(n*1)}{[\ln D_{ij} - \ln \alpha_{ij}]} \tag{5}$$

The inverse demand curve for a single commodity is

$$P_{ij} = c_{ij} \prod_{k=1}^{n} D_{ik}^{bijk} \quad \text{for} \quad i=1,...,m; \; j=1,...,n; \; k=1,...,n; \tag{6}$$

where $c_{ij} = \prod_{k=1}^{n} \alpha_{ik}^{-bijk}$;

b_{ijk} is the jk^{th} element of the inverse of the matrix of own- and cross-price demand elasticities.

After the inverse supply and demand have been solved for, three sets of equilibrium conditions must be satisfied for the model to solve for the unknowns. The first set of equilibrium conditions states that inverse supply must equal inverse demand for each commodity in each region. The price linkage is

$$a_{ij} \prod_{k=1}^{n} S_{ik}^{d_{ijk}} = c_{ij} \prod_{k=1}^{n} D_{ik}^{b_{ijk}} \qquad (7)$$

The number of price linkage conditions needed to specify the model is determined by the number of commodities times the number of regions.

The second set of equilibrium conditions is the quantity linkages. This condition states that total supply equals total demand for each commodity

$$\sum_{i=1}^{m} S_{ij} = \sum_{i=1}^{m} D_{ij} \qquad \text{for} \quad j=1,\ldots,n. \qquad (8)$$

The final set of equilibrium conditions is the transfer linkage. This condition states that price in one region must be less than or equal to the price in another region plus a transfer cost.

$$a_{ej} \prod_{k=1}^{n} S_{ek}^{d_{ejk}} + T_{eij} > c_{ij} \prod_{k=1}^{n} D_{ik}^{b_{ijk}} ; \qquad (9)$$

where T_{eij} is the transfer cost from an exporting region to an importing region and subscripts e and i denote potential exporting and importing regions, respectively. For each commodity, N(N-1)/2 conditional transfer linkages are specified to allow the algorithm to chose N-1 optimal transfer linkages which then become binding.

CHAPTER VI. MODELING THE CATTLE-FEEDING INDUSTRY

This chapter describes the structure of the cattle-feeding industry model for North America. The model outlined in Chapter V has been applied to the cattle-feeding industry data in Chapter IV to replicate the industry as it was in 1990. Per head prices and per head transfer costs are used in developing the model, however, results are reported in hundred weight and metric ton amounts. Based on present and potential issues affecting the cattle-feeding sector over the next five years, three scenarios where executed by shocking the 1990 base model. Description and results of the scenarios follow in Chapter VII. The logarithmic model has been solved using GINO (LINDO 1990 and Liebman 1986).

There are eleven regions as defined in Chapter IV: eight U.S. regions, two Canadian regions, and Mexico. Three commodities are simultaneously traded: feeder cattle, feedgrain, and fed cattle. The subscripts that assist in defining the equations are the numbers assigned to the regions and commodities:

Region Numbers ($i=1,...,11$)

1. Northwest
2. Southwest
3. Northern Plains
4. Central Plains
5. Southern Plains
6. Southeast
7. Lake States
8. Northeast
9. Western Canada
10. Eastern Canada
11. Mexico

Commodity Numbers ($j=1, 2, 3$)

1. Feeder cattle
2. Feedgrain
3. Fed cattle

Supply and Demand Equations

The structure of the supply and demand equations is identical for each region. Supply and demand equations, corresponding to equations (1) and (4) in Chapter V, are specified for the Central Plains.

<u>Supply Equations Defined</u>

$$S_{41} = \gamma_{41} P_{43}^{\delta 11}$$

$$S_{42} = \gamma_{42} P_{42}^{\delta 22}$$

$$S_{43} = \gamma_{43} P_{41}^{\delta 31} P_{42}^{\delta 32} P_{43}^{\delta 33}$$

<u>Demand Equations Defined</u>

$$D_{41} = \alpha_{41} P_{41}^{\beta 11} P_{42}^{\beta 12} P_{43}^{\beta 13}$$

$$D_{42} = \alpha_{42} P_{41}^{\beta 21} P_{42}^{\beta 22} P_{43}^{\beta 23} \quad (10)$$

$$D_{43} = \alpha_{43} P_{43}^{\beta 33}$$

<u>Supply Elasticities</u>

$\delta 11$	0	0
0	$\delta 22$	0
$\delta 31$	$\delta 32$	$\delta 33$

<u>Demand Elasticities</u>

$\beta 11$	$\beta 12$	$\beta 13$
$\beta 21$	$\beta 22$	$\beta 23$
0	0	$\beta 33$

Price Linkage

Inverse supply and inverse demand of each commodity are set equal to each other for each region. Thirty three price linkages are needed for this model. The following illustrates setting equations (3) and (6) equal to each other for the Central Plains.

Inverse Supply = Inverse Demand

$$a_{41}S_{41}^{d411} = c_{41}D_{41}^{b411}D_{42}^{b412}D_{43}^{b413} \tag{11a}$$

$$a_{42}S_{42}^{d422} = c_{42}D_{41}^{b421}D_{42}^{b422}D_{43}^{b423} \tag{11b}$$

$$a_{43}S_{41}^{d431}S_{42}^{d432}S_{43}^{d433} = c_{43}D_{43}^{b433} \tag{11c}$$

Equations (11a,b,c) are expressed in logarithmic form in the GINO program (Appendix) as equations 10, 11, and 12, respectively.

Quantity Linkage

The second set of equilibrium conditions (8) is the quantity linkage, where total supply equals total demand. Three quantity linkages are needed for this model because there are three commodities. Equation (13) is the quantity linkage for feeder cattle.

$$D_{11}+D_{21}+D_{31}+D_{41}+D_{51}+D_{61}+D_{71}+D_{81}+D_{91}+D_{101}+D_{111}+D_{ROW1} =$$

$$S_{11}+S_{21}+S_{31}+S_{41}+S_{51}+S_{61}+S_{71}+S_{81}+S_{91}+S_{101}+S_{111}\ ; \tag{13}$$

where D_{ROW1} is the rest of world demand for feeder cattle.

The quantity linkage for feeder cattle is expressed in logarithmic form in the GINO program (Appendix) as equation number 94.

Transfer Linkage

Transfer linkages are developed by setting equation (3) equal to or greater than equation (6) and adding the transfer cost. This condition is illustrated in equation (12) for linking the Central Plains to the Southeast for feeder cattle. The Central Plains is deficit feeder cattle and the Southeast is surplus feeder cattle, therefore, the Central Plains inverse demand equation for feeder cattle will be linked to the Southeast inverse supply equation for feeder cattle.

$$a_{61}S_{61}^{d611} + T_{641} > c_{41}D_{41}^{b411}D_{42}^{b412}D_{43}^{b413} \qquad (12)$$

Equation (12) is expressed in logarithmic form in the GINO program (Appendix) as equation 40.

Elasticities

The own-price supply elasticities collected from Meyers et al. (1991) were adjusted using regional elasticities estimated by Shumway et al. (1988). The regional differences in Shumway's short-run elasticities were used to adjust Meyers's five-year elasticities. The adjustment was made by taking the average of Shumway's elasticities and identifying the region that was the closest to the average. That region, the Central Plains (Corn Belt), was chosen as the base region and given Meyers' five-year elasticities. The own-price five-year elasticities for the other regions were adjusted according to the percentage differences between Shumway's short-run regional elasticities. Mexico is assumed to be equal to the Southwest. Western Canada is assumed to be equal to the Northern Plains. Eastern Canada is assumed to be equal to the Northeast. Shumway's Pacific and Mountain regions' elasticities were averaged and used for the Northwest and the Southwest in the model. In addition, the feeder-cattle demand elasticities are assumed to be equal to the fed-cattle supply elasticities to restrict these two equations to equal.

All equations are restricted to be homogeneous of degree zero. Because feeder cattle and feedgrain make up over 95 percent of the cost of producing fed cattle, the elasticity that is collapsed into the constant must be negative and small in the fed-cattle supply equation. In addition, the size of the two input demand elasticities in the fed-cattle supply equation must be proportionate to the value of the inputs. The input demand elasticity by fed-beef producers for all inputs other than feeder cattle and feedgrain is collapsed into the constant in the fed-cattle supply and feeder-cattle demand equations and is restricted to be -0.26 in all regions. Given the homogeneity and proportionality restrictions, the -0.26 implicit elasticity was minimized because the value of other inputs is small relative to feeder cattle and feedgrain. Based on Meyers cross-price elasticity of feeder-cattle price on fed-cattle supply, the other two elasticities in the fed-cattle supply equation are estimated using a technique from Moschini and Meilke (1991) to achieve proportionality and homogeneity restrictions. This method uses the proportionality of the price of inputs to the output. The method is to take the -0.88 cross-price elasticity times the ratio of per-head value of fed cattle to per-head value of feeder cattle to get the own-price supply elasticity for fed cattle. The cross-price supply elasticity of feedgrain price on fed-cattle supply is adjusted to restrict the equation to homogeneous of degree -0.26. As with the other supply and demand equations, the -0.26 is implicitly collapsed into the constant to restrict the entire equation to homogeneous of degree zero.

Therefore by using Meyers input elasticity of feeder-cattle price on fed-cattle supply, the other two elasticities can be calculated. The fed-cattle own-price supply elasticity is calculated using the proportionality condition, and the feedgrain demand elasticity is found by imposing the homogeneity condition.

CHAPTER VII. RESULTS

This chapter describes the rationale and results of the three scenarios applied to the base model. The scenarios chosen are present and potential issues that may affect the structure and performance of the cattle-feeding industry. The scenario results are presented as changes from the 1990 base model in this chapter. The initial operation of the model was performed to precisely replicate the 1990 data outlined in Chapter IV, therefore, the results of the 1990 base model are not presented.

The 100 equation limit of GINO restricted this model from having N(N-1)/2 transfer linkages for each commodity. To relax this programming restriction, N-1 transfer linkages for each commodity were used in the initial operation of each scenario. Whenever the policy shocks changed the optimal transfer linkages (This was apparent in the model whenever one of the transfer linkage equations had a non-zero slack value to indicate that the linkage structure itself was influencing the results) other conditional transfer linkages were added, using inequality signs, until the model determined the optimum N-1 binding transfer linkages. In this manner the results satisfy the law of one price.

Scenario 1. Relative Transportation Costs

This scenario is designed to represent the effects of a change in the relative cost of transporting meat versus transporting feedgrain. The justification for this analysis lies in the potential opportunities caused by technological advances available for meat and livestock distribution versus feedgrain distribution. It is believed that there are more opportunities for structural and technological advancements in meat distribution systems than grain distribution systems (Nalivka 1991). Issues such as shipping tray-ready meat directly to retail stores or poor performance in the railroad industry could change the relative transportation costs. If this type of change occurs, then the cost of transporting feedgrain will increase in relation to the cost of transporting meat (cattle). For scenario 1, the base model is shocked by increasing the cost of transporting feedgrain by one-third to represent the change in the relative transportation costs.

Results of scenario 1 indicate that an increase in the relative cost of transporting feedgrain forces the feedgrain to be used where it is produced. Feedgrain deficit regions yield an increase in the price of feedgrain. This leads those regions to increase the production of feedgrain and decrease the use of feedgrain, therefore, the deficit regions become less reliant on importing feedgrain. All but two surplus regions experience a decrease in feedgrain price. This leads to an increase in the use of feedgrain and a decrease in the production of feedgrain in the surplus regions because fewer feedgrain imports are now demanded by deficit regions. The two regions that are surplus regions, but did not behave as such, are the Northwest and the Southern Plains. This is because the transfer linkages that became binding for these regions linked two surplus regions. This is logical because these regions are major international grain-exporting centers where grain is transported through. Table 5 presents the results from scenario 1 as changes from the 1990 base model.

Table 5. Results of scenario 1

	Feeder Cattle			Feedgrain			Fed Cattle		
Reg	Prod[a]	Use[a]	Price[b]	Prod[c]	Use[c]	Price[d]	Prod[a]	Use[a]	Price[b]
NW	-1	-17	-0.13	171	-60	5.15	-17	-1	0.08
SW	-1	-36	-0.13	93	-198	9.10	-36	-1	0.08
NP	-4	23	-0.13	-382	39	-2.45	23	-0	0.08
CP	-4	87	-0.13	-383	171	-0.95	87	-13	0.08
SP	-4	-15	-0.13	76	-124	2.20	-15	-4	0.08
SE	-4	-2	-0.13	283	-147	2.50	-2	-0	0.08
LS	-1	5	-0.13	-504	116	-0.95	5	-2	0.08
NE	-1	-0	-0.13	171	-64	2.20	-0	-0	0.08
WC	-3	99	-0.13	-403	158	-5.40	99	-1	0.08
EC	-0	-2	-0.13	337	-130	4.85	-2	-0	0.08
MX	-7	-171	-0.13	122	-197	11.30	-171	-5	0.08
Ttl	-29	-29		-437	-437		-29	-29	

[a]thousand head
[b]U.S. dollars per hundred weight
[c]thousand metric tons
[d]U.S. dollars per metric ton
Note: total may not add due to rounding

Because it is less efficient to transport feedgrain to deficit regions, the cattle-feeding industry shifts to regions that are surplus in feedgrain. The change in total supply and demand for the three commodities in North America is small, however, *regional* production and utilization adjustments are noteworthy.

Scenario 2. Grazing Fees

This scenario attempts to demonstrate the response to increasing grazing fees on public land to a point that it would become less profitable to raise cattle in regions where a significant amount of cattle are grazed on public land. Scenario 2 is performed by shifting the feeder-cattle supply curve to the left by 50 percent in the Northwest, Southwest, and Northern Plains. The important considerations in this scenario are the *relative changes* in production, utilization, and price. Table 6 presents the results of scenario 2 as changes from the 1990 base model.

Table 6. Results of scenario 2

	Feeder Cattle			Feedgrain			Fed Cattle		
Reg	Prod[a]	Use[a]	Price[b]	Prod[c]	Use[c]	Price[d]	Prod[a]	Use[a]	Price[b]
NW	-559	-40	10.28	-14	-18	-0.41	-40	-35	3.16
SW	-789	-52	10.28	-8	-39	-0.41	-52	-44	3.16
NP	-1,534	-42	10.28	-63	-13	-0.41	-42	-14	3.16
CP	315	-409	10.28	-164	-156	-0.41	-409	-465	3.16
SP	286	-156	10.28	-16	-76	-0.41	-156	-151	3.16
SE	284	-12	10.28	-47	-84	-0.41	-12	-9	3.16
LS	64	-42	10.28	-217	-98	-0.41	-42	-75	3.16
NE	46	-7	10.28	-32	-37	-0.41	-7	-16	3.16
WC	260	-76	10.28	-32	-20	-0.41	-76	-51	3.16
EC	34	-15	10.28	-28	-46	-0.41	-15	-18	3.16
MX	519	-223	10.28	-5	-36	-0.41	-223	-198	3.16
Ttl	-1,075	-1,075		-622	-622		-1,075	-1,075	

[a]thousand head
[b]U.S. dollars per hundred weight
[c]thousand metric tons
[d]U.S. dollars per metric ton
Note: Total may not add due to rounding

Results indicate that production of feeder cattle decreases by less than 50 percent in the three shocked regions. The feeder-cattle price increases in all regions by $10.28. The Northwest and Southwest change from surplus to deficit feeder cattle, while the Northern Plains remains surplus. As a result of the increase in the price, feeder-cattle use decreases in all regions. Because fewer cattle are fed throughout North America, feedgrain production, use, and price decrease everywhere. The restriction that feeder-cattle use must equal fed-cattle production forces fed-cattle production to decrease the same as feeder-cattle use in all regions. Fed-cattle price increases in all regions resulting in a decrease in the demand for fed cattle.

Scenario 3. Mexican Feeder-Cattle Tariff

In 1990, there was a 5 percent export tariff paid on feeder cattle from Mexico. This tariff was scheduled to be reduced to 1.67 percent in September 1991 (USDA May 1991). This scenario was executed by reducing the transfer cost of feeder cattle from Mexico to the Southern Plains. The reduction in the transfer cost is equal to the reduction in the export tariff from 5 percent to 1.67 percent based, on 600-pound feeder cattle. The initial tariff was estimated at $3.87 per hundred weight. The reduction from 5 percent to 1.67 percent results in a $2.59 per hundred weight reduction in the transfer cost. Table 7 presents the results of scenario 3. The numbers illustrated in Table 7 are changes from the 1990 base model.

Results show that Mexico increases its net exports of feeder cattle to the United States, decreases its need for imported feedgrain, and requires fed-cattle imports to

Table 7. Results of scenario 3

	Feeder Cattle			Feedgrain			Fed Cattle		
Reg	Prod[a]	Use[a]	Price[b]	Prod[c]	Use[c]	Price[d]	Prod[a]	Use[a]	Price[b]
NW	-4	6	-0.57	2	3	0.05	6	0	-0.01
SW	-6	8	-0.57	1	6	0.05	8	0	-0.01
NP	-18	7	-0.57	7	2	0.05	7	0	-0.01
CP	-18	67	-0.57	19	27	0.05	67	1	-0.01
SP	-16	24	-0.57	2	12	0.05	24	0	-0.01
SE	-16	2	-0.57	5	13	0.05	2	0	-0.01
LS	-4	7	-0.57	25	18	0.05	7	0	-0.01
NE	-3	1	-0.57	4	6	0.05	1	0	-0.01
WC	-14	14	-0.57	4	4	0.05	14	0	-0.01
EC	-2	2	-0.57	3	7	0.05	2	0	-0.01
MX	104	-137	2.02	1	-26	0.05	-137	0	-0.01
Ttl	3	3		72	72		3	3	

[a]thousand head
[b]U.S. dollars per hundred weight
[c]thousand metric tons
[d]U.S. dollars per metric ton
Note: Total may not add due to rounding

satisfy its demand. The feeder cattle price in Mexico increases by $2.02, while the feeder-cattle price in other regions decreases by $0.57. Consequently, the use of feeder cattle in Mexico decreases and the production of feeder cattle increases. The additional excess production of feeder cattle in Mexico is demanded by the other North American regions because of the price reduction and a smaller feeder-cattle supply inthose regions. In all regions except Mexico, feedgrain production, use, and price increase because more cattle will be fed in those regions. Mexico decreases its use of feedgrain, but still realizes an increase in the price of feedgrain because Mexico is a net importer of feedgrain from the United States, where the price increases. Mexican grain producers are willing to provide more feedgrain to their domestic users because of the higher price. Fed-cattle use is unchanged; however, the United States must now export fed cattle to Mexico because fewer cattle are fed in Mexico.

CHAPTER VIII. SUMMARY

This thesis examines how the location of the cattle-feeding industry in North America might respond to these realistic scenarios. The nonlinear, nonspatial model uses prices and elasticities to specify supply and demand for feeder cattle, feedgrain, and fed cattle in eleven regions. The model precisely replicates the 1990 base case and is shocked with three scenarios: change in relative transportation cost, increase in federal grazing fees, and reduction in the Mexican feeder-cattle tariff.

Results show that regional differences in the response to changes in the industry are important to the outcome of policy and industry changes. When transfer costs increase, the industry tends to use the commodities where they are produced. When feeder-cattle supply is shocked to the left, fed-cattle production and use change in response to the change in the fed-cattle price, not the feeder-cattle supply shock. The tariff-reduction scenario indicates small changes in the total for North America, but Mexico sees the largest changes in the three commodities, as would be expected in a small-country case.

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APPENDIX

Table A. U.S. feedgrain production, 1989 (89/90)

Region	Corn	Barley	Sorghum	Wheat	Corn	Barley	Sorghum	Wheat	Feedgrain
Northwest		1,000 Bushels					1,000 Metric Tons		
ID	6,250	59,500		91,420	156	1,275		2,449	3,880
OR	3,520	12,060		53,835	88	258		1,442	1,788
WA	15,750	28,420		110,610	394	609		2,963	3,966
Total	25,520	99,980	0	255,865	638	2,142	0	6,854	9,634
% of Feedgrains					6.6%	22.2%	0.0%	71.1%	100.0%
Southwest									
AZ	1,885	1,236	240	10,722	47	26	6	287	367
CA	29,600	14,500	810	52,605	740	311	20	1,409	2,480
NV		990		1,200		21		32	53
UT	2,640	9,006		5,950	66	193		159	418
Total	34,125	25,732	1,050	70,477	853	551	26	1,888	3,319
% of Feedgrains					25.7%	16.6%	0.8%	56.9%	100.0%
Northern Plains									
MT	320	68,800		145,030	8	1,474		3,885	5,367
ND	34,875	98,050		242,320	872	2,101		6,491	9,464
SD	190,800	19,250	10,400	83,080	4,770	413	260	2,225	7,668
WY	3,895	7,000		4,708	97	150		126	373
Total	229,890	193,100	10,400	475,138	5,747	4,138	260	12,727	22,872
% of Feedgrains					25.1%	18.1%	1.1%	55.6%	100.0%
Central Plains									
CO	134,850	12,160	11,375	62,100	3,371	261	284	1,663	5,580
IA	1,445,500			3,290	36,138			88	36,226
KS	155,000	576	198,750	213,600	3,875	12	4,969	5,721	14,578
MO	219,840		45,030	86,950	5,496		1,126	2,329	8,951
NE	847,000	650	101,060	55,350	21,175	14	2,527	1,483	25,198
Total	2,802,190	13,386	356,215	421,290	70,055	287	8,905	11,285	90,532
% of Feedgrains					77.4%	0.3%	9.8%	12.5%	100.0%
Southern Plains									
AR	7,076		21,080	52,800	177		527	1,414	2,118
LA	13,490		6,175	10,850	337		154	291	782
NM	9,600	375	12,500	4,000	240		313	107	660
OK	9,360	800	17,640	153,900	234	17	441	4,122	4,814
TX	148,400	480	164,300	60,000	3,710	10	4,108	1,607	9,435
Total	187,926	1,655	221,695	281,550	4,698	27	5,542	7,542	17,809
% of Feedgrains					26.4%	0.2%	31.1%	42.3%	100.0%
Southeast									
AL	14,580		1,500	6,600	365		38	177	579
FL	5,920			1,885	148			50	198
GA	52,250		2,000	22,400	1,306		50	600	1,956
KY	136,880	1,139	720	22,500	3,422	24	18	603	4,067
MS	9,800		4,505	15,300	245		113	410	767
NC	88,350	2,064	3,240	21,420	2,209	44	81	574	2,908
SC	30,940	560	450	17,835	774	12	11	478	1,274
TN	56,710		2,025	18,900	1,418		51	506	1,975
Total	395,430	3,763	14,440	126,840	9,886	81	361	3,398	13,725
% of Feedgrains					72.0%	0.6%	2.6%	24.8%	100.0%
The Lakes									
IL	1,322,250		11,620	105,020	33,056		291	2,813	36,160
IN	691,600			51,920	17,290			1,391	18,681
MI	222,610	2,320		33,920	5,565	50		909	6,524
MN	700,000	44,000		102,504	17,500	943		2,746	21,189
OH	342,200			62,730	8,555			1,680	10,235
WI	310,800	3,705		9,320	7,770	79		250	8,099
Total	3,589,460	50,025	11,620	365,414	89,737	1,072	291	9,788	100,887
% of Feedgrains					88.9%	1.1%	0.3%	9.7%	100.0%
Northeast									
CT									0
DE	13,300	2,200		3,108	333	47		83	463
MA									0
MD	44,000	4,000		8,600	1,100	86		230	1,416
ME									0
NH									0
NJ	7,242	472		1,365	181	10		37	228
NY	53,010			5,850	1,325			157	1,482
PA	98,880	5,015		7,955	2,472	107		213	2,793
RI									0
VA	40,150	4,875		12,650	1,004	104		339	1,447
VT									0
WV	4,370			516	109			14	123
Total	260,952	16,562	0	40,044	6,524	355	0	1,073	7,951
% of Feedgrains					82.0%	4.5%	0.0%	13.5%	100.0%
United States	7,525,493	404,203	615,420	2,036,618	188,137	8,653	15,386	54,552	266,729
% of Feedgrains					70.5%	3.2%	5.8%	20.5%	100.0%

Source: USDA, NASS, Annual Crop Summary, January 1991.

Table B. Calculation of U.S. feedgrain prices, 1990

Region	Corn ($/bu)	Barley ($/bu)	Sorghum ($/cwt)	Wheat ($/bu)	Ration Feedgrain ($/mt)	Consumption Feedgrain ($/mt)
Northwest						
ID	2.70	2.65		2.50		
OR	2.75	2.30		2.75		
WA	2.75	2.15		2.70		
Weighted average	2.74	2.47		2.64		
($ / MT)	109.51	115.06		98.52	109.61	106.42
Southwest						
AZ	3.15	2.80		3.46		
CA	3.05	2.65		3.29		
NV		2.20		2.39		
UT	2.80	2.40		2.82		
Weighted average	3.04	2.55		3.26		
($ / MT)	121.45	119.11		121.74	121.49	117.09
Northern Plains						
MT	2.50	2.25		2.65		
ND	2.20	1.85		2.47		
SD	2.05	1.75	3.25	2.51		
WY	2.40	3.40		2.40		
Weighted average	2.08	2.04	3.25	2.53		
($ / MT)	83.17	95.14	72.80	94.50	86.73	83.54
Central Plains						
CO	2.35	3.10	3.65	2.45		
IA	2.20			2.75		
KS	2.25	1.70	3.60	2.50		
MO	2.35		3.90	2.70		
NE	2.30	2.20	3.70	2.55		
Weighted average	2.25	3.00	3.67	2.54		
($ / MT)	90.08	139.82	82.16	94.92	90.80	89.98
Southern Plains						
AR	2.60		3.95	3.10		
LA	2.60		4.30	3.25		
NM	2.65		4.25	2.80		
OK	2.25	1.95	3.80	2.55		
TX	2.50	2.15	4.15	2.75		
Weighted average	2.51	2.03	4.11	2.73		
($ / MT)	100.25	94.50	92.13	101.78	100.30	98.53
Southeast						
AL	2.80		4.05	3.05		
FL	2.70			2.80		
GA	2.80		4.50	3.00		
KY	2.50	2.20	3.85	2.75		
MS	2.60		4.10	3.10		
NC	2.55	2.05	3.90	3.00		
SC	2.70	2.20	4.35	3.00		
TN	2.40		4.00	3.05		
Weighted average	2.57	2.12	4.09	2.97		
($ / MT)	102.75	98.83	91.54	111.06	101.07	102.44
The Lakes						
IL	2.35		3.70	2.75		
IN	2.30			2.80		
MI	2.20	1.70		2.40		
MN	2.15	1.90		2.45		
OH	2.35			2.70		
WI	2.20	1.75		2.60		
Weighted average	2.28	1.88	3.70	2.63		
($ / MT)	91.16	87.72	82.88	98.11	91.16	91.06
Northeast						
CT						
DE	2.40	1.90		2.85		
MA						
MD	2.45	1.95		2.85		
ME						
NH						
NJ	2.40	1.95		3.10		
NY	2.45			2.65		
PA	2.60	2.15		2.85		
RI						
VA	2.50	2.10		2.95		
VT						
WV	2.25			2.70		
Weighted average	2.51	2.05		2.86		
($ / MT)	100.29	95.58		106.73	100.29	99.47

Source: USDA, NASS, Agricultural Prices, April 1991.

Table C. U.S. feedgrain consumption by livestock, 1990

Region	Corn	Barley	Sorghum	Wheat	Corn	Barley	Sorghum	Wheat	Feedgrain
Northwest	1,000 Bushels				1,000 Metric Tons				
ID	19,918	35,010	4,880	5,337	498	750	122	143	1,513
OR	11,459	15,186	326	3,967	286	325	8	106	726
WA	21,395	30,347	490	8,814	535	650	12	236	1,434
Total	52,772	80,543	5,696	18,118	1,319	1,726	142	485	3,673
% of Feedgrains					35.92%	46.99%	3.88%	13.21%	100.00%
Southwest									
AZ	12,717	19,924	2,736	2,235	318	427	68	60	873
CA	102,421	104,901	3,021	38,410	2,561	2,248	76	1,029	5,913
NV	864	2,024	81	197	22	43	2	5	72
UT	11,845	16,434	2,886	2,689	296	352	72	72	792
Total	127,847	143,283	8,724	43,531	3,196	3,070	218	1,166	7,651
% of Feedgrains					41.78%	40.13%	2.85%	15.24%	100.00%
Northern Plains									
MT	12,999	3,015	219	554	325	65	5	15	410
ND	20,831	2,541	208	2,173	521	54	5	58	639
SD	68,210	3,022	12,131	3,273	1,705	65	303	88	2,161
WY	8,662	1,865	80	167	217	40	2	4	263
Total	110,702	10,443	12,638	6,167	2,768	224	316	165	3,472
% of Feedgrains					79.70%	6.44%	9.10%	4.76%	100.00%
Central Plains									
CO	105,702	12,888	844	1,000	2,643	276	21	27	2,967
IA	832,361	0	2,366	3,841	20,809	0	59	103	20,971
KS	78,228	1,007	28,544	3,839	1,956	22	714	103	2,794
MO	83,001	3	19,592	10,741	2,075	0	490	288	2,853
NE	297,251	1,952	70,698	7,774	7,431	42	1,767	208	9,449
Total	1,396,543	15,850	122,044	27,195	34,914	340	3,051	728	39,033
% of Feedgrains					89.45%	0.87%	7.82%	1.87%	100.00%
Southern Plains									
AR	95,818	0	16,688	7,063	2,395	0	417	189	3,002
LA	25,655	0	5,495	0	641	0	137	0	779
NM	7,425	918	9,576	4,994	186	20	239	134	578
OK	56,191	2	10,955	3,864	1,405	0	274	104	1,782
TX	287,690	21,429	90,986	18,063	7,192	459	2,275	484	10,410
Total	472,779	22,349	133,700	33,984	11,819	479	3,343	910	16,551
% of Feedgrains					71.41%	2.89%	20.19%	5.50%	100.00%
Southeast									
AL	86,707	2,354	27,320	3,865	2,168	50	683	104	3,005
FL	44,601	2,178	5,952	9,603	1,115	47	149	257	1,568
GA	133,462	2,234	12,070	26,603	3,337	48	302	713	4,399
KY	71,947	864	2,353	5,040	1,799	19	59	135	2,011
MS	42,929	0	3,175	3,150	1,073	0	79	84	1,237
NC	89,391	3,494	9,584	10,824	2,235	75	240	290	2,839
SC	20,975	1,087	6,445	3,760	524	23	161	101	810
TN	46,911	0	4,094	7,018	1,173	0	102	188	1,463
Total	536,923	12,211	70,993	69,863	13,423	262	1,775	1,871	17,331
% of Feedgrains					77.45%	1.51%	10.24%	10.80%	100.00%
The Lakes									
IL	297,048	0	1,061	1,873	7,426	0	27	50	7,503
IN	110,986	1,776	8,468	4,303	2,775	38	212	115	3,140
MI	50,689	1,028	5,047	2,240	1,267	22	126	60	1,475
MN	255,992	6,719	666	647	6,400	144	17	17	6,578
OH	84,308	6	4	527	2,108	0	0	14	2,122
WI	216,773	8,022	238	226	5,419	172	6	6	5,603
Total	1,015,796	17,551	15,484	9,816	25,395	376	387	263	26,421
% of Feedgrains					96.12%	1.42%	1.47%	1.00%	100.00%
Northeast									
CT	7,679	13	68	221	192	0	2	6	200
DE	16,232	103	223	145	406	2	6	4	417
MA	3,528	12	60	191	88	0	2	5	95
MD	36,705	0	6	557	918	0	0	15	933
ME	26,353	21	93	285	659	0	2	8	669
NH	2,219	12	48	141	55	0	1	4	61
NJ	3,465	12	50	145	87	0	1	4	92
NY	52,506	258	1,448	4,795	1,313	6	36	128	1,483
PA	104,013	283	1,324	4,039	2,600	6	33	108	2,748
RI	588	1	5	20	15	0	0	1	15
VA	52,540	0	60	1,575	1,314	0	2	42	1,357
VT	9,378	48	279	937	234	1	7	25	268
WV	8,970	3	2	2	224	0	0	0	224
Total	324,176	766	3,666	13,053	8,104	16	92	350	8,562
% of Feedgrains					94.65%	0.19%	1.07%	4.08%	100.00%
United States	4,037,538	302,996	372,945	221,727	100,938	6,493	9,324	5,939	122,694
% of Feedgrains					82.27%	5.29%	7.60%	4.84%	100.00%

Source: Wailes, 1989

Table D. Canada & Mexico feedgrain data, 1990

Region		Production	Feed Use	Own-Country Price	Exchange Rate	Feedgrain Price
		(1,000 Metric Tons)		(Price / mt)	(Foriegn $ / US $)	(US $ / mt)
Western Canada (Prairies) a						
	Barley	10,400	5,700	90.40	1.1668	77.48
	Corn	0	0			
	Total	10,400	5,700			
Eastern Canada (East) a						
	Barley	1,260	1,380	130.43	1.1668	108.50
	Corn	6,380	6,980	122.76		
	Total	7,640	8,360			
Mexico b						
	Sorghum c	3,700	6,500		2812.6	128.00

Source: a. Agriculture Canada, Ottawa, Policy Branch, Farm Model
b. USDA, ERS; Grain and Feed Report, Atache'
Note: c. price = Southern Plains sorghum price + 5% duty + transportation

Table E. Percent grain used in feedgrain part of ration

Region	Corn	Barley	Sorghum	Wheat	Feedgrain
1. NW	0	67	0	33	100
2. SW	85	0	0	15	100
3. NP	70	25	0	5	100
4. CP	85	0	0	15	100
5. SP	65	0	5	30	100
6. SE	85	0	15	0	100
7. LS	100	0	0	0	100
8. NE	100	0	0	0	100
9. WC	0	100	0	0	100
10. EC	50	50	0	0	100
11. MX	0	0	100	0	100

Sources: Gill 1991; Martin 1991; Nelson 1991; and Snyder 1991

Table F. Available feeder cattle, 1990

Region	1990 Calf Crop	1991 Replacements Beef	Dairy	1991 Bulls > 500#	1990 Commercial Calf Slaughter	Available Feeder Cattle
	1,000 head					
Northwest						
WA	530	82	110	27	49.5	262
OR	650	120	45	39	6.2	440
ID	690	100	90	40	0.4	460
Total	1,870	302	245	106	56.1	1,161
Southwest						
CA	1850	155	525	70	92.1	1,008
NV	265	35	8	15		207
AZ	280	45	20	26		189
UT	360	58	52	19	0.5	231
Total	2,755	293	605	130	92.6	1,634
Northern Plains						
MT	1,400	323	8	79		990
ND	1,000	130	30	45		795
SD	1,650	207	34	71		1,338
WY	620	145	2	40		433
Total	4,670	805	74	235	0	3,556
Central Plains						
CO	830	143	30	48	0.1	609
NE	1,740	245	35	90		1,370
IA	1,360	180	135	80		965
KS	1,370	194	38	68		1,070
MO	2,070	330	105	110	3.9	1,521
Total	7,370	1,092	343	396	4.0	5,535
Southern Plains						
NM	520	79	18	40		383
TX	5,000	880	100	400	80.1	3,540
OK	1,850	300	35	110	2.8	1,402
AR	810	135	23	53		599
LA	520	92	21	34	37.8	335
Total	8,700	1,486	197	637	120.7	6,259
Southeast						
KY	1,200	185	80	70		865
TN	1,075	190	60	60		765
MS	690	121	21	49	26.4	473
AL	850	140	14	65	0.2	631
NC	460	76	36	29	2.6	316
SC	245	50	16	20	5.5	154
GA	670	98	44	45	12.8	470
FL	1,000	150	30	65	74.7	680
Total	6,190	1,010	301	403	122.2	4,354
The Lakes						
MN	1,070	72	315	45	1.2	637
WI	1,900	33	800	32	297.0	738
MI	400	29	162	17	54.9	137
IL	650	70	70	35	129.1	346
IN	460	50	65	25	136.0	184
OH	610	65	160	38	88.0	259
Total	5,090	319	1,572	192	706.2	2,301
Northeast						
CT	37	1	14	1		21
ME	58	5	18	2		33
MA	34	3	8	2		21
NH	22	2	8	1		11
RI	4	0	1	0		2
VT	165	3	49	3	89.9 a	20
NY	810	22	322	18	279.6	168
NJ	32	2	13	2	27.2	(12)
MD	141	12	41	4		84
DE	11	1	3	0	31.3	(25)
PA	780	43	280	29	234.6	193
VA	795	120	80	42	1.6	551
WV	265	45	10	17	9.4	184
Total	3,154	259	847	121	673.6	1,252
United States	39,799	5,566	4,184	2,220	1,775	26,052

Note: a. VT Calf Slaughter = CT+ME+MA+NH+RI+VT Calf Slaughter
Source: USDA Cattle; USDA Livestock Slaughter.

Table G. Fed marketings and F.I. steer & heifer slaughter, 1990

Region	January 1, 1990 Cattle & Calves on Feed	Fed Marketings Reported	Fed Marketings Estimated a	Total Fed Marketings	Federally Inspected Slaughter Steers	Federally Inspected Slaughter Heifers	Federally Inspected Slaughter Total
Northwest							
WA	170	416					
OR	84		17				
ID	200	597					
Total	454			1,030	700	430	1,130
Southwest							
CA	490	825					
NV	28		64				
AZ	253	313					
UT	41		93				400
Total	812			1,295	815	164	1,378
Northern Plains							
MT	80		182				
ND	40		91				
SD	260	505					
WY	75		170				
Total	455			947	1,502	1,332	430
Central Plains							
CO	900	2,195					2,004
NE	2,060	5,000					
IA	980	1,855					
KS	1,595	4,210					
MO	90		204				
Total	5,625			13,464	7,856	5,129	14,989
Southern Plains							
NM	118		268				
TX	2,100	4,840					
OK	325	800					
AR	10		23				
LA	9		20				
Total	2,562			5,951	3,110	1,740	4,851
Southeast							
KY	20		45				
TN	20		45				
MS	8		18				
AL	30		68				
NC	20		45				
SC	17		39				
GA	13		29				
FL	20		45				
Total	148			336			295
The Lakes							
MN	300	495					
WI	120		272				
MI	220		499				
IL	310	510					
IN	235		533				
OH	210		476				
Total	1,395			2,786	1,656	757	2,413
Northeast							
CT	0		0				
ME	0		0				
MA	0		0				
NH	0		0				
RI	0		0				
VT	0		0				
NY	18		41				
NJ	2		5				
MD	12		27				
DE			0				
PA	80		182				
VA	30		68				
WV	7		16				
Total	149			338			505
United States	11,600	22,561	3,586	26,147			25,992

Note: a. Estimation factor is the ratio of actual marketings to cattle & calves on feed, 13–states.
Estimated marketings for non–reporting states is the ratio times cattle & calves on feed.
Source: USDA Cattle; USDA Cattle on Feed; USDA Livestock Slaughter.

Table H. Canadian & Mexican cattle data, 1990

Canadian cattle data

	January 1, 1990	1990 Marketings		Fed Steer & Heifer		Total Fed	1990 Federally Inspected Slaughter		
	Calves < 1 yr old	Steers	Heifers	Exports	Imports	Marketings	Steers	Heifers	Total
				(1,000 Head)					
Ontario	600	342	198	5.2	7.2	538	306	172	478
Quebec	159	34	9			43	37	7	44
Maritimes	82	28	11		1.5	38	35	13	48
East	841	404	218	5.2	8.8	619	377	192	570
B.C.	228	31	17	1.5	0.7	48	32	16	48
Alberta	1,535	767	420	188.6		1,376	735	407	1,142
Sask.	640	130	59	19.2		208	131	57	188
Manitoba	273	46	26	35.0		107	47	23	70
West	2,676	974	522	244.2	0.7	1,739	944	503	1,448
Canada	3,517	1,378	740	249	9	2,358	1,322	696	2,017

Source: Livestock Market Review; Livestock Report

Canadian cattle prices

	Feeder Steers 500–600 lbs.		Fed Steers A1,2 + 1050 lbs	
	(Can $)	(US $)	(Can $)	(US $)
	dollars per cwt.			
Eastern Canada (Toronto)	99.63	85.39	88.89	76.18
Western Canada (Edmonton)	103.09	88.35	81.15	69.55

Note: Exchange Rate = 1.1668 (C$/US$)
Source: Livestock Market Review

Mexico cattle data

	Calf Crop	Replacements	Calf Slaughter	Available Feeder Cattle	Steer & heifer Slaughter
		1,000 Head			1,000 head
Mexico	9,018	588	1,900	6,530	5,269

Source: USDA, ERS

Mexico cattle prices

	Pesos/kilogram	U.S. $/cwt
Grass-fed live steer average wholesale price, Mexico City a	4005	64.58
Mexico feeder steer price b		77.30

Note: b. Souther Plains Feeder Steer Price
- $5.50/cwt quality discount – 5% tariff – transportation

Source: a. National Livestock Federation, Mexico
b. Davis, Texas A & M; USDA

The GINO Program for the 1990 Base Model

Below is the program for the 1990 base model. Equations 1 through 33 are the price linkages stating that inverse supply equals inverse demand for three commodities in each region. Equations 34 through 53 are the conditional transfer linkages for feeder cattle. Equations 54 through 73 are the conditional transfer linkages for feedgrain. Equations 74 through 93 are the conditional transfer linkages for fed cattle. Equations 94 through 96 are the quantity linkages for the three commodities. Equations 97 through 99 use the results of the log supply and log demand to calculate the prices for each commodity in the Northwest region.

Scenario 1 is executed by increasing the transfer cost by one-third in the feedgrain transfer equations. Scenario 2 is run by decreasing the constant term in the supply equation for feeder cattle in the Northwest, Southwest, and the Northern Plains and re-calibrating the model. Scenario 3 was run by reducing the transfer cost for feeder cattle from Mexico by $15.50 in equations 38 and 46.

```
MODEL:
  1) - 5.2466169125522 + 1.63551401869159 * LS11 = 17.9181882603248 -
    1.2031445417188 * LD11 + 1.41531864597793 * LD12 - 2.1186920190762 *
    LD13 ;
  2) - 18.516067255991 + 2.60601753139067 * LS12 = 28.8004021133169 +
    0.4877613006968 * LD11 - 3.2764805321532 * LD12 + 0.01433460232817 *
    LD13 ;
  3) - 10.174106747188 + 0.96775977437372 * LS11 + 0.6660966735401 * LS12
    + 0.587248832214765 * LS13 = 15.6269425778618 - 1.25 * LD13 ;
  4) - 5.8222972505864 + 1.63551401869159 * LS21 = 17.5586874510404 -
    1.2031445417188 * LD21 + 1.41531864597793 * LD22 - 2.1186920190762 *
    LD23 ;
```

5) - 15.635014114328 + 2.60601753139067 * LS22 = 31.1942455631173 + 0.4877613006968 * LD21 - 3.2764805321532 * LD22 + 0.01433460232817 * LD23 ;

6) - 9.9369965418308 + 0.96775977437372 * LS21 + 0.6660966735401 * LS22 + 0.58724832214765 * LS23 = 15.8674391300329 - 1.25 * LD23 ;

7) - 3.3887037805675 + 1.18946474086661 * LS31 = 11.5045062141931 - 0.9063623026502 * LD31 + 1.70486229384974 * LD32 - 2.1199587725356 * LD33 ;

8) - 12.013119486663 + 1.71019900497512 * LS32 = 30.2134723540603 + 0.36744417675007 * LD31 - 3.3938630921012 * LD32 + 0.01484815102794 * LD33 ;

9) - 6.9609945699376 + 0.70382529045362 * LS31 + 0.5083407571965 * LS32 + 0.42708968883466 * LS33 = 14.4030176332152 - 1.25 * LD33 ;

10) - 9.7714000248674 + 1.86915887850467 * LS41 = 26.0821225328952 - 1.3548150860491 * LD41 + 1.28158183815452 * LD42 - 2.1228487733431 * LD43 ;

11) - 23.187681517773 + 2.48756218905473 * LS42 = 33.8941240242622 + 0.54924935920908 * LD41 - 3.2222629073599 * LD42 + 0.01601977297693 * LD43 ;

12) - 15.713687836446 + 1.10393276045914 * LS41 + 0.58432668870413 * LS42 + 0.67114093959732 * LS43 = 18.870024774657 - 1.25 * LD43 ;

13) - 14.486149673676 + 2.37892948173322 * LS51 = 29.1861540653078 - 1.6546470913447 * LD51 + 0.97482835365998 * LD52 - 2.1167648740473 * LD53 ;

14) - 39.335007311711 + 4.56053067993367 * LS52 = 29.4517785032077 + 0.67080287486946 * LD51 - 3.0979033866189 * LD52 + 0.01355332731646 * LD53 ;

15) - 21.190718168041 + 1.40765058090723 * LS51 + 0.84915888898043 * LS52 + 0.85417937766931 * LS53 = 17.458801351452 - 1.25 * LD53 ;

16) - 8.3463204011788 + 1.74454828660436 * LS61 = 12.5685324733803 - 1.2725949863462 * LD61 + 1.34756211463414 * LD62 - 2.1183955842515 * LD63 ;

17) - 6.0210701328071 + 1.18970365563487 * LS62 = 33.9423959170884 + 0.51591688635655 * LD61 - 3.2490116680949 * LD62 + 0.01421442604792 * LD63 ;

18) - 8.2613421733824 + 1.0322770926653 * LS61 + 0.2919776529227 * LS62 + 0.62639821029083 * LS63 = 13.9221637949357 - 1.25 * LD63 ;

19) - 22.586058790729 + 3.73831775700935 * LS71 = 38.6976887654917 - 2.3645078038589 * LD71 + 0.28228131706072 * LD72 - 2.1137349807621 * LD73 ;

20) - 19.047681015498 + 2.10486031381554 * LS72 = 26.1880638968216 + 0.95858424480767 * LD71 - 2.8171410744841 * LD72 + 0.01232499220087 * LD73 ;

21) - 22.367235027619 + 2.21202234142565 * LS71 + 0.12479871524271 * LS72 + 1.34228187919463 * LS73 = 16.5773980585089 - 1.25 * LD73 ;

22) - 14.417542344013 + 2.90758047767394 * LS81 = 24.5803427984096 - 1.9468898622374 * LD81 + 0.689713455228 * LD82 - 2.1155174963666 * LD83 ;

23) - 3.798554576455 + 1.01345126220748 * LS82 = 27.6312168546255 + 0.78927967388005 * LD81 - 2.982316265633 * LD82 + 0.01304763366214 * LD83 ;

24) - 12.757569205145 + 1.72046182110884 * LS81 + 0.13868553448517 * LS82 + 1.04399701715138 * LS83 = 14.6191032374415 - 1.25 * LD83 ;

25) - 3.1144720076827 + 1.18946474086661 * LS91 = 13.7202085845669 - 0.9063623026502 * LD91 + 1.70486229384974 * LD92 - 2.1199587725356 * LD93 ;

26) - 10.775165047326 + 1.71019900497512 * LS92 = 31.5447157146626 + 0.36744417675007 * LD91 - 3.3938630921012 * LD92 + 0.01484815102794 * LD93 ;

27) - 6.7156856969174 + 0.70382529045362 * LS91 + 0.5083407571965 * LS92 + 0.42708968883466 * LS93 = 15.8248549410329 - 1.25 * LD93 ;

28) - 13.343042610604 + 2.90758047767394 * LS101 = 25.9484927506153 - 1.9468898622374 * LD101 + 0.689713455228 * LD102 - 2.1155174963666 * LD103 ;

29) - 3.6815253204752 + 1.01345126220748 * LS102 = 27.1574645157062 + 0.78927967388005 * LD101 - 2.982316265633 * LD102 + 0.01304763366214 * LD103 ;

30) - 12.719708557281 + 1.72046182110884 * LS101 + 0.13868553448517 * LS102 + 1.04399701715138 * LS103 = 14.7498760224899 - 1.25 * LD103 ;

31) - 8.2288934028982 + 1.63551401869159 * LS111 = 22.1786525562379 - 1.2031445417188 * LD111 + 1.41531864597793 * LD112 - 2.1186920190762 * LD113 ;

32) - 15.866092180006 + 2.60601753139067 * LS112 = 30.0084675525914 + 0.4877613006968 * LD111 - 3.2764805321532 * LD112 + 0.01433460232817 * LD113 ;

33) - 12.353285569208 + 0.96775977437372 * LS111 + 0.6660966735401 * LS112 + 0.58724832214765 * LS113 = 17.364857867115 - 1.25 * LD113 ;

34) 17.9181882603248 - 1.2031445417188 * LD11 + 1.41531864597793 * LD12 - 2.1186920190762 * LD13 < LOG(EXP(- 3.1144720076827 + 1.18946474086661 * LS91) + 12.00) ;

35) 26.0821225328952 - 1.3548150860491 * LD41 + 1.28158183815452 * LD42 - 2.1228487733431 * LD43 < LOG(EXP(- 5.2466169125522 + 1.63551401869159 * LS11) + 24.00) ;

36) 26.0821225328952 - 1.3548150860491 * LD41 + 1.28158183815452 * LD42 - 2.1228487733431 * LD43 < LOG(EXP(- 5.8222972505864 + 1.63551401869159 * LS21) + 33.00) ;

37) 26.0821225328952 - 1.3548150860491 * LD41 + 1.28158183815452 * LD42
- 2.1228487733431 * LD43 < LOG(EXP(- 3.3887037805675 +
1.18946474086661 * LS31) + 1.00) ;
38) 29.1861540653078 - 1.6546470913447 * LD51 + 0.97482835365998 * LD52
- 2.1167648740473 * LD53 < LOG(EXP(- 8.2288934028982 +
1.63551401869159 * LS111) + 87.00) ;
39) 26.0821225328952 - 1.3548150860491 * LD41 + 1.28158183815452 * LD42
- 2.1228487733431 * LD43 < LOG(EXP(- 14.486149673676 +
2.37892948173322 * LS51) + 16.00) ;
40) 26.0821225328952 - 1.3548150860491 * LD41 + 1.28158183815452 * LD42
- 2.1228487733431 * LD43 < LOG(EXP(- 8.3463204011788 +
1.74454828660436 * LS61) + 37.00) ;
41) 38.6976887654917 - 2.3645078038589 * LD71 + 0.28228131706072 * LD72
- 2.1137349807621 * LD73 < LOG(EXP(- 8.3463204011788 +
1.74454828660436 * LS61) + 45.00) ;
42) 38.6976887654917 - 2.3645078038589 * LD71 + 0.28228131706072 * LD72
- 2.1137349807621 * LD73 < LOG(EXP(- 14.417542344013 +
2.90758047767394 * LS81) + 18.00) ;
43) 38.6976887654917 - 2.3645078038589 * LD71 + 0.28228131706072 * LD72
- 2.1137349807621 * LD73 < LOG(EXP(- 13.343042610604 +
2.90758047767394 * LS101) + 62.00) ;
44) 11.5045062141931 - 0.9063623026502 * LD31 + 1.70486229384974 * LD32
- 2.1199587725356 * LD33 < LOG(EXP(- 3.1144720076827 +
1.18946474086661 * LS91) + 35.00) ;
45) 11.5045062141931 - 0.9063623026502 * LD31 + 1.70486229384974 * LD32
- 2.1199587725356 * LD33 < LOG(EXP(- 5.2466169125522 +
1.63551401869159 * LS11) + 23.00) ;
46) 17.5586874510404 - 1.2031445417188 * LD21 + 1.41531864597793 * LD22
- 2.1186920190762 * LD23 < LOG(EXP(- 8.2288934028982 +
1.63551401869159 * LS111) + 70.00) ;
47) 17.9181882603248 - 1.2031445417188 * LD11 + 1.41531864597793 * LD12
- 2.1186920190762 * LD13 < LOG(EXP(- 5.8222972505864 +
1.63551401869159 * LS21) + 9.00) ;
48) 13.7202085845669 - 0.9063623026502 * LD91 + 1.70486229384974 * LD92
- 2.1199587725356 * LD93 < LOG(EXP(- 13.343042610604 +
2.90758047767394 * LS101) + 18.00) ;
49) 38.6976887654917 - 2.3645078038589 * LD71 + 0.28228131706072 * LD72
- 2.1137349807621 * LD73 < LOG(EXP(- 3.3887037805675 +
1.18946474086661 * LS31) + 9.00) ;
50) 38.6976887654917 - 2.3645078038589 * LD71 + 0.28228131706072 * LD72
- 2.1137349807621 * LD73 < LOG(EXP(- 9.7714000248674 +
1.86915887850467 * LS41) + 8.00) ;
51) 29.1861540653078 - 1.6546470913447 * LD51 + 0.97482835365998 * LD52

- 2.1167648740473 * LD53 < LOG(EXP(- 5.8222972505864 + 1.63551401869159 * LS21) + 17.00) ;

52) 24.5803427984096 - 1.9468898622374 * LD81 + 0.689713455228 * LD82 - 2.1155174963666 * LD83 < LOG(EXP(- 8.3463204011788 + 1.74454828660436 * LS61) + 27.00) ;

53) 29.1861540653078 - 1.6546470913447 * LD51 + 0.97482835365998 * LD52 - 2.1167648740473 * LD53 < LOG(EXP(- 8.3463204011788 + 1.74454828660436 * LS61) + 21.00) ;

54) 28.8004021133169 + 0.4877613006968 * LD11 - 3.2764805321532 * LD12 + 0.01433460232817 * LD13 < LOG(EXP(- 10.775165047326 + 1.71019900497512 * LS92) + 64.00) ;

55) 31.1942455631173 + 0.4877613006968 * LD21 - 3.2764805321532 * LD22 + 0.01433460232817 * LD23 < LOG(EXP(- 12.013119486663 + 1.71019900497512 * LS32) + 70.00) ;

56) 31.1942455631173 + 0.4877613006968 * LD21 - 3.2764805321532 * LD22 + 0.01433460232817 * LD23 < LOG(EXP(- 18.516067255991 + 2.60601753139067 * LS12) + 24.00) ;

57) 31.1942455631173 + 0.4877613006968 * LD21 - 3.2764805321532 * LD22 + 0.01433460232817 * LD23 < LOG(EXP(- 23.187681517773 + 2.48756218905473 * LS42) + 61.00) ;

58) 33.9423959170884 + 0.51591688635655 * LD61 - 3.2490116680949 * LD62 + 0.01421442604792 * LD63 < LOG(EXP(- 23.187681517773 + 2.48756218905473 * LS42) + 21.00) ;

59) 29.4517785032077 + 0.67080287486946 * LD51 - 3.0979033866189 * LD52 + 0.01355332731646 * LD53 < LOG(EXP(- 23.187681517773 + 2.48756218905473 * LS42) + 19.00) ;

60) 30.0084675525914 + 0.4877613006968 * LD111 - 3.2764805321532 * LD112 + 0.01433460232817 * LD113 < LOG(EXP(- 39.335007311711 + 4.56053067993367 * LS52) + 55.00) ;

61) 27.6312168546255 + 0.78927967388005 * LD81 - 2.982316265633 * LD82 + 0.01304763366214 * LD83 < LOG(EXP(- 23.187681517773 + 2.48756218905473 * LS42) + 19.00) ;

62) 27.6312168546255 + 0.78927967388005 * LD81 - 2.982316265633 * LD82 + 0.01304763366214 * LD83 < LOG(EXP(- 19.047681015498 + 2.10486031381554 * LS72) + 19.00) ;

63) 27.1574645157062 + 0.78927967388005 * LD101 - 2.982316265633 * LD102 + 0.01304763366214 * LD103 < LOG(EXP(- 10.775165047326 + 1.71019900497512 * LS92) + 62.00) ;

64) 30.2134723540603 + 0.36744417675007 * LD31 - 3.3938630921012 * LD32 + 0.01484815102794 * LD33 < LOG(EXP(- 10.775165047326 + 1.71019900497512 * LS92) + 18.00) ;

65) 28.8004021133169 + 0.4877613006968 * LD11 - 3.2764805321532 * LD12 + 0.01433460232817 * LD13 < LOG(EXP(- 12.013119486663 +

1.71019900497512 * LS32) + 46.00) ;

66) 28.8004021133169 + 0.4877613006968 * LD11 - 3.2764805321532 * LD12 + 0.01433460232817 * LD13 < LOG(EXP(- 23.187681517773 + 2.48756218905473 * LS42) + 37.00) ;

67) 30.0084675525914 + 0.4877613006968 * LD111 - 3.2764805321532 * LD112 + 0.01433460232817 * LD113 < LOG(EXP(- 15.635014114328 + 2.60601753139067 * LS22) + 13.00) ;

68) 31.1942455631173 + 0.4877613006968 * LD21 - 3.2764805321532 * LD22 + 0.01433460232817 * LD23 < LOG(EXP(- 39.335007311711 + 4.56053067993367 * LS52) + 42.00) ;

69) 33.9423959170884 + 0.51591688635655 * LD61 - 3.2490116680949 * LD62 + 0.01421442604792 * LD63 < LOG(EXP(- 39.335007311711 + 4.56053067993367 * LS52) + 2.00) ;

70) 33.8941240242622 + 0.54924935920908 * LD41 - 3.2222629073599 * LD42 + 0.01601977297693 * LD43 < LOG(EXP(- 12.013119486663 + 1.71019900497512 * LS32) + 9.00) ;

71) 26.1880638968216 + 0.95858424480767 * LD71 - 2.8171410744841 * LD72 + 0.01232499220087 * LD73 < LOG(EXP(- 12.013119486663 + 1.71019900497512 * LS32) + 9.00) ;

72) 27.1574645157062 + 0.78927967388005 * LD101 - 2.982316265633 * LD102 + 0.01304763366214 * LD103 < LOG(EXP(- 3.798554576455 + 1.01345126220748 * LS82) + 16.00) ;

73) 33.9423959170884 + 0.51591688635655 * LD61 - 3.2490116680949 * LD62 + 0.01421442604792 * LD63 < LOG(EXP(- 3.798554576455 + 1.01345126220748 * LS82) + 2.00) ;

74) 15.6269425778618 - 1.25 * LD13 < LOG(EXP(- 6.7156856969174 + 0.70382529045362 * LS91 + 0.5083407571965 * LS92 + 0.42708968883466 * LS93) + 99.00) ;

75) 15.6269425778618 - 1.25 * LD13 < LOG(EXP(- 6.9609945699376 + 0.70382529045362 * LS31 + 0.5083407571965 * LS32 + 0.42708968883466 * LS33) + 15.00) ;

76) 18.870024774657 - 1.25 * LD43 < LOG(EXP(- 6.9609945699376 + 0.70382529045362 * LS31 + 0.5083407571965 * LS32 + 0.42708968883466 * LS33) + 26.00) ;

77) 18.870024774657 - 1.25 * LD43 < LOG(EXP(- 21.190718168041 + 1.40765058090723 * LS51 + 0.84915888898043 * LS52 + 0.85417937766931 * LS53) + 1.00) ;

78) 15.8674391300329 - 1.25 * LD23 < LOG(EXP(- 6.9609945699376 + 0.70382529045362 * LS31 + 0.5083407571965 * LS32 + 0.42708968883466 * LS33) + 8.00) ;

79) 15.8674391300329 - 1.25 * LD23 < LOG(EXP(- 12.353285569208 + 0.96775977437372 * LS111 + 0.6660966735401 * LS112 + 0.58724832214765 * LS113) + 152.00) ;

80) 18.870024774657 - 1.25 * LD43 < LOG(EXP(- 8.2613421733824 + 1.0322770926653 * LS61 + 0.2919776529227 * LS62 + 0.62639821029083 * LS63) + 35.00) ;
81) 18.870024774657 - 1.25 * LD43 < LOG(EXP(- 22.367235027619 + 2.21202234142565 * LS71 + 0.12479871524271 * LS72 + 1.34228187919463 * LS73) + 9.00) ;
82) 14.6191032374415 - 1.25 * LD83 < LOG(EXP(- 8.2613421733824 + 1.0322770926653 * LS61 + 0.2919776529227 * LS62 + 0.62639821029083 * LS63) + 23.00) ;
83) 14.6191032374415 - 1.25 * LD83 < LOG(EXP(- 12.719708557281 + 1.72046182110884 * LS101 + 0.13868553448517 * LS102 + 1.04399701715138 * LS103) + 19.00) ;
84) 18.870024774657 - 1.25 * LD43 < LOG(EXP(- 10.174106747188 + 0.96775977437372 * LS11 + 0.6660966735401 * LS12 + 0.58724832214765 * LS13) + 11.00) ;
85) 14.4030176332152 - 1.25 * LD33 < LOG(EXP(- 6.7156856969174 + 0.70382529045362 * LS91 + 0.5083407571965 * LS92 + 0.42708968883466 * LS93) + 84.00) ;
86) 15.6269425778618 - 1.25 * LD13 < LOG(EXP(- 9.9369965418308 + 0.96775977437372 * LS21 + 0.6660966735401 * LS22 + 0.58724832214765 * LS23) + 7.00) ;
87) 18.870024774657 - 1.25 * LD43 < LOG(EXP(- 9.9369965418308 + 0.96775977437372 * LS21 + 0.6660966735401 * LS22 + 0.58724832214765 * LS23) + 18.00) ;
88) 17.4588013514452 - 1.25 * LD53 < LOG(EXP(- 12.353285569208 + 0.96775977437372 * LS111 + 0.6660966735401 * LS112 + 0.58724832214765 * LS113) + 169.00) ;
89) 18.870024774657 - 1.25 * LD43 < LOG(EXP(- 12.353285569208 + 0.96775977437372 * LS111 + 0.6660966735401 * LS112 + 0.58724832214765 * LS113) + 170.00) ;
90) 16.5773980585089 - 1.25 * LD73 < LOG(EXP(- 12.719708557281 + 1.72046182110884 * LS101 + 0.13868553448517 * LS102 + 1.04399701715138 * LS103) + 22.00) ;
91) 16.5773980585089 - 1.25 * LD73 < LOG(EXP(- 12.757569205145 + 1.72046182110884 * LS81 + 0.13868553448517 * LS82 + 1.04399701715138 * LS83) + 3.00) ;
92) 16.5773980585089 - 1.25 * LD73 < LOG(EXP(- 8.2613421733824 + 1.0322770926653 * LS61 + 0.2919776529227 * LS62 + 0.62639821029083 * LS63) + 26.00) ;
93) 16.5773980585089 - 1.25 * LD73 < LOG(EXP(- 6.9609945699376 + 0.70382529045362 * LS31 + 0.5083407571965 * LS32 + 0.42708968883466 * LS33) + 17.00) ;
94) EXP(LD11) + EXP(LD21) + EXP(LD31) + EXP(LD41) +

EXP(LD51) + EXP(LD61) + EXP(LD71) + EXP(LD81) + EXP(LD91) + EXP(LD101) + EXP(LD111) + 2325 = EXP(LS11) + EXP(LS21) + EXP(LS31) + EXP(LS41) + EXP(LS51) + EXP(LS61) + EXP(LS71) + EXP(LS81) + EXP(LS91) + EXP(LS101) + EXP(LS111) ;

95) EXP(LD12) + EXP(LD22) + EXP(LD32) + EXP(LD42) + EXP(LD52) + EXP(LD62) + EXP(LD72) + EXP(LD82) + EXP(LD92) + EXP(LD102) + EXP(LD112) + 145215 = EXP(LS12) + EXP(LS22) + EXP(LS32) + EXP(LS42) + EXP(LS52) + EXP(LS62) + EXP(LS72) + EXP(LS82) + EXP(LS92) + EXP(LS102) + EXP(LS112) ;

96) EXP(LD13) + EXP(LD23) + EXP(LD33) + EXP(LD43) + EXP(LD53) + EXP(LD63) + EXP(LD73) + EXP(LD83) + EXP(LD93) + EXP(LD103) + EXP(LD113) + 496 = EXP(LS13) + EXP(LS23) + EXP(LS33) + EXP(LS43) + EXP(LS53) + EXP(LS63) + EXP(LS73) + EXP(LS83) + EXP(LS93) + EXP(LS103) + EXP(LS113) ;

97) P11 = EXP(- 5.2466169125522 + 1.63551401869159 * LS11) ;

98) P12 = EXP(- 18.516067255991 + 2.60601753139067 * LS12) ;

99) P13 = EXP(15.6269425778618 - 1.25 * LD13) ;

END